MEASURING PAVEMENT CONDITION

OFFICE OF RAIL AND ROAD

MAY 2018

FINAL REPORT

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CONTENTS

Glossary

AADT	Annual Average Daily Traffic
ARRB	Australian Road Research Board
AC	Asphalt Concrete
BCD	Base Condition Data
CVI	Coarse Visual Inspection
DBFM	Design Build Finance Maintain
DBFO	Design Build Finance and Operate
DRD	Danish Road Directorate
DVI	Detailed Visual Inspection
FWD	Falling Weight Deflectometer
GPR	Ground Penetrating Radar
HGV	Heavy Goods Vehicle
HMDIF	Highways Maintenance Data Interchange Format
IRI	International Roughness Index
KPI	Key Performance Indicator
LCMS	Laser Crack Measurement System
LEM	Life Extending Maintenance
MPD	Mean Profile Depth
NMM	Highways England Network Management Manual
OCI	Overall Condition Indicator
OMM	Highways England Operational Metrics Manual
PI	Performance Indicator
PS	Performance Specification
PSMC	Performance-Specific Maintenance Contracts
RAMSSHEEP	Reliability, Availability, Maintainability, Safety, Security, Health, Environment, Economics, Politics
RCI	Road Condition Index
RIS	Road Investment Strategy
RWS	Rijkswaterstaat
SCANNER	Surface Condition Assessment for the National Network of Roads
SCRIM	Sideway-force Coefficient Routine Investigation Machine
SMTD	Sensor Measured Texture Depth
SRN	Strategic Road network
TfL	Transport for London
TRN	Trunk Road Network
TRACS	TRAffic-speed Condition Survey
TRASS	TRAffic-speed Structural Survey
TSD	Traffic-Speed Deflectometer
TS RCI	Transport Scotland Road Condition Index

1.   EXECUTIVE SUMMARY

The Office of Rail and Road (ORR) has commissioned CEPA and TRL to consider how pavement condition metrics are designed and measured across road networks managed by several organisations that are in some way comparable to Highways England. Those organisations studied include two local authorities (LAs), Transport Scotland, the Welsh Government and selected European nations and other developed countries.

ORR requested that our research into the comparators considered:

- *Methodology and approach* used to measure pavement condition (including the elements of condition measured, and the reporting and monitoring of this data).
- How any pavement condition *targets* are set.
- How performance against any *metrics is incentivised*.
- Any incentives contractors have to *influence performance*.

This study provides ORR with an understanding of:

- the different approaches taken to measuring and monitoring pavement condition;
- the data that might be available to benchmark Highways England against pavement condition metrics used in other jurisdictions ahead of RIS2.

Major findings

Our research reveals that of the road management agencies studied, most measure similar pavement characteristics using similar equipment and techniques. Nonetheless, there are differences of detail in the approaches taken by organisations in the comparator set. One of those differences is that Highways England measures pavement condition more often than any other road management agency and surveys more lanes than any of the comparators.[1]

Financial incentives to drive performance are not widely used across the comparator group. Road management agencies are not generally made subject to any such incentives by their respective external overseeing authority. The most common types of financial incentive are therefore those included in third-party contracts and are either symmetric (reward and penalty) or asymmetric (penalty-only) and are used to incentivise work quality, e.g. ride quality, rather than good overall network condition.

The LAs, Transport for London (TfL) and most other countries studied have indicators in place to monitor pavement condition for internal management and planning purposes. However, only a few comparators have developed these into formal performance metrics. Only some have targets to monitor performance over time. Pavement condition data is widely used to help plan maintenance work, rather than as a monitoring tool or to drive performance through financial incentives. Where they exist, the detail of other road management

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[1] We note that TfL carries out SCANNER surveys (similar to Highways England's TRACS) on 100% of the network annually and SCRIM surveys on 100% of Lane 1 annually. This is very similar to Highways England's coverage and frequency for these two surveys.

authorities' pavement metrics differs to those used by Highways England. This makes comparison difficult, but our research indicates that of the organisations studied, the LAs, TfL and the Netherlands are the most comparable to Highways England and might permit some form of benchmarking if the data underlying current measures could be obtained and analysed.

Local Authorities and TfL

Although the LAs and TfL measure similar pavement condition characteristics to Highways England, the metric used to summarise condition for LAs and TfL (i.e. the Road Condition Index) is not directly comparable to that used by Highways England (i.e. KPI8[2]). Nevertheless, some of the underlying pavement condition data collected by the LAs and reported to the Department for Transport (DfT) can be compared to Highways England (see discussion in Section 5.3.1) although we note that the thresholds currently used to categorise pavement condition differ between these organisations.[3] As such, the only measure that appears to be directly comparable on a like-for-like basis is 'the percentage of lane length surveyed that falls under Category 4 ('red rating') for surface condition'.

Notwithstanding the current lack of direct comparability, additional aspects of pavement condition could be compared in the future if the underlying data or techniques used to monitor pavement condition and the thresholds used for different asset classifications were made more consistent across LAs and Highways England. Modifying the thresholds that result in a different classification for comparable roads might be a first step towards improving comparability and establishing a benchmark.

The Netherlands

The Dutch pavement condition metric is on the face of it quite similar to Highways England's KPI8, but a direct comparison cannot be made on a like-for-like basis because the Dutch metric includes different components, sets different intervention levels for maintenance and measures skid resistance differently. For the two metrics to be comparable, the measured values for each aspect of condition on one network would need to be converted to the scale of values used for the other network and the same indicator then calculated for both networks or the two indicators would need to be related on a common scale. Neither of these approaches is entirely straight-forward. A more detailed assessment of the comparability between the approaches used by Highways England and the Netherlands can be found in Section 5.3.2.

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[2] In RIS1, KPI8 is the 8th key performance indicator (KPI) out of a total of 11 forming the Performance Specification for Highways England. The KPI for pavement condition (KPI8) is measured as the percentage of the network that needs no further investigation for possible maintenance.
[3] DfT publishes data for London boroughs which is provided by Road2010 condition surveys via the London Borough of Hammersmith and Fulham. The latter manages these surveys on behalf of TfL. However, DfT does not publish an RCI figure for TfL as a management authority. Due to changes in funding, TfL does not calculate the RCI for its network.

2. INTRODUCTION

Highways England is responsible for operating, maintaining and improving the Strategic Road Network (SRN) in England. The Office of Rail and Road (ORR) undertakes the on-going monitoring of Highways England's performance by observing and reporting on the performance required in the Performance Specification which forms part of the Road Investment Strategy (RIS). The RIS includes efficiency and operational performance targets, as well as investment requirements.

As part of the first Road Investment Strategy (RIS1), one of the metrics Highways England is formally assessed against is KPI8, the key performance indicator (KPI) for pavement condition, measured as *the percentage of the network that needs no further investigation for possible maintenance*. Currently, outputs and funding for the second RIS (RIS2) are being determined, and the Performance Specification is being reviewed and revised.

ORR has commissioned CEPA and TRL to consider how pavement metrics are designed and measured across several organisations that are comparable to Highways England, including Local Authorities (LAs), Transport Scotland, the Welsh Government, selected European nations, and other developed countries.

The objective of this work is to assess what other road management agencies do in terms of measuring and monitoring pavement condition, and the extent to which this can be compared to the approach adopted by Highways England.

This study provides ORR with an understanding of the different approaches taken to measuring and monitoring pavement condition across the UK and beyond and may also assist in the preparations for RIS2 and the revised performance specification requirements for pavement condition.

2.1. Structure of the document

The remainder of the document is structured as follows:

- **Section 3** gives an overview of our approach.
- **Section 4** contains a case study on how Highways England measures pavement condition.
- **Section 5** provides a comparison between Highways England and the organisations identified for analysis.

The annexes contain the detail underpinning our approach and analysis, as follows:

- **Annex A** contains our detailed case studies.
- **Annex B** contains a summary of the approach to reporting the condition of Local Authority roads in England (i.e. the SCANNER Road Condition Index (RCI) methodology).

3. PROJECT APPROACH

3.1. Approach

To meet ORR's requirements we split our analysis into two stages, as shown below, which is discussed in the subsequent sections.

Figure 3.1: Overall project approach
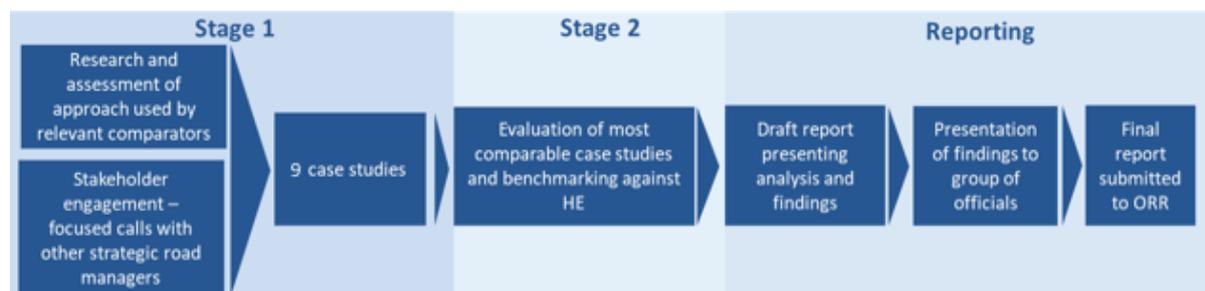
Stage 1

The first stage of the project involved:

1) Researching the approach to pavement condition measurement used by relevant comparators in other geographical locations; and

2) Developing a case study for each comparator.

With input from ORR, we drew up a list of road management agencies that would potentially be comparable to Highways England. Engagement with each comparator was undertaken to supplement our desk-based analysis. This allowed us to gain further perspectives and experiences from those organisations that were willing to assist with the study. The list of case studies with the associated provider and types of road network is set out in Table 3.1.

We created a standardised case study template that we used to collate our research on each comparator in a consistent manner to facilitate comparison with Highways England. This covered:

- Road network characteristics;
- Approach to managing the road network;
- Methodologies used in measuring pavement condition;
- Setting of targets;
- Use of incentives;
- Role of contractors in the management of network performance; and
- The potential for incentives to contractors to influence performance.

Table 3.1: Case study jurisdictions

Jurisdiction	Provider
Australia	Australian Road Research Board (Motorways and Freeways)
Austria	Asfinag (Motorways and Expressways)
Cornwall Council	Cornwall Council (Local Road Network)
Denmark	Danish Road Directorate (State Road Network);
Netherlands	Riijkswaterstaat (National Roads)
Scotland	Transport Scotland (Trunk Road Network)
South Lanarkshire Council	South Lanarkshire Council (Local Road Network)
London	Transport for London (Local and Trunk Roads)[4]
Wales	Welsh Government (Trunk Road Network)

By the end of Stage 1 we had developed a set of nine case studies which focus on the approaches taken by the other organisations and brought together our in-house knowledge, desk-based research, and input from stakeholder engagement.

Stage 2

In stage 2, we assessed the comparability of the case studies with the current approach adopted by Highways England by considering the following questions:

1. Is the comparator's network similar to the Highways England network?
2. What is measured?
3. How is the information used?
4. What performance metrics and targets are there to measure performance over time?

Each case study was initially evaluated at a high level with each of the questions, being awarded one of four possible categorisations ("yes", "to a considerable degree", "somewhat", "no"). The results of the nine case studies were then evaluated in more detail in order to draw out key points of similarity and difference between Highways England and each comparator.

We then specifically consider pavement condition reporting for those organisations that are sufficiently comparable to Highways England.

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[4] We note that TfL is currently reviewing its practices and was only able to provide limited information on what it does at the moment or intends to do in the future with regards to pavement condition. TfL noted that DfT no longer funds the TfL asset management/maintenance activities and no central government funding is used for the London strategic road network. Therefore, condition monitoring for proactive maintenance is no longer required by DfT and TfL now operates a safety risk-based approach and is delivering only minor interventions where necessary and the RCI is not available for the network. **However, we know that in the recent past, TfL did have some performance metrics in place based on annual condition surveys and we report on that.**

4. CASE STUDY ON HIGHWAYS ENGLAND

This section:

- Provides background on the SRN in England;

- Discusses the management of SRN condition;

- Explains how pavement condition is measured by Highways England; and

- Describes the pavement condition metrics used by Highways England and which form part of the Performance Specification.

This information forms the basis of the comparisons made with the other organisations. More detail on the comparators is given in ANNEX A.

4.1. The Strategic Road Network

The SRN comprises motorways and all-purpose trunk roads in England, totalling almost 7,000km (with approximately 35,000 lane km), as well as a range of supporting physical assets including bridges, earthworks, drainage, fencing, signage, lighting and a wide range of technology. Whilst the SRN makes up less than 3% of the total length of all roads in England, it carries a third of all traffic miles and two thirds of heavy goods traffic. The following table provides approximate network lengths.

Table 4.1: Description of the SRN

		Approximate Carriageway Length (km)
Main Carriageways (km)	**Dual 2 Lane**	6,198
	Dual 3 Lane	4,395
	Dual 4 Lane	581
	Dual 5 Lane	11
	Dual 6 Lane	4
	Single 1 Way	28
	Single 2 Way	1,297
Slip Roads (km)	**Motorway**	1,443
	All Purpose Trunk Road — **Dual or Single 1 Way**	1,171
	Single 2 Way	46
Managed motorways	**Hard shoulders**	98

Source: CEPA based on Highways England publications

Around four million vehicles per day travel on the SRN, and 2017 saw around 92 billion miles driven in total on the network[5], making it a crucial national asset. Motorways carry the most traffic, with an average flow[6] of 87,800 vehicles/day. The busiest motorway i the M25, between the A1(M), and M23, which on average carries 214,000 vehicles/day.

According to Highways England's Pavement Management System[7] approximately 61% of the network is surfaced using a Thin Surface Course System, 32% with hot rolled asphalt (HRA)[8]. The remaining 7% is made up of concrete, High Friction Surfacing and other materials.

4.2. Management of roads and pavement condition

Highways England has been given more freedom to operate on a day-to-day basis. ORR's monitoring of Highways England is part of the governance system that holds it to account. Within this, ORR monitors Highways England's management and reporting of road condition data.[9]

The SRN is split into six regions each made up of two areas. Eight of these are each managed by an Asset Support Contractor and four areas are managed by internal Highways England Asset Delivery Teams[10]. Highways England commissions road network condition surveys centrally for all of the areas. Data from these surveys is used with locally collected data (from coarse visual inspection (CVI) and detailed visual inspection (DVI) surveys) to identify lengths of carriageway in need of maintenance. Capital renewal investment for maintenance is prioritised through a value management process. Funding is allocated on a regional basis and how this budget is spent is the responsibility of each region. Proposed maintenance schemes are technically assessed, and approved schemes are developed into a renewals maintenance programme for each region.

In addition, there are 11 DBFO (Design, Build, Finance and Operate) companies[10] responsible for the operation and maintenance of parts of the SRN. Each company takes responsibility for the roads contracted to it. The Highways England network condition surveys include the DBFO roads but each DBFO company also commissions its own surveys (to a specification set by Highways England), often using the same survey contractor as Highways England. The DBFO companies have responsibility for maintaining the roads to levels prescribed in each DBFO contract and will carry out maintenance and specified improvement schemes to achieve this.

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[5]https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/666857/Strategic_Road_Ne twork_Initial_Report_Overview.pdf - page 2
[6] Traffic flow is the rate at which vehicles pass through a specified point on a road in a given time period. It is typically presented in terms of vehicles per day.
[7] Data extracted in February 2018
[8] All permanent lanes, section functions and areas (including DBFOs) are scored in the Highways England Pavement Management System (HAPMS) in February 2018.
[9] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/674584/road-conditions-technote.pdf
[10]https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/677493/s170085_Network _Manangement_Map.pdf

4.3.   Measuring pavement condition

The general approach to pavement condition assessment comprises consideration of:

- structural condition;
- surface unevenness; and
- surface skid resistance.

Highways England uses the:

- TRAffic-speed Condition Surveys (TRACS) for surface condition;
- Sideway-force Coefficient Routine Investigation Machine (SCRIM) to measure skid resistance; and
- Traffic Speed Deflectometer (TSD) for TRAffic-speed Surveys of Structural condition (TRASS).[11]

<u>TRACS</u>

TRACS was developed to provide a consistent surface condition measure that was not disruptive to traffic on the SRN. The survey uses laser-based methods to assess the shape and texture of the pavement surface at the speed of the road traffic, as well as recording video footage of the road to measure defects such as cracking. Since 2000, Highways England has commissioned TRACS to be carried out by independent contractors (each contract has been for a period of around five years). The TRACS data is processed and provided to Highways England in a format that allows it to be uploaded to the Highways England Pavement Management System (HAPMS). The data has several applications including maintenance scheme design, network condition reporting and technical assessment of maintenance proposals as part of value management.[12]

The surveys measure and collect data on the following:

- Road geometry (gradient, crossfall, curvature) using inertial systems;
- Transverse profile, using a laser scanner, from which rut depths are calculated;
- Longitudinal profile in two lines lying in the wheelpaths, using laser measurements, from which ride quality parameters (with 3m, 10m and 30m wavelengths) are calculated;
- Pseudo longitudinal profile, using a laser scanner, from which parameters indicating where users would experience a bump-like sensation e.g. from a pothole, are calculated;

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[11] Data from TRASS, using a relatively new machine, is not currently included in network condition reporting in England, because the measurements and analysis results are not yet considered sufficiently reliable.
[12] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/674584/road-conditions-technote.pdf

- Texture profile, measured using a laser system in a single line in the nearside wheelpath, from which SMTD (sensor measured texture depth) and MPD (mean profile depth) are calculated;

- Pseudo texture, measured in 200 longitudinal lines spread evenly across the width of the lane, using a laser scanner, from which a fretting (i.e. breaking up of the surface) parameter is calculated;

- Images of the pavement surface, which are automatically analysed to estimate the amount of cracking present;

- Forward-facing images from the cab of the survey vehicle;

- Retro-reflectivity of road markings, from the whole width of the lane;

- Ground penetrating radar (GPR) data, from which layer thickness and pavement material can be obtained (these surveys commence in 2019-20).

The majority of the Highways England network is surveyed each year, covering mainline (running lanes), the hard shoulders on managed motorways and half of the slip roads. Every lane is surveyed on the main carriageway, whilst only one lane is surveyed on slip roads (Lane 1).

Skid resistance

Highways England currently uses SCRIM to measure the road surface's contribution to the friction that develops between vehicle tyres and the road surface when vehicles are accelerating, braking or cornering. Measurements are taken after the road has been wetted by the survey vehicle, at a vehicle speed of 80km/h on the SRN. This is undertaken every year for the whole length of the most heavily trafficked lane (usually Lane 1, the inside lane), as well as slip roads and roundabouts. Some DBFO companies also follow this approach, but others are required to survey their network every three years (but do three surveys in that year) and some (e.g. M25) have a requirement to survey additional lanes.

Skid resistance surveys are tendered on the basis of four separate regional contracts (South West, South East, Midlands and North). Each contract usually has a duration of three years, with an option to extend to five. Currently, all four regions are surveyed by the same contractor.

Traffic Speed Deflectometer (TSD)

Before the introduction of TRACS in 2000, Highways England carried out comprehensive surveys of the network using the Deflectograph. This vehicle surveys at about 2.5km/h, and thus requires road closures for surveys. One-fifth of lane 1 of the network was surveyed each year (i.e. aimed to achieve complete network lane 1 coverage in five years). The survey speed was considered too slow for acceptable levels of safety and the need for improved coverage by the survey. Highways England no longer carries out this routine survey and instead makes only targeted investigations with the Deflectograph where other surveys (e.g. TRACS) indicate

a requirement for further investigation. Other national road administrations in the UK (e.g. the Welsh Government and Transport Scotland), still carry out routine Deflectograph surveys of the complete network (lane 1). The Deflectograph has been replaced by the Traffic Speed Deflectometer (TSD).

The TSD has been introduced to carry out network structural condition surveys at traffic speed. The TSD is owned by Highways England but operated by a contractor. The current contract lasts for three years, with an option to extend. The TSD measures the slope of the road surface as it deflects under a loaded wheel (i.e. as the vehicle moves along the road). Surveys are carried out annually for 100% of Lane 1 and Lane 2 of the main carriageways on the network and for 50% of Lane 1 on slip roads. This data is then reported and combined with details of the pavement structure to determine the Network Structural Category (NSC) for the structural strength for each 100m of the pavement.

Ground penetrating radar (GPR)

GPR equipment is installed on the TSD, to measure the pavement type and thickness with the pavement strength for Lanes 1 and 2 of the mainline carriageway and Lane 1 of slip roads.

The current TRACS contractor is also required to collect pavement structure data on the outer lanes of mainline carriageways (in 2020). This data will be used to check the accuracy of pavement construction data currently stored in HAPMS.

Frequency of measurement

The following table sets out the frequency and extent of measurement for each survey type for the part of the SRN managed by Highways England.

Table 4.2: Summary of frequency of measurement by survey-type

Survey	Frequency of measurement					
	Lane 1	Lane 2	Outer lanes (for >2 lane carriageways)	Slip roads (Lane 1)	Roundabouts	Hard shoulders (Managed Motorways)
TRACS	Annual	Annual	Annual	50% per year	N/A	Annual
SCRIM	Annual[13]	N/A	N/A	Annual	Annual	N/A
TSD	Annual	Annual	N/A	50% per year	N/A	N/A
GPR	Annual (TSD)	Annual (TSD)	Every 5 years (TRACS)	50% per year	N/A	N/A

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[13] It is the most heavily trafficked lane. This is usually Lane 1.

4.4. Targets and Performance

Highways England uses the condition data that these surveys collect as the basis for a KPI. Its Operational Metrics Manual[14] describes the KPI for pavement condition as the percentage of the network that needs no further investigation for possible maintenance. The KPI is based on the condition of each 10m length of Lane 1 of main carriageway (i.e. not lay-bys, slip roads, link roads or roundabouts) on the network and excludes the part of the network managed as a part of DBFO concessions as Highways England has no direct control of maintenance works undertaken on these roads.

The condition of the pavement for the KPI is measured as part of annual TRACS and skid resistance surveys of Lane 1 of main carriageways (non-DBFO parts only). The data from these two surveys, describing rutting, (3m, 10m and 30m wavelength) longitudinal profile and skid resistance, are used to assess the condition of each 10m length of the network.

Four categories are used to define the pavement condition measured by TRACS:

1. Category 1: No visible deterioration;

2. Category 2: Low level deterioration and no action required;

3. Category 3: Moderate level of deterioration and investigation is required; and

4. Category 4: Severe level of deterioration and investigation is required at the earliest opportunity.

For skid resistance the Investigatory Level is equivalent to Category 3 (i.e. the condition is to be investigated).

The target for the KPI is to maintain 95% or above of the network (Lane 1) at a level where further investigation is not required for each year of RIS1 (defined as Category 3a[15] or better).[16] The percentage of pavement that did not require further investigation in 2016/17 was 94.3%, an improvement on 92.3% in 15/16, but below the targeted 95% level.

The following condition measurements are also made as part of the TRACS contract but are omitted from the KPI analysis:

- Texture depth data is not used in the analysis because data for other aspects of the pavement (e.g. pavement surface type) need to be considered when interpreting the results of texture depth measurements and the data for those aspects is not considered sufficiently reliable for use on the entire network.

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[14] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/678303/OMM_Minor_-_PDF_Final_January_2018_.pdf

[15] Category 3a is mid-way between Categories 3 and 4. For skid resistance, the Category 3a threshold is given by (Intervention Level – 0.05)

[16] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/678303/OMM_Minor_-_PDF_Final_January_2018_.pdf

- Lane Fretting has only recently been included in surface condition surveys and is not included in the analysis because, currently, the thresholds for this aspect of condition have not been formally defined (there are only guidance levels available).

- Cracking has also only recently been re-introduced into surface condition surveys so only guidance levels, rather than defined required levels, are available.

- The Bump Measure is not used in the analysis because it only identifies whether or not there is a 'bump' in the 10m length so is not a continuous measure of condition (e.g. there may be one or more bumps in the 10m length) and the count does not categorise the bump measurements. (These measurements started in 2017).

- Noise levels derived from the texture measurements are an indication of the noise caused by the pavement surface but do not meet the standard noise assessment procedure for the road surface so are not a reliable measure for a network performance report.

Outputs and funding for RIS2 are currently being determined, and the Performance Specification is being revised so the measures and the responsibilities for undertaking survey work may change. Highways England manages road maintenance and renewals through contractors in eight areas and in-house in four areas. The contractor undertakes routine repairs where required and develops the annual renewal programme using the network level and locally collected condition data.

Since 2016 Highways England has been working towards changing the way the network is managed through the process of bringing selected operational roles in-house, as existing contracts expire[17]. Suppliers are still used for certain services, but Highways England teams identify repairs and develop the renewals maintenance programme, something previously done by contractors (but reviewed and approved by Highways England), with the aim of improving efficiency and reducing network disruptions.[18]

The table below provides a summary of Highways England's approach to pavement condition measurement.

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[17] This has only happened in 4 of the 12 areas so far.
[18]
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/666884/Highways_England_Strategic_Road_Network_Initial_Report_-_WEB.pdf

Table 4.3: Summary of Highways England's approach to pavement condition measurement

Area of interest	Description
Summary of techniques used by Highways England	• **TRACS** – used to measure different elements of pavement surface condition. • **SCRIM** – measures skid resistance. • **TSD** – measures the (structural) strength (expressed as the Network Structural Category) of the road pavement**.** • **GPR** – data used in combination with TSD measurement in the identification of the Network Structural Category (NSC) • **Deflectograph** - measures the pavement deflection (to show the pavement strength); used for targeted investigations only when the other surveys indicate that further investigation is needed.
Metric construction	• Data on the surface condition and skid resistance of the pavement on the network is used. Not all of the network can be surveyed in a year for a range of reasons, so the length examined is less than the total length of Lane 1 on the SRN (but the annual data coverage is high at >96%). • The condition of each 10m length of Lane 1 of the main carriageways is identified using a variety of defects (rutting, 3m, 10m and 30m longitudinal profile, and skid resistance). All defects in each 10m length must be in better condition than Category 3a for the 10m length to be considered as good condition for the KPI analysis. The total length without condition data is assumed to be the same condition (i.e. the percentage length in good condition) as the part of the network with condition data • The targeted condition is for 95% (or more) of Lane 1 to be in good condition (i.e. condition better than Category 3a) for the KPI. Anything worse than Category 3a is deemed to require further investigation (i.e. in poor condition for the KPI). • Records of completed maintenance are entered into HAPMS. Any 10m length that has been maintained since the condition survey is assumed to be in better condition than Category 3a. • The overall % of the network not requiring further investigation is calculated as **(Total length of network data not requiring further investigation / Total lane 1 length of the network) *100**
Target in place	• Maintain the amount of SRN not requiring further investigation at 95% or above (target in place for each year of RIS1). • Does not include areas of the SRN where DBFO contracts are in place, therefore includes only those roads in the SRN where Highways England has direct control of the maintenance undertaken.

Source: CEPA

5. ASSESSMENT OF COMPARABILITY OF CASE STUDIES

In this section we assess how comparable the countries/LAs are to Highways England in terms of pavement condition measurement and use of condition reporting. To do so, we have considered the following:

1. A summary of the similarities and differences between the country/LA networks and the Highways England network.

2. What is measured? Does the country/LA use the same techniques and tools as Highways England to assess pavement condition?

3. How is the information used? Are there financial incentives to drive performance? How is the information used to plan maintenance?

4. What performance metrics and targets are there to measure performance over time?

We have used a four-point scale to assess comparability to Highways England. The scale is, 'Yes', 'To a considerable degree', 'Somewhat' and 'No'.

5.1. Pavement condition measurement

1) Network similarities and differences

Table 5.1 overleaf compares the similarity of the network characteristics of the road management agencies studied. The network types managed by the national organisations are most similar to the SRN in England. For TfL and the LAs considered, the A-roads are the most similar to the SRN in England but even the A-roads carry lighter, local traffic than the SRN. Many A-roads and more of the lower hierarchy LA roads are evolved rather than designed so they are less consistent in terms of performance than the SRN. Most LA rural roads have no edge support (i.e. to stop vehicles running off the side of the road) so are vulnerable to edge deterioration (the road edge breaks) and this is a major cause of maintenance for LAs (especially on the B, C and Unclassified hierarchy roads). The comparison for the Cornwall, TfL and South Lanarkshire road networks addresses mainly the A-roads.

The Netherlands has the most similar network to Highways England, in terms of characteristics. The network lengths, climates, and traffic levels are comparable but the surface materials (i.e. mainly Porous Asphalt) used in the Netherlands is not used by Highways England.

The A-roads in Cornwall are similar to the SRN but the traffic levels in Cornwall are lower and the pavement structure of the A-roads in Cornwall is less consistent (i.e. many are evolved roads). Exact network length, traffic volume and surface material information for TfL is not currently known, although the length is much shorter than the SRN. The volume of traffic for Principal Roads in the TfL network are high (compared to most other local roads) but are lower than the heaviest trafficked parts of the SRN.

Table 5.1: Is the network of the comparator similar to that of Highways England?

Australia	Austria
NO Highways England network length is much shorter (and less dispersed), traffic volume is much higher, and the climate is very different compared to Australia.	**NO** Network length and traffic volumes are lower than Highways England, and pavement type is different.
Cornwall	**Denmark**
TO A CONSIDERABLE DEGREE The traffic on this network (i.e. A-roads) is more local than on the Highways England SRN. The SRN carries much higher levels of traffic. The networks have generally the same climate, the network length (all road types in Cornwall) is similar (length of A-roads is much shorter than the SRN) and the pavement surface materials are similar.	**SOMEWHAT** The Danish network length is shorter, and the traffic is lower but climate and surface materials are similar.
Netherlands	**Scotland**
YES Similar network length, traffic level and climate. The surface material in the Netherlands is generally Porous Asphalt but this is not used by Highways England. Porous asphalt generally has a shorter life than the surface materials used by Highways England.	**SOMEWHAT** Network length is shorter and traffic level is lower but, climate and surface materials are similar.
South Lanarkshire	**Transport for London**
NO The South Lanarkshire network length and traffic volumes are much lower than Highways England. It also carries local traffic rather than the SRN in England.	**NO** Length and traffic volume values are lower than Highways England. Climate is similar. Road surface materials for Principal Roads are similar (i.e. Thin Surfacing) but may use different proprietary types. For lower hierarchy LA roads surface dressing is used but this is not used by Highways England.

Wales
SOMEWHAT   Network length is shorter and traffic volume is lower but, climate and surface materials are similar.

Source: CEPA

Denmark, Scotland and Wales are all somewhat similar to Highways England. Network length and traffic volume were the main areas of difference (Highways England has a longer network and the traffic levels are higher), with all three experiencing comparable climates to England and using similar surface materials.

The comparability of the characteristics of the road networks in Australia, Austria and South Lanarkshire network with the Highways England network is low. Network length and traffic

volumes were particular areas of large difference but climate and (as a result) pavement surface materials are different for Australia and Austria. The South Lanarkshire network is mainly for local traffic and the traffic levels are lower than on the SRN in England.

2) What is measured?

Table 5.2 overleaf assesses the similarity of the tools and techniques used by road management agencies as well as the extent and frequency of pavement condition measurement.

The LAs, TfL, the Welsh Government and Transport Scotland use similar tools and techniques to Highways England to measure pavement surface condition, but road surface condition is surveyed automatically using a machine based on the Surface Condition Assessment for the National Network of Roads (SCANNER) specification whereas the SRN is assessed using TRACS machines[19].

Like Highways England, TfL, the Welsh Government and Transport Scotland also include skid resistance as part of overall pavement condition measurement. This is also measured using SCRIM by Cornwall (A-roads), but not all LAs measure skid resistance (e.g. South Lanarkshire).

The other countries considered also measure surface condition in a similar way to Highways England but only Australia measures skid resistance in the same way (using SCRIM) and only Denmark, Netherlands and Australia measure the pavement strength in a similar way (using the TSD). As the use of the TSD is relatively new, Highways England also makes targeted investigations with the Deflectograph where other surveys (e.g. TRACS and TSD) indicate there may be a requirement for maintenance.

The TSD is a relatively new technology and has not been universally adopted. It is a large machine and is not easily used on local roads. Some countries use machines similar to the TSD (e.g. Denmark and Australia) but others use different techniques. The comparability of the different techniques has not been considered. The use of different approaches is mainly due to the cost and complexity of the equipment (more than £1m for each machine). None of the methods are yet considered "tried and tested".

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[19] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/674583/road-conditions-guide.pdf

Table 5.2: Does the country/LA use the same techniques/tools as Highways England to assess pavement condition? To what extent and how frequent is pavement condition measured?

Australia	Austria
TO A CONSIDERABLE DEGREE Equipment and surveys for surface condition and skid resistance are similar to those used by Highways England. Both use the TSD (or equivalent) to measure the pavement structural condition but both machines are relatively new and not well established. With the more dispersed network in Australia, the survey contracts are not managed centrally. Each State uses slightly different equipment and survey contractors and the extent and frequency of measurement varies by State. Most States collect data over a portion of its network each year, but all survey the most heavily trafficked lane.	**SOMEWHAT** Similar equipment to TRACS used but different equipment for skid resistance and deflection. Extent and frequency of measurement is different - only done at four-year intervals and only Lane 1.
Cornwall	**Denmark**
TO A CONSIDERABLE DEGREE Similar equipment but uses SCANNER instead of TRACS. Also uses SCRIM. Extent and frequency of measurement varies – SCANNER: only Lane 1 every two years for A roads. Most LAs carry out CVI surveys approximately once each month on A-roads.	**SOMEWHAT** Both use TSD and Denmark use a laser-based system that is similar to TRACS. Skid resistance equipment is different. Extent and frequency of measurement is similar - surveys motorways and slip roads although only two lanes surveyed.
Netherlands	**Scotland**
TO A CONSIDERABLE DEGREE Similar equipment to TRACS used and both use TSD but different skid resistance equipment. Extent and frequency of measurement similar for Lane 1 but other lanes not surveyed.	**SOMEWHAT** Similar equipment used, but Scotland uses SCANNER instead of TRACS and Deflectograph instead of TSD. Extent and frequency of measurement is different - half of the network is surveyed annually. Only Lane 1, other lanes not surveyed.
South Lanarkshire	**Transport for London**
TO A CONSIDERABLE DEGREE Similar equipment used, but South Lanarkshire uses SCANNER instead of TRACS. Extent and frequency of measurement: SCANNER - only Lane 1 every two years for A roads. Most LAs carry out CVI surveys approximately once a month.	**TO A CONSIDERABLE DEGREE** Similar equipment used, but TfL uses SCANNER instead of TRACS. TfL also uses SCRIM. Extent and frequency of measurement: SCANNER – 100% of the network is surveyed annually. SCRIM – 100% of Lane 1 annually.
Wales	
SOMEWHAT Similar equipment used, but Wales uses SCANNER instead of TRACS and Deflectograph for structural condition. Extent and frequency of measurement: SCRIM and SCANNER cover Lane 1 each year. No other lanes surveyed.	

Source: CEPA

Skid resistance measurement methods have been developed over many years and a lot of countries have developed their own methods – even if the approach is similar e.g. measurement of longitudinal slip, the details can be different (e.g. angle of wheel, how much water is put down). Much work has been done to compare the different measurement methods but there is not as yet a common European scale of skid resistance in operation (see discussion in Section 5.3.2 on comparing skid resistance between Highways England and the Netherlands).

All countries assess similar condition characteristics but sometimes the approach to collecting each characteristic is different.

In Austria, ASFINAG measures cracking by manually analysing pavement images, which gives a more accurate and stable parameter but is resource intensive to interpret so is more suited to smaller networks. Rutting, ride quality, surface defects and skid resistance are combined to obtain a Comfort and Safety Index, whilst rutting, ride quality, surface defects, cracking, age and theoretical bearing capacity are combined for a Structural Index. The calculations of the indices are very different to the Highways England calculation of the KPI and the indices are used only for internal purposes.

In Denmark, pavement condition is also measured in a comparable way to the UK but surface defects (e.g. fretting, cracking) are only identified from visual surveys. The survey equipment is owned and operated by the road authority (DRD).

Until mid-2017, the Netherlands monitored pavement condition in a very similar way to Denmark, in that it owned the survey equipment and only used contractors to carry out maintenance works. This approach to measurement and the characteristics assessed is expected to remain the same but the condition surveys may be contracted out in future.

In Australia, the management of the road network is different to other small European countries. It is split between states meaning that there is no central body responsible for the strategic network. The techniques used to measure condition and the characteristics assessed are very similar, with structural condition measurements using a machine similar to the TSD recently added.

In terms of extent and frequency of measurement, DfT requires each LA to survey its' A road network every two years (B and C roads are surveyed with SCANNER every four years). Only Lane 1 is surveyed on all roads. TfL surveys 100% of its network annually, in accordance with the guidance set out under the UK Pavement Management System (UKPMS). SCANNER surveys are not usually carried out on U roads due to the challenge that these roads present – for example, some are very narrow, which restricts access for the survey vehicles without traffic management. The lower hierarchy roads are therefore surveyed differently (e.g. using only visual condition surveys) to the Highways England approach. South Lanarkshire Council and Cornwall follow the DfT requirement which is different to the Highways England approach, to survey all lanes annually on the mainline carriageway but only one lane on slip roads (50% of the slip road network is surveyed each year). TfL however, goes beyond this,

surveying 100% of Lane 1 every year with SCANNER and SCRIM, which is more comparable to Highways England's approach. Highways England does not use CVI surveys, but similar drive-over surveys are used daily to identify safety defects that need urgent repair.

In Wales, residual life values are obtained from Deflectograph surveys and skid resistance values from SCRIM surveys for each 10m on the network. These are used to calculate the percentage of the network needing structural monitoring and the percentage of the network in need of investigation for skid resistance. This approach is very similar to Highways England (i.e. SCRIM skid resistance data is reported for 10m lengths).

Pavement surface condition in Austria is measured in a similar way to Highways England but the frequency is much lower (i.e. every four years and no network level deflection measurement)[20]. Most of the countries considered in this study appear to survey Lane 1 only (Netherlands, Scotland, Wales, Austria) but the frequency of measurement differs between annual surveying to once every four years. Only Denmark and Australia aim to survey more lanes.

The comparable information collected by the road management agencies is shown in Table 5.3. The aspects of pavement condition measured by Highways England as part of the network level surveys are: rutting, ride quality (longitudinal evenness), texture, fretting, cracking, skid resistance and pavement strength. Visual (drive-over) surveys are used to identify safety defects. The surface condition surveys also measure the road layout (i.e. gradient, crossfall, curvature) but these are not used in the condition reporting. Pavement material type and layer thicknesses will be identified from 2020 using GPR as part of the TSD surveys.

Table 5.3: Does the country/LA measure the same pavement characteristics as Highways England?

Australia	Austria, Denmark, Netherlands, Scotland and TfL
TO A CONSIDERABLE DEGREE Yes, apart from roughness.	✓ YES All characteristics measured by the comparators are also measured by Highways England (as described in the paragraph above). Note. The details of the equipment and measurement method may be different to those used by Highways England
South Lanarkshire and Cornwall	**Wales**
TO A CONSIDERABLE DEGREE All characteristics measured by these local authorities are measured by Highways England, apart from edge deterioration and surface loss.	TO A CONSIDERABLE DEGREE All characteristics measured in Wales, apart from surface loss.

Source: CEPA

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[20] Before 2018: Surveys of all lanes and slip roads have been carried out at an interval of 5 years. Roundabouts and hard shoulders are not surveyed. From 2018: There will be a change to 4-year interval. After 4 years, all lanes in both directions and slip roads will be surveyed.

3) How is the information used? Are any financial incentives in place to drive performance of sub-contractors or road management agencies?

Although there are similarities in the data collected by the road agencies, it is not clear from the information provided by them how the information collected is used for maintenance planning. However, the Netherlands provided insight into how the condition data is used – this is presented in the discussion box below:

> **DISCUSSION BOX – Contractor Performance Management – the Netherlands[21]**
>
> RWS became an agency in 2006 and is responsible for design, construction, management and maintenance of the strategic road network in the Netherlands. This saw the introduction of service level agreements (SLAs) between the government and RWS. This resulted in KPIs being developed for these SLAs.
>
> The outsourcing of RWS asset management activities created the need for more detailed, functional network performance specifications between RWS and its contractors. RWS therefore, moved to using performance-based contracts for its own DBFM and maintenance outsourcing. Contractor performance requirements are detailed within these contracts through the use of RAMSSHEEP (**R**eliability, **A**vailability, **M**aintainability, **S**afety, **S**ecurity, **H**ealth, **E**nvironment, **E**conomics, **P**olitics), which is used to specify RWS aims and requirements for the works being undertaken and evaluate contractor performance. RAMSSHEEEP is a categorisation, based on systems engineering, used in road performance management.
>
> Based on the information provided and experience of Highways England and the Netherlands practice, it is clear that Highways England focuses more on the technical suitability of maintenance options than on the wider impacts of maintenance considered by the Netherlands.

Similar to the Dutch RAMSSHEEP approach, Highways England has a Value Management (VM) process in place to assist with maintenance planning. The discussion box below provides a description of how the VM process is used by Highways England and the Service Providers.

> **DISCUSSION BOX – Condition data for the Highways England Value Management process**
>
> The Value Management (VM) process requires the contractors to justify why and how a length of road needs to be maintained. The results are also used to prioritise the proposed maintenance schemes. TRACS and skid resistance data are used, with other local data, by Service Providers (the contractors who operate the road network in each Area) to support the requests for maintenance funding. TRACS data is very important in the VM process as

[21] Source: Schoenmaker, R. and van der Lei, T. (2015) 'Towards a line-of-sight, Implementation of performance measurement by road agencies: a European and Western Australian perspective', Int. J. Strategic Engineering Asset Management, Vol. 2, No. 4, pp.370–394.

it provides the data to support the maintenance decisions. The data is measured (i.e. not subjective) so is less open to question than the condition from (subjective) visual assessments. Thus, Service Providers require the provision of up-to-date data, to use in this process. Indeed, the M25 DBFO company performs six-monthly surveys to have access to up-to-date data to justify its maintenance decisions and show that the network is being kept in an appropriate condition.

Highways England consults the Service Providers on each change of TRACS contract, to ask about the frequency of TRACS surveys. In 2017, the response was that an annual survey is the minimum frequency that the Service Providers would be happy with.

Previously, Highways England only surveyed Lane 1 with TRACS, as this is the lane most heavily trafficked by HGVs. Measurements on Lane 1 were used to give an indication of the worst condition likely to be present on the carriageway. When Lane 1 was maintained, Lane 2 would also be maintained, thus expecting that the other lane trafficked by HGVs would be in as good or better condition than Lane 1. However, this practice ceased some time ago, with maintenance now only carried out where it is needed. This was because it was often found that Lane 2 was not in need of maintenance at the same time as Lane 1 and the maintenance did not offer good value for money.

Since Lane 1 is generally maintained more regularly than Lane 2, Lane 2 can be in worse condition than Lane 1 and thus there is a need to monitor its condition, to reduce the risk of the condition becoming too bad. Similarly, just because only light vehicles travel in the outer lanes, and thus deterioration of these lanes is slower than lanes subjected to HGV trafficking, the condition of the outer lanes cannot be reliably assumed. Hence the extent of the surveys has been increased to include the outer lanes in the current TRACS contract. Maintenance work for the outer lanes is still subject to the VM process and subjective data, such as "there is rutting present" or "the ride quality is poor", which does not help to justify nor prioritise the maintenance.

It is expected that as part of taking the operational contracts back in-house, the approach to surveying all lanes will be reviewed but at this stage good use is made of the data from all lanes.

As part of our research, we also considered whether there are any financial incentives in place to drive the performance of sub-contractors or road management agencies.

The case studies suggest that road management agencies are not subject to any financial incentives to drive performance by the respective external overseeing authority (if one exists)[22]. We note that some road management agencies that sub-contract elements of pavement condition maintenance and monitoring do use financial incentives in contracts with

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[22] We note that TfL may be subject to financial incentives to drive performance but we were not able to find more details around such incentives.

third-party suppliers. The table below indicates whether the LAs/countries have financial incentives in place to drive performance for good overall network condition.

Table 5.4: Are there financial incentives in place to drive performance for good overall network condition?

Australia	Austria
❌ NO	SOMEWHAT
No, however, bonuses/penalties are in place for maintenance contractors, dependent on quality of work (e.g. ride quality).	There are some financial incentives for deviations below the required standards on completion and during the warranty period after maintenance work.
Cornwall	**Denmark**
❌ NO	❌ NO
No, but may benefit from the Local Highways Maintenance Challenge Fund and the Local Highways Maintenance Incentive/ Efficiency Element Funding. (see Discussion box below).	There are no pavement network condition indicators. From Autumn 2018, a bonus/penalty scheme-based contract may be introduced for surface evenness of new surfaces after construction/maintenance.
Netherlands	**Scotland**
❌ NO	❌ NO
There are some performance-based contracts between RWS and sub-contractors (see Discussion box above).	Network condition is not used to incentivise contractors as Transport Scotland decides on the maintenance to be carried out. Transport Scotland has bonus/penalty payments for operational (routine) maintenance activities but not for overall network condition.
South Lanarkshire	**Transport for London**
❌ NO	✅ YES
No. But may benefit from the Local Highways Maintenance Challenge Fund and the Local Highways Maintenance Incentive/ Efficiency Element Funding. (see Discussion box below)	There are financial incentives in place for both TfL and its contractors. Parties are incentivised through the management of lump sum maintenance activities, achievement of various service and key performance indicators, and the achievement of whole-life cost savings.
Wales	
❌ NO	
No financial incentives are used to drive performance.	

Source: CEPA

In Australia, bonuses/penalties are used for maintenance contractors, based on quality of pavement delivered (i.e. ride quality). Austria has some financial incentives for deviations below the required standard of road surface, etc. (i.e. penalty only). These are similar to Denmark as they apply only to each delivered maintenance works, not the overall network condition.

The Welsh Government does not use financial incentives with contractors. In Denmark, contractors are only used to perform maintenance – DRD tells them where and what maintenance to carry out on the network. No incentives have been used so far but it is planned that bonus/penalty-based contracts may be used from autumn 2018, based on requirements for the evenness of new surface layers. This is not the same as a measure of the condition of the overall network. As DRD defines the maintenance work packages for contractors, the contractors are not in a position to influence performance.

TfL and its contractors are subject to financial incentives which are realised through maintenance activities, achievement of various service and key performance indicators as well as through the achievement of whole-life cost savings.

The Cornwall and South Lanarkshire case studies showed no use of financial incentives for contractors. However, although not a pure financial incentive and not solely focused on pavement condition, the DfT now offers some funding to encourage LAs to keep the infrastructure well maintained. The discussion box below outlines how DfT funds incentivise LAs to compete for roads funding.

> **DISCUSSION BOX - Local Highways Maintenance Challenge Fund**[23]
>
> Although not specific to pavement condition, this mechanism was introduced in 2014 to encourage better management and maintenance planning for the local highway infrastructure. The aim was to help local highway authorities deal with ageing assets that are costlier to maintain that newer ones. A proportion of the highways maintenance budget was assigned to a Local Highways Maintenance Challenge Fund. The purpose of the Fund was to enable local highway authorities[24] in England (excluding London) to bid for major maintenance projects that are otherwise difficult to fund through the normal needs element allocations received.
>
> The 2017/18 bidding round value is £75m which DfT expects to fund around 10 projects. Major maintenance of renewal of roads carriageways is one type of project that is eligible for funding. Factors that are considered in terms of carriageway projects include:
>
> - Whether the rate of deterioration is exceeding the rate at which road maintenance can be undertaken;
> - Importance of the proposed route and the level of traffic delays currently experienced;
> - Improvement of safety; and
> - Use of new and innovative resurfacing methods being proposed.

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[23] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/399022/challenge-fund-application-process.pdf
[24] outside of London only,

This mechanism incentivises LAs to plan ahead and prepare a well-justified application to DfT for additional funding but does not address the level of overall network condition.

DISCUSSION BOX - Local Highways Maintenance Incentive/Efficiency Element Funding[25,26]

Also, not specific to pavement condition, this funding provides funds to LAs to encourage the adoption of an asset management approach for the road network and efficiency and best practice principles for local highways maintenance are being adopted. This funding mechanism also allows authorities to receive additional funding beyond that allocated in the Needs Based Formula.

Within this funding system, the LAs are not competing against each other but the LA is demonstrating to DfT that efficiency measures are being worked towards, in order to receive its full share of the funding. LAs who are able to demonstrate that value for money is being delivered within a scheme of cost effective improvements will be rewarded through the proportion of the available funds received. Unlike the Challenge Fund where application does not guarantee funding, each LA receives a share of the funding, with the quality of its application determining the share awarded.

Whilst the two DfT funds are not strictly performance-based financial incentives, due to each LA having to apply for the funding as opposed to being assessed based on its on-going performance, these are still an incentive tool designed to encourage certain performance and behaviour characteristics within local highway authorities' road management.

5.1.1. Summary of condition measurement

Summary: pavement condition measurement

Assessment of the case studies reveals that most road management agencies measure similar pavement characteristics using similar equipment. Nonetheless, there are differences in the detail of how they do it. One of those differences is that Highways England surveys the network more often than any of the other road management agencies in the case studies.

Highways England appears to be measuring and monitoring pavement condition as often, or more often, than any of the comparators and surveys more lanes. This is an interesting observation as although there are no direct measures to compare the conditions of the different networks, those countries with similar network characteristics are not known for the network being in poorer pavement condition than Highways England. It is worth noting, however, that many of the other countries included carry lower levels of traffic so either have

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[25] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/487481/guidance-and-self-assessment-questionnaire.pdf

[26] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/583263/roads-funding-information-pack.pdf

much newer roads (e.g. motorways built in the '80s not the '60s/'70s as for Highways England) which perhaps do not need as much monitoring or assumptions about the condition of the other (not surveyed) lanes being based on the measurement of Lane 1 are less significant (e.g. because the agency will repair the whole carriageway width when Lane 1 is maintained). The case studies do suggest many of the comparator organisations make assumptions on the condition and maintenance requirements for the lanes not surveyed. Whether these assumptions are justified will depend on the road management agency's approach to carrying out maintenance:

- Are all lanes replaced when maintenance is done in Lane 1?

- How maintenance proposals are reviewed to determine what maintenance is needed or do some areas of the carriageway get replaced before the work is needed?

- The need for condition reports for all lanes. It is noted that the proposal for the new KPI for the pavement network condition during RIS2 is to use the condition data for all lanes surveyed (not just lane 1 as in RIS1).

A key aspect of the higher frequency and coverage of TRACS surveys is therefore the greater use made by Highways England of the data. From the case studies, many of the organisations collect similar data to Highways England but less use is made of the data to report network condition or develop maintenance plans. Therefore, is Highways England approach to pavement condition measurement and monitoring entirely justified, given the rate at which the condition changes[27] and the level of use of the network? Would Highways England's performance change if there were changes to the frequency of measurement and the number of lanes surveyed? Is this level of monitoring necessary to support the use of the data, detect changes in condition and improve the effectiveness of maintenance planning? These are questions to consider when planning for RIS2.

Our research suggests that road management agencies are not generally subject to any financial incentives to drive performance by its respective external overseeing authority. The most common types of financial incentive are those included in third-party contracts and are either symmetric (reward and penalty) or asymmetric (penalty-only). These are used to incentivise work quality.

5.2. Pavement condition performance

Having compared what countries/LAs measure, the following sections consider how performance is measured and how the data is reported to their overseeing authority.

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[27] We note that road deterioration is highly dependent on the level of traffic – e.g. a pavement carrying 20 lorries/day will deteriorate quicker than an identical road that only carries 10 lorries/day.

4) What performance metrics and targets are there to measure performance over time?

Table 5.5 shows whether the countries/LAs have any metrics and/or targets in place to show the pavement condition performance over time and whether those metrics, if any, are comparable to Highways England.

Table 5.5: Does the country/LA have any metrics and/or targets in place to measure performance over time?

Australia		Austria	
❌ NO		**❌ NO**	
No metric is currently in place, but one was proposed, but not implemented.		Two indicators are in place but are not similar to the indicator used by Highways England.	
Cornwall		**Denmark**	
SOMEWHAT		**❌ NO**	
RCI is the indicator. There are no performance targets in place.		Denmark has no metrics or targets.	
Netherlands		**Scotland**	
✔ YES		**❌ NO**	
Both Highways England and the comparator have % pavement condition metrics that measure similar attributes and targets are at a similar level.		There are no public condition targets. The metric is different to that used by Highways England or LAs. The LA RCI is extended to include structural condition from the network level Deflectograph surveys.	
South Lanarkshire		**Transport for London**	
SOMEWHAT		**SOMEWHAT**	
RCI is the indicator. There are no performance targets in place.		RCI, OCI[28] and various customer satisfaction indicators. Not aware of any performance targets in place.	
Wales			
❌ NO			
Metrics based on Deflectograph data and SCRIM only, but no targets are specified. SCANNER data is not included.			

Source: CEPA

The case studies show that nearly all of the comparators have indicators of pavement condition, but not many have formal performance targets in. Only the Netherlands has a metric that is in some way comparable to the Highways England KPI8.

For the LAs and TfL, rutting, ride quality, cracking and texture are taken from SCANNER surveys to produce the RCI (Road Condition Index) for each 10m on each local authority network. LAs in England have a common RCI metric in place and report the results to DfT on an annual basis. Results are then made publicly available. However, there are currently no

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[28] Overall Condition Indicator

performance metrics and/or targets that DfT requires LAs to adhere to at a local or national level for the local road networks.

TfL also has an Overall Condition Indicator (OCI) and various customer satisfaction indicators in place, but no further details as to the nature of these indicators, or any targets, were provided to us by TfL. There does not seem to be any publicly available information on these additional indicators either.

SCANNER data was formerly used by each LA to produce a national indicator and more recently a best value performance indicator; this was however abolished in 2011 and replaced by the single data list[29]. In theory each LA could choose to create its own metrics/targets internally at the local level. However, this is not something DfT actively monitors so how widespread this might be is not known. Surrey County Council, for example, does go beyond the DfT reporting requirements. This is discussed in the discussion box below:

> **DISCUSSION BOX - Surrey County Council**
>
> Despite being subject to the same reporting requirements as other LAs, Surrey County Council considers network condition to be a high priority. It is very transparent in its road plans, publishing, like some other Authorities, a Highways and Transport Strategic Business Plan for 2016-2021 that outlines clearly the outcomes against which it measures its performance[30].
>
> A quarterly performance review is also published for roads[31], and performance is measured in two ways: i) repair of road defects and ii) progress of maintenance programme (i.e. the Council does not appear to specifically measure performance against the observed condition of the pavement).

In Wales the indicators recorded, based on Deflectograph data and SCRIM, are reported to the Welsh Government on an annual basis and made publicly available but there is no performance regime in place where performance is incentivised or monitored.

Austria utilises two combined indicators ("gebrauchswert/comfort and safety index" and "substanzwert/structural index"). One is a combination of safety and comfort related indicators (ruts, longitudinal evenness, skid resistance), the other is related to structural properties (surface defects, etc.). However, the indicators collected by Austria are for internal use and are not reported publicly; there is no performance regime in place where performance is incentivised or monitored. However, as part of this study we discussed with ASFINAG how the indices are calculated and found that these are compiled in a very different way to those used by Highways England.

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[29] List of all datasets that LAs must submit to the government.
[30] https://www.surreycc.gov.uk/__data/assets/pdf_file/0018/104346/Highways-and-transport-Business-Plan.pdf
[31] https://www.surreycc.gov.uk/__data/assets/pdf_file/0020/154604/EP2-2017-12-31-Priority-Roads.pdf

The Netherlands employs intervention limits for skid resistance, rutting, IRI, cracking and ravelling which have similarities to the Highways England KPI8[32] but it includes defects that Highways England does not have standards for (i.e. cracking, ravelling/fretting) or uses different measures (i.e. Highways England uses Longitudinal Profile Variance, not the International Roughness Index, for longitudinal unevenness). The rutting value is derived from height measurements made by lasers positioned on the survey vehicle across the lane width (or in the case of the latest Highways England TRACS machine a laser that scans the width of the lane) but the different algorithms to transform the height measurements are different for different machines. Ravelling and cracking are very important in the Netherlands, as the most common surfacing on the SRN is porous asphalt, a material that is not commonly used on the UK network. The Netherlands reports the percentage of lengths for which all defects are below these intervention limits. The metric is not published but an internal target of 97% is set for 'good' condition.

DRD in Denmark does not calculate a metric to report road condition but it uses the parameters to identify where there is a potential maintenance need. In Australia there is no centralised indicator calculated or reported. The introduction of a national indicator was considered but the proposal was rejected by the different states across Australia. This may have been to avoid direct comparison between the states as they have a much bigger influence on the maintenance of the national network than Area Service providers have on the Highways England network.

Table 5.6: Summary of indicators/metrics and thresholds by country/LA

Country/LA	Metric/Indicator	Threshold
Australia	No metric or target in place.	Thresholds for indicators measured are currently unknown.
Austria	Gebrauchswert/comfort and safety index	For newly paved roads, thresholds exist for skid resistance, longitudinal and transversal evenness (defined in Austrian regulations), but not publicly available.
	Substanzwert/structural index	
Cornwall, South Lanarkshire and TfL[33]	Road Condition Index (RCI) - Rutting, ride quality, cracking and texture	Rutting ≤ 10mm LPV (3m) ≤ 4mm² LPV (10m) ≤ 21mm² texture depth ≥ 0.7 rural and 0.6 urban cracking ≤0.15%
Denmark	No metric or target in place.	Thresholds for indicators measured are currently unknown.
Netherlands	Skid resistance	0.51 at 80 km/h for porous asphalt and 0.53 at 80 km/h for impervious asphalt

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[32] The target of the KPI is to maintain 95% or above of these lengths at a level where it does not require further investigation for each year of RIS1 (Category 3a or better).
[33] TfL informed us that the RCI indicator used by TfL is the same as most other highway authorities. In the absence of any additional information, it is reasonable to assume that the thresholds used by TfL would be the same as the other Local Authorities case studies.

Country/LA	Metric/Indicator	Threshold
	Rutting	17mm
	IRI	3.4m/km
	Cracking	30% of the 100m length affected by cracking and a maximum crack width of 20mm
	Ravelling	25% of the length affected by ravelling with a maximum severity of 20 % stone loss per square metre.
Scotland	Transport Scotland Road Condition Indicator (TS RCI) - Rutting, ride quality, cracking, texture, and structural condition	Surface condition thresholds as for Cornwall and South Lanarkshire. For structural condition, the length of the network (by road type) with a residual (or remaining useful) life of 0 years.
Wales	Structural condition	Percentage of network length with a residual (or remaining useful) life of 0 years.
	Skid resistance	Percentage of the network where the skid resistance falls below "investigatory level".

Source: CEPA analysis based on case studies

5.2.1. Summary of condition performance monitoring

Summary: Pavement condition performance

Our assessment of the case studies reveals that the LAs, TfL and most countries studied have indicators in place to monitor pavement condition for internal management purposes. However, only a few comparators have developed these into metrics and/or targets to monitor performance over time.

Although LAs and TfL measure the same pavement condition characteristics, the RCI metric is not directly comparable to the Highways England KPI8. Nevertheless, the pavement condition data collected by LAs and TfL can be compared to Highways England, as discussed in Section 5.3.1.

The only country that has a pavement condition metric similar to Highways England is the Netherlands, as described above. A detailed assessment of comparability can be found in Section 5.3.2.

5.3. Pavement condition reporting

5.3.1. Comparing pavement condition data collected: LAs, TfL and Highways England

In this sub-section we explore whether the pavement data collected by the LAs and TfL is comparable to the data used by Highways England.

Highways England, TfL and LAs collect data on a range of different pavement characteristics, using several different tools and techniques. The data is reported to DfT. Data for roads in London is reported for each London Borough but not summarised for the overall TfL network.

Of these, surface condition and skid resistance (for those LAs using skid resistance surveys) are reported to DfT annually. ORR monitors Highways England's management and reporting of road condition information but for LAs, road condition data is part of the single data list, meaning that its provision to DfT is mandatory. DfT publishes the road condition data annually in its Road Conditions in England statistics publication (RDC tables)[34]. This publication includes the condition of the Highways England network using data similar to the surface condition and skid resistance data used for KPI8.

Skidding resistance

The *% of surveyed road length requiring further investigation*, in terms of skid resistance, is reported by Highways England and LAs[35] each year and, is published by DfT in Tables RDC0140 (LAs) and RDC0210 (Highways England). The data underlying these figures is recorded in skid resistance surveys of the road surface in 10m lengths. Highways England and many LAs currently use SCRIM surveys for this data, and the data is saved as the Characteristic Skid Coefficient (CSC). Other types of skid resistance measurements are available (and are used by some LAs) but data from those surveys is not included in the DfT summary of the skid resistance of the network. The CSC values are derived from the measurements by adjusting for speed, temperature, seasonal and annual variations. The 10m lengths are normally averaged into lengths of uniform level of risk (i.e. the site category length), typically 100m, for further analysis. The average of the annual figures is normalised to the three-year average for the road, in order to smooth out the annual fluctuations[36]. The difference in the approaches used by LAs and some LAs not undertaking skid resistance surveys are the reasons that skid resistance is not published for all LAs.

The degree of skid resistance required depends on the road type and geometry of the site so the threshold beyond which further investigation is required also varies (higher skid resistance is needed at bends and junctions than on straight roads with no junctions). Consequently, skid resistance results for LA and Highways England roads are not directly comparable as both manage different road types and the distributions of types of site (and consequently the thresholds) are different.

For the Highways England KPI8, the skid resistance is compared to the (Investigatory Level – 0.05)[37] but for the DfT publication, the skid resistance data is compared to the Investigatory Level, the same threshold used for the LA data.

Surface condition

TRACS and SCANNER surveys are used to measure a number of different road condition characteristics that for LAs are combined to provide an overall index of the road condition.

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[34] RCD 2017 Tables: https://www.gov.uk/government/statistics/road-conditions-in-england-2017
[35] Note: Not all LAs measure skid resistance
[36] This method is described in Design Standard HD28/15. Some LAs and DBFO concessions still use the method given in the previous version of the Standard (HD28/04) which uses a different approach to allow for the annual and seasonal variations.
[37] This is the Category 3a threshold used for all defects in KPI8

Highways England considers the defects independently and does not combine the measurements into a condition index. For the Highways England KPI, the ride quality (Longitudinal Profile Variance) and rutting data is used from the TRACS data. For DfT, texture data is also included. TRACS data is delivered to Highways England from the sub-contractor in the form of *Base Condition Data (BCD)*, which allows for it to be uploaded into the *Highways England Pavement Management System* (HAPMS). The data provided to DfT from the TRACS surveys is different to the data used for the Highways England KPI (the Highways England KPI uses TRACS data for each 10m of Lane 1, but the data provided to DfT is aggregated over 100m). The condition of the SRN is assessed by comparing the values of each aspect of surface condition for each 10m or 100m length of Lane 1, against pre-determined thresholds for each road condition characteristic measured by TRACS. If the condition is worse than the pre-determined thresholds for the road type, the length of road is deemed to require further investigation; the thresholds used by Highways England in the current KPI and for DfT are referred to as Category 3a. The results for the TRACS parameters for each 100m length, from Lane 1 only, are combined and are published in Table RDC0201 by DfT as *the percentage of lane length surveyed requiring further investigation*.

SCANNER is the recommended method for use by LAs to measure road surface condition, although its use is only mandatory for the assessment of classified roads. SCANNER data is processed and HMDIF files (similar to BCD files) are delivered for loading into a UKPMS compliant pavement system. Unlike TRACS, SCANNER data is reported over 10m subsections although like TRACS, it too has thresholds for the different road condition characteristics it measures. The results for each pavement characteristic measured against its threshold value are combined to calculate a weighted score for each 10m subsection. The SCANNER RCI takes the weighted scores and calculates the RCI value for each 10m length which provides an overall value for the proportion of the LA's roads that fall into the 'red' category. This 'red' category' is reported to DfT as the *proportion of road network that requires further investigation.* DfT publishes the data in Tables RDC0120 and RDC0121[38].

Comparability

In terms of being able to compare Highways England's data to that of LAs, difficulties arise due to the difference in methodologies and thresholds used.

For skid resistance, it is possible to compare the skid resistance results of local authority principal roads (LA maintained 'A' roads), in Table RDC0140, with the results from Highways England's trunk 'A' roads, in Table RDC0210. However, due to the fact that not every LA measures skid resistance and some LAs do not measure all of the network (i.e. they use targeted surveys), and issues around LA data quality, the comparison would have to be undertaken using the aggregated groups of LAs which, does not allow for clarity regarding the specific road sections being compared and reduces the usefulness of the comparison.

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[38] This is for classified roads, results for the surface condition of local authority unclassified roads can be found in Tables RDC0130 and RDC0131.

Additionally, local authority principal roads consist of 'A' roads and motorways. Whilst local authority managed motorways make up a tiny fraction of motorways within the 'A' roads and motorways group, these two road types have different skid resistance thresholds. Therefore, the lack of breakdown between 'A' roads and motorways for LAs means that Highways England's road categories cannot be precisely compared with the LA network.

For surface condition, similar issues faced by skid resistance also apply. Here though, surface condition is published for each LA (Table RDC0120) in addition to aggregated regional results (Table RDC0121). Whilst, all LAs report on surface condition for classified roads using SCANNER, this measures surface condition using a similar, but different approach to TRACS used by Highways England (Table RDC0201), which means the two datasets are not perfectly comparable even for the same road types.

Also, as above, the reporting of local authority principal roads poses a problem, with 'A' roads and motorways holding different surface condition thresholds and therefore, not being directly comparable. The lack of available breakdown for local authority principal roads again means that Highways England's separate reporting of trunk 'A' roads and motorways data cannot be matched precisely with LA results, although it should be noted that LA managed motorways are a tiny proportion of the total 'A' roads and motorways all LAs manage, so the impact on the results is minimal.

Therefore, LA data on surface condition are likely to be the closest comparators with Highways England for the SRN. However, the approach to identifying the pavement condition from LAs and Highways England datasets differs. Highways England requires only one defect to be beyond its threshold for the length to be classed as poor but the Road Condition Index for local roads combines the level of condition from all defects to create the index value. For example, on a local road more than one defect just below the relevant thresholds could combine to give a 'red' value but for Highways England none of the defects would break the thresholds. It would be possible to calculate the index value for all or parts of the SRN, but it would not be a simple task. The SCANNER data held by DfT could be analysed to create an indicator equivalent to the TRACS data used in the Highways England indicator.

5.3.2. Comparing pavement condition KPIs: Highways England vs. the Netherlands

As described above, the Netherlands has a pavement condition KPI that is similar to the current Highways England KPI8. Across all comparators, the Netherlands appears to be the closest to Highways England. We have therefore summarised below how these two KPIs compare:

Table 5.7: Pavement condition KPI comparison

Description	Highways England	Netherlands	Differences
Description of KPI	KPI8: 'Keeping the Network in Good Condition' is the **percentage of the network that needs no further investigation for possible maintenance**.	The number of lengths where skid resistance, rutting, ride quality, cracking, ravelling, are all below the intervention limit.	Although different in detail and using different thresholds, the indicators seem to achieve very similar results. Highways England's KPI will 'trigger' additional investigation whilst the Dutch KPI will identify additional maintenance needed if intervention limits are not met (but the breaking of the thresholds is still only used to highlight pavement lengths to be considered for maintenance).
KPI intervention limit	The **target of the KPI is to maintain 95% or above of these lengths at a level where they do not require further investigation for each year of RIS1** (referred to as Category 3a[39] or better).[40]	97%	Netherlands has a higher target, but the intervention limits of individual components are different to those of Highways England. As such, the Netherlands' target is not necessarily more difficult to achieve than Highways England's (see below).
Intervention limit of individual components[41]	The KPI is described by the condition of each 10m length of Lane 1 of main carriage-way[42] on the network[43]. Intervention limits for **Category 3a** are: • Skid resistance: Investigatory Level - 0.05 • Rutting: 15.5mm	For each 100m on the network, the following intervention limits are applied: • Skid resistance: 0.51 at 80 km/h for porous asphalt and 0.53 at 80 km/h for impervious asphalt • Rutting: 17mm • IRI[47]: 3.4m/km • Cracking: 30% of the 100m length affected by	The Netherlands looks at data over 100m compared to Highways England using 10m. The Dutch require all parameters to be beyond the thresholds to show poor condition. The techniques used by Highways England and the Netherlands to measure skid resistance are different, hence are not directly comparable.

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[39] Category 3a is mid-way between Categories 3 and 4.
[40] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/678303/OMM_Minor_-_PDF_Final_January_2018_.pdf
[41] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/678303/OMM_Minor_-_PDF_Final_January_2018_.pdf
[42] i.e. not lay-bys, slip roads, link roads or roundabouts
[43] Excludes the part of the network managed as a part of a DBFO concession
[47] Ride quality

Description	Highways England	Netherlands	Differences
	• Ride quality (3m LPV): 3.3-6.55mm^2 depending on type of road[44] • Ride quality (10m LPV): 10.6-27.45mm^2 depending on type of road[45] • Ride quality (30m LPV): 88-145mm^2 depending on type of road[46] • Cracking and fretting: These have also only recently been re-introduced into surface condition surveys so only guidance levels, rather than defined required levels, are available.	cracking and a maximum crack width of 20mm • Ravelling: 25% of the length affected by ravelling with a maximum severity of 20 % stone loss per square metre.	The threshold for rutting in Netherlands is higher by 1.5mm than for Highways England. The analysis of parameter measurement is different (e.g. rutting). Highways England aims to show the effect of short lengths of rutting rather than them being diluted by using the longer (100m) length. The ride quality is set at an IRI of 3.4 in the Netherlands which is poorer than the condition required for the Highways England network for the KPI (based on a relationship derived to convert Longitudinal Profile Variance to IRI. Netherlands also consider cracking and ravelling while Highways England does not.
Published KPI?	Yes	No	As this KPI is published for Highways England, it may feel it has greater accountability in meeting the target than the Netherlands where the internal target is not published.
Has the intervention limit been met?	No. The % of pavement that did not require further investigation in in 16/17 was 94.3%, an improvement on 92.3% in 15/16, but below the targeted 95% level. The indicator exceeded the 95% threshold in each year between 2008/09 and 2013/14.	Yes. In 2017 98% of the network met the intervention limits i.e. did not require maintenance.	The Netherlands has met its KPI whilst Highways England has not met it as of 16/17.
Reporting frequency	Annually as part of RIS1.	Annually.	N/A

Source: CEPA

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[44] Motorways: 3.3, Rural Dual Carriageways: 3.3, Urban Dual Carriageways: 3.85, Rural Single Carriageways: 3.85 and Urban Single Carriageways: 6.55

[45] Motorways: 10.6, Rural Dual Carriageways: 10.6, Urban Dual Carriageways: 15.7, Rural Single Carriageways: 15.7 and Urban Single Carriageways: 27.45

[46] Motorways: 88, Rural Dual Carriageways: 88, Urban Dual Carriageways: 98, Rural Single Carriageways: 98 and Urban Single Carriageways: 145

The differences highlighted in Table 5.7 show that evaluating the ease of achieving the KPI for a country compared to another country is not straightforward. This is due to the difference in the components included in those KPIs, the difference in the intervention limits of each component for the KPI, as well as the different techniques used to measure each component (e.g. skid resistance is different). However, maintenance planning uses the survey data so availability of data for this can be assessed. Both organisations do annual surveys but maintenance planning in the Netherlands is based only on the condition in Lane 1 while Highways England uses the condition data in all lanes.

Nevertheless, the comparison gives an overall proxy of how different/similar these KPIs are and can assist decision makers in defining pavement condition measurement in the future.

5.3.3. Summary of data reporting

Key takeaway points: pavement condition data reporting

Our assessment of the case studies reveals that there are two aspects that might be sufficiently comparable for ORR to monitor and benchmark in the future:

- In GB: the percentage of lane length surveyed that falls under Category 4 ('red rating') for surface condition. The disadvantages for using this threshold are the small percentage of the network (~2 or 3 %) that is beyond the threshold and that part of the network is repaired (initially) by reactive maintenance rather than planned renewals;

- Internationally: the pavement condition KPI in the Netherlands.

In GB, additional aspects of pavement condition could be compared in the future if the techniques used to monitor pavement condition and the thresholds used for different asset classification are made consistent across LAs, TfL and Highways England. Modifying the thresholds that result in a different classification might be a first step towards improving comparability and establishing a benchmark.

Internationally, although different pavement surface materials are used on the SRN in England and by the Netherlands, the characteristics of the networks are generally the most consistent of the networks considered in the case studies. Comparing Highways England's KPI8 to the Dutch pavement condition indicator would be a challenging exercise – the main reasons being that the Dutch indicator includes additional components, has different intervention limits and skid resistance is measured differently. In addition, the level of skid resistance needed is relative to the Investigatory Level for each road length. For Highways England, the assignment of the Investigatory Level is risk-based and it would be difficult to assign the same levels of risk on the two networks. For the two KPIs to be comparable, skid resistance would also need to be measured on a common scale and measured using the same tools. A relationship would also be needed to convert the indicators to a common scale. All these differences mean it is not easy to transfer the condition values on one network to another network.

ANNEX A   DETAILED CASE STUDIES

A.1.   Australia

Country: Australia	
1. General	
a. Demography (population)	24.13 million
b. Climate	Due to the size of the country, Australia has several different climate zones. The northern section of Australia has a more tropical influenced climate, hot and humid in the summer, and quite warm and dry in the winter, while the southern parts are cooler with mild summers and cool, sometimes rainy winters. The southern areas of Australia are generally more temperate to warm, with summer daytime temperatures usually between 25 and 30°C and winter temperatures between 5 and 10°C The Tasmanian mountains and the "Australian Alps" in the southeast of Australia have a typical mountain climate; the winter can be very harsh, with the highest peaks usually covered by snow from late Autumn to early Spring. The hotter climate in the northern regions reduces the life of bitumen surfacing by up to 50% compared with those in the cooler temperatures in the south. The climate affects the quality of pavement and failure/deterioration rates through: • more rapid oxidation of the bitumen binders in hotter, and drier regions than in temperate zones and those which have less seasonal temperature variation; • influence of higher rainfall (ranging from less than 500 mm p.a. up to 4000 mm p.a.) and lower evaporation rates (as measured by the Thornthwaite Moisture Index) on pavement strength, and its change over time; • more significant impacts from cyclonic activity leading to inundation, concentrated water flow and high levels of pavement moisture.
c. Length of road network and description	The motorway network (including rural freeways) is 4,121km, compared with 3,764km in the UK. In 2015/16, 251.20 billion vehicle kilometres were travelled on the motorway network, with 18.64 of these being made by heavy goods vehicles[48]. In 1992, the average national AADT/lane was 2,900, which is approximately an AADT of 6,000. Assuming that traffic has grown at a similar rate to the UK, this equates to a current AADT of approximately 8,400. Urban freeways are typically flexible pavements, while rural freeways typically have a granular base. There is very little use of concrete pavements on freeways.
d. Name of the road management agency	Each state and territory has its own road agency (Australian Capital Territory, New South Wales, Northern Territory, Queensland, South Australia, Tasmania, Victoria and Western Australia). Also, New Zealand is included under the Austroads banner.

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[48] Australian Infrastructure Statistics—Yearbook 2017
https://bitre.gov.au/publications/2017/yearbook_2017.aspx

Country: Australia	
e. Name of external overseeing authority, e.g. regulator, if any	None
f. Road management agency accountable to	Road agencies report performance of the network to the Federal government and apply for funding for the National Highways.
2. Management of roads and pavement conditions	
a. Approach to managing the road network	Road agencies contract out both condition measurement (to ARRB) and maintenance work.
b. Methodology used in measuring pavement conditions	The standard pavement condition parameters that are measured at a network level are roughness, rutting, texture, cracking and in recent times, with the introduction of the TSD, strength or deflection.
c. Quality/ condition of roads	This varies by State, but an example long term maintenance concession is targeting a low percentage of pavements in a very poor (needs replacement) condition, and a distribution of poor (low), fair and good based on optimum strategies with defined criteria for roughness and rutting. The condition is not published.
d. Techniques used to assess pavement condition	The Austroads specifications[49] state how these should be measured using similar equipment to that used for Highways England.

How frequently surveys are carried out varies by state. Some agencies collect data across the entire network they are responsible for every year, others cover the network over a 2-year cycle, and others may only survey the network every 2 years. However, most will at least collect data over a portion of the road network each year.

In terms of survey extent, the general rule is to survey the outermost (slow) lane if there is more than one lane. Some surveys are performed in both directions, but most are in one direction only on single carriageway roads. Dual carriageways are surveyed in both directions. |
| **3. Targets and performance** | |
| **a. Metrics and target setting (if any)** | The indicators of condition that are calculated vary by agency, with examples of individual measures and composite indices being used in optimisation. On specific contracts (multi-year maintenance) indicators and criteria are defined. The approaches however vary by agency.

The following flowchart shows a proposal, raised in 2011, for a national network performance indicator, that Austroads wanted to be implemented by each of the states and regions[50]. |

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[49] Austroads is the principal organisation of Australian road transport and traffic agencies
http://www.austroads.com.au/road-operations/asset-management/resources/specifications-test-methods
[50] "Network Performance Indicators – Next Generation". Austroads Publication AP-T176-11, published May 2011. https://www.onlinepublications.austroads.com.au/items/AP-T176-11
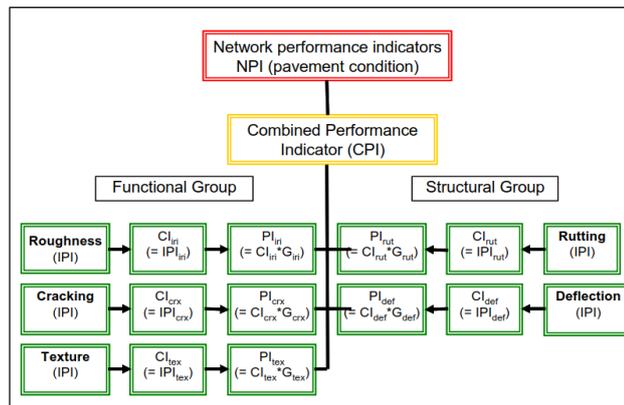
As can be seen, ride quality, cracking, texture, rutting and deflection measures are combined to generate the indicator.

$$CPI_i = \frac{\sum G_i \times CI_i}{\sum G_i} = \frac{\sum PI_i}{\sum G_i}$$

$$NPI = \frac{\sum CPI_i \times L_i}{\sum L_i}$$

Where

CPI_i	=	Combined performance index on road type "i"
CI_i	=	Single condition index on road type "i"
PI_i	=	Performance indicator on road type "i"
G_i	=	Weighting of each individual CIi, for road type "i", e.g. =0.33 (major); =0.22 (moderate); =0.11 (minor)
NPI	=	Network performance indicator of road types comprising the network
Li	=	Defined length of road type "i"

Details of how the individual condition indices might be calculated are given in the report AP-T176-11.

b. Use of financial incentives to drive performance (if any)	Financial incentives are used in maintenance contracts – the contractor gets a bonus for constructing a high- quality pavement but is penalised if the pavement is lower quality. A mixture of performance and method-based specifications is used, but significant performance-specific maintenance contracts (PSMCs) exist as do schedule of rates with warranties.
c. Performance monitoring	The way that performance is monitored varies between regions, in that some do no monitoring at all, whilst others do some monitoring. For those that do monitor performance, only maintenance performance is monitored (i.e. the pavement quality of new construction, or reconstruction is checked). Checks on surface evenness and texture are carried out and sometimes skid resistance is checked. Some of the contracts just check the quality at the start of the pavement's life, whilst others will monitor quality for up to 5 years of service.
d. Role of contractors in performance	In some cases, the contractors have the ability to influence (positive and negative) the results of performance monitoring.
e. Potential for incentives to influence performance	There are specific cases where a link between performance measures and incentives in the contracts can be demonstrated

A.2. Austria

Country: Austria	
1. General	
a. Demography (population)	8.75 million
b. Climate	Austria is located within a temperate climatic zone. In the west and northwest, the influence of the temperate Atlantic climate is felt more strongly, in the east the influence of the continental climate. Temperatures depend largely on altitude, with averages 5°C lower for each additional 300 m of elevation.
	Precipitation is quite evenly distributed over the year, but May, September and the first half of October tend to be the driest, April and November tend to be the wettest periods. Again, altitude determines the precipitation pattern; while high-level areas in the Alps may have a high average rainfall in excess of 2000 mm per year, some regions in the flatlands of Austria have only 600 mm annually
	Thus, areas that have similar altitude to the UK, have a similar, although drier climate, so the Austrian climate will affect the road network the same. In the mountainous regions, the colder temperatures and mechanical snow removal may damage the roads and cause deterioration to occur more quickly.
c. Length of road network and description	There are 2,223 km of autobahns/motorways and expressways in Austria (approx. 2 % of Austria's total road network) with a high proportion of demanding mountainous sections. Some network key figures (2017):
	• approx. 11,900 lane km
	• Tunnels: 164 (383 km in tunnels + 69 km under construction)
	• Bridges: around 5,200
	The motor vehicle density on the network of roads in Austria is just over half of that in the UK, with 42.30 vehicles per km of road, compared to 76.90. Similarly, the road traffic intensity is about 60% of that of the UK SRN (697.3 vehicle-km/km in Austria and 1181.81 in the UK)[51]
	The total traffic: 30,770 m vehicle-km, with 4,496 m vehicle km being heavy traffic (gross weight over 3.5 tons)[52].
	AADT ranges from 15,000 on some remote expressways to 190,000 on the most heavily trafficked motorways (8 lanes) in and around Vienna. HGV percentage is in a range of 15 % (expressways) to 40 % (transit corridors). Detailed information from ASFINAG's counting points (overhead detectors and induction loops) can be found at https://www.asfinag.at/verkehr/verkehrszaehlung/
	About 1/3 of the Austrian motorway network is concrete (rigid construction), which is mostly built with exposed aggregate surface (approx. 3 % of concrete pavement have a 3.5-4 cm bituminous overlay of SMA (Stone mastic asphalt)). The remaining 2/3 of pavements are flexible, with SMA as the dominant surfacing. The share of porous asphalt is negligible (due to uneconomical characteristics and behaviour and has not been used in the last 15 years and replaced with noise reducing SMA).
	Depending on (heavy) traffic the standard asphalt road construction is designed as described below:
	• Wearing course: 3.0 cm SMA (max. grain size 11 mm)

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[51] *"Road traffic, vehicles and networks | Environment at a Glance 2013: OECD Indicators"* *(Press release). Paris, France: OECD Publishing. 2013. Retrieved 2018-02-22.*

[52] https://www.asfinag.at/about-us/facts-and-figures/

- Binder course: 9,0 -13 cm Asphalt Concrete (AC) (max. grain size 32 mm)
- Base layer: 9 - 15 cm AC (max. grain size 22 mm). Asphalt usually mixed with Polymer Modified Bitumen.

Concrete pavement is usually carried out as a two-lift jointed plain concrete pavement. The standard design is described below:

- Upper concrete layer with exposed aggregate surface ("top lift"): 4 cm (increased requirements concerning aggregates; max. grain size 8 mm for noise reducing sections, 11 mm for motorway sections without special demands)
- lower concrete layer ("bottom lift"): 18 – 21 cm
- Asphalt base layer: 5 cm

The choice between asphalt and concrete is made under consideration of the economic efficiency (including vehicle operating costs).

d. Name of the road management agency	ASFINAG - Autobahnen- und Schnellstraßen-Finanzierungs-Aktiengesellschaft (Motorway and Expressway financing plc.) ASFINAG is not a typical road administration, but more like a concessionaire. ASFINAG has a contract ("usufructus contract") with the Republic of Austria which defines rights, obligations and duties concerning operation, maintenance, planning, new construction and toll collection within Austria's motorways and expressway network. ASFINAG finances itself by collecting tolls from customers. ASFINAG doesn't receive money from the state budget. The internal organisation of ASFINAG is:
e. Name of external overseeing authority, e.g. regulator, if any	Ministry of Transport, Innovation and Technology (bmvit)
f. Road management agency accountable to	ASFiNAG is a self-financed stock company, based in Vienna, which is wholly owned by the Austrian republic and earns revenue from road-user charges and tolls. ASFINAG is a limited company completely owned by the state. The rights and obligations of the owner (Republic of Austria) were specified by the Ministry of Transport, Innovation and Technology (bmvit) and – to a lesser extent – the Ministry of Finance.

Country: Austria	

2. Management of roads and pavement conditions

a. Approach to managing the road network	Machine surveys of road condition are carried out by the contractor AIT (Austrian Institute of Technology). There is also a daily routine ("Streckendienst" several times per day) visual inspection by ASFINAG staff (from operations) but this is mainly for solving immediate problems (e.g. potholes, broken bridge joints, accidents, winter service, contamination or broken traffic sign, etc.). The maintenance programme is derived by: Survey data is processed by a contractor that maintains a database and homogenises the condition for the survey sections (>50 m in length). The maintenance programme is derived from life cycle analyses considering • road surface properties (from routine surveys) • age/pavement type/layer structure • structural condition (derived from crack and distress survey). Finally, the maintenance program is created by ASFINAG by taking into consideration the availability (internally defined goals must be met), the budget (budget dedicated to maintenance must not be exceeded) and maintenance needs of other assets (measures were bundled and carried out in one scheme to increase the availability and to reduce the disturbance caused by construction sites). Maintenance/construction work is contracted to construction companies. The project management and project lead is done by the ASFINAG Construction Company.
b. Methodology used in measuring pavement conditions	Aspects of condition measured: Transverse shape (rutting), ride quality, gradient, crossfall/camber, curvature, texture, visual defects (cracking, bleeding, patches, potholes, surface homogeneity, fretting), plus skid resistance. Some pavement deflection surveys are carried out but only on short lengths of roads, not on the whole network (the Falling Weight Deflectograph (FWD) is used). Similarly, pavement structure is only measured using GPR (ground penetrating radar) on short lengths of the network. The FWD surveys are mainly done during preparation of a section for maintenance. There are no network-wide surveys on structural condition. The equipment used for measuring transverse shape, ride quality, gradient, crossfall, curvature, texture and visual condition (cracking, potholes, patching, etc.) is very similar to that used for Highways England's TRACS surveys. However, fretting is obtained from imaging systems (as used by the Netherlands). All surface defects are derived from images and there is a catalogue of defects for the different pavements (concrete and asphalt). Skid resistance is measured using the RoadSTAR. Unlike SCRIM, RoadSTAR measures the longitudinal skid resistance with a slip of 18% (near μ_{peak}). There is a well-established correlation of RoadSTAR's μ-values to braking deceleration of passenger cars. The whole measurement device represents a quarter of a car at full braking (see also CEN TS 15901-1).
c. Quality/ condition of roads	Information on current condition is confidential. A strategic goal of ASFINAG is network availability for the user (above 95%). Furthermore, there are some other customer related indicators (maximum number of construction sites, severity of construction sites, maximum time loss due to construction sites, etc.). For condition indicators, the goal is to be below 3% in "poor condition" for safety relevant indicators (safety index which depends on skid resistance and ruts).
d. Techniques used to assess	Transverse evenness, ride quality and texture are measured with laser-based systems. More information about these kinds of systems can be found in the HiSPEQ equipment

Country: Austria		

pavement condition	template guidance[53]. Gradient, crossfall and curvature are measured using a combination of laser systems and inertial measurements. Visual condition (cracking, potholes, patching, fretting etc.) is measured by manual analysis of images of the pavement surface.
	Before 2018: Surveys of all lanes and slip roads have been carried out at an interval of 5 years. Roundabouts and hard shoulders are not surveyed.
	From 2018: There will be a change to 4-year interval. After 4 years, all lanes in both directions and slip roads will have been surveyed.

3. Targets and performance	

a. Metrics and target setting (if any)	There are two combined indicators ("Gebrauchswert/comfort and safety index" and "Substanzwert/structural index"). One is a combination of safety and comfort related indicators (ruts, longitudinal Evenness, skid resistance), the other one related to structural properties (surface defects, …)
	Target values: See "2c. Quality/ condition of roads"

b. Use of financial incentives to drive performance (if any)	For newly paved roads, thresholds exist for skid resistance, longitudinal and transverse evenness (defined in Austrian regulations). New work approval is done by independent testing institutes (which need an accreditation for this work). For small deviations, financial penalties are used or the contractor improves the work. Larger deviations must be corrected by the contractor or at the contractor's cost.
	For these parameters, thresholds also exist at the end of the warranty period (5 years for motorways and expressways) where only improvement by the contractor is accepted.
	There is no incentive/bonus scheme in place.

c. Performance monitoring	The following flow chart show how the Comfort/Safety and Structural indices are calculated for flexible pavements.
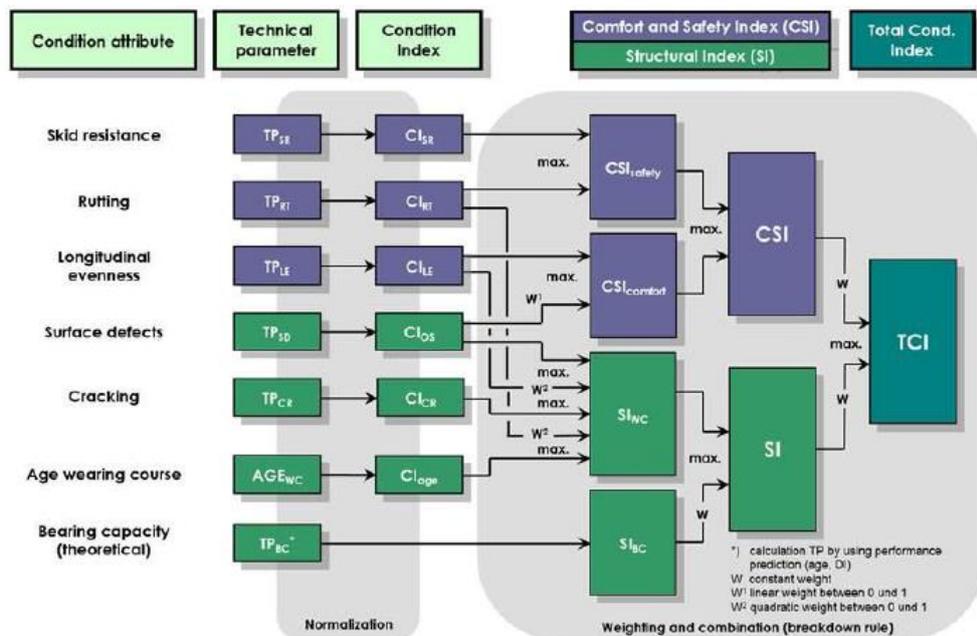
Technical Parameter	Definition
TP$_{SR}$	Skid resistance measurements, averaged over 50m lengths

[53] https://hispeg.com/projectoutput/equipment-specifications-and-guidance/

	TP_{RT}	Max (average rut depth in left wheelpath, average rut depth in right wheelpath) over 50m lengths
	TP_{LE}	The average IRI value (m/km units), reported over 50m lengths. This is calculated from longitudinal profile measured in the nearside wheelpath. (This will soon be replaced by "Weighted longitudinal profile" measure)
	TP_{SD}	Surface deterioration is assessed by visual inspection of pavement images to assess if surface deterioration is present. A manual of defects is used to rate each defect and a rating of S1 or S2 is assigned, with S2 being the most severe. For each 50m length, the weighted sum of the area affected by S1 defects, and S2 defects is calculated to obtain the technical parameter: $TP_{SD} = 100\% * ((\sum AM_{CR} * G_{CR}) / A_b$ $[0\% \le TP_{SD} \le 100\%]$ Where the sum is over each defect in the length, AM = Length affected by the defect G_{SD} = 1.0 if the rating is S1, and 5.0 if the rating is S2 A_b = Area of the 50m length
	TP_{CR}	Cracking is assessed by visual inspection of pavement images and the assessor records if cracks are present in each 0.5m square covering the width and length of the lane. For the squares containing cracking, the pavement is rated S1, S2 or S3, where S1 is minor cracks, S3 is major cracking. TP_{CR} is calculated for each 50m of the network. $TP_{CR} = 100\% * (0.5 * (\sum AML_{CR} * G_{CR}) + \sum AMA_{CR} * G_{CR}) / A_b$, $[0\% \le TP_{CR} \le 100\%]$ Where the sum is over each crack in the length AML = length of crack G_{CR} = 0.4 if the rating is S1, 1.0 if the rating is S2 and 4.0 if the rating is S3 AMA = Area affected by cracking and A_b = Area of the 50m length.
	AGE_{WC}	The age, in years, of the wearing course (surface)
	TP_{BC}	Theoretical bearing capacity

The condition indices (i.e. Comfort and Safety Index and the Structural Index) are calculated using the indexes given below.

Condition Index	Calculation
Skid resistance CISR	CI_{SR} = 9.9286 - 14.286 * TP_{sr} $[3.5 < CI_{sr} < 5.0]$ and $[TP_{sr} < 0.45]$ CI_{SR} = 6.5 - 6.6667 * TP_{sr} $[1.0 < CI_{sr} < 3.5]$ and $[TP_{sr} > 0.45]$
Rutting CI_{RT}	CI_{rt} = 1.0 + 0.175 * TP_{rt} $[1.0 < CI_{rt} < 5.0]$
Longitudinal Evenness CI_{le}	CI_{le} = 1.0 + 0.7778 * TP_{le} $[1.0 < CI_{le} < 5.0]$

Surface defects CI_{SD}	$1.0 + 0.0875 * TP_{le}$ $[1.0 < CI_{sd} < 5.0]$	
Cracking CI_{CR}	$CI_{SD} = 1.0 + 0.35*TP_{cr}$ $[1.0 < CI_{le} < 5.0]$	
Age of wearing course CI_{Age}	$CI_{Age} = 0.21 * AGE_{wc} - 0.17$ For asphalt wearing courses with a thickness > 2cm $CI_{Age} = 0.30 * AGE_{wc} - 0.17$ For asphalt wearing courses with a thickness < 2cm $CI_{Age} = 0.35 * AGE_{wc} - 0.17$ For porous asphalt wearing courses $[1.0 <= CI_{Age} <= 5.0]$	

The Comfort and Safety Index is calculated using the condition indices:

Comfort and Safety Index (CSI)	Calculation
CSI_{Safety}	$CSI_{Safety} = max(CI_{RT};CI_{SR}) + 0.1*min(CI_{RT};CI_{SR}) - 0.1$ $[1.0 < CSI_{Safety} < 5.0]$
$CS|_{Comfort}$	$CS|_{Comfort} = max(CI_{LE}; 1 + 0.0021875*TP_{SD}^2) + 0.1 * min(CI_{LE}; 1 + 0.0021875*TP_{SD}^2) - 0.1$ $[1.0 < CSI_{Comfort} < 5.0]$
CSI	$CSI = max(CS|_{Safety}; CS|_{Comfort}) + 0.1 min(CS|_{Safety}; CS|_{Comfort}) - 0.1,$ $[1.0 < CSI < 5.0]$

The Structural Index is calculated using the condition indices:

Structural Index (SI)	Calculation
SI_{WC}	$SI_{WC} = max\{max(CI_{CR}; CI_{SD}) + 0.1 * min(CI_{CR}; CI_{SD}) - 0.1;$ $max[min(1.0 + 0.00010938 * TP_{RT}^3; 5); min(1.0 + 0.03840988*TP_{LE}^3; 5)];$ $min(0.08*CI_{CR} + 0.61; 0.85) * CI_{Age}\}$ $[1.0 < SI_{wc} < 5.0]$
SI_{BC}	$SI_{BC} = 1.0 + 0.35 * TP_{BC}$ $[1.0 < SI_{BC} < 5.0]$

d. Role of contractors in performance	Surveys are contracted by an EC-wide tendering process – the winning bidder delivers the data but is not involved with maintenance planning. Construction companies cannot influence the results of the performance monitoring.
e. Potential for incentives to influence performance	There are currently no incentives used.

A.3.   Cornwall

Local Authority: Cornwall

1. General	
a. Demography (population)	536,000
b. Climate	Comparable to the rest of England
c. Length of road network and description	Cornwall Council is a predominantly rural area, with a publicly maintained road network of 7,244 km.

Cornwall considers its roads by hierarchy (i.e. a road's importance, based on traffic), not class, since this is just a label, which can often be out of date. The following tables show the distribution of the network length by hierarchy class and environment. Please note that the figures given are for local authority-maintained roads and do not include Trunk Roads.

Hierarchy/Class	A Road	B Road	C Road	U Roads	Total Length
2a Strategic Routes	222.8				222.8
2b Strategic Routes	342.8				342.8
3a Main Distributor		480.9	216.8	20.8	718.5
3b Secondary Distributor		102.8	684.0	147.0	933.8
4a Local Roads		0.1	549.9	95.1	645.1
4b Local Access Roads		0.1	747.4	2606.0	3353.5
5 Other Access Roads			438.5	488.6	927.2
6a Green Lanes			1.2	25.3	26.6
6b Green Lanes			1.3	72.7	74.0
Totals	**564.4**	**583.8**	**2640.3**	**3455.6**	**7244.2**

Hierarchy/Environment	Urban	Rural	Total Length
2a Strategic Routes	43.3	179.5	222.8
2b Strategic Routes	70.0	272.8	342.8
3a Main Distributor	192.4	526.1	718.5
3b Secondary Distributor	209.9	723.9	933.8
4a Local Roads	140.2	504.9	645.1
4b Local Access Roads	989.1	2364.4	3353.5
5 Other Access Roads	3.6	923.6	927.2
6a Green Lanes	0.0	26.6	26.6
6b Green Lanes	0.0	74.0	74.0
Totals	**1648.5**	**5595.7**	**7244.2**

	The construction of the road network is mainly flexible composition with bituminous surfacing material (used to be HRA (Hot Rolled Asphalt) and chips but now SMA (stone mastic asphalt), thin surfacing or surface dressing). This is very similar to construction used for Highways England roads, but the pavements are built to a lower specification (e.g. thinner, weaker), due to the lower levels of traffic using the roads, in particular the HGV traffic.
	The highest AADT (annual average daily traffic) on the A Roads is around 30,000 but this is generally confined to the A390 and A39 around Truro. The remainder of the roads are on a sliding scale running down to relatively low flows, around 3500-4000 AADT, particularly on the A roads that serve coastal communities on the Roseland and Lizard Peninsulas (A3078 & A3083 are good example). To allow differentiation between the management of this diverse network the A roads are split into two hierarchies, hence the national category 2 became 2a (higher usage like A390 & A39 around Truro) and 2b (lower usage like A3078). About 9% of the traffic is HGV.
d. Name of the road management agency	Cornwall Council
e. Name of external overseeing authority, e.g. regulator, if any	DfT
f. Road management agency accountable to	N/A
2. Management of roads and pavement conditions	
a. Approach to managing the road network	Cornwall Council is responsible for measuring condition, interpreting the maintenance need and carrying out the maintenance on its road network.
b. Methodology used in measuring pavement conditions	SCANNER Each LA is required by the DfT to commission SCANNER surveys of its network to obtain measures of rutting, ride quality (3m and 10m LPV), texture, cracking, edge deterioration, transverse unevenness and images of the pavement surface. These surveys are contracted out. CVI It also carries out CVI (coarse visual inspection) surveys, which can be used to verify the SCANNER data and also supplement the SCANNER surveys to aid identification of maintenance need. These are performed by employees of Cornwall Council. SCRIM It uses SCRIM surveys (contracted out) to obtain skid resistance measurements for all of the higher hierarchy roads, i.e. 2a, 2b & 3a. This encompasses all A roads, and higher usage B, C & U roads. It also measures deflection (using Deflectograph or FWD) on the hierarchy 2a network (the higher usage A roads) but only as a scheme identification and diagnostic tool.
c. Quality/ condition of roads	1% of Cornish A roads required maintenance in 2016/17[54].

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[54] http://www.ukroadsliaisongroup.org/en/asset-condition/road-condition-information/data-management/uk-pavement-management-system-ukpms/national-reporting.cfm for current condition reporting

Local Authority: Cornwall	
d. Techniques used to assess pavement condition	SCANNER SCANNER surveys were developed in 2000. These were based on TRACS surveys at the time (used for the strategic road network), with small adjustments to suit the local road network. Thus, the devices used for these SCANNER surveys use similar technology to the TRACS survey to collect condition. However, since the SCANNER survey specification has not been updated since 2006, unlike TRACS, the SCANNER equipment is not used to its full potential e.g. lower resolution data is collected/reported. DfT requires each LA to survey its A road network every 2 years and its B and C roads every 4 years. SCANNER surveys are not usually carried out on U roads, due to the challenge that these roads present, however, Cornwall Council does commission SCANNER surveys on some of its U road network. CVI CVIs are carried out by inspectors travelling in a car on the network. These will record the location of any aspects of visual condition that need further investigation. The whole network is subjected to a CVI survey approximately once a month. SCRIM Skid resistance is measured every other year on the A road network. DVI Once a length has been confirmed as needing further investigation, a DVI (detailed visual inspection) is carried out. This records visual features, such as rutting, fretting[55], cracking, road deformation.
3. Targets and performance	
a. Metrics and target setting (if any)	Rutting, ride quality, cracking and texture are used from SCANNER surveys to produce the RCI (Road Condition Index) for each 10m on a local authority's network. See South Lanarkshire 3a for RCI calculation details. There are then two "Data Topic" indicators produced: 130-01 for principal roads and 130-02 for non-principal classified roads. The indicator is the percentage of lengths where the RCI indicates that there is need for maintenance (RCI≥100). These indicators are reported to DfT on an annual basis and made publicly available[56]. DfT does not set targets for road pavement network condition, however, it may check why RCIs were deteriorating if it spotted a trend. Network conditions are no longer included in the DfT capital budget allocation calculations. Capital budgets are now allocated on criteria such as network length, rural/urban split, traffic volumes etc. Cornwall Council also identifies the lengths where the RCI has a value between 80 and 100, in order to know where the RCI might exceed 100 the following year. It also applies different thresholds and weightings to calculate an alternative RCI for some of its C roads, as there is a huge diversity in these roads and the thresholds set for standard RCI calculation are not appropriate for all of the C roads. This is not reported externally. Cornwall set itself the target of being in the top quartile of all LAs for its 130-01 and 130-02 scores but this is not a national requirement.

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[55] Also known as ravelling, is where stones are lost from the surface course of the pavement.
[56] http://www.ukroadsliaisongroup.org/en/asset-condition/road-condition-information/data-management/uk-pavement-management-system-ukpms/national-reporting.cfm

Local Authority: Cornwall	
b. Use of financial incentives to drive performance (if any)	None used – the Council is provided with a budget from government and prioritises the maintenance as best it can.
c. Performance monitoring	Rutting, ride quality, texture, cracking, fretting, surface loss, pavement deformation, and potholes are monitored (using SCANNER and CVI data), along with skid resistance on A roads.
	Indicators are calculated annually and are based on SCANNER data only – see section 2d for frequency of data collection.
	See section 3a for reporting on performance as a result of monitoring.
d. Role of contractors in performance	Contractors are used to collect the SCANNER and SCRIM data and also to perform maintenance. Thus, there is no ability to influence the results of performance monitoring.
e. Potential for incentives to influence performance	N/A

A.4.   Denmark

Country: Denmark	

1. General	
a. Demography (population)	5.731 million
b. Climate	Denmark has a temperate climate characterised by mild winters and cool summers. Daytime temperatures are about 1.5°C in the winter and 17°C in the summer. Thus, the climate in Denmark is similar to that in the UK and thus will have the same effect on the road network.
c. Length of road network and description	The State road network constitutes almost 4,000 km, which represents about five percent of the entire road network in Denmark. 1,130km of these are motorways. The AADT is between 5,000 and 125,000 on the state road network. The following table shows the total 10^9 km travelled on the State roads each year, split by vehicle type.

	Passenger car	Small truck	Truck without trailer	Truck with permanent trailer	Truck with trailer	Bus	Total
Motorway	13.93	1.69	0.21	0.17	0.83	0.08	16.90
Other state road	5.89	0.66	0.09	0.06	0.19	0.06	6.95

All of the Danish roads are flexible pavements and most of the surface layers are SMA-type (stone mastic asphalt) but on roads with less traffic asphalt concrete (AC) is also used.

d. Name of the road management agency	Vejdirektoratet = Danish Road Directorate (DRD)
e. Name of external overseeing authority, e.g. regulator, if any	DRD does not have an overseeing authority.
f. Road management agency accountable to	The Danish Road Directorate is based at six service centres across the country and form part of the Ministry of Transport.

2. Management of roads and pavement conditions	
a. Approach to managing the road network	DRD owns all of the survey equipment used to monitor condition and so carries out the surveys. It also decides where there is maintenance need but hires contractors to do the maintenance work.
b. Methodology used in measuring pavement conditions	On a network level DRD measures: Transverse shape (rutting), ride quality, gradient, curvature, crossfall/camber, texture, deflection (TSD). Some skid resistance surveys and falling weight deflectometer (FWD) are carried out but only on short lengths of roads, being considered for maintenance, not on the whole network.

Country: Denmark	

	The equipment used for measuring transverse shape, ride quality, road geometry, and texture is very similar to that used for Highways England's TRACS surveys.
	Similarly, the TSD is used for deflection surveys, which is the same as Highways England, although the two devices are not identical.
	Visual condition (cracking, fretting etc.) is obtained from visual inspections of the road network. DRD carries out visual surveys on approximately 50% of the network where cracking and fretting account for approximately 90% of the visually assessed damage, but also bleeding, potholes and other types of distresses are evaluated.
	Skid resistance is measured at a scheme level using a Viafriction device, which operates on the same principle as the previous RoAR device i.e. the longitudinal friction principle and thus measures the "longitudinal friction coefficient" (LFC). The LFC is the ratio between horizontal force (drag) and vertical force (load) for a braked wheel in controlled conditions.
	The LFC is different from the sideway-force coefficient (SFC) that is measured by SCRIM, which is the ratio between the vertical force (load) and horizontal force (side force) in controlled conditions. The two measurements are not always correlated. A good description of these measurement devices and techniques and how they differ is given in the TYROSAFE deliverable D04[57].
c. Quality/ condition of roads	In the last six years, DRD has worked towards one goal only and that is to get rid of its backlog. The backlog is based on an overall visual score of the road.
	As discussed below, it does not use a condition metric, so the only way that it could report condition would be on a per-parameter basis, but it does not publish these figures.
d. Techniques used to assess pavement condition	Transverse evenness, ride quality, and texture are measured with laser-based systems. More information about these kinds of systems can be found in the HiSPEQ equipment template guidance[58]. Road geometry (gradient, crossfall, curvature) is measured using a combination of laser systems and inertial measurements.
	DRD surveys 2 lanes in each direction on the motorways and one lane in each direction on the rest of the State roads on an annual basis. Slip roads are surveyed every second year.
	Cracking, fretting, bleeding, patches, and potholes are recorded during visual inspections. Approximately 50 % of the network in worst condition is selected for visual survey. The selection is based on the results from the year before.
	Pavement deflection is measured using the TSD and 1/6 of the heavy lanes (usually lanes 1 and 2) on the motorways and 1/3 of the rest of the State roads are surveyed every year.
3. Targets and performance	
a. Metrics and target setting (if any)	Rutting and other defects are to be repaired when reaching a certain level. A cost benefit analysis is performed by comparing the cost of a new surface layer with the cost of continued repairs over a 10-year period. This cost benefit analysis considers most of the parameters measured, with rutting and ride quality (IRI) being key parameters, however no metric is calculated from the data.
	DRD is in the process of buying a new asset management system and one of the things the system will do is to calculate KPIs for safety, surface heath, structural heath etc. However, how to calculate the KPIs has not been decided.

[57] TYROSAFE (Tyre and Road Surface Optimisation for Skid Resistance and Further Effects) D04: "Report on state-of-the-art of test methods". Report can be found at http://tyrosafe.fehrl.org
[58] https://hispeq.com/projectoutput/equipment-specifications-and-guidance/

Country: Denmark	
b. Use of financial incentives to drive performance (if any)	DRD decides where to do repairs and where to put new surface layers. There are some quality demands with regards to evenness, friction and crossfall on new surface layers but otherwise the contractors get paid an agreed amount for completing the maintenance.
c. Performance monitoring	DRD does not monitor performance in a formal manner.
d. Role of contractors in performance	The contractors have no influence on the work programme – the work to be done is specified.
e. Potential for incentives to influence performance	In the fall of 2018 a tender will be published with a bonus/penalty based on the evenness of the new surface layer. The same kind of incentive has been used with low noise surfaces before and has worked well to deliver better quality pavements.

A.5.   The Netherlands

Country: The Netherlands	
1. General	
a. Demography (population)	17.02 million
b. Climate	The Netherlands has a temperate maritime climate influenced by the North Sea and Atlantic Ocean, with cool summers and moderate winters. Daytime temperatures vary from 2°C-6°C in the winter and 17°C-20°C in the summer. Rainfall is distributed throughout the year with a dryer period from April to September. Thus, the climate in the Netherlands is very similar to that in the UK and thus will have the same effect on the road network.
c. Length of road network and description	There are 5,191km of national roads in the Netherlands, including 3,070km of motorways and 1,650km of access and exit roads and connecting roads. The total length of traffic lanes, including access and exit ramps, access roads and service areas is approximately 7,500 km.
	The motor vehicle density on the network of roads in the Netherlands is very similar to the UK, with 63.71 vehicles per km of road, compared to 76.90. Similarly, the distance travelled is comparable: 954.36 vehicle-km/km of network in the Netherlands and 1181.81 in the UK[59]
	The annual average daily flow (AADF) is 2261 vehicles per hour[60] with 20% being HGV[61]
	The road construction is mainly flexible composition with porous asphalt surfacing (not commonly used in the UK). 90% of the network is now constructed with porous asphalt, with the remaining 10% regular asphalt[62].
d. Name of the road management agency	Rijkswaterstaat (RWS)
e. Name of external overseeing authority, e.g. regulator, if any	None
f. Road management agency accountable to	RWS has a Service Level Agreement with The Ministry of Infrastructure and Water Management.
2. Management of roads and pavement conditions	
a. Approach to managing the road network	**Strategy for road maintenance** RWS implements a variable road maintenance programme that is condition dependent and is performed upon reaching the intervention levels. Within variable maintenance, a distinction is made between major maintenance (MM) and life-extending maintenance (LEM). In the case of Major Maintenance, the road surface is replaced carriageway-wide and the underlying asphalt layers are repaired where necessary. For

[59] *"Road traffic, vehicles and networks | Environment at a Glance 2013: OECD Indicators"* (Press release). Paris, France: OECD Publishing. 2013. Retrieved 2018-02-22.

[60] CBS, Statline, numbers valid for 2017

[61] *"Road traffic, vehicles and networks | Environment at a Glance 2013: OECD Indicators"* (Press release). Paris, France: OECD Publishing. 2013. Retrieved 2018-02-22.

[62] BEST4ROAD "Country-specific reports on road maintenance procurement". Deliverable no. 1.2. Available: http://www.cedr.eu/strategic-plan-tasks/research/cedr-call-2014/call-2014-asset-management-maintenance/best4road-project-results/

the purpose of reprofiling or strengthening of the pavement structure, an interlayer is also applied during Major Maintenance. Life-extending maintenance (LEM) consists of measures that are implemented 'in the interim' to ensure that the intended life cycle of the road surface can be achieved.

Maintenance is carried out according to a set pattern whereby the first maintenance interval (usually LEM) after construction, or carriageway-wide maintenance, comprises lane-wide (right-side lane) maintenance, and the next maintenance interval once more comprises carriageway-wide maintenance (usually MM). In the case of multi-lane roads, the 2 rightmost lanes are replaced during this first maintenance interval. The following interval will again be carriageway-wide maintenance, including the emergency lane.

Every year RWS gives advice on the variable pavement maintenance. This is the Strategic Planning Road Surfaces and is discussed with the road district before it is adopted. There are 16 districts in the Netherlands. This advice will then form the technical foundation for the programming in RUPS (Rijkswaterstaat Uniform Programming System), which regions use to prepare the regional programming for all assets. Output from RUPS is an integral maintenance planning programme for all assets.

Strategic Planning Road Surfaces

For Strategic Planning Road Surfaces the road network is monitored every year to minimize the risks. The following defects are monitored: Skid resistance, Rutting / crossfall, Ride quality (IRI), Ravelling (or fretting), and Cracking. In addition, the deflection has been measured with a one-off survey, using the Falling Weight Deflectometer (FWD).

For each defect it calculates how many years the road section will last until maintenance is needed. It then checks which defect is the most critical and the maintenance plan produced with a maximum horizon of five years based on the results of the monitoring. It also estimates the budget after the five years, but this is theoretically based on a life cycle approach and the age of the pavement.

There are four contracts let for condition surveys:

- Two contractors are used to measure skid resistance
- One contractor is used for the other defects (rutting, crossfall, ride quality, ravelling and cracking). Two contractors will be used from May/June 2019.
- The developed algorithms for ravelling are not completely suitable for two-layer porous asphalt. So, a visual survey is carried out, to perform a check on the results from the machine survey on approximately 30% of the network.
- Contract for the one-off FWD survey (may be repeated in the future).

Until a recent fire destroyed all of the survey equipment, Rijkswaterstaat carried out part of the condition surveys. Skid resistance was already surveyed by external companies and Rijkswaterstaat is currently in the process of deciding whether to purchase new measuring equipment or contract all measurements.

Contracts for regular maintenance

For regular pavement maintenance performance contracts are used. There

	are approximately eight of these contracts for the network. For several years, the regular maintenance is performed based on indicators and, in the case of pavements, concerns the following:
	- Minor maintenance of pavements (the so-called grey maintenance), such as repaving activities and kerbstones, cleaning of porous asphalt, cleaning and maintenance of roadsides and water drains (gutters, drains and tubes), earthworks (e.g. roadside finishing and the removal of overgrown edges) and several small jobs for the purpose of the conservation of the pavement, such as treatment with bitumen and split, the roughening of slippery spots and the filling of cracks and holes (contracts include the supply of the materials). - Controlling weeds on pavements/cleaning of the pavement. - Repairing damage to pavements because of accidents and emergencies. ***Contracts for major maintenance*** Every region will have a contract for doing major maintenance. Before any maintenance, further investigation is performed: core drilling, FWD, visual survey, research of base material and asphalt. Based on this research the need to reinforce the pavement or if surface maintenance is sufficient will be identified.
b. Methodology used in measuring pavement conditions	Skid resistance RWS use the Side-way Force method according the German Method (TP-Griff – SKM). The contractors are certified by BAST, who also quality control the other monitoring. Whilst the measurement technique is similar to SCRIM, it uses different tyres: SKM tyres produce SR values 4-8% higher than SCRIM tyres. Other defects Rutting, evenness, ravelling and cracking are measured with an LCMS, a laser scanner similar to that used by the TRACS contractor. The cracks are detected automatically and then manually checked to confirm the accuracy (if the crack existed in a previous survey, then it will be confirmed automatically, which reduces the amount of checking needed).
c. Quality/ condition of roads	In 2017 98% of the network met the intervention limits i.e. did not require maintenance (see section 3a below for intervention limits).
d. Techniques used to assess pavement condition	Pavement shape, ravelling and cracking are measured with laser-based systems (LCMS). Crossfall is measured using a combination of laser systems and inertial measurements. For cracking a manual check is also performed. Skid resistance is monitored every year in the right lane (Lane 1) and locations with high risks e.g. roundabouts. The defects rutting, crossfall and riding quality are monitored every year on only the right-hand lane (Lane 1). Ravelling (referred to as fretting in England) and cracking are monitored every year on all lanes with traffic (i.e. not the emergency lane).
3. Targets and performance	
a. Metrics and target setting (if any)	For each 100m on the network, the following intervention limits are applied: Skid resistance: 0.51 at 80 km/h for porous asphalt and 0.53 at 80 km/h for impervious asphalt

	- Rutting: 17mm - IRI: 3.4m/km - Cracking: 30% of the 100m length affected by cracking and a maximum crack width of 20mm - Ravelling: 25% of the length affected by ravelling with a maximum severity of 20 % stone loss per square metre. The percentage of lengths for which all defects are below the intervention limits is reported. Its target is to meet the limits for 97% of the network.
b. Use of financial incentives to drive performance (if any)	None
c. Performance monitoring	Rutting, ride quality, cracking, ravelling and skid resistance are monitored. Indicators are calculated annually and are based on all of these defects – see section 2d for frequency of data collection. See section 3a for reporting on performance as a result of monitoring.
d. Role of contractors in performance	None
e. Potential for incentives to influence performance	None

A.6.   Scotland

Country: Scotland	
1. General	
a. Demography (population)	5.295 million
b. Climate	Colder and wetter than England but comparable, so will not have a significant effect on the road condition.
c. Length of road network and description	The Trunk Road Network[63] (TRN) in Scotland is 3,507 km long, including slip roads and roundabouts. 596km of this is motorway, with a further 518km of dual carriageway and 2,315km of single carriageway. 501 km of the network has a hard shoulder. An average of 24,698 vehicles[64] use the trunk road network every day, with a maximum of over 165,000 on the M8. 8.2% of the traffic comprises HGVs, with 0.4% motorcycles, 75.9% cars, 0.7% buses/coaches, and the remaining 14.7% LGV. The dominant construction type is fully flexible, with around 20-30% of flexible composite construction. There is very little concrete present. The preferred material for surfacing is TS2010 surface course.
d. Name of the road management agency	Transport Scotland
e. Name of external supervisory authority, e.g. regulator, if any	Transport Scotland employs the Performance Audit Group (PAG) to monitor the performance of the Operating Companies. PAG performs more than 80 detailed audits per annum, monitoring more than 1,200 road works sites each year and reporting on the financial, technical and performance aspects of the Operating Companies. PAG also reviews payment requests from the Operating Companies and carries out inter-unit comparisons. Transport Scotland is also audited on an annual basis by Audit Scotland. The Road Asset Management Plan (RAMP) 2016 describes the TRN and its condition together with Transport Scotland history and plans for maintenance spends and future maintenance funding.
f. Road management agency accountable to	Transport Scotland is accountable to Scottish Ministers (i.e. Scottish Government).
2. Management of roads and pavement conditions	
a. Approach to managing the road network	The TRN is split into 4 regional units and the Forth Bridges unit. These contracts are operated as follows: • North West – operated by BEAR Scotland since April 2013 • North East – operated by BEAR Scotland since August • South East – operated by Amey since August 2014 • South West – operated by Scotland TranServ since April 2013 • Forth Bridges Unit - operated by Amey since June 2015. The Operating Companies carry out annual road visual condition surveys as part of their contract. They ensure that the best value is achieved from the

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[63] Data from the Transport Scotland Road Asset Management Plan (RAMP) 2016 and DfT Transport Statistics 2016. No more recent editions of these reports are available.
[64] The average traffic is from the annual traffic divided by the road length and number of days in the year

	maintenance scheme by analysing the information and condition trends before prioritising and planning work accordingly. The Road Asset Management Plan (RAMP) 2016 describes this in more detail.
b. Methodology used in measuring pavement conditions	Three types of vehicle are used for surveying: • Deflectograph surveys measure the deflection of the road under load. This data can be used to estimate the strength of road structures, enabling the "useful life" of a road to be determined and enable identification of areas needing strengthening. The condition survey data is stored in the Transport Scotland Pavement Management System. • SCANNER (Surface Condition Assessment for the National Network of Roads) surveys measure the surface condition and ride quality, pointing Transport Scotland towards the road lengths in the network that need maintenance. The condition survey data is stored in the Transport Scotland Pavement Management System. • Skid resistance surveys are used to help reduce accident rates by measuring the wet skidding resistance of road surfaces. The SCRIM (Sideway-force Coefficient Routine Investigation Machine) is currently used for these surveys. The condition survey data is stored in the Transport Scotland Pavement Management System. These are all operated by contractors. See 2d below for more information on these surveys.
c. Quality/ condition of roads	The Road Asset Management Plan (RAMP) 2016[65] provides the latest published condition information for 2014/15. Network condition is reported in 3 bands: Red, Amber Green defined by the TS RCI as shown below:

Green	Good (TS RCI <40)	Considered to be in a good state of repair; and does not require investigation or maintenance.
Amber	Fair (TS RCI ≥40- <100)	Should be investigated to provide the optimum time for planned maintenance intervention.
Red	Poor (TS RCI ≥100)	Should be investigated to determine if structural maintenance is required.

In 2014/15 the percentage of Transport Scotland roads in poor condition was 13% Later figures (unpublished) for 2015/16 and 2016/17 show 14% of the network in poor condition.

Transport Scotland also uses a separate SCRIM measure with the network condition shown in the table below. It is important to note that the Transport Scotland network is very different to the Highways England network in that the Highways England network has a large proportion of non-event carriageways (mainline motorways and dual carriageways) but the Transport Scotland network has a larger proportion of single carriageways containing more event sites **Data showing the skid resistance of the TRN in Scotland is not published.**

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[65] https://www.transport.gov.scot/publication/road-asset-management-plan-for-scottish-trunk-roads-january-2016/

Country: Scotland	

d. Techniques used to assess pavement condition	**SCANNER** Transport Scotland adopts the same surveys for road surface condition as used by Local Authorities in England. SCANNER surveys were developed in 2000 and were based on TRACS surveys at the time (used for the English strategic road network). Thus, the devices used for these SCANNER surveys use similar technology to the TRACS survey to collect condition. However, since the SCANNER survey specification has not been updated since 2006, unlike TRACS, the SCANNER equipment is not used to its full potential e.g. lower resolution data is collected/reported. Transport Scotland is considering requiring data delivered to the TRACS specification when the next survey contract is let (contracts to date have lasted at least 5 years). Half of the network is surveyed annually, giving full network coverage every two years. Lane 1 of main carriageways and slip roads are surveyed, along with some roundabouts. **Deflectograph** The Deflectograph is a self-contained lorry-mounted system, where a loaded wheel passes over the road, the road deflects, and the size of the deflection is then measured. The data from this device can then be used, along with pavement construction information, to calculate the strength of the pavement, which is reported as remaining useful life. It can be used to identify areas requiring strengthening. Deflectograph surveys are slow speed – the vehicle travels at a speed of 2.5 km/h and thus it requires road closures and/or traffic management when used on the SRN. One-fifth of the network is surveyed annually, giving full network coverage every five years. The survey is in Lane 1 of main carriageways and roundabouts but not slip roads. **Safety Inspection** Safety Inspections are carried out by inspectors travelling in a car on the network. They record the location of any aspects of visual condition that need prompt attention. The whole network is subjected to a safety inspection approximately once a week, along with safety patrols on selected routes. This enables Transport Scotland to identify and repair the most serious defects quickly **Routine Detailed Inspection** Detailed inspections of carriageways are carried out annually, usually on foot. Defects are recorded on data capture devices and stored in Transport Scotland's Routine Management Maintenance System. The purpose of detailed inspections is to identify defects that cannot be seen from safety inspections and, generally, do not present an immediate or imminent safety issue **Scheme visual inspection** When a length of carriageway has been confirmed as needing further investigation, a Scheme visual inspection is carried out. This records visual features, such as rutting, fretting[66], cracking, road deformation (i.e. defects not reliably measured as part of the traffic speed surveys) in a precise, detailed manner which is used to support bids for funding to deliver a maintenance scheme. **Skid resistance**

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[66] Also known as ravelling, is where stones are lost from the surface course of the pavement.

	Transport Scotland undertakes annual wet skidding resistance surveys of all the SRN. The surveys of the SRN are currently using a SCRIM (Sideway-force Coefficient Routine Investigation Machine). Each length of road is assigned a skid resistance threshold known as an Investigatory Level. Lengths that are at or below the Investigatory Level are investigated in accordance with the Design Standard (HD28/15) and Transport Scotland's Skid Resistance Policy. A length of road with skid resistance values below the Investigatory Level does not in itself mean that the road surface is deficient, sub-standard or unsafe. It is merely a trigger for a more detailed investigation. This approach is the same as that used by Highways England. The whole network is surveyed annually, with Lane 1 of all main carriageways, slip roads and roundabouts included. Some, but not all, outer lanes are surveyed on main carriageways.
3. Targets and performance	
a. Metrics and target setting (if any)	Transport Scotland has developed a condition performance measure to show the percentage of the network in different levels of condition. Transport Scotland uses the condition data to generate a score for each length of carriageway, known as the Transport Scotland Road Condition Indicator (TS RCI). The three Transport Scotland RCI condition categories are shown in section 2b. In recent years Transport Scotland has had a short-term target to maintain the TS RCI at current levels (86% in good or fair condition). However, there is also an optimum long-term target for Ministers to consider as an option in Scottish Government Spending Reviews - 97% of motorways, 94% of dual carriageways and 92% of single carriageways in good or fair condition.
b. Use of financial incentives to drive performance (if any)	The Operating Company Contract Schedule contains details of Payment Adjustment Factors which are applied to certain Operations for inspection and maintenance but not for renewals maintenance. The factors are calculated based on performance and deducted from payments accordingly.
c. Performance monitoring	Rutting, ride quality, texture, cracking, fretting, surface loss, pavement deformation, and potholes are monitored (using SCANNER and inspection data), along with skid resistance (SCRIM) and pavement deflection (Deflectograph). The TS RCI values are reported internally and were included in the 2016 Road Asset Management Plan and reported by Audit Scotland[67] (no more recent published information). The TS RCI uses SCANNER, SCRIM and Deflectograph data (see section 2d above for frequency of data collection). This is different to the RCI used by Local Authorities in England and Scotland as these organisations do not include Deflectograph data in their RCI calculation. It is unclear if the algorithms and thresholds used for TS RCI are the same as those used for the Local Authority RCI for the defects included in both indicators. See section 3a for reporting on performance as a result of monitoring.
d. Role of contractors in performance	Survey contractors collect and analyse the condition measurements before they are stored in the Transport Scotland Pavement Management System. The contractors have no influence on the level of condition. The Operating Companies use the condition data to propose maintenance schemes, but Transport Scotland approves the maintenance programme to implement.

[67] http://www.audit-scotland.gov.uk/maintaining-scotlands-roads

Country: Scotland	
e. Potential for incentives to influence performance	The Scottish Government allocates funds through the Spending Review; Transport Scotland uses a carriageway financial model to allocate the available budget to each Operating Company on the basis of the network condition in their area. For the allocated funds, Transport Scotland has established a robust value for money processes to enable the Operating Companies and Transport Scotland to work together to ensure that the proposed structural maintenance schemes deliver the correct treatment, offer value for money and will improve the condition of the trunk road network. Road condition data for each proposed road structural maintenance scheme is assessed to ensure that a high percentage of the poor condition band (i.e. to be considered for maintenance) will be treated. Prior to scheme approval the proposed schemes are prioritised based on the lengths in poor condition.
	As described in section 3b, for operational (routine) maintenance, the payment adjustment factors have been calculated by Transport Scotland based on performance and applied during the contracts accordingly.

A.7.   South Lanarkshire

Local Authority: South Lanarkshire	
1. General	
a. Demography (population)	>300,000
b. Climate	On average a couple of degrees colder than England and slightly more rainfall. The climate in South Lanarkshire isn't likely to affect pavement condition in a different way than it does in other parts of England.
c. Length of road network and description	South Lanarkshire Council is a semi-urban area, with a publicly maintained road network of 2,295Km. The table below shows the distribution of the network length by class and environment. Please note that the figures given below are for local authority-maintained roads and do not include Trunk Roads. _(table below)_ The construction of the road network is mainly flexible composition with bituminous surfacing material (mainly HRA (Hot Rolled Asphalt)). Whilst this is similar to Highways England construction, the design of the pavements will be to a lower specification (i.e. thinner, weaker, due to the requirement to carry less traffic and in particular less HGV traffic. Between 615 to 40,902 vehicles use the network per day, with an average AADF (annual average daily flow) for the whole network of 10,818.

Class	Environment	
	Urban	Rural
A	85.152 km	196.997 km
B	66.985 km	186.390 km
C	88.737 km	356.169 km
U	971.997 km	342.814 km
Total	**1,212.871 km**	**1,082.370 km**
Overall total		**2,295.241 km**

d. Name of the road management agency	South Lanarkshire Council
e. Name of external overseeing authority, e.g. regulator, if any	DfT
f. Road management agency accountable to	N/A
2. Management of roads and pavement conditions	
a. Approach to managing the road network	South Lanarkshire Council is responsible for measuring condition, interpreting the maintenance need and carrying out the maintenance on its road network. The measurement of condition at traffic speed (e.g. SCANNER) is contracted out, as is the actual maintenance. Otherwise, the council manages the work.
b. Methodology used in measuring pavement conditions	**SCANNER (see 2d below)** Each LA is required by the DfT to commission SCANNER surveys of its networks to obtain measures of rutting, ride quality (3m and 10m LPV), texture, cracking,

edge deterioration, transverse unevenness and images of the pavement surface. South Lanarkshire contracts out these surveys.

Coarse visual inspection (CVI)

CVI surveys are also carried out to verify the SCANNER data and also supplement the SCANNER surveys to aid identification of maintenance need. These are performed by employees of South Lanarkshire Council.

No other carriageway condition testing is carried out by South Lanarkshire.

c. Quality/ condition of roads	In 2016-17, 33.5% of South Lanarkshire's roads were deemed to be requiring consideration for maintenance treatment[68]. This figure is lower than the 36.7% for Scotland as a whole. These figures are obtained through Road Maintenance Condition Surveys. South Lanarkshire's overall road network condition has improved in recent years, as evident through a decline in the % of roads that should be considered for maintenance treatment.[69]
d. Techniques used to assess pavement condition	**SCANNER** SCANNER surveys were developed in 2000. These were based on TRACS surveys at the time (used for the strategic road network), with small adjustments to suit the local road network – for example the addition of an edge roughness parameter in 2007, to detect lengths where overriding HGVs had damaged the edge of the road and a transverse roughness parameter to report transverse roughness where the width of the road would mean that it is inappropriate to calculate rut depths. Thus, the devices used for these SCANNER surveys use similar technology to the TRACS survey to collect condition. However, since the SCANNER survey specification has not been updated since 2006, unlike TRACS, the SCANNER equipment is not used to its full potential e.g. lower resolution data is collected/reported. DfT requires each LA to survey its A road network every 2 years and its B and C roads every 4 years. Only Lane 1 is surveyed on all roads. SCANNER surveys are not usually carried out on U roads, due to the challenge that these roads present – for example, some are very narrow, which restricts access to the survey vehicles without traffic management; some have grass growing in the middle of the road, which will adversely affect transverse evenness measurements. South Lanarkshire Council follows this requirement. **CVI** CVIs are carried out by inspectors travelling in a car on the network. It will record the location of any aspects of visual condition that need further investigation. The whole network is subjected to a CVI survey approximately once a month. **Detailed visual inspection (DVI)** Once a length has been confirmed as needing further investigation, a DVI is carried out. This records visual features, such as rutting, fretting[70], cracking, road deformation.

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[68] Source: http://www.audit-scotland.gov.uk/maintaining-scotlands-roads
[69] Source:
[70] Also known as ravelling, is where stones are lost from the surface course of the pavement.

Local Authority: South Lanarkshire	

a. Metrics and target setting (if any)	Rutting, ride quality, cracking and texture are taken from SCANNER surveys to produce the Road Condition Index (RCI) for each 10m on a local authority's network.
	The calculation of the RCI is as follows for A roads:
	RCI = RutContr + LPVContr + TexContr + CrackContr,
	Where

RutContr	=	0	if rutting ≤10mm
		100	if rutting ≥20mm
		$10*(\text{rut depth} - 10)$	otherwise

LPVContr	=	Max(LPV3Contr,LPV10Contr)

LPV3Contr	=	0	if LPV3 ≤4mm^2
		80	if LPV3 ≥10 mm^2
		$40*(\text{LPV3}-4)/3$	otherwise

LPV10Contr	=	0	if LPV10 ≤21mm^2
		60	if LPV10 ≥56 mm^2
		$12*(\text{LPV10}-21)/7$	otherwise

TexContr	=	0	If texture depth ≥ a mm
		w	If texture depth ≤ b mm
		$w*(a - \text{texture})/(a-b)$	otherwise
		a = 0.7, b = 0.4, w = 75 for rural roads	
		a = 0.6, b = 0.3, w = 50 for urban roads	

CrackContr	=	0	If cracking ≤0.15%
		60	If cracking ≥2%
		$60*(\text{crack} - 0.15)/1.85$	otherwise

Note that the LPV parameters are not the same as those used by Highways England. Highways England uses eLPV, an enhanced LPV measure, introduced due to standard LPV reporting falsely high values where there are extremes of road geometry (gradient, curvature, crossfall). See Section 4.1 of PPR131[71] for details of the differences. Also, the SCANNER survey does not deliver 30m LPV and thus this parameter is not included in the RCI.

There are then two "Data Topic" indicators produced: 130-01 for principal roads and 130-02 for non-principal classified roads. The indicator is the percentage of lengths where the RCI indicates that there is need for maintenance (where the RCI≥100).

These indicators are reported to the DfT on an annual basis and made publicly available (see link: http://www.ukroadsliaisongroup.org/en/asset-condition/road-condition-information/data-management/uk-pavement-management-system-ukpms/national-reporting.cfm). DfT does not set targets for road network condition, however it may check why RCIs were deteriorating if it spotted a trend. Network conditions are no longer included in the DfT

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[71] Benbow E, K Nesnas and A Wright "Shape (surface form) of Local Roads". TRL Published Project Report PPR131. Available from http://www.trl.co.uk/

	capital budget allocation calculations. Capital budgets are now allocated on criteria such as network length, rural/urban split, traffic volumes etc.
	South Lanarkshire also calculates a "reduced" RCI that excludes ride quality from the indicator, as the LA finds this helps to identify lengths where maintenance would bring most benefit.
	To decide where to carry out maintenance, it uses an in-house scoring system, which uses weightings for condition (based on SCANNER and DVI), maintenance category[72]/accessibility, claims/defect reports/members.
b. Use of financial incentives to drive performance (if any)	None used – the Council is provided with a budget from the government and prioritises the maintenance as best it can.
c. Performance monitoring	Rutting, ride quality, texture, cracking, fretting, surface loss, pavement deformation, and potholes are monitored (using SCANNER and CVI data).
	Indicators are calculated annually and are based on SCANNER data only – see section 2d for frequency of data collection.
	See section 3a for reporting the performance as a result of monitoring.
d. Role of contractors in performance	Contractors are only used to collect the SCANNER data and also to perform maintenance. Thus, there is no ability to influence the results of performance monitoring.
e. Potential for incentives to influence performance	N/A

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[72] For example, A roads will need to be maintained to be stronger than B roads, as these are likely to carry more traffic and a larger percentage of HGVs, etc.

A.8. Transport for London

Transport for London	
1. General	
a. Demography (population)	8.7 million
b. Climate	Comparable to the rest of England.
c. Length of road network and description	Responsibility for managing London's road network is shared between TfL, Highways England, and the 32 London boroughs, plus the City of London. TfL manages the Transport for London Road Network (TLRN) or London's 'red routes'. The red routes make up 5% of London's roads but, carry 30% of traffic. The 32 London boroughs are responsible for all remaining roads within their boundaries.
d. Name of the road management agency	Transport for London
e. Name of external overseeing authority, e.g. regulator, if any	DfT
f. Road management agency accountable to	Greater London Authority (GLA)
2. Management of roads and pavement conditions	
a. Approach to managing the road network	TfL maintains the Transport for London Road Network (TLRN) and the Congestion Charge system in London. The TLRN is managed under four highways alliance contracts split by geographical areas. The contracts cover operational maintenance and design and build for renewal and improvement schemes. Since 1999, the London Borough of Hammersmith and Fulham (LBHF) has managed road condition surveys (SCANNER, SCRIM and DVI), on behalf of TfL and all London Boroughs, on London's Principal Road Network, which includes the TLRN. TfL then compensates LBHF for this work.
b. Methodology used in measuring pavement conditions	LBHF, on behalf of TfL, carries out the following three surveys in accordance with the guidance set out under the United Kingdom Pavement System (UKPMS): **Detailed Visual Inspection (DVI):** A walked survey of all TLRN lanes carried out by an in-house team of Highway Condition Surveyors on 50% of the network annually. The results are processed in accordance with the UKPMS. Results are presented as the Condition Index (CI) value (similar to the Road Condition Index used by LAs) for each 20m section of the network. The higher the CI value is, the worse the condition of the road. Values above 70 indicate that structural maintenance should be investigated. The DVI is converted to CVI results and the percentage of the carriageway network with a CI of 70+ was recorded as BVPI96 (this is no longer used by DfT for LAs). **SCANNER survey:** This survey is carried out in each direction on 100% of the TLRN each year. SCANNER data is used to calculate the Road Condition Indicator (RCI) value for each 10m section. RCI has a range of 0 to 370 – the higher the value, the worse the road condition. RCI values are used to produce BVPI223 - the percentage of the surveyed running lanes that have an RCI value of 100+, indicating the amount of the network which will likely require maintenance work (BVPI223 is also no longer used by DfT for the LAs).

	SCRIM survey: Carried out in each direction on 100% of the main running lane of the TLRN each year. Helps to determine priority areas for capital renewal and safety-related planning. However, it has a different role from SCANNER and DVI surveys as it also influences safety-related planning.
c. Quality/ condition of roads	The percentage of the TLRN carriageway where structural maintenance is not required (condition score of 70+) was 91% in 2016/17[73].
d. Techniques used to assess pavement condition	SCRIM, SCANNER and DVI. The specific condition attributes measured by each are defined in the UKPMS specifications for the specific survey types. This is common across all local highway authorities (but not Highways England).
3. Targets and performance	
a. Metrics and target setting (if any)	DfT no longer funds the Transport for London asset management/maintenance activities and no central government funding is used for the London strategic road network. Therefore, condition monitoring for proactive maintenance is no longer required by DfT and TfL now operates a safety risk-based approach and delivers only minor interventions where necessary. The RCI is not available for the network.
	TfL is currently reviewing its practices and was unable to provide any information on what it currently does or intends to do in the future. However, in the recent past, TfL did have some performance metrics in place based on annual condition surveys.
	For performance reporting TfL has in the past used the following indicators but has not yet fixed on its current approach to reporting network condition:
	● **Road Condition Index (RCI) –** Rutting, ride quality, cracking and texture are used from SCANNER surveys to produce the RCI for each 10m length. See South Lanarkshire Section 3a for RCI calculation details.
	● **Overall Condition Indicator (OCI) –** an internally developed measure adapted from the old BVPI 96 indicator. The former BVPI 96 indicator measured the percentage of carriageway length with a condition index score worse than 70, as collected from DVI survey data, which is converted to CVI. It was monitored on an annual basis. Details of how the OCI was adapted from the old BVPI 96 indicator were not provided.
	● **Various customer satisfaction indicators –** As recently as the 2017/18 Q1 TLRN Performance Report, TfL have reported on overall satisfaction among TLRN users, which is also broken down by transport mode (e.g. Bus, Car, Pedestrian, etc.). The results are obtained through a quarterly survey.
	As recent as the 2017/18 Q2 London Streets Performance Report, TfL monitored the **State of Good Repair (SOGR)** for carriageways and footways, measuring the percentage of the London road network that does not require structural maintenance or major repairs (condition indicator value of 70+), against a targeted level of performance. The condition of the carriageways was scored through analysis of the results of structural surveys, guided by the UKPMS. In 2016/17 the target level was 91%, which TfL met.
	The **BVPI 223** measures the percentage of carriageway length with a condition index score worse than 100, as collected from the SCANNER survey data. This follows the scoring structure that the LA RCI metric uses, which is also calculated using SCANNER data (see South Lanarkshire case study, section 3a), with a value of 100 or higher signalling that planned maintenance is required soon. It is monitored on an annual basis.

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[73] http://content.tfl.gov.uk/street-performance-report-quarter2-2017-2018.pdf

Transport for London	
b. Use of financial incentives to drive performance (if any)	TfL contractors are subject to financial incentives through the management of lump sum maintenance activities, achievement of various service and key performance indicators and the achievement of whole-life cost savings.
c. Performance monitoring	See 2b.
d. Role of contractors in performance	Contractors are encouraged to innovate, and TfL supports innovation initiatives put forward by the contractors. Performance can also be driven through the various lump sum maintenance activities, as well as the scheme option assessment process.
e. Potential for incentives to influence performance	See 3d.

A.9.   Wales

Country: Wales	

1. General	
a. Demography (population)	3.063 million
b. Climate	Similar to England, so will have a similar effect on the road network.
c. Length of road network and description	There is 1,709km of strategic road network in Wales, of which 133km is motorway. Of the remaining 1,576 km of trunk roads, 350km are dual carriageway. An average of 22,680 vehicles use the trunk road network every day, with a maximum of almost 122,000 on the M4. The following table shows the number of billion vehicle kilometres travelled on Welsh strategic roads and the proportion of traffic in 2016.

		Motorway	Trunk roads Urban	Trunk roads Rural
	Billion vehicle km	3.7	0.5	6.7
Percentage of traffic	Motorcycles	0.4%	0.6%	0.7%
	Cars and taxis	76.6%	81.1%	76.8%
	Buses and coaches	0.3%	0.7%	0.6%
	Light vans	14.7%	13.7%	16.0%
	HGVs	8.0%	4.0%	5.9%

	Approximately 95% of the network has a fully flexible construction and 70% of the network is surfaced using Thin Surface Course System.
d. Name of the road management agency	Department for Economy and Infrastructure, Welsh Government
e. Name of external overseeing authority, e.g. regulator, if any	Welsh Government
f. Road management agency accountable to	Welsh Government

2. Management of roads and pavement conditions	
a. Approach to managing the road network	The road authority is responsible for measuring condition, interpreting the maintenance need and carrying out the maintenance on its road network. The measurement of condition (e.g. SCANNER, SCRIM, Deflectograph) is contracted out, currently to WDM, and the survey contract is tendered on a 5-yearly basis for the whole of Wales. The maintenance is also contracted out. Otherwise, the road authority manages everything else.
b. Methodology used in measuring pavement conditions	Deflectograph The Deflectograph is used to assess the structural condition of flexible pavements. Last year, the Welsh Government changed from using the 'Deflec' programme for the analysis of the Deflectograph measurements to be in line with the rest of the UK by using the 'Pandef' analysis programme. Again, this has been a historical approach rather than any practical requirement – although there is use in checking if visual structural failure

	aligns with deflection data. However, on a network level, the problem lies with surfacing, not structural issues.
	SCANNER
	SCANNER data (see South Lanarkshire section 2b for explanation of SCANNER) is collected throughout the network but is not part of the reporting requirement.
	SCRIM
	Skid resistance data, measured using SCRIM, is used by the Welsh Government for national reporting although this is basically in the form of a statistical bulleting for informing Assembly Members – as is the Deflectograph.
	Visual Assessment
	The Welsh Government has its own bespoke visual assessment, which basically has involved splitting the network into 100m sections and applying a rating to each length. It has found this to work well as it informs programmes well and gives a more realistic picture for funding requirement as we have related a deterioration model to the data. This forms part of an annual report due in March.
c. Quality/ condition of roads	4.3% of the motorway network and 5.7% of the Trunk Road Network needed close monitoring for structural condition in 2015/16, whilst 9.5% of the network was found to be at or below investigatory level for skid resistance[74].
	Approximately 20% of the network required resurfacing treatment in 2016/17.
d. Techniques used to assess pavement condition	The SCRIM and SCANNER vehicles survey the whole network each year, whilst the Deflectograph covers about 20% of the network each year. Only Lane 1 is covered by all of the surveys.
3. Targets and performance	
a. Metrics and target setting (if any)	The percentage of lengths on the network with a residual (or remaining useful) life of 0 years is calculated and reported as the percentage of the network in need of close monitoring for structural condition.
	Also, the percentage of the network where the skid resistance falls below "investigatory level" is reported as the percentage of the network in need of close monitoring for skid resistance.
	No targets are set for these metrics.
b. Use of financial incentives to drive performance (if any)	There are no financial incentives used in any of the contracts.
c. Performance monitoring	Deflection (Deflectograph), skid resistance (SCRIM), rutting, ride quality, texture, cracking, fretting, surface loss, pavement deformation, and potholes are monitored (using SCANNER and CVI data).
	Indicators are calculated annually and are based on Deflectograph and SCRIM data only – see section 2d for frequency of data collection.
	See section 3a above for reporting on performance as a result of monitoring.

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[74] "Road lengths and conditions, 2015-16" Welsh Government Statistical Bulletin:
http://gov.wales/docs/statistics/2017/170208-road-lengths-conditions-2015-16-en.pdf

Country: Wales	
d. Role of contractors in performance	Contractors are only used to collect the network level condition data and also to perform maintenance. Thus, there is no ability to influence the results of performance monitoring.
e. Potential for incentives to influence performance	N/A

ANNEX B   SCANNER RCI

Extract from DfT document: Technical Note: Road Condition and Maintenance data[75] for quick reference.

The SCANNER RCI is calculated using a sub-set of the parameters measured by SCANNER. These are:

- Maximum rut depth;

- 3m Moving Average Longitudinal Profile Variance;

- 10m Moving Average Longitudinal Profile Variance;

- Whole carriageway cracking; and

- Texture depth.

To obtain an RCI value each parameter is scored between two thresholds – a lower threshold below which there is no need to consider maintenance, and an upper threshold above which further deterioration does not increase the score. These thresholds were based on engineers' experience of each parameter. The score increases linearly between the lower and upper threshold from zero at the lower threshold to 100 at the higher.

The score for each parameter is then multiplied by two factors, each having a value between zero and one. One factor reflects the "relevance" or importance of the measurement to the maintenance condition of the road. The other reflects the "reliability" of the method of measurement. The result is a weighted score for each parameter for the 10m subsection.

To avoid Longitudinal Profile Variance having a disproportionate effect on the reported condition, the weighted scores for 3m Moving Average Longitudinal Profile Variance and 10m Moving Average Longitudinal Profile Variance are compared, and only the largest of these two scores is taken forward to contribute to the calculation of the RCI. The same is true for rutting, with only the maximum of the offside and nearside rut depths being taken forward to the calculation of the RCI. The weighted scores are summed to give a single RCI value for each 10m subsection length, representing the overall condition.

The SCANNER RCI values reported by SCANNER can be used by highway engineers (often by displaying the data on a map background in a GIS) to identify lengths of the network in need of further, more detailed, investigation.

An example of the RCI calculation is provided in Appendix A.1.

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[75] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/674584/road-conditions-technote.pdf

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