Interim Advice Note 122/09

Rapid Condition Assessment of Hard Shoulder Pavements. Interim guide to data and maintenance advice

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Executive Summary

Hard Shoulder Running (HSR) has been identified by the DfT and Highways Agency as a cost effective method of increasing motorway capacity in a timely manner. In the DfT's January 2009 white paper 'Motorways and Major Trunk roads' a number of HSR schemes were identified, a significant proportion of which have start of work dates prior to 2015.

HSR involves motorway traffic using the hard shoulder at peak times under managed conditions. Prior to this occurring it is necessary to evaluate the condition of the hard shoulder pavement to ensure fitness for purpose and to mitigate against early pavement failure. There is a degree of uncertainty regarding the structural condition of many hard shoulder pavements, particularly in terms of layer thickness, construction type and mechanical properties. Consequently, there is a need to develop a consistent and rigorous framework to ensure that hard shoulder assessment and any resulting pavement upgrade is undertaken according to best practice and that value for money is achieved.

To facilitate the HSR objective and the government's fiscal stimulus, the Highways Agency has initiated a programme of rapid pavement condition assessment surveys to provide an outline of the works required to the hard shoulder pavement for all HSR schemes.

This document provides a framework to enable the consistent investigation, assessment and design for the hard shoulder pavements designated as HSR schemes, accounting for the on-going rapid hard shoulder pavement survey programme and resultant Pavement Information Packs (PIPs). This document is not prescriptive but rather offers best practice advice. It is not intended to be a substitute for the expertise and judgement of the designer.
Specifically this document covers:

- a description of the data collated under the rapid pavement survey programme,;
- the assessment criteria used on these data, and reported on in the PIPs, to provide four maintenance classifications: no treatment required, surfacing only, strengthening and reconstruction;
- the basic pavement construction types catered for;
- guidance on the detailed investigations that will be required prior to detailed scheme pavement design, building on the rapid surveys and PIPs;
- a rational approach for pavement treatment design; and
- consideration of adjacent assets such as drainage, earthworks and emergency refuge areas (ERA).

It is important that the evaluation and subsequent design and construction of hard shoulders pavements is not undertaken in isolation, and that other scheme considerations such as geometric design and gantry placement are considered.

For further advice on the use of this guidance note, please contact Louise Caudwell (Louise.Caudwell@highways.gsi.gov.uk).

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1. Introduction

1.1 Background

Hard shoulder running (HSR) has been identified by the DfT and Highways Agency as a cost effective method of increasing motorway capacity in a timely manner, making best use of the available highway asset. In the DfT's January 2009 paper 'Motorways and Major Trunk roads' a number of Managed Motorway schemes were identified, a significant proportion of which have starts of work dates prior to 2015.

HSR involves motorway traffic using the hard shoulder at peak times under managed conditions, however, there is a degree of uncertainty regarding the structural condition of many hard shoulder pavements, particularly in terms of layer thickness, construction type and mechanical properties and how largely untrafficked materials will perform under many years of exposure to the environment.

Despite this uncertainty it has been recognised that some hard shoulder pavements are not to current standards for trafficked lanes and are likely to require strengthening prior to implementation of HSR. As part of the Government's *fiscal stimulus* the Highways Agency is proposing to undertake a programme of strengthening works to the hard shoulder pavements of managed motorway schemes.

In order to develop a better understanding of where pavement strengthening works could be targeted and the potential costs of any such works, the Highways Agency has initiated a programme of rapid hard shoulder pavement surveys across all proposed Managed Motorway schemes. This programme of surveys will deliver high level pavement condition information for each scheme in a Pavement Information Pack (PIP). Each PIP will provide indicative costs of strengthening works for each scheme and give guidance on where more detailed surveys should be targeted to enable subsequent strengthening design.

Existing knowledge of hard shoulder pavement construction and condition and their expected performance under HSR is limited and current standards do not adequately cater for this unique circumstance. Consequently, there is a need to develop a consistent and rigorous framework to ensure that hard shoulder assessment and any resulting pavement strengthening is undertaken according to best practice and that value for money is achieved.

The development of this assessment framework and design advice is ongoing, but it is recognised that several Managed Motorway schemes are currently at the detailed design stage and urgently need better guidance. Given this immediate need, a 'rationale' has been developed to aid pavement treatment design. This is based on the best information available at the current time and may be subject to some changes once the outcomes of the existing research project are fully realised.

1.2 Scope

This document provides information on the surveys undertaken as part of the on-going rapid hard shoulder pavement survey programme and describes what information will be included within the resultant PIPs. It will describe the framework and rationales used to assess this condition data used to categorise the condition of the hard shoulder pavement.

This document will also provide best practice advice which should be utilised on any subsequent pavement treatment design.

Specifically this includes:

- a description of the data collated under the rapid condition assessment programme,;
- the assessment criteria used on these data, and reported on in the PIPs, to provide 4 indicative maintenance classifications;
- the basic pavement construction types catered for;
- guidance on the detailed investigations that will be required prior to detailed scheme pavement design, building on the rapid condition assessment surveys and PIPs;
- best practice advice on pavement treatment design; and
- consideration of adjacent assets such as drainage and earthworks.

There are a number of issues considered as part of this document that require hard shoulders to be considered differently to normally trafficked lanes:

- relatively thin pavement construction, particularly prevalent in hard shoulders built prior to 1980;
- pavements that are brittle due to environmental effects (i.e. untrafficked pavements that have been in place for many years and have oxidised);
- lane width considerations, particularly with rigid pavements.

The main stages in assessing the need for hard shoulder pavement maintenance are shown in Figure 1.

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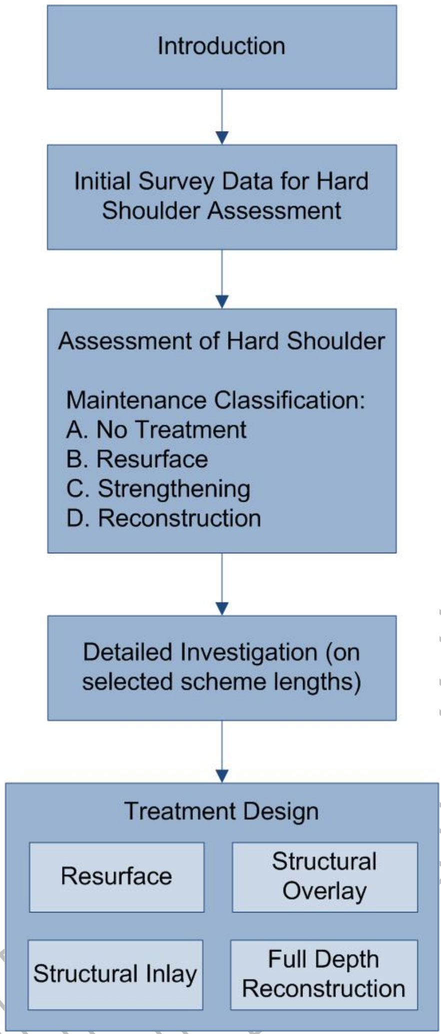

Figure 1: Investigation and Assessment Process

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2. Rapid Condition Assessment Survey Data

The first stage of the hard shoulder assessment programme involves a standardised set of investigation surveys focused on assessment methods that minimise disruption to road users. These indicative surveys provide a certain degree of information regarding the structural condition, surface condition and pavement thickness of the targeted hard shoulders, to identify the potential need for remedial action. The techniques used in this stage are described below.

2.1 Ground Penetrating Radar (GPR)

GPR is a non-destructive technique used to indicate variation in the construction thicknesses and material types along the length of the pavement. It can be carried out at traffic speed but better results can be obtained when done at slower speeds. With appropriate calibration and verification of the survey using cores, it can provide continuous construction and thickness information. Further guidance on the use of GPR is provided in HD 29 (DMRB 7.3.2). In these investigations GPR survey data has been collected at speeds of around 15 – 20 mph in the nearside and offside wheel path of the hard shoulder of each scheme.

2.2 Highways Agency Road Research Information System (HARRIS)

HARRIS is a non-destructive rapid van-based survey system which collects surface condition data at up to traffic speed. The survey has been used to provide high quality downward facing video images which are digitised then assessed manually to provide a detailed visual survey from which quantitative assessments of cracking and other surface defects can be derived. The survey is also used to provide transverse profile (rutting), longitudinal profile, surface texture and crossfall.

HARRIS provides data on road shape (longitudinal profile, transverse profile, texture and geometry) that are comparable with those provided by the TRACS survey technique described in HD 29 (DMRB 7.3.2). The data are processed to obtain measurements of rutting, texture depth (SMTD) and ride quality (3m and 10m variance). HARRIS also collects video images of the road surface. For this work these images were interpreted manually to obtain quantitative information on the area of cracking present on the pavement surface. For these investigations HARRIS were undertaken on the hard shoulder of the schemes at a target speed of 70 km/h (approx. 45 mph).

2.3 Traffic Speed Deflectometer (TSD)

The TSD is a large articulated lorry-based survey system that measures the vertical deflection velocity of the pavement under a loaded wheel (a proxy for road strength) using Doppler laser technology. The TSD measures deflection under the nearside wheelpath of the vehicle. Due to the size of the vehicle and the limited width of hard shoulders it has been generally necessary for the TSD to survey in a position straddling the Hard Shoulder/Lane 1 joint with the ***nearside*** measuring line of the vehicle coinciding with the ***offside*** wheelpath of the hard shoulder.

The TSD results will identify areas where the equivalent Deflectograph deflection would be relatively high and thus warrant further investigation. As the results are being related to Deflectograph measurements, the findings may not be meaningful for pavements considered to be of rigid or overlaid rigid construction.

TSD surveys have also been undertaken in the nearside wheel path of Lane 1 of each scheme in order to provide an assessment of the relative difference in deflection between the hard shoulder and lane 1. The surveys on each lane are undertaken at the same target speed of 70 km/h (approx. 45 mph).

2.4 Coring Surveys

The investigation of the bound layers through coring is required to i) determine layer and total pavement thicknesses; ii) establish the broad material type and 'visual' condition of layers; and iii) to calibrate GPR surveys. The cores will be retained and may also be used at a later stage to provide samples for compositional and physical tests to support the detailed investigation stage. Further details on coring are provided in HD 29 (DMRB 7.3.2) and HD 30 (DMRB 7.3.3).

To support rapid condition assessment, cores have been taken through the bound depth of the pavement at an approximate spacing of 400 m adjacent to, but not in, the nearside wheel path of the hard shoulder of each scheme (where not on a structure). The cores taken are generally of 150 mm diameter but with every fifth core being of 200 mm diameter to provide asphalt samples that are suitable for subsequent wheel tracking testing as part of the detailed investigation stage.

2.5 Other Data Sources

Other investigations carried out to support the rapid condition assessment surveys include:

- A review of existing TRACS and HARRIS forward facing videos to identify other characteristics such as hard shoulder and drainage provision.
- Sample lengths of Deflectograph survey to provide deflection data for the nearside and offside wheel path of the hard shoulder to calibrate the TSD response.
- Relevant historic data which could aid the assessment process.

The pavement condition data provided by the rapid assessment are analysed as described in Section 4 and may be used to identify where subsequent detailed investigations are likely to be required as described in Section 5.

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3. Classification of Pavement Type

For the purposes of this document and the reporting of the findings of the rapid survey programme in the PIPs, the construction of each 100m of hard shoulder pavement, where present, has been classified into one of four following types from inspection of the core and GPR findings:

- Flexible Pavement (flexible with asphalt base or flexible with hydraulically bound base).
- Rigid Pavement (jointed or continuous).
- Overlaid Rigid Pavement. (with any thickness of asphalt overlay).
- Structure (underbridges with an asphalt surface).

The basic classification process is summarised in Figure 2.

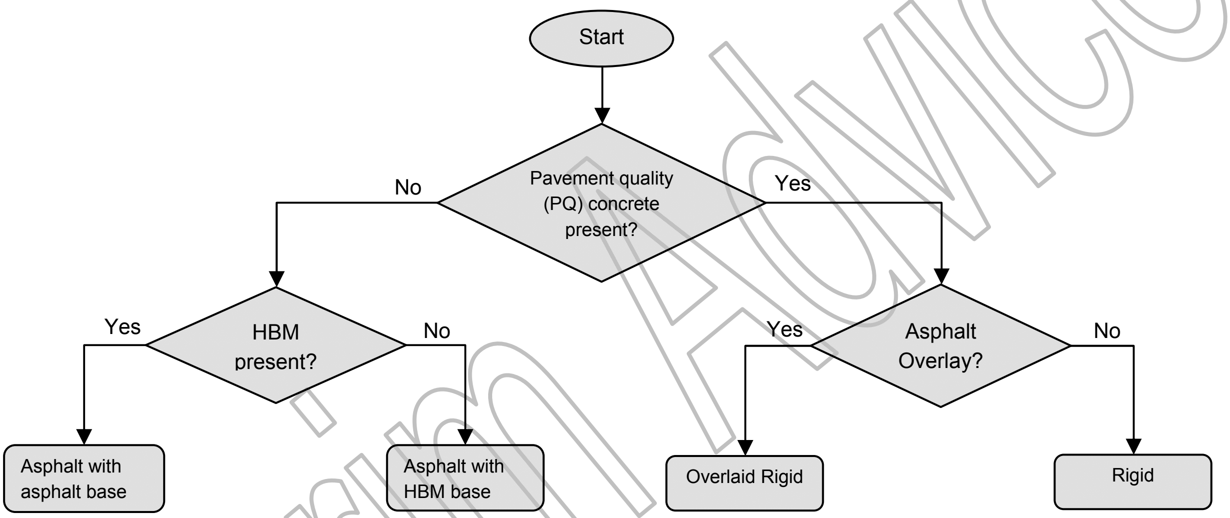

Figure 2: Classification of Pavement Type

In addition, lengths where there is no hard shoulder provision, or the hard shoulder is insufficiently wide to permit progress of the survey vehicles within the lane have been classed as having no hard shoulder and are recorded and reported as such in the PIPs.

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4. Identification of maintenance class from rapid condition survey data

4.1 Approach

The overall aim of the assessment and design approach set out in this document is to identify the maintenance that would be required to bring the hard shoulder pavement construction up to current design standards for a newly-built trafficked lane. As the hard shoulders that are considered for HSR are necessarily located on some of the most heavily trafficked lengths of the HA Network, the overall maintenance principles employed by the indicative maintenance classification rationale is defects should be made good and that DLP or ULLP hard shoulder pavements should be converted or upgraded to long-life pavements wherever practicable and cost-effective.

The objective of this assessment stage is to assemble the information from the rapid condition surveys and to identify lengths where maintenance is likely to be required and the likely scope of that maintenance. The indicative maintenance has been divided into four broad classes, namely:

A. No treatment;
B. Resurface (replacement of surfacing only);
C. Strengthen (overlay / deep inlay);
D. Reconstruct (full depth reconstruction).

The maintenance options available for treating hard shoulders considered to be in need of strengthening are constrained by the following considerations under the fiscal stimulus package:

- No provision is to be made for widening of the hard shoulder;
- Surface levels should not increased where this would result in surface levels in the adjacent trafficked lanes to also be increased where not otherwise justified.

As a result, the opportunities for strengthening by use of overlays is generally limited to cases where reprofiling of the hard shoulder is necessary to facilitate HSR or where the adjacent trafficked lanes are also considered to be in need of maintenance. Both of these circumstances are considered only at the detailed design stage and are therefore outside the scope of the rapid condition assessment procedure. Consequently, the maintenance classification process has had to assume that structural overlays are not an option.

The decision making process employed for the selection of indicative maintenance classes using information obtained from the rapid assessment surveys is illustrated as a flowchart in Figure 3 for flexible pavements. The corresponding flowcharts for rigid pavements without asphalt overlay (rigid), asphalt overlay (overlaid rigid) and for structures are illustrated in Figure 4, Figure 5, and Figure 6 respectively. The criteria used in each step are described in the following section.

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Flexible with Asphalt base
Flexible with HBM base

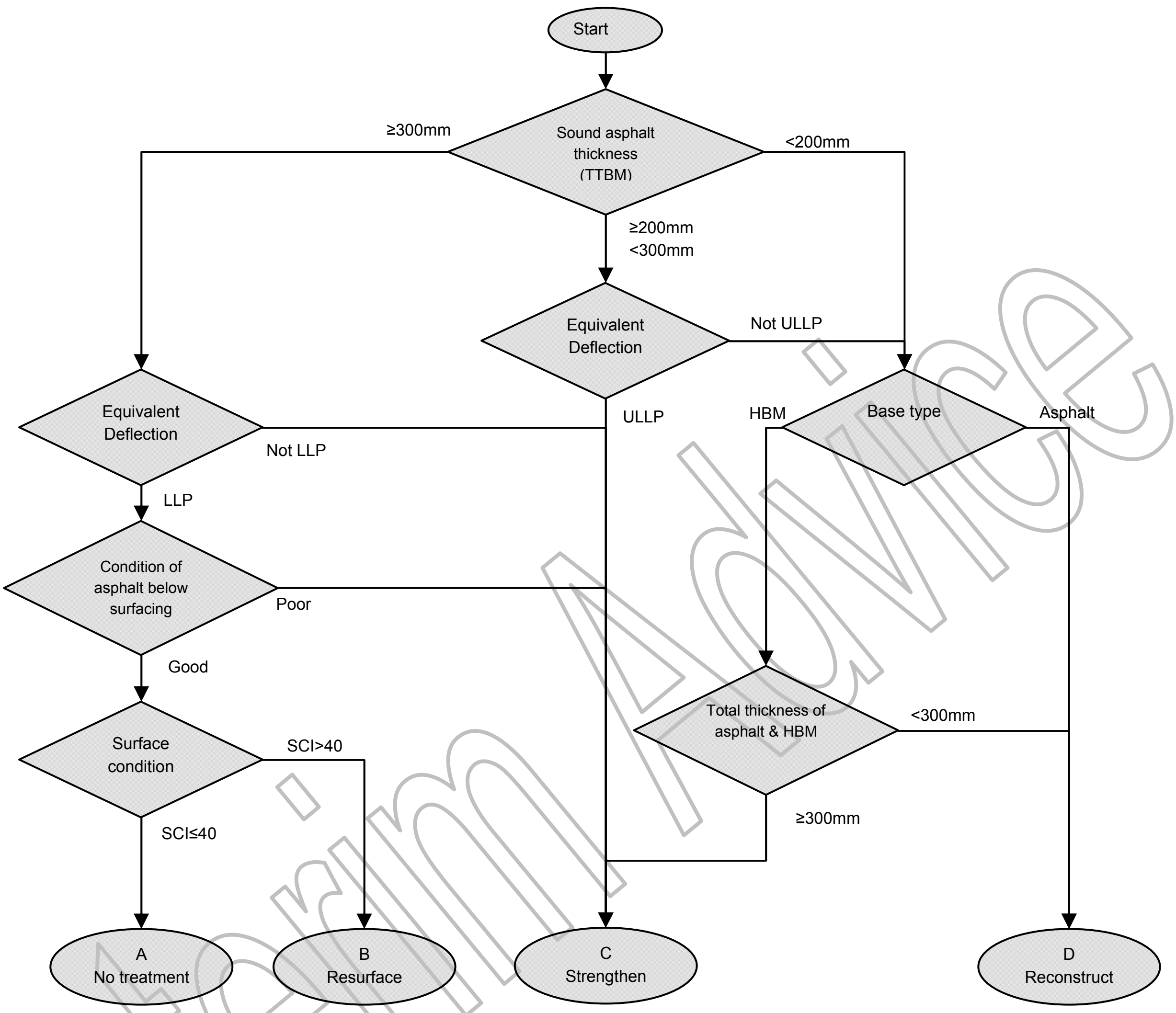

Figure 3: Decision Process for Flexible Pavements

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Jointed Rigid

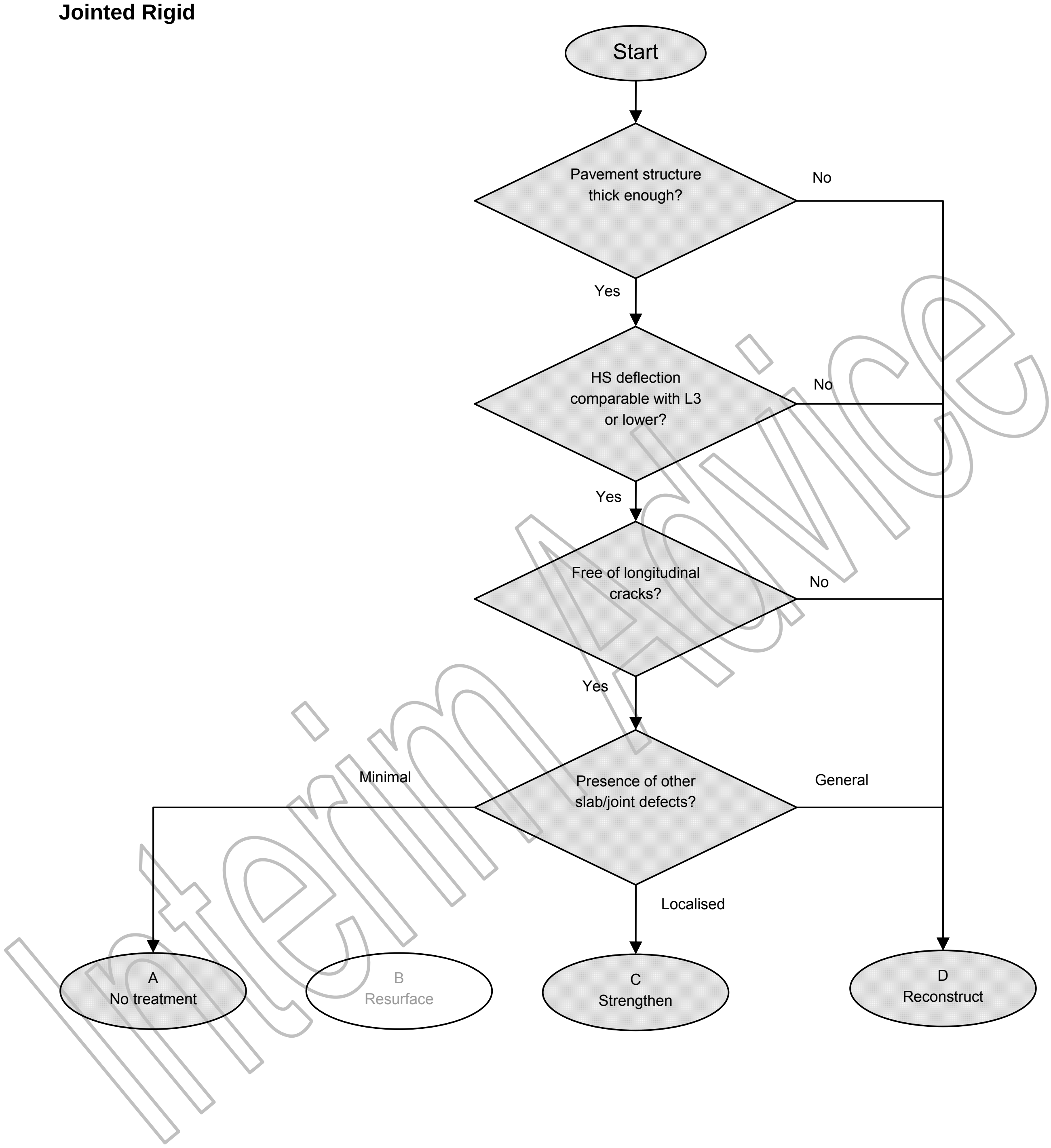

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Figure 4: Decision Process for Rigid Pavements (no asphalt surfacing)

Overlaid Rigid

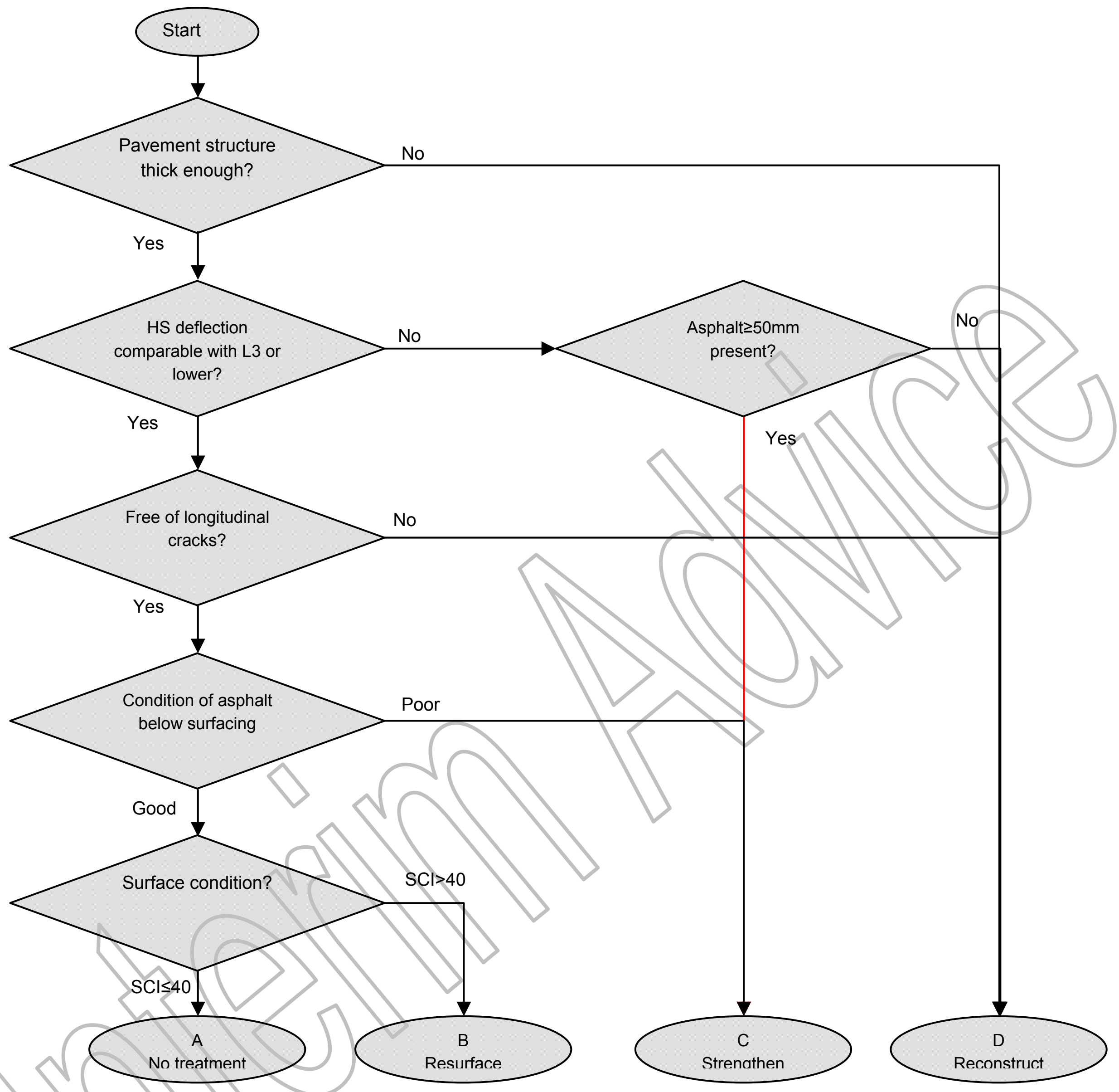

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Figure 5: Decision Process for Overlaid Rigid Pavements (any asphalt surfacing thickness)

Structure

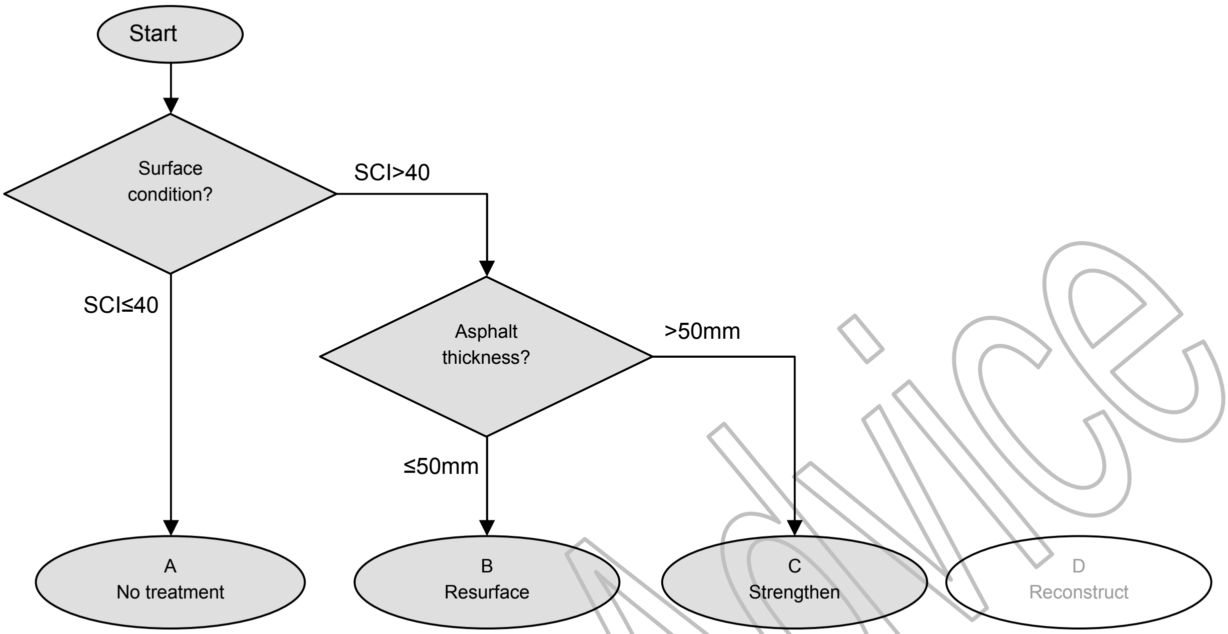

Figure 6: Decision Process for Structures (underbridges with any asphalt surfacing thickness)

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4.2 Assessment Criteria

4.2.1 Flexible pavements

For flexible pavements with either asphalt or HBM bases the method of assigning maintenance classification is based on the approach provided in HD 30 (DMRB 7.3.3) and is primarily driven by the thickness of sound asphalt and an equivalent Deflectograph deflection derived from TSD measurements calibrated against a sample Deflectograph survey.

The sound asphalt thickness and pavement construction determination is provided by a combination of GPR and coring which is carried out in the nearside wheelpath of the hard shoulder. The TSD, however, generally measures equivalent deflection in the offside wheelpath of the hard shoulder and therefore it is assumed in the indicative maintenance classification procedure that the construction and structural condition of the hard shoulder is equivalent across the width of the shoulder.

The thickness of sound asphalt and the equivalent Deflectograph deflection are used to characterise the deflection category of each 100m of pavement according to the following classifications provided in HD30;

- Long-life Pavement (LLP);
- upgradeable to Long-life Pavement (ULLP);
- Determinate-life Pavements (DLP)

For the purposes of the PIP reports, DLP pavements are sub-divided further into *not Long-life:* (N-LLP); or *not upgradeable to Long-life*: N-ULLP).

Following assessment of asphalt thickness and deflection, the condition of lower layers and the surface condition are used to further define the indicative maintenance class. Inspection of cores is used to reveal where lower bound layers are in poor condition and are likely to adversely affect the durability of the hard shoulder under prolonged trafficking. The core findings are supplemented by inspection of the GPR results to determine the likely extent of the poor quality materials in the hard shoulder.

Data from the HARRIS survey was used to obtain a measure of surface condition. Typically data on road shape provided by HARRIS (and hence that provided by the TRACS equivalent survey) is used to identify lengths in need of further investigation, based on the assessment of individual survey measurements of rutting, texture and ride quality against defined thresholds. Due to the rapid delivery timescales required for this work it was necessary to devise an approach that would automatically highlight such lengths based on the combination of these surface condition measurements and also the assessment of cracking. An established technique was not available to provide this information. The approach taken was therefore to devise a score for each 100m length that combined the rutting, texture, ride quality and cracking information and highlight lengths exceeding a certain score as in need of maintenance. The approach taken to obtain this Surface Condition Index (SCI) is set out in Appendix B.

The maintenance classification rationale for flexible pavements takes into consideration that there is no standard assessment methodology available for ascribing long-life status to flexible pavements with HBM base with less than 300 mm of asphalt. Pavements with such a construction are classed as requiring either strengthening or reconstruction dependent on prevailing structure and condition of the pavement.

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The assessment criteria used in the decision making process for flexible pavements are shown in Table 1.

Table 1: Assessment Criteria for Flexible Pavements

Survey Criteria	Parameters	Measures
Sound asphalt thickness	Category 1	> 300 mm
	Category 2	200 – 300 mm
	Category 3	< 200 mm
Pavement life category	LLP ULLP N-LLP[1] N-ULLP[2]	Depends on the equivalent deflection and the Total Thickness of Bituminous Material (TTBM) according to figure 2.1 in HD30
Surface condition	Good	SCI <40
	Poor	SCI≥40
Core condition	Good	Cracks < 40 mm deep and zero to low / moderate voiding
	Poor	Cracks > 40 mm deep or severe voiding
Total thickness of asphalt and HBM (only where HBM bases present)	Sufficient	> 300 mm
	Insufficient	< 300 mm

1. *Pavements with TTBM > 300mm and a deflection greater than the LLP criteria are labelled not Long-life Pavement (N-LLP).*
2. *Pavements with 200mm < TTBM < 300mm and a deflection greater than the ULLP criteria OR pavements with TTBM < 200mm are labelled not upgradeable to Long-life Pavement (N-ULLP)*

4.2.2 Rigid pavements

For jointed rigid construction the method of assigning maintenance classification is primarily driven by the thickness of the concrete slab and whether a bound sub-base is present or not. The design relationships provided in HD26 have been used to determine the thickness of a typical Pavement Quality (PQ) slab with a 28-day compressive strength of 40MPa needed to provide a life of 40msa for the cases of (i) unbound and (ii) bound sub-bases.

Standard rigid pavement design allows for the thickness of a trafficked lane to be reduced where it is tied to an adjacent hard shoulder or edge strip. As a consequence, a concrete hard shoulder will usually have a lower design life than an adjacent trafficked lane of the same pavement construction. It is assumed that hard shoulders will not be widened to accommodate HSR and therefore the lack of tied edge is taken into account in the derivation of the satisfactory thickness criterion.

Where the hard shoulder concrete slab thickness is found to be thinner than would be required, reconstruction of the hard shoulder is considered to be appropriate where there is no scope to increase surface levels.

The maintenance classification rationale for rigid pavements takes into consideration that there is no standard deflection-based assessment methodology for ascribing remaining life to concrete pavements. The approach taken is to compare the deflection responses of the hard shoulder and lane 1 when measured by the TSD. Where the construction of the hard shoulder would appear to be sufficient, yet the deflection response of the hard shoulder

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appears to be significantly greater than that of the adjacent Lane 1 then reconstruction should be considered.

The assessment criteria used in the decision making process for rigid pavements are shown in Table 2.

Table 2: Assessment Criteria for Rigid Pavements

Survey Criteria	Parameters	Measures
PQC thickness (bound sub-base present)	Sufficient Insufficient	≥ 300 mm < 300 mm
PQC thickness (bound sub-base not present)	Sufficient	≥ 340 mm
	Insufficient	< 340 mm
Relative HS deflection	Good Poor	Difference between HS and L1 deflection ≤ 20% of L1 deflection Difference between HS and L1 deflection > 20% of L1 deflection
Longitudinal cracking	Minimal Significant	≤10% slabs in each 100m length affected >10% slabs in each 100m length affected
Failed joints or slabs	Minimal Localised General	≤5% joints or slabs failed >5%, <30% joints or slabs failed ≥ 30% joints or slabs failed

4.2.3 Overlaid rigid pavements
The maintenance classification rationale for overlaid rigid pavements is treated as a combination of the considerations for flexible and rigid construction.

4.2.4 Structures (underbridges and elevated sections)
A significant proportion of the length of some HSR schemes consists of underbridges or elevated sections, with their extent determined by examination of the GPR response. As it is not possible to take cores and there are no suitable deflection-based methods available for this construction type, a simplified rationale has been developed to provide a maintenance classification for this construction type based solely on surface condition and asphalt thickness.

Where the surface condition is good, no maintenance treatment is identified, however further detailed investigation is recommended to establish the structural soundness of the construction. Where the surface condition is poor, the maintenance classification depends on the asphalt thickness, with strengthening recommended where the thickness is greater than 50mm and resurfacing where it is less than 50mm thick.

4.3 Reporting
The findings and recommendations of the rapid assessment stage are provided in a PIP report. The PIP report is a factual report including a summary of the scheme maintenance requirements and other relevant scheme specific information including a breakdown of indicative costs. A strip plan (similar to an ‘E1 form’ used in Value Management) is included as an appendix of the PIP report, and provides the results from the various rapid assessment surveys and the resulting indicative maintenance classes for every linear 100 lane metre section.

In areas where there is no hard shoulder present, due to intrusions into the hard shoulder from bridges and other structures, or the physical width of the pavement being insufficient to allow survey vehicles to proceed, this situation is indicated on the PIP reports as “No Hard Shoulder”, (N-HS) and no maintenance classification has been provided.

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In areas where a hard shoulder is present, but at the time of the individual survey, it was not possible for the survey vehicle to access the hard shoulder, this is indicated in the PIP report by the designation “Out of Lane” (OOL). This situation generally arises in response to the requirements for safe operations at slip roads and as a consequence of the presence of planned and unplanned hard shoulder obstructions such as programmed roadworks or broken down vehicles. In this circumstance engineering judgement has been used to provide the most likely Maintenance Classification based on the information available and from consideration of the condition of adjacent sections.

It should always be borne in mind that the rapid surveys will not provide all the information required to establish the precise nature of any strengthening or reconstruction that may be required. Where the assessment process has identified that maintenance would be appropriate, these lengths will require additional detailed investigations to provide the information required for the development of robust treatment designs. The techniques available for use in the detailed investigations are provided in the following sections of this document together with a framework for carrying out detailed design.

While drainage and/or geotechnical considerations may also be significant drivers for detailed pavement strengthening or reconstruction design, these are highly scheme specific and are not considered in the determination of maintenance classification for the schemes. The extant crossfall of the hard shoulder and an indication of drainage provision is, however, provided for information in the PIPs.

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5. Detailed Investigations

5.1 General

The results of the rapid condition assessment surveys will provide an indication of where pavement maintenance is most likely to be required and, in most cases, a detailed investigation will also be required. In those areas where full survey coverage has not been possible, for example in the vicinity of junctions, further detailed investigations will be essential. This investigation will determine the current pavement condition and potential condition as a result of trafficking and enable the most appropriate maintenance works to be designed economically.

It should always be borne in mind that the rapid condition assessment surveys do not assess the skidding resistance of hard shoulder surfaces. Therefore, areas classed as likely to require 'No treatment' (Class A) will also require surface friction assessment before they should be considered for opening to long-term traffic.

The types of investigations likely to be needed at this stage and the reason for their use are described in brief in this section. A more detailed description on most of these investigations can be found in various DMRB, MCHW and British Standards. The list is not exhaustive. Not all surveys are required and other methods can be adopted. Designers need to determine the appropriate surveys on a scheme specific basis.

5.2 Techniques

5.2.1 Deflectograph

The deflectograph is the HA standard technique for providing deflection measurements used for the assessment of pavement residual life and to calculate the thickness of structural overlays that may be required. Its use is described in HD29 and HD30. While the TSD results are able to provide an indication of the likely extent of long-life pavements and pavements likely to need structural maintenance, additional detailed deflectograph testing is advisable to provide robust residual lives and strengthening requirements for determinate life pavements. As the Deflectograph can measure deflection in both wheelpaths its further use is especially recommended where there are indications that the strength of the hard shoulder is not uniform across its width and in areas where the TSD was not able to access during the rapid condition assessment surveys.

5.2.2 Falling Weight Deflectometer (FWD)

This non-destructive device is used to record the deflection bowl under a known load from which stiffnesses of the pavement layers including the foundation can be determined by the process of back-analysis. These stiffnesses may be used to provide a good indication of the in situ properties of the material. It can also be used to investigate the condition of the joints of unreinforced jointed concrete pavements. Guidance on the use of FWD and the analysis of data is provided in HD 29 (DMRB 7.3.2).

The back-analysed stiffnesses can help identify potential weak layers (including foundation) and may be used in analytical design processes. In the case of flexible pavements it may help in the identification of asphalt layers that have become age-hardened and brittle.

5.2.3 Coring Surveys (where needed)

Further targeted coring may be required to obtain more detailed information regarding pavement materials, both in terms of 'visual' condition and to provide samples for compositional and physical tests. Details on coring are provided in HD 29 (DMRB 7.3.2) and HD 30 (DMRB 7.3.3).

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5.2.4 Dynamic Cone Penetrometer (DCP)

DCP tests are normally carried out in core holes and it may be advisable to undertake tests where further coring is to be undertaken. These tests provide a quick and cost-effective method of estimating the approximate strength of unbound foundation layers. In situations where high deflections and/or thin pavement thicknesses exist, DCP will especially be useful to assess the contribution of the foundation to overall pavement strength. Further details of its use is provided in HD 30 (DMRB 7.3.3).

5.2.5 Sideway-force Coefficient Routine Investigation Machine (SCRIM)

SCRIM is the standard method for monitoring in service skid resistance. Its use is described in HD 28 (DMRB 7.3.1).

For the purpose of this investigation SCRIM surveys may need to be undertaken on the hard shoulder pavement lengths classified under Class A. However it is apparent that there are complications with interpreting these results on relatively untrafficked (and hence unpolished) pavement surfaces. These results may be compared against lane 1 network survey results (and where available to historic hard shoulder information) to gauge the likely future performance under conditions of HSR and so establish whether resurfacing is required.

SCRIM surveys should be undertaken in consultation with NetServ Pavement Engineering to ensure that any surveys are undertaken, where possible, within the optimum survey season to enable Local Equilibrium Correction Factors to be established in accordance with HD28.

5.2.6 Indirect Tensile Stiffness Modulus (ITSM)

Where there is a doubt regarding the adequacy of the stiffness of asphalt layers or where there is concern regarding age hardening of materials, Indirect Tensile Stiffness Modulus (ITSM) tests may be carried out on core samples. The test procedure is provided in BS EN 12697 Part 26 (under Annex C – Tests applying Indirect Tension to Cylindrical Specimens). For consistency with design practices, this test should be carried out at the reference temperature of 20°C.

5.2.7 Compressive Strength

Compressive strength of intact concrete layers may be required to verify the strength of the pavement. These results can also assist in the design process of rigid pavements. The test procedure is provided in BS EN 12504 Part 1 and BS EN 12390 Parts 3 & 7.

5.2.8 Wheel Tracking (using small size device)

Where there is a concern regarding the susceptibility of the asphalt to rutting under HSR, and where it has not been possible to clearly identify the rut susceptible layers from examination of the cores, it may be advisable to carry out wheel tracking tests. BS EN 12697 Part 22 provide details on the test procedure using the small size wheel track device. This may be particularly relevant where the upper 100mm of the surfacing is HRA.

5.2.9 Binder Properties

Where there is concern regarding the age hardening of asphalt layers, a rheological assessment can be carried out on recovered binder to determine penetration and softening point broadly to BS EN 14770. This method is preferred over the methods in BS EN 1426 (for penetration) and BS EN 1427 (for softening point). The reasons for the preference for rheological assessment include:

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- It provides an indication of the present condition of the binder in addition to the extent of binder hardening;
- It is not dependent on knowing the existing material type; and
- It requires a smaller sample quantity.

5.2.10 Fatigue Resistance
Resistance to fatigue especially of aged material layers on thinner pavements may need to be assessed given that such layers are susceptible to brittle failure (due to flexing and cracking) when subjected to traffic loading under HSR. The test procedure for undertaking resistance to fatigue is provided in BS EN 12697 Part 24.

5.2.11 Moisture-related Durability
Where moisture-related durability is of concern, the test procedure provided in BS EN 12697 Part 12 for determining water sensitivity of materials should be undertaken to determine the adequacy of the asphalt layer.

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6. Detailed Treatment Design

6.1 General

This section provides advice on carrying out the maintenance options of resurfacing, strengthening (overlay and inlay) and full depth reconstruction for flexible, overlaid rigid and rigid pavements. The design approach presented is based mainly on TRL Report 615 for flexible construction (with asphalt or HBM base); TRL Report 630 for rigid (continuous) construction; and TRL Report RR87 for rigid (jointed) construction. These documents have been used in developing the methodologies presented in HD 26 (DMRB 7.2.3) and HD 30 (DMRB 7.3.3).

Evidence from all the investigations, other collated data, available advice and a degree of engineering judgement should be used in the decision making process pertaining to design. This process should be undertaken in line with the 'interpretation process' provided in HD 30 (7.3.3). This assessment enables the condition of the pavement structure to be established, and, where appropriate, nature of the maintenance required to both remedy defects and meet the future traffic requirement. Where defective materials are retained within the pavement these defects have to be considered in the design, for example by down-rating of stiffnesses of HBM layers considered to be of poor integrity to account for future deterioration under HSR.

Where hard shoulder maintenance is carried out, consideration should be given to the anticipated positions of the wheelpaths under HSR. It is likely that the future implementation of HSR will be carried out within the extent of the existing paved width of the motorway. Therefore, whenever practicable, reconstruction, inlays and resurfacing should be carried out to such a width that the longitudinal construction joints do not coincide with the anticipated positions of the wheelpaths under HSR.

Designers should take all opportunities to minimise the need for changes to the civil infrastructure. For example, the use of overlays will require changes to adjacent lanes and may impact on drainage and safety barriers. Designers should also, in designing strengthening measures, take opportunities to avoid reconstruction through the use of stiffer replacement materials.

6.2 Design Life

In terms of pavement structural capacity, the current requirement for a new hard shoulder is that it should be designed to the same standard as the heaviest loaded lane (which is normally lane 1). The full text is provided in HD 24 paragraph 2.15 (DMRB 7.2.1). The same philosophy should be adopted for existing hard shoulders considered for HSR. Hence, where a need for structural maintenance has been identified, the detailed design should aim to provide a long life pavement wherever practicable.

Exceptions to this approach may include schemes where the likely disruption to traffic is unacceptable or where practical reasons such as continuity of hard shoulder structure with that for lane 1 for drainage purposes dictates the use of a shorter design life.

In some cases, the relevant HSR implementation scheme may have progressed to a stage where traffic flow projections can provide a realistic estimate of future hard shoulder traffic for use in maintenance design. In the remaining cases, the design traffic (in msa) should be obtained in accordance with HD 24 (DMRB 7.2.1) using a proportion of the traffic currently carried by Lane 1.

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6.3 Resurfacing

6.3.1 Flexible and overlaid rigid pavements

The resurfacing of hard shoulders with an existing asphalt surface will generally require the milling-off of a depth of the existing surface material (and, where needed, localised treatment) prior to applying the new surface material. This process allows the removal of age hardened surface material and the removal of surface cracks, thereby preventing them from propagating into the lower structural layers of the pavement. When resurfacing is employed, this should be subject to the following further considerations.

- Where surface levels may be raised, the application of new surfacing directly onto an existing defective surface is not recommended.
- Where surface defects are minimal and treatment is mainly to rectify non structural defects such as skidding resistance or texture, a minimum depth of 40mm should be milled out prior to laying new surfacing. The actual planed depth will depend on factors such as whether the adjacent lanes also require resurfacing and the thickness of the surfacing layer.
- Where cracks or other defects are still apparent following planing, crack sealing or other localised treatments should be considered prior to laying the new surfacing. In the case of transverse cracks above joints or cracks in a lower hydraulically bound layer, these can be treated after local planing to the full depth of the crack or a minimum depth of 100mm prior to resurfacing.
- Where the extent of the existing defects in fully flexible pavements are more pronounced (such as more deeply cracked, fretted or rutted surfacing) or wheel tracking results (where undertaken) show potential for future surface rutting, a more robust inlay treatment should be used.

Details of asphalt surface treatments are given in HD 31 (DMRB 7.4.1).

6.3.2 Rigid pavements

Where finished levels permit, the preferred resurfacing treatment for rigid pavements is the application of new asphalt surfacing to the existing concrete surface. Treatments such as joint repairs should, however, be undertaken prior to the application of the surfacing. It is also vital to ensure a good bond between the concrete surface and the new asphalt layer. This surfacing method would, however, require the adjacent lanes to also be surfaced to maintain the pavement levels. Where this is not practicable or cost-effective, some form of mechanical treatment method may be considered (in addition to other localised treatment) to rectify surface defects.

Further guidance on the surface treatment of rigid pavements is provided in HD 32 (DMRB 7.4.2).

6.4 Strengthening

6.4.1 General

Where the overall evaluation process has identified that strengthening is required, due to weak material in the structural bound layers or to upgrade or convert the existing construction into a long-life pavement, the recommendation is to generally consider treatment by overlay or deep inlay. For strengthening of hard shoulders, overlay is unlikely to be the most appropriate option unless the adjacent lanes also require strengthening treatment and the physical constraints (such as overbridge clearances or barrier heights) are not a major issue. Furthermore, the quality of the existing layers should, in most cases, be at an acceptable level as the original pavement would be retained (except perhaps the surface course) together with all its defects. One exception on quality would be where tar-bound materials are encountered. In such cases it may be desirable to leave these in situ, even

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when in poor condition, to avoid the complications and costs of the proper disposal of this material (DMRB 7.3.3).

Where the most viable option (of overlay or inlay) is not clearly evident, the general strategy should be to provide designs for both (and if required for full depth reconstruction), and select the most feasible based on the lowest Whole Life Cost (WLC).

6.4.2 Overlay Design
Where strengthening is by overlay, it is generally necessary to remove defective aged surface material (and where needed carry out localised treatment) prior to overlaying. This process enables the removal of age hardened surface material and surface cracks, thereby preventing them from propagating into the lower structural layers of the pavement.

Flexible pavements
For flexible pavements the thickness of overlay should be determined by reference to the guidance provided in HD30.

Points to note include:

- Where appropriate, an overlay thickness should be selected to provide a total asphalt thickness equivalent to 300 mm of traditional DBM125 material. This should constitute an upgrade to a long-life pavement.
- It is possible to achieve a reduction in overlay thickness with the use of stiffer material, such as EME2, however, such decisions should be based on overall financial viability and other technical issues.

Rigid pavements
There are currently no HA standard methods available for determining the most appropriate thickness of asphalt for strengthening jointed or continuous concrete pavements.

HD 30 (DMRB 7.3.3) states that 15 mm of concrete is equivalent to 100 mm of asphalt for new CRCB pavement designs In some circumstances it may be appropriate to use this equivalence as a basis for a design approach for asphalt overlay to continuously reinforced pavements using the standard design (chart-based) approach in HD 26 (DMRB 7.2.3). It should be borne in mind, however that the equivalence does not specify the stiffnesses of the concrete or the asphalt in question, and that is suitability for use for in-service pavements has not been assessed.

The maintenance of jointed rigid pavements depend on the nature of the deterioration. The recommendations described in TRL Report 657 and set out in DMRB 7.3.3 are:

- For jointed unreinforced pavements with a degree of major defects (not sufficient to justify full depth reconstruction), the recommendation is to crack and seat (C&S) and overlay with a minimum of 150 mm. For jointed reinforced pavements the saw-cut, crack and seat method should be used which includes an additional preceding saw-cut stage to sever the steel at pre-set spacings;

- For jointed concrete pavements with no major structural defects, the recommendation is to undertake an asphalt overlay, with saw-cut and seal. The minimum suggested overlay thickness is 70 mm but this may need to be increased for heavily trafficked high stressed sites. Slab lengths in excess of the maximum effective length of 8 m should be treated to SCCS prior to overlay.

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In all of the above situations, any slab and/or joint defects should be rectified prior to applying the overlay. Details on concrete pavement maintenance are provided in HD 32 (DMRB 7.4.2).

Overlaid rigid pavements

In the case of overlaid continuous concrete pavements, a similar approach to overlaying *rigid pavements without overlay* (discussed above) can be adopted. However, some allowance will need to be given to account for the defects in the remaining asphalt.

For overlaid jointed concrete pavements, where the whole thickness of asphalt is in poor condition or reflection cracking is very severe, it may be cost-effective to remove the full depth the asphalt layers and consider maintenance options as for a rigid pavement. Where the thickness of asphalt precludes this, the pavement may be considered in the same way as a flexible pavement with HBM base.

6.4.3 Inlay Design

The replacement of structural pavement layers is termed inlay or partial reconstruction. Where strengthening is by inlay, the recommendation given in HD 30(DMRB 7.3.3) is to remove only those layers which are defective and to retain as much of the sound existing material as possible. HD 30 (DMRB 7.3.3) further states that:

> '*This will not only save materials and expenditure, but also provide a firm basis for the new layers. Retained layers should be left undisturbed. However, the dual constraints of finished pavement level and design thickness may require the removal of some sound material.*'

The amount of sound material removed may be minimised by using stiffer replacement materials such as EME2 where financially and technically viable.

Flexible pavements

The standard approach for designing structural inlays to flexible pavements is provided in HD30. Where total bound layer thickness permits, such pavements may be upgraded to long-life by use of deep inlays comprising an asphalt thickness equivalent to 300 mm of traditional DBM125 material.

Where the inlay thickness required to convert a flexible pavement with an asphalt base into a long-life pavement corresponds to removal of all of the bound layers, the design can be carried out using the appropriate standard (chart-based) approach in HD 26 (DMRB 7.2.3). In such cases it may be prudent to retain a thin layer of asphalt to protect the subbase and/or to enhance the foundation. In such cases the remaining material should be classed as part of the foundation. The resulting composite foundation stiffness should be obtained using the method provided in IAN 73 (draft HD 25).

In the case of inlays to flexible pavements with a HBM base, the structure may be converted to a long-life pavement by using a thickness of new asphalt inlay that provides an overall pavement structure that is consistent with an 80msa life according to the standard (chart-based) approach in HD 26 (DMRB 7.2.3). It may be necessary to treat cracks in the HBM base prior to laying the asphalt to reduce the risk of reflection cracking. Alternatively, crack and seat may be used.

Where the HBM base has been found to be severely deteriorated, consideration may be given to retaining all or part of the HBM and using it as part of the foundation for a new flexible pavement with an asphalt base. The design in such cases can be carried out using the standard (chart-based) approach in HD 26 (DMRB 7.2.3). The effective foundation class

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of the HBM base would need to be established using the method provided in IAN 73 (draft HD 25).

Rigid pavements
Occasionally, a pavement section falling within this category would require replacement. In such situations, the approach should be to replace with an appropriate pavement type using the procedure set out in HD 26 (DMRB 7.2.3).

Overlaid rigid pavements
Where the problem which prompted the need for strengthening is mainly due to defects in the asphalt, the pavement should be treated as per flexible pavements with an HBM base:

- Where a thick asphalt layer is present, it should be planed to the required depth and replaced.

- On thinner layers the preference should be to replace all the asphalt, with treatment of slab and/or joint defects undertaken prior to placing the asphalt.

Where the concrete also requires replacement, the approach should be to replace with the appropriate pavement type using the procedure set out in HD 26 (DMRB 7.2.3), followed by a suitable overlay to maintain the finished pavement level.

On jointed concrete pavements the recommendation would be to saw-cut and seal the overlying asphalt layers.

6.5 Reconstruction
The replacement of all the structural layers and at least some of the foundation is termed full depth reconstruction. The need for such reconstruction depends upon factors such as the structural adequacy of the layers including the foundation, due to existing deterioration or expected deterioration (due to future trafficking), and/or the adequacy of the existing layer thicknesses.

Where the investigation has revealed that full depth reconstruction is required, the design of the reconstruction can be carried out in accordance with advice in HD 26 (DMRB 7.2.3) and IAN 73 (Draft HD 25). The subgrade may need to be assessed to determine whether it provides a satisfactory platform for reconstruction, and if not, capping may also be required (DMRB 7.3.3).

The pavement type of the reconstructed hard shoulder does not necessarily need to be the same as that of lane 1. For example, the hard shoulder can be reconstructed to be a flexible pavement whilst lane 1 comprises of rigid construction. Nevertheless, it may be advantageous to use the same form of construction (at least in the base) to provide continuity across the carriageway width and so reduce the risk of compromising drainage paths. An exception to the use of different construction types on adjacent lanes is that a continuous concrete construction should not be used next to a jointed concrete construction.

It should be noted that when the standard design method in HD 26 (DMRB 7.2.3) is not appropriate then the alternative analytical approach set out in HD 26 (DMRB 7.2.3), may be used. For example, the standard design for flexible pavements with asphalt base assumes that the binder course is the same as the base. Where a variation to this is required then using the alternative analytical approach may be more appropriate.

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The options for the foundation types, methods for designing and testing regime are provided in IAN 73 (Draft HD 25). Options for the pavement types, their suitability, the permitted material and design are provided in HD 26 (DMRB 7.2.3). Further details on surfacing options are set out in HD 36 (DMRB 7.5.1) and also provided in HD 37 (DMRB 7.5.2) and HD 38 (DMRB 7.5.3). Details pertaining to composition, manufacture and laying are given in the MCHW1 Series 800, 900 and 1000 together with MCHW2 and in relevant material standards.

6.6 Value for Money

Value for money for hard shoulder maintenance under Fiscal Stimulus needs to be assured for each proposed scheme. Given the scale of the works and the delivery timetable, it is not practicable to undertake a full Value Management review, as currently undertaken on Roads Renewals maintenance schemes, on all HSR schemes. However, a simplified process that includes a form of peer review with representatives from the Managing Agent, NetServ (TSD), Major Projects and the HA Area Team will be adopted that assesses the proposed works on the same criteria as used for Roads Renewals maintenance schemes. The objective of this process will be to ensure that appropriate technical solutions are selected and that VfM is achieved. The peer review workshop will consider the overall benefits of undertaking the work and the appropriateness of different technical solutions including the deliverability and programming issues. The process will rank contending options and agree on a preferred option. For each hard shoulder strengthening scheme the need for routine maintenance in Lane 1 should also be assessed. If it is expected that Lane 1 would require maintenance in the next few years then a proposal which includes Lane 1 works should be brought forward as an option.

It is necessary to ensure that ***all*** proposed maintenance will provide the Agency with value for money. As part of this process, to assess the need for maintenance of the pavement, the maintenance of all other assets (e.g. drainage, structures, geotechnics, lighting) over the length of the scheme is also to be assessed.

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7. Consideration of other assets

Providing detailed design guidance for the following elements is outside the scope of this document. They are only included here with the intention of raising awareness on the importance of their consideration as part of the overall maintenance and construction process in the light of future HSR implementation.

7.1 Drainage

Drainage failure can cause severe damage to the various elements in the pavement structure (directly or indirectly) with the potential to even causing a complete pavement failure under traffic loading. It should be remembered that it would only take a one or two metre failed length of hard shoulder to prevent its use.

Hence, the location, layout and condition of the drainage should be considered as part of the overall HSR assessment process. The assessment should enable counter measures, such as modifications (e.g. relocation, extension etc.) and strengthening, required by HSR to be designed. Where extension of the drainage system is required, the design must ensure continuity of drainage, both in and below the pavement layers and across the carriageway. HA 43 (DMRB 4.1.7) provides some advice on drainage considerations associated with widening.

HA 39 (DMRB 4.2.1) provides advice on the use of various edge of pavement drainage types and HA 83 (DMRB 4.2.4) provides advice on the safety aspects of such edge drainage features. Some of the advice is relevant for HSR, such as the close proximity to of vehicles to filter drains.

7.2 Earthworks

The use of the hard shoulder as a trafficked lane is likely to increase the burden exerted on the adjacent geotechnical asset, especially as a result of vehicles travelling closer to the side slopes. Hence, the condition of these assets should be carefully assessed such that they can be suitably maintained and, where needed, to also enable appropriate modifications to be designed. HD 41 (DMRB 4.1.3) provides guidance associated with those aspects. HA 43 (DMRB 4.1.7) provides further advice on earthworks associated with widening.

7.3 Edge Strip Considerations

In circumstances where an edge strip is required to increase the width of the hard shoulder, the works can be undertaken in accordance with advice in Chapter 2 of the HD 27 (DMRB 7.2.4) which is on widening of existing pavements.

Chapter 2 of the HD 27 (DMRB 7.2.4) provides guidance on some of the pavement design, material and construction elements that should be considered where widening is proposed. However, it does not cover earthworks or general drainage associated with widening.

7.4 Emergency Refuge Areas

While outside the scope of hard shoulder maintenance works to be funded under fiscal stimulus, Emergency Refuge Areas (ERAs) will be required on motorways with HSR to accommodate vehicles stopping in an emergency and maintenance vehicles. Therefore, wherever practicable, their planned siting and provision should be considered when maintenance treatments are designed.

These lay-bys constitute new construction and should be designed as such. This includes consideration of earthworks, drainage, foundation design (IAN 73 – Draft HD 25) and new pavement design (DMRB 7.2.3). The structure will be expected to be similar to that of the hard shoulder for continuity with hard shoulder, drainage and so on.

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Given the nature of its use (parked vehicles), special emphasis should be placed on ensuring resistance to permanent deformation of structural layers. The surfacing should be a deformation resistant surfacing made with a proprietary fuel resisting binder.

7.5 ITS Services

Any work within the hard shoulder will impact on the availability of the ITS services used by the Highway Agency and other organisations because sensors in the carriageway will be damaged and power supply to adjacent equipment may be interrupted to allow safe working. The ITS services use a variety of technology systems deployed at the roadside. The nature, scale and impact caused by the loss of function of each type of roadside technology needs to be established at the detailed design stage of any works.

The potential impact can be:

- Permanent damage (i.e. things that will not work after the hard shoulder strengthening works is complete, for example detector loops will have been removed), and
- Temporary loss of service (i.e. services that will be unavailable during the roadworks because the power supply has been disconnected) that will arise due to the Hard Shoulder Strengthening work.

The table in Appendix C contains a list of the equipment or infrastructure likely to be impacted. The table is comprehensive but there may be additional equipment not listed that the designer will need to include. The table gives a theoretical discussion of the potential impact and possible mitigation of damage to typical road side infrastructure. Each scheme will be different as a different mix and quantity of technology systems will be present.

Each scheme may impact on a number of different users of technology systems. The primary impact will be on those systems operated by the Regional Control Centre (RCC), such as MIDAS and VMS. This is of particular importance because these systems have a role in road safety. The schemes may also impact on the operations of the National Traffic Control Centre (NTCC) in terms of data collection and information dissemination. Information Directorate are affected both from the NTCC perspective and because the data is used more widely across the HA. There may also be an impact on data collection for TAME and on the provision of ice detection information.

Non HA systems such as those used for data collection by DBFO Co and the DfT could also be significantly affected.

Scheme designers should correlate the HS Strengthening works with the location of ITS infrastructure on the network to create a scheme specific assessment of how the Hard Shoulder Strengthening works will impact on ITS Services.

Required Action

1. Scheme designer to undertake a survey of the technology that will be affected by the scheme as part of the detailed design and complete and record an assessment of the impact on the function of the technology systems.

2. Scheme designer to discuss results of survey with affected RCC, ID (Damian Morris) and other stakeholders (e.g. TAME, DfT Statistics Branch) the implications of the proposed disruption.

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3. Scheme designer to agree with project sponsor a strategy for avoiding or minimising disruption in the first instance, reinstatement and, if the loss of function is critical or the disruption has a long duration, what mitigation measures such as temporary equipment might be necessary.

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Appendix A List of HSR Schemes

A.1 Tranche 1 - HSR Schemes

ID	Scheme	MAC Area
1	M4 Jct 19 - 20 & M5 Jct 15 - 17	**2**
2	M4 Jct 3 – 12	J3 - 5 - **5**; J5 - 12 - **3**
3	M6 Jct 5 – 8	**9**
4	M60 Jct 8 – 12	**10**
5	M62 Jct 18 – 20	**10**
6	M62 Jct 25 - 30 (Jct 25 – 28 & Jct 29 - 30)	J25 - 28 & J29 - 30 - **12**; J28 - 29 - **27**
7	M1 Jct 23a – 25	J23a - 24 - **11**; J24 - 25 - **7**
8	M3 Jct 2 - 4a	J2 to MP 37 - **5**; MP37 - Jct 4a - **3**
11	M6 Jct 10a – 13	J10a - 12 - **9**; J12 - 13 - **11**
12	M6 Jct 15 - 19	J15 - 16 - **11** J16 - 19 - **10**
13	M6 21a - 26	**10**
14	M60 Jct 12 - 18	**10**
15	M62 10 - 12	**10**
16	M1 Jct 28 – 31	J28 - 30 - **7**; J30 - 31 - **12**
22	M27 Jct 4 - 11	**3**

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A.2 Tranche 2 - HSR Schemes

ID	Scheme	MAC Area
21	M3 Jct 9 – 14	3
23	M20 Jct 3 – 5	4
24	M23 Jct 8 – 10	4
25	M1 Jct 13 – 19	8
26	M5 Jct 4a – 6	9
27	M5 Jct 2 - 4a	9
28	M6 Jct 8 - M5 Jct 2	9
29	M6 Jct2 – 4	11
30	M6 Jct 13 - 15	11
31	M60 Jct 24 - 27 & 1 - 4 (incl link to M56 Jct 3)	10

A.3 Future HSR Schemes not being surveyed under rapid assessment

These schemes are sufficiently advanced as to not require surveys.

ID	Scheme	MAC Area
9	M25 Jct 5 – 7	5
10	M25 Jct 23 – 27	5
17	M1 Jct 10 – 13	8
18	M6 Jct 8 - 10a	9
19	M1 Jct 32 - 35a	12
20	M1 Jct 39 – 42	12

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Appendix B HARRIS data and calculation of SCI

HARRIS is a multifunction road assessment vehicle capable of outputting a range of different surface condition parameters. The parameters reported under the rapid assessment survey programme are as follows:

- **Crossfall** – a standard measure of transverse slope of road, equivalent to that delivered by a TRACS survey.
- **Profile** - 3m, 10m and 30m Enhanced Longitudinal Profile Variance (ELPV) – the standard measure of ride quality, equivalent to that delivered by a TRACS survey.
- **Texture** – Sensor Measured Texture Depth (SMTD) measured in the Nearside wheelpath, equivalent to that delivered by a TRACS survey.
- **Rutting** – The measure of rutting reported during a TRACS survey is calculated from the transverse profile by laying a 2m straight edge on the transverse profile data (in software). Unfortunately the rutting algorithms can be affected by the presence of features at the edge of the transverse profile that cause the straight edge to be placed incorrectly. This is not a problem on the vast majority of the trunk road network. However, it was found that that hard shoulders contained many features likely to cause errors in the measurement. Therefore a more simple approach was taken, known as the 3-point rut. This measure uses the height measurements recorded in the nearside wheelpath, offside wheelpath and at the centreline of the vehicle. The nearside rut is calculated as the difference between the heights of the centre and nearside wheelpath while the offside rut is calculated as the difference between the heights of the centre and offside wheelpath. The reported rut value is the average of the nearside and offside rut depths.
- **All Cracking** – A manual visual analysis was carried out on the downward facing video data provided by HARRIS to identify the location and extent of cracking on the hard shoulder. In this analysis a 200mm square grid was placed over the video images and any grid square containing a crack was recorded. The total area of cracking identified over each 100m length was summed. The value reported in the E1 form is the percentage of cracking present in any 100m length.
- **Longitudinal Cracking** – Any longitudinal cracks have been noted in the manual analyses and the length of longitudinal cracking in any 100m length is reported in the E1 form.

For the purposes of the maintenance classification process, it was necessary to devise an approach that would automatically assess each 100m length, based on the combination of the above surface condition measurements. An established technique was not available to provide this information. The approach taken was therefore to devise a score for each 100m length that combined the rutting, texture, ride quality and cracking information.

In the calculation of the SCI a score was obtained for each 100m length using the rutting, longitudinal profile variance, texture and cracking data.

Each parameter was scored as follows:

- If the parameter value is better than the lower threshold, its contribution is 0.
- If the parameter value is worse than the upper threshold set, its contribution is 100.
- Otherwise, the contribution is 100 x (upper threshold - parameter value)/(upper threshold – lower threshold)

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The thresholds used to obtain the score for each parameter are provided in Table B-1. These were derived from the thresholds and guidance levels for TRACS data given in HD 29.

Table B-1: SCI weightings and thresholds

Parameter	Lower threshold	Upper threshold	Weight
Rutting	10mm	20mm	1
3m ELPV	2.2mm^2	5.5mm^2	0.8
10m ELPV	8.5mm^2	23mm^2	0.6
30m ELPV	75mm^2	121mm^2	0.4
Texture	0.8mm	0.4mm	0.75
Cracking	0.45%	1.5%	0.8

The individual scores were then weighted (according to the significance of the parameter to the condition) and combined. Hence:

$$SCI = w_R \times S_R + \max(w_{3mELPV} \times S_{3mELPV} + w_{10mELPV} \times S_{10mELPV} + w_{30mELPV} \times S_{30mELPV}) + w_T \times S_T + w_C \times S_C$$

where, w represents the weighting and S represents the score for each parameter. Note that, to avoid placing disproportionate weighting on the variance data, only the maximum score from variance was used in the SCI (as shown above). The weightings used for each parameter are provided in Table B-1.

The resulting overall SCI is classified into three defined levels as shown below in Table B-2. For the purposes of the maintenance classification rationale, 100m lengths with an SCI greater than 40 were considered to require maintenance.

Table B-2: SCI classification levels

	Good	Moderate	Poor
SCI	<=40	>40, <100	>=100

The principle behind the SCI was derived from that developed for the road condition index (RCI) used in the SCANNER survey of local roads:

http://www.dft.gov.uk/pgr/roads/network/local/servicelevels/).

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Appendix C Summary of potential impact on Technology Systems

System	Description of Impact	Permanent or Temporary	Possible Mitigation	Stakeholders/Contact/Comment
MIDAS	Detector loops removed	Permanent	Contractor required to reinstate within 28 days of carriageway becoming open to traffic (to meet RWSC section 2.8)	RCC, ID(Damian Morris), ID(Roy Jones) Note that detection system will need re-tuning as well as reinstatement.
MIDAS	Loss of power to MIDAS outstations	Temporary	Loss of detector loops overrides this problem.	
Traffic data collection sites	Detector loops removed	Permanent	Contractor required to reinstate in a timescale agreed with stakeholder	ID (Roy Jones). Note that detection system will need re-tuning as well as reinstatement.
NTCC traffic data collection sites	Detector loops removed	Permanent	Contractor required to reinstate in a timescale agreed with stakeholder.	ID(Damian Morris), Note that detection system will need re-tuning as well as reinstatement.
DBFO Traffic data collection sites	Detector loops removed	Permanent	Contractor required to reinstate in a timescale agreed with stakeholder	DBFO Co Note that detection system will need re-tuning as well as reinstatement.
DBFO Traffic data collection sites	Loss of power to DBFO Traffic data outstations	Temporary	Loss of detector loops overrides this problem	
DfT Core census data collection sites	Detector loops and other sensors feeder cables removed	Permanent	Contractor required to reinstate in a timescale agreed with stakeholder	DfT Statistics Branch (contact Andy Lees) Note that detection system will need re-tuning as well as reinstatement.
DfT Core census data collection sites	Loss of power to DfT Traffic Data outstations	Temporary	Loss of detector loops overrides this problem	
HA ice detection system	Sensors and sensors feeder cables removed	Permanent	Contractor required to reinstate in a timescale agreed with stakeholder	National Winter Team (John Wainwright) System operated and maintained by specialist contractor (Viasala TMI Ltd)
HA ice detection system	Loss of power to ice detection system outstations	Temporary	Loss of sensors overrides this problem	
Weather Stations	Damage to equipment/ cabling by contractors plant during work.	Permanent	Contractor to ensure stations are undamaged and working at works completion and to make good if not.	National Winter Team (John Wainwright) Most stations are against boundary so not expected to be damaged.
Weather Stations	Loss of power	Temporary	Inform system owners that they may suffer a degradation in data.	National Winter Team (John Wainwright)

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System	Description of Impact	Permanent or Temporary	Possible Mitigation	Stakeholders/Contact/Comment
NTCC ANPR sites	Re-alignment of traffic lanes during Traffic Management will reduce system effectiveness	Temporary	Assess loss of service, Realign ANPR cameras for duration of Traffic Management. Contractor required to agree with stakeholder timing and method for re-alignment.	ID (Damian Morris)
Other ANPR	Re-alignment of traffic lanes during Traffic Management will reduce system effectiveness	Temporary	Inform system owners that they may suffer a degradation in data. Contractor required to agree with stakeholder timing and method for re-alignment.	Stakeholder will need to be identified on a case by case basis
Emergency Roadside Telephones	No hard shoulder available so will not be in use	Temporary	Contractor may have to provide free recovery service and CCTV monitoring	RCC
Cantilever VMS signs (e.g. MS3 and MS4)	There may be a need to isolate the electricity for safety reasons. However, power should be kept on to prevent condensation within signs.	Temporary	Safe method of working with power at signs to be used by Contractor as far as possible. Designer to confirm to stakeholder the extent that sign will remain active and usable.	RCC, ID(Damian Morris),
Cantilever VMS signs (e.g. MS3 and MS4)	Damage to signs/ cabling by contractors plant during work.	Permanent	Contractor to ensure signs are undamaged and working at works completion and to make good if not.	RCC, ID(Damian Morris),
Gantry mounted signs (e.g. MS2, AMI, LCS)	There may be a need to isolate the electricity for safety reasons. However, power should be kept on to prevent condensation within signs.	Temporary	Safe method of working with power at signs to be used by Contractor as far as possible. Designer to confirm to stakeholder the extent that sign will remain active and usable.	RCC, ID(Damian Morris),
Gantry mounted signs (e.g. MS2, AMI, LCS)	Damage to signs/ cabling by contractors plant during work.	Permanent	Contractor to ensure signs are undamaged and working at works completion and to make good if not.	RCC, ID(Damian Morris),
CCTV	Power expected to be turned off to allow safe working in the area	Temporary	Contractor to provide temporary CCTV	RCC, ID(Damian Morris), Most CCTV masts are at junctions and position well away from carriageway so physical damage is not expected.
Ramp Metering	Detector loops removed	Permanent	Contractor required to re-instate in a timescale agreed with stakeholder.	National RM Maintenance Contractor (Peek)
Ramp Metering	Loss of power to Ramp Metering outstations and signal heads	Temporary	Loss of detector loops overrides this problem	

Interim Advice

System	Description of Impact	Permanent or Temporary	Possible Mitigation	Stakeholders/Contact/Comment
Communications	Cable damaged during works	Permanent	NRTS to provide temporary cabling for duration of works. Contractor required to reinstate in a timescale agreed with stakeholder.	RCC, ID(Damian Morris), NRTS
Communications	Loss of power to transmission equipment	Temporary	Temporary generator or battery packs.	RCC, ID(Damian Morris), NRTS A risk where cable ducts are close to carriageway or run through transverse ducts.

Interim Advice