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PREMiUM – Understanding network-level measurement and management of road equipment

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Abstract

The PREMiUM project aims to deliver improvements in the ability to manage road equipment at the network level, focusing on *road markings, road signs, vehicle restraint systems and noise barriers*. The key condition characteristics a road administration should include in their asset management strategy to manage the risks of loss of performance have been established. Following this, the views of users were sought on the characteristics that should be measured at the network level to manage the risks of loss of performance, and the alternative technologies available to obtain this data identified. The project has proposed survey regimes that could be implemented, subject to suitable development, to provide the key condition data that would assist in understanding and managing these assets. It has then considered the parameters that such a network level monitoring regime would provide, and proposed a set of condition indicators that could be utilised to quantify the condition of each of the assets, and how these could be used to assist in targeting maintenance planning.

Keywords: Transport infrastructure Systems and Components, Monitoring/Maintenance/Asset management.

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1. Introduction

Road operators must draw on the knowledge of their assets to efficiently manage their networks. This includes information on asset inventory, asset condition and understanding of the most appropriate maintenance approach to take for those assets. There has been significant growth in the routine use of objective tools to measure and interpret pavement condition at the network level. However, this progress has not been matched for the assessment of road equipment. Therefore network level understanding of the condition of equipment assets continues to present a challenge to road operators.

The PREMiUM project has aimed to deliver improvements in network-level management of road equipment, by identifying potential methods that could be implemented by road administrations to improve the management of these. In summary the underlying objectives of PREMiUM were to:

- Establish the key condition characteristics a road administration should include in their asset management strategy, in order to manage the risks of loss of performance of these assets (Section 3).
- Establish both the existing and the potential condition measurement methods for these assets, enabling the project to propose survey regimes that could be implemented, subject to suitable development (Section 4).
- Consider the parameters that a network level monitoring regime could provide, and hence propose a set of condition indicators that could be utilised to quantify the condition of each of the assets (Section 5).

PREMiUM has focused on the following equipment assets:

- Road markings and retroreflective studs – which play a key role in optimising the safety by providing guidance and information to road users.
- Road signs - PREMiUM has only considered unpowered permanent fixed road signs.
- Vehicle restraint systems (VRS) - a device installed alongside the road with the principal function of providing a level of containment for errant vehicles. PREMiUM has focussed on permanent verge-side and central reserve vehicle restraint barriers, which are often referred to as safety barriers.
- Noise barriers - structures placed alongside the edge of a carriageway to obstruct the direct transmission of airborne sound emanating from road traffic.

2. Approach

PREMiUM aimed to achieve its objectives through four technical work packages. The first two work packages, (WP1) *Understanding the Asset*, and (WP2) *Monitoring the Asset* drew on a review of standards and guidance documents to identify the current objective condition characteristics that are used to understand the performance and condition of road equipment assets. A consultation was undertaken with National Road Administrations (NRAs) / asset managers to seek information on their current practice in managing the condition of the four asset types. This knowledge gathering consultation with asset managers, and further consultation with experts, was then used to identify the key data requirements for road equipment condition assessment. The current measurement practice for each of the road equipment assets was reviewed (WP2), along with emerging technologies, by liaising with survey consultants and equipment developers/providers. The results of the review were then used to determine how the key characteristics of condition could be monitored and measured at the network level, along with the feasibility of carrying out the monitoring. PREMiUM hence delivered four documents, which are provided on the PREMiUM website (http://www.premiumcedr.com, Spielhofer et al., 2017). These describe the key characteristics of condition that the project proposed should be monitored to understand the condition of road equipment, and to support maintenance/asset management decisions at the network level for markings and studs, road signs, vehicle restraint systems and environmental noise barriers. The documents were sent to relevant stakeholders for peer review, which was used to refine and finalise the key characteristics for each of the road equipment assets considered. This paper presents some of the summary observations from the review, in sections 3 and 4. It is clearly beyond the scope of this paper to present the full detail of the consultation and review, but this can be found in the documents on the PREMiUM website.

The advantage of an objective approach to the management of equipment assets is that the NRA is able to employ a more efficient and effective approach to managing their assets. The NRA can apply maintenance operations or methods focussed on preventative and curative maintenance purposes. They can also plan maintenance according to need, rather than based on regular time intervals. Information on asset performance can be encapsulated through the development of indicators, which assist NRAs in understanding the performance of the network. The third and fourth work packages of PREMiUM (WP3, *Understanding how the key monitoring data should be assessed to evaluate asset condition* and WP4, *Understanding how the key asset condition data should be assessed to identify maintenance need*) sought to develop a set of performance

indicators to link the information provided from WP1 and WP2 to network level maintenance need. Again, these work packages began with a review of standards and discussion with asset managers and asset management system providers to understand how indicators are typically developed and applied. This lead to the development of a set of potential indicators and proposals for how these might be applied in the maintenance management process. Section 5 of this paper summarises this work. Again, it is beyond the scope of this paper to present the full details of PREMiUM's work on indicators. However, these are available in a fifth project document (Carey et al., 2017) which is also available on the PREMiUM website.

3. Key characteristics of equipment assets for network level understanding

A common requirement identified in the consultation of WP1 and WP2 was that, to effectively manage road equipment assets, it is important to have information on the asset inventory. A robust and accurate inventory is an essential tool for providing engineers and decision makers with key information about the assets on their road network. For all types of assets up-to-date inventories are a prerequisite to ensure that continual gains in network quality are made in an efficient way. A vigorous and effective asset management strategy cannot be designed or implemented if a road authority does not have knowledge of the most basic features and records of their assets. If maintenance, renewal or modernisation of an asset is required, decision makers must be able to efficiently evaluate the specific needs of each part of the asset. To achieve this, a complete inventory is the starting point.

However, PREMiUM found that, even though this information is critical for understanding the performance of the asset, many current inventories are out-of-date and incomplete. PREMiUM identified many of the key requirements for network level inventory that should be obtained by a road administration for the asset types considered by the project (Table 1).

Table 1. Inventory requirements for road equipment assets

Road markings and studs	**Road signs**	**Vehicle Restraint Systems**	**Noise barriers**
Location reference	Location Reference	Location reference	Location Reference
Type of marking/stud	Identification Code	Manufacturer declared design and performance characteristics	Acoustic Type (Absorptive/Reflective)
Colour of marking/stud	Date of Installation	Date of Construction	Acoustic Element Composition
Date of installation	Maintenance Records	Method of post installation	Post Type (if used) and Mounting Description, fitment
Dates and details of maintenance	Cleaning Interval	Length of barrier	Date of Installation
Dates and details of last inspection.	Manufacturer Declared Performance Characteristics	Terminals on the safety barrier	Date/Details Previous Inspections
		Hazards protected	Physical Condition Reports
		Speed limit of road	Geometric Properties
		Historical maintenance records	Manufacturer Declared Initial Performance Characteristics
		Dates and references to inspections and inspection data	Details of Complaints
		Scheme/Contract references.	

Having established a network inventory, a road administration must then identify the key condition characteristics that need to be understood in order to manage these assets. Currently there are a large number of standards and processes defined for the measurement of the performance of each of the assets. For example, for environmental noise barriers PREMiUM examined four key EN standards and guidance documents that relate to the noise barrier performance criteria, some of which include up to six sub-requirements, and which cover performance characteristics ranging from characteristics of sound absorption and assessment methods for acoustical characteristics through to mechanical stability (e.g. EN 14388, EN 1793, and further standards as listed in the references). These are further added to by local management and measurement approaches defined in each country, such as within the Design Manual for Roads and Bridges in the UK (e.g. HA 65/94). Such a wide range of requirements presents a challenge to road administrations in selecting the characteristics to target for network level assessment. The observed lack of formal network level condition assessment for equipment assets may be a consequence of this, as a result of the perceived (and actual) impracticality of measuring all the defined characteristics, combined wit the uncertainty over the key characteristics that should be included in an assessment regime.

To better understand current practice, and the opinions of asset owners regarding the key requirements for assessing the performance of equipment assets PREMiUM, undertook a stakeholder engagement exercise using questionnaires for NRAs and survey/equipment providers. The consultation included responses from the NRAs of Sweden, Netherlands, Ireland, Austria, Belgium, Germany, Norway and the UK, with respondents managing over 140,000km of motorways, dual and single carriageways. The questionnaire asked about the NRA's current level of understanding of the equipment assets, and their current approach to managing them, in particular seeking views on the characteristics that are actually measured by NRAs, and asking (for each characteristic identified in the standards) whether that characteristic was measured or recorded, how it is measured and what level of importance is assigned to this by the NRA for the assessment of asset condition. This allowed PREMiUM to identify common/good practice across different networks. By combining this with the review of the standards and input from technical experts in the design, management and assessment of these assets, we have proposed in Table 2, and ranked in order of importance, the key characteristics that would ideally be measured to effectively understand and manage these assets, for each of the asset types considered (with a rank of 1 being the most important).

Table 2, Key condition characteristics for assets

Rank	Road Markings and Studs	Road Signs	Vehicle Restraint Systems	Noise Barriers.
1	Night-time visibility (markings)	Damage/Loss	Presence of damage	Airborne sound insulation
2	Night-time visibility (studs)	Obstruction/ Obscuration	Presence of corrosion/rust	Sound absorption/ reflection
3	Day-time Visibility (markings)	Orientation	Ground bearing capacity	Vibration and Fatigue
4	Wear (markings)	Panel Alignment (for signs that are constructed using more than a single panel)	Mounting height	Impact from Collision
5	Skid Resistance (markings)	Night-time Visibility	Fixing condition	Resistance to loads
6		Colour Fade		

Table 2 appears concise and potentially straightforward to achieve. However, the practical delivery of the key condition characteristic data is not simple. In addition to asking their views on the key characteristics, PREMiUM asked road administrators whether they currently measure these characteristics. For most, the answer was either no or only on a project level – for example, none of the NRAs consulted routinely measured the acoustic performance of their noise barriers, once in service (Figure 1). Most relied on the manufacturer's statement of performance. This is mainly due to the impracticality of accessing noise barriers, the impractical nature of some of the tests and the restriction of most tests to laboratory settings.

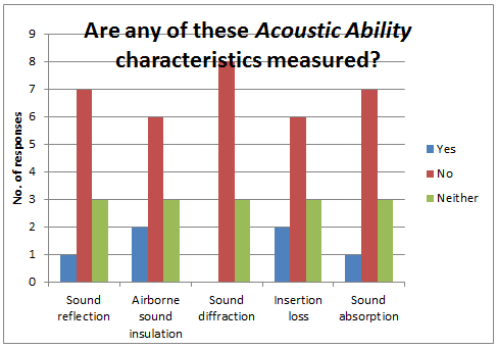

Figure 1, Measurement of acoustic characteristics of noise barriers

4. Options for Monitoring Road Equipment Condition at the Network Level

4.1. Obtaining Inventory Information

As noted above, a good inventory is critical for understanding the performance of the asset. Several methods are currently being used measure the inventory of road equipment:

- Historical Record Review: Reference to existing records - construction drawings, documentation, contracts.
- Slow Speed Visual Survey: Manual survey requiring traffic management (TM) for road closures.
- Traffic-speed Visual Survey: Using vehicles fitted with GPS/GNSS recording devices, forward facing imaging and odometer. Manual analysis of the images is used to record equipment assets
- A desktop survey utilising up-to-date satellite and street-view maps/imagery.

However, PREMiUM also noted that there are a number of emerging methods that can be used to assist NRAs in establishing a robust inventory database. These include multiple camera photogrammetric techniques and Traffic speed LiDAR surveys. The photogrammetric recording methods deliver video-sequences or photos using one or several cameras, with each image accurately geographically referenced so that inventory items can be identified in the images and their position extracted using either manual or automated methods. The point clouds currently delivered by LIDAR surveys claim to provide absolute position accuracy of up to ~10 cm, and control points can be used to improve this to better than 5 cm. These methods are becoming more widely applied and practical assessments have confirmed their potential (Spielhofer, 2014).

PREMIUM has therefore recommended that NRAs should continue to make use of their ongoing maintenance programmes to maximise the accuracy of their databases. For those assets replaced on a fairly regular basis (e.g. road markings) it should be possible to populate and update the inventory for such assets relatively frequently using maintenance records. However, video and LiDAR based methods show strong potential for inventory data collection and could be more widely adopted by NRAs to update and maintain the population of their inventory databases on road equipment assets. To achieve this there would be benefit in establishing formal performance requirements for the systems that would be used to provide the image/LIDAR point cloud data – for example the image resolution and quality and the positioning accuracy. This could be based on the needs of the NRA, and not be led by equipment specification, as most NRAs probably will not require their equipment inventory to be located to cm level accuracy.

4.2. Measuring condition – road markings

The PREMiUM WP2 review identified a number of potential methods to measure the key characteristics of road markings listed in Table 2, covering both current and emerging techniques. These are shown in Figure 2.

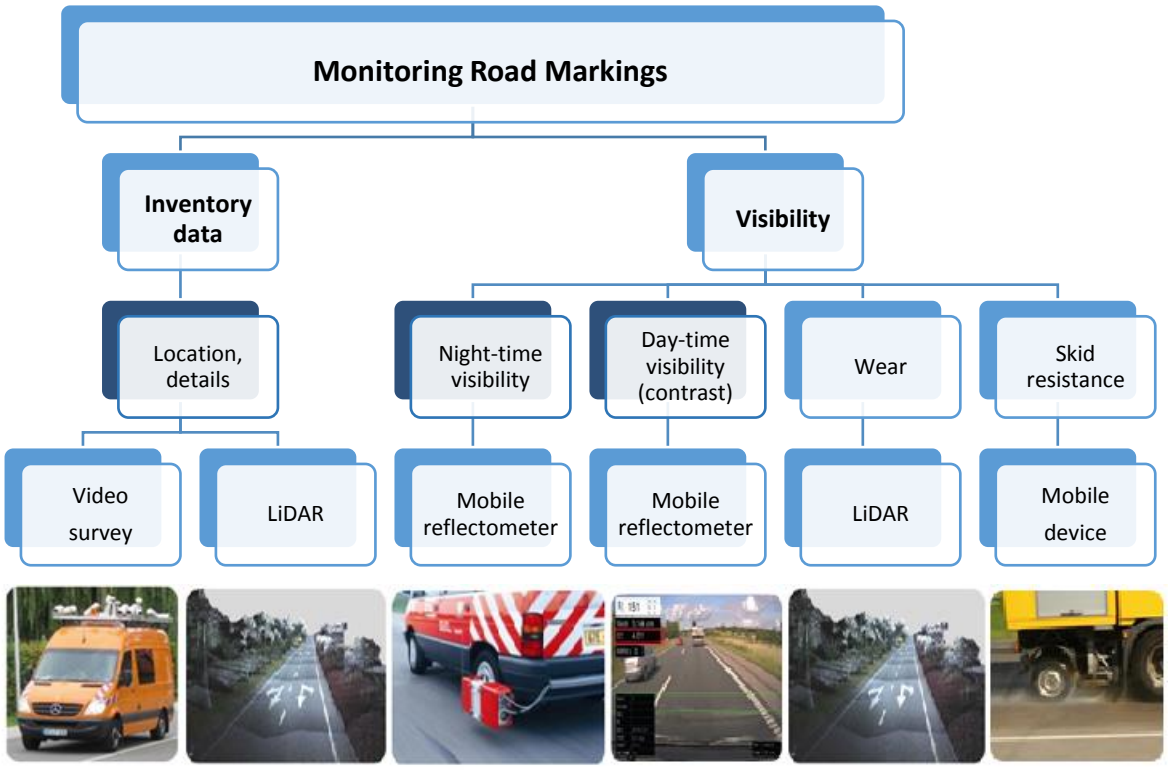

Figure 2, Recommended measurement methods (current and emerging) to monitor key characteristics of road markings

We found that many existing traffic-speed systems have the potential to measure the night-time visibility of road markings. However, they are not yet widely implemented for network level assessment, probably because of practicality issues with some of the older devices, and the need to better understand the capability and measurements provided by the latest devices. Also, systems can only provide measurements of night-time visibility in dry conditions. It is known that visibility in wet conditions can be substantially reduced (see

RAINVISION). Again there is emerging equipment that claims to be able to measure visibility in wet conditions, but limited testing has been carried out to date. Models to predict wet visibility have also been developed and show promise but need further work.

Although many methods to measure night time visibility were identified, network level measurements of other key characteristics of road markings are less well advanced. Current measurements of day-time visibility are typically carried out at slow speed. However, this may be overcome by reconsidering the requirements for the measurement. Current traffic retro-reflectometers cannot measure the required luminosity parameter, but they can provide information about the daytime contrast (the ratio between the light reflected from the line and the light reflected from the pavement), which could be a valuable proxy indicator of day-time visibility. Similarly, wear of markings is typically carried out via walked or slowly driven inspections. However, the images provided by traffic-speed video surveys, or the latest retro-reflectometers, could enable the automatic assessment of wear. Of greater challenge is the measurement of skid resistance. Whilst measurement systems exist for road surfaces, there are practical issues with applying these to the measurement of road markings. However, it may also be possible to obtain a proxy for skid resistance from other measurements of road marking performance.

Although PREMiUM identified a number of current and emerging methods to measure the key characteristics of road marking condition at the network level, there is a clear requirement for further development before all the key characteristics can be assessed. This could be achieved through investment in the emerging methods and by considering proxy measurements to overcome the impracticality of making direct measurements of characteristics such as skid resistance and daytime visibility.

4.2.1. Measuring condition – other equipment

PREMiUM did not identify measurement many methods that are currently being applied *routinely at the network level* to assess the condition of equipment, other than for road markings. For most of the key characteristics current measurement methods are slow speed and manual, which makes network level implementation impractical. We therefore investigated alternative potential measurements that could be implemented, given suitable investment and development. These are summarised in Table 3.

Table 3. Proposed measurement methods to monitor road equipment assets at a network level

Road signs	Vehicle Restraint Systems	Noise barriers
Night-time Visibility: Existing mobile reflectometer or LiDAR but not widely tested	**Presence of damage:** Potential for visual inspection from video, but only for the front of barrier	**Sound reflection, Airborne Sound Insulation, Sound Diffraction:** Requires in-situ (smart technology)
Damage/Loss, Obstruction/ Obscuration, Panel Alignment: Potential for visual inspection from video, with automatic analysis feasible in the long term	**Presence of corrosion/rust:** Potential for visual inspection from Video, but only for the front of barrier	**Vibration & Fatigue:** No potential network level method identified
Orientation: Potential for visual inspection from video or LiDAR, with automatic analysis feasible in the long term	**Ground Bearing capacity:** Requires in-situ (smart technology) measurements	**Resistance to loads:** No potential network level method identified
Colour fade: Potential for Visual inspection from video	**Mounting height:** Potential for use of video or LiDAR surveys and automatic analysis	**Impact from collision:** No potential network level method identified
	Fixing condition: Requires in-situ (smart technology) measurements	

The cells highlighted in grey in Table 3 represent the methods that are considered practical for development or implementation in the next 5 years, subject to appropriate investment. Of these, the traffic-speed methods showing the most potential for near term application are those used for the assessment of signs using mobile-relfectometers, for which commercial systems are now available. For the other equipment/characteristics there will be a need for significant further development if network level assessment is to be achieved. As can be seen from Table 3, we have noted that LIDAR, video and in-situ techniques show significant potential for the measurement of several characteristics. The use of LIDAR/video would exploit the same capability identified for use in inventory measurement, but would draw more value from the video data via the classification of

condition. The challenge for this application is the development of assessment processes that deliver consistent quantitative information, and that the video itself contains enough detail to observe deterioration. There is even less experience in the use of in-situ technologies. However, we have found that options are now becoming available for small low cost sensors that could be applied to (e.g.) measure vibration and movement in VRS, or even to continuously monitor traffic noise and hence track changes in the ability of a barrier to attenuate this. Thus, PREMiUM has recommended further development of these new approaches, as shown in Table 4.

Table 4. Potential measurements that could be obtained through further development of measurement techniques

Measurement technique	**Characteristics that can be potentially measured**
Mobile reflectometers	Night-time visibility of road markings and studs, day-time visibility of road markings (contrast), night-time visibility of road signs.
LiDAR surveys	Road equipment inventory, wear of road markings; night-time visibility, orientation of road signs; mounting height of VRS.
Video survey	Road equipment inventory; damage/loss, obstruction/obscuration, panel alignment, orientation of road signs; presence of damage, corrosion/rust, mounting height of VRS.
In situ equipment	Acoustic properties of noise barriers.

5. Evaluating Condition

The WP3 and WP4 of PREMiUM sought to build on the outcomes of WP1 and WP2 by demonstrating how a network equipment condition assessment regime could benefit the NRA, through the asset management process. The overall objective of asset management is not to determine the exact maintenance required for an individual asset (as this is assessed at the project level) but to provide the NRA with an overall indication of the level of asset condition across the whole of the network. Thus PREMiUM considered the objective tools that would be needed to provide a network level indication of the performance of each of the equipment asset considered, based on the survey regimes identified in WP1 and WP2 and discussed in the sections above.

Information on asset performance in asset management systems is encapsulated through the development of performance indicators, which transform the measured condition data into indicator against which the performance of the network can be assessed. Therefore the objective of the PREMiUM WP3 and WP4 was to develop a set of performance indicators that could be linked to network level maintenance needs. It should be noted that there was a fundamental assumption within the indicator work of PREMiUM that the required condition data would be available at the network level. The outcomes of WP1 and WP2 were examined and a judgement made on the key characteristics for which a measurement regime could be implemented within 3-5 years, and hence for measurements would be available. These are highlighted grey in Table 3 above. For these key characteristics, the potential measurements were combined with a review of the current approaches taken to manage the assets (and to trigger maintenance), discussion with operators and review of existing performance standards, in order to propose indicators.

5.1. PREMiUM Indicators

The indicator development was based on the approach taken in the COST 354 project (Litzka et al., 2008). Three types of indicator were proposed – single performance indicators, combined indicators and asset (global) indicators. Single performance indicators are calculated using measurements for individual characteristics e.g. retro-reflectivity of road markings for a single indicator of for night-time visibility. Combined indicators are then calculated using two or more of these indicators. Three types are proposed for each equipment type:

- **Functional** indicators that indicate whether the road equipment meets its purposes.
- **Structural** indicators that indicate the structural condition of the equipment.
- **Durability** indicators that are based on the expected lifetime of the equipment.

An overall indicator can be a combination of the functional, structural and durability indicators, giving an overall assessment of the condition for the equipment asset. In PREMiUM, in line with most of the asset management systems used worldwide, a rating scale from 0 to 5 was used to express the condition indices, with 0 meaning that the asset is in good condition.

5.2. Aggregation of data

As described in (PIARC, 2012) inspection data must be aggregated over a distance or number of assets as a first step in the development of an indicator, e.g. an indicator to describe the condition of 1km of road markings. As many equipment assets are more complicated than simple linear assets such as pavements, we considered several approaches for data aggregation. Ultimately we propose that data should be aggregated based on the way in which maintenance operations are performed on these equipment assets. For continuous equipment assets (road markings, VRS), there is usually a minimum length for which maintenance is considered. Whereas for point assets (road signs, noise barriers) elements of the individual asset are usually maintained (e.g. post, panel, acoustic element). This approach has been taken in PREMiUM.

5.3. Thresholds to obtain single indicator

To link a measurement of condition to the rating and hence the likelihood that maintenance is required, there is a need to apply thresholds to the measured data. For example, there will be a level of retro-reflectivity of a road marking below which the marking is not providing the level of service required, or there will be a level of panel alignment for a road sign beyond which the sign becomes hard to interpret. Therefore, to obtain a single indicator for each of the key characteristics, there is a need to specify thresholds for the measurement data. We drew on current standards and documentation to identify suitable thresholds for each asset type However, this was not straightforward as the standards can be complex for some equipment assets, or in some cases there is no clear set of exiting thresholds for condition. This is probably to be expected, given the complex nature of the assessment of condition discussed in section 2 above, and the lack of current network implementation. Therefore, where published thresholds exist for the measurements of the key characteristics, these were used in the development of the single indicators. However, where these were not available we used the information available to us to propose initial thresholds to assist NRAs in establishing a regime. For example thresholds are already published to categorise the night-time visibility performance of road markings. These were used to develop a night time visibility indicator, Table 5. However, for road studs, only minimum performance values are published and therefore a method to determine further thresholds was developed, Table 6.

Table 5. Single indicator for night time visibility of markings

Night-time-visibility Indicator (Road Markings) =	0 if $TP\_NTV \geq 100$
(Where TP_NTV is the retro-reflectivity value measured for the marking)	1 if $TP\_NTV \geq 95$ but <100
	2 if $TP\_NTV \geq 90$ but <95
	3 if $TP\_NTV \geq 85$ but <90
	4 if $TP\_NTV \geq 80$ but <85
	5 if $TP\_NTV < 80$

Table 6. Single indicator for night time visibility of road studs

Night-time-visibility Indicator (Road Studs) =	0 if $TP\_NTV \geq 1.3*X$
(Where TP_NTV is the retro-reflectivity value measured for the stud and X is the intervention level defined in the standards)	1 if $TP\_NTV \geq 1.2*X$ but $<1.3*X$
	2 if $TP\_NTV \geq 1.1*X$ but $<1.2*X$
	3 if $TP\_NTV \geq X$ but $<1.1*X$
	4 if $TP\_NTV \geq 0.9*X$ but $<X$
	5 if $TP\_NTV < 0.9*X$

For several characteristics, e.g. damage to VRS, it is anticipated that a visual assessment of video images will be needed to provide a network level measurement of condition. In this case, it has been assumed that the visual inspection will itself produce an assessment that can be directly related to an indicator i.e. an inspector would rate the asset's condition using a value between 0 and 5.

5.4. Combined Indicator

To combine single indicators into a combined indicator, a weight is assigned to each characteristic. We propose that indicators for equipment could be combined using weightings based on the ranking of the characteristics provided in the consultation carried in WP1 (Table 2). For example, the combined functional indicator for road signs would be calculated from the single indicators for night-time visibility and colour fade (*PI_NTV* and *PI_CF* respectively), with equal weightings, since they received equal ratings in the consultation:

$$FI\_signs = minimum(5, maximum(PI\_NTV, PI\_CF)+0.2*minimum(PI\_NTV, PI\_CF))$$

5.5. Maintenance and use in Asset Management

Having established single and combined condition indicators, these may be applied to determine likely maintenance needs. PREMiUM proposes that these indicators could be used to identify the need for different types of maintenance - either preventative or curative. For example, the maintenance options shown in Table 7 were identified for noise barriers. An indicator value of 5 would suggest that curative maintenance is likely to be needed in order to return the condition of the asset to an acceptable level. An indicator value of 3 or 4 would suggest that preventative maintenance is likely to be needed.

Table 7. Maintenance methods for noise barriers

Preventative maintenance:	Cleaning of transparent (glass or plastic) screens
	Brushing of the back of the noise barrier
	Cleaning/removal of graffiti
	Repainting of metal screens
	Patching
Curative maintenance:	Post reinforcement
	Repairs or partial replacement after collision or vandalism
	Replacement of some panels
	Replacement of the noise barrier

Having established a condition regime according the recommendations of sections 3 and 4, and condition indicators according to this section, the NRA could then apply this approach to understand the overall implications for the management of their equipment assets. For example, combining number percentage of assets present on a network that are likely to need maintenance, with the basic costs to carry out maintenance treatments would enable the asset owner to calculate the level of budget needed to keep equipment assets in good condition. Also it would enable them to determine whether their maintenance regimes are effective e.g. whether the percentage of assets needing maintenance is decreasing or staying the same year on year. Currently NRAs do not have good access to this type of information.

6. Conclusions

An objective approach to the management of equipment assets allows NRAs to employ a more efficient and effective approach to managing these assets. Maintenance operations or methods can be focused on preventative and curative maintenance purposes and NRAs can plan maintenance according to need. However, to achieve this NRAs require objective, network level information on the equipment inventory and its condition. PREMiUM has been carried out with the objective of determining the requirements to achieve this level of understanding.

Via consultation and review the project has found that there is a significant lack of information on the inventory of equipment present on national road networks. However, there are many current and merging technologies that should allow NRAs to populate inventory databases. We have also investigated the data that is currently used to understand the condition of these assets. We have found that current requirements for condition assessment are focused on scheme or project level understanding, and many are not suited to application at the network level. As a result there is little network level condition information available to NRAs on equipment assets.

Therefore the project sought to identify the key characteristics that would need to be monitored. These characteristics form a subset of the full range specified in the standards, but should provide the core information required for a road owner to understand and manage the condition of road equipment assets. The list has been assessed against potential monitoring technologies and we have found that, for road markings, there are a number of current and emerging technologies that have strong potential to provide network level information on many of the key characteristics. Fewer systems are currently available for other equipment. However, it is suggested that video, LIDAR and in-situ technology could offer the potential to assess many of the key characteristics. PREMiUM has recommended that development of these methods be undertaken for the purpose of collecting inventory and to investigate their suitability to provide condition data. Further development should be focused on the requirements of NRAs, and could consider both mobile techniques and new smart sensing technologies that offer potential for low cost widespread application.

The project has also demonstrated that, should suitable network level information become available, this could be applied robustly within asset management systems using indicators that would assess the condition of the assets at a network level, and which could be used to determine the level of maintenance need. These have the potential to significantly improve the ability of road owners to understand, manage and maintain road equipment assets.

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