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PREMiUM

Summary of Deliverables 1 and 2 of the PREMiUM project

and the Work Required to Achieve the Recommendations

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Project Partners

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Summary of Deliverables 1 and 2 – Identifying the key characteristics for road equipment condition measurements

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1 The PREMiUM project

The trans-national research programme "**Call 2014: Asset Management and Maintenance**" was launched by the Conference of European Directors of Roads (CEDR). CEDR is an organisation which brings together the road directors of 25 European countries. The aim of CEDR is to contribute to the development of road engineering as part of an integrated transport system under the social, economical and environmental aspects of sustainability and to promote co-operation between the National Road Administrations (NRA). The participating NRAs in this Call are Belgium-Flanders, Finland, Germany, Ireland, Norway, the Netherlands, Sweden, United Kingdom and Austria. As in previous collaborative research programmes, the participating members have established a Programme Executive Board (PEB) made up of experts in the topics to be covered. The research budget was jointly provided by the NRAs who provide participants to the PEB as listed above.

Road operators draw on their knowledge of their assets to efficiently manage their road networks. This includes information on asset inventory, asset condition and information on the most appropriate maintenance approach to take for those assets. Although there has been significant growth in the use of objective tools to measure and interpret pavement condition at the network level, this has not been matched for the assessment of road equipment. ERANet research on the assessment of equipment assets has found that the management of equipment such as road signs, lighting, markings, restraint systems, noise barriers and Variable Message Signs is often excluded from the integrated management process. There is a clear need to deliver improvements in the ability to manage these assets. The objective of PREMiUM was to deliver improvements in the ability to manage road equipment by developing guidance that can be implemented by road administrations to improve the management of equipment assets. In summary:

- To establish the condition characteristics a road administration should include in their asset management strategy to manage the risks of loss of performance of these assets;
- To help road owners to understand and balance network and project level management of these assets so that they can establish a practical monitoring regime that enables the condition to be understood and the risks to be managed;
- To identify the existing and emerging measurement tools that could be applied by road owners to understand, monitor and manage these assets;
- To propose objective measures that could be applied to understand and quantify the performance of these assets, which are feasible for use at the network level;
- To hence assist road administrations in establishing a maintenance regime that minimises risks and yet enables the road administration to focus maintenance expenditure on these assets in an efficient manner.

PREMiUM considered ***road markings***, ***road signs***, ***vehicle restraint systems*** *and* ***noise barriers*** and aimed to achieve its objectives through four technical work packages:

- **WP1 Understanding the Asset:** The development of better understanding of the equipment asset and the key characteristics of the asset which need to be monitored to manage the asset;
- **WP2 Monitoring the Asset:** How these key characteristics can be monitored across all equipment assets (i.e. on the network level);
- **WP3 Evaluating Condition:** How this data can be translated into the information required to determine the condition and hence evaluate the risk of failure;
- **WP4 Management of the Asset:** How the information can be used within a management strategy.

2 Purpose of this document

Deliverables 1 and 2 of PREMiUM have presented the results of the work carried out in WP1 and WP2. They present the results of a consultation and research undertaken to determine the key characteristics of condition that should be monitored to understand the condition of road equipment, to support maintenance/asset management decisions at the network level. They also suggest potential condition monitoring regimes that could be implemented to provide the data required to understand the condition of road equipment to support maintenance/asset management decisions at the network level, along with how these regimes might be developed. These deliverables, which are provided as four separate reports (each covering one of the equipment types) are available on the project website: http://www.premiumcedr.com

There is a common theme in the four deliverable documents – that the measurement of the condition of road equipment at the network level is challenging, but techniques are becoming available that show promise. Consequently there would be benefit if central investment could expedite the implementation of these techniques and technologies. Therefore this report has been assembled to collate the technical recommendations of the four WP1 and WP2 deliverables, to assist in identifying potential research programmes that could be pursued. The layout of this report is as follows:

- Section 3 provides a summary of the key characteristics identified in WP1 and WP2.
- Section 4 provides a summary of the methods identified in WP1 and WP2 to measure these key characteristics.
- Section 5 discusses the methods that it was felt could be achieved within 3-5 years if suitable investment was made, along with the work required to implement these methods.
- Section 6 discusses the research needed to implement measurement regimes, based on the technology used, rather than split by asset type (as in section 0).

3 Understanding Road Equipment Condition

WP1 (“Understanding the asset”) combined technical expertise drawn from the project consortium with a direct stakeholder consultation and a review of current standards. This was used to propose the key characteristics of condition that need to be understood for each of the equipment asset types. The key characteristics identified for road markings and studs are given in Table 1, whilst those for road signs, environmental noise barriers and vehicle restraint systems (VRS) are given in Table 2, Table 3, and Table 4 respectively. The characteristics are presented in the order of importance identified in the consultation (most important at the top).

Further details of the review and the results of the consultation are given in the four project deliverables D1&2 (Spielhofer et al., 2017) on the project website (www.premiumcedr.com).

Table 1: Key condition characteristics for Markings and Studs

Key characteristic	Measurement	Units
Night-time visibility (markings)	Coefficient of retro-reflected luminance, R_L	mcd.m^{-2}.lx^{-1}
Night-time visibility (studs)	Coefficient of luminous intensity, *R* (mcd.lx^{-1})	mcd.lx^{-1}
Day-time Visibility (markings)	Contrast (greyscale pixel difference) Coefficient of Luminance, *Qd* Luminance Factor (β)	Unit-less mcd.m^{-2}.lx^{-1} Unit-less
Wear (markings)	Amount of marking missing	Percentage (%)
Skid Resistance (markings)	Skid resistance value, *SRT*	Unit-less

Table 2: Key condition characteristics for road signs

Key Characteristic	Measurement	Units
Damage/Loss	General overall assessment by visual inspection. Potential quantitative assessment: % of sign area affected % of “important”* part of sign affected	Unit-less % %
Obstruction/ Obscuration	General overall assessment by visual inspection. Potential quantitative assessment: % of sign area affected % of “important”* part of sign affected	Unit-less % %
Orientation	Angle of orientation relative to carriageway by visual assessment.	Degrees
Panel Alignment (for signs that are constructed using more than a single panel)	General overall assessment by visual inspection. Potential quantitative assessment: Horizontal shift relative to font size Vertical shift	Unit-less mm(?) mm
Night-time Visibility	Coefficient of retro-reflectivity (R_A). (Hand-held retro-reflectometer)	cd/m^2/lx.
Colour Fade	Chromaticity coordinates by slow speed assessment device.	factor

Table 3: Measurements of key condition characteristics for Environmental Noise Barriers

Key Characteristic	Measurement	Units
Airborne sound insulation	DL_R in reverberant fields	dB
	$DL_{SI,E}$, $DL_{SI,P}$ and $DL_{SI,G}$ in non-reverberant fields	dB
Sound absorption/ reflection	DLα in reverberant fields	dB
	DLRI in non-reverberant fields	dB
Vibration and Fatigue	Not measured	N/A
Impact from Collision	Behaviour under impact	N/A
Resistance to loads	Self weight of an acoustic element	kN/element
	Maximum vertical load an acoustic element can withstand	kN/m
	Maximum normal load an acoustic element can withstand	kPa on the element
	Maximum normal a structural element can withstand (wind, static load and self weight	kN/m along the structural element
	Maximum bending moment a structural element can withstand (dynamic load from snow clearance)	kN/m at ground level
	Maximum normal load an acoustic element can withstand	kN/m on a 2m x 2m reference surface on the element

Table 4: Key condition characteristics for vehicle restraint systems

Characteristic	Current Measurement	Units
Presence of damage	Number or percentage of posts affected in a length or for the whole barrier. Number or length of beams affected.	% Length in m
Presence of corrosion/rust	Number or percentage of posts affected in a length or for the whole barrier. Number or length of beams affected	% Length in m
Ground bearing capacity	Deflection of post when subjected to a push or pull load of up to 6000N (in 1000N steps)	mm
Mounting height	Height of middle of beam or centre of rope pair from pavement surface (where set-back is 1.5m or less) or general ground level beneath barrier.	mm
Fixing condition	Presence of rust Tightness of fixing	N/A Torque in Newton metre (Nm)

4 Monitoring Road Equipment Condition

In WP2 ("Monitoring the asset") current practice for measuring obtaining the key characteristics was reviewed. It was clear that for many of the characteristics the current approach was either unsuitable for network level application (i.e. slow speed, requires closures etc.) or there was no routine practice in place. A further review of emerging technologies and liaison with survey consultants and equipment developers/providers was therefore used to determine how the key characteristics of condition could potentially be monitored and measured at a network level, along with the feasibility of applying the identified potential monitoring method. Again, these are discussed in detail in the four deliverables (Spielhofer et al., 2017).

For this report we summarise the characteristics and methods identified in WP2 for which we believe (if suitable investment is made) routine network level monitoring could be achieved within 3-5 years. These are presented in the following tables (separated into equipment inventory and equipment condition) and discussed further in Section 0.

Table 5: Current and proposed measurement methods to monitor road markings and studs

Property	Characteristics	Recommended method to achieve network level requirement
Inventory	Location reference Type of marking/stud Road marking/stud details	Video survey LiDAR
	Date of construction Dates and details of maintenance Dates and details of last inspection	Historical records
Visibility	Night-time visibility (Dry)	Mobile reflectometers are available and there are new emerging systems
Visibility	Night-time visibility (Wet)	Not currently achievable at a network level. However, there are emerging systems
Visibility	Day-time Visibility	The standard measurement of luminance is not achievable. However, a proxy measure contrast could be achieved at network level.
Visibility	Wear	Not currently achievable at a network level However, there are emerging systems
Durability	Skid Resistance	Not currently achievable at network level However, there are emerging systems, and proposed proxy approaches that should be able to provide this.

Table 6: Current and proposed measurement methods for monitoring road signs

Property	Characteristic	Recommended measurement method to achieve network level requirement
Inventory	Location - e.g. road name, number, area, chainage, section label, GPS, etc.	Extraction from Video images or LiDAR – manual and automatic.
	Cleaning Interval (years) Material Performance Class Date of installation Dates and details of maintenance	Historical records
Visibility	Damage/Loss	Not currently implemented at a network level. However, could be obtained through visual inspection of video images
	Obstruction/ Obscuration	
	Panel Alignment	
Visibility	Night-time Visibility	Not currently implemented at a network level. However, could be achieved using a mobile reflectometer or LiDAR
Visibility	Orientation	Not currently implemented at a network level. However, could be achieved using video or LiDAR
Visibility	Colour Fade	Not currently implemented at a network level. However, could be achieved with visual inspection of Video.

Table 7: Current and proposed measurement methods for monitoring noise barriers

Property	Characteristic	Recommended measurement method to achieve network level requirement
Inventory Data	Acoustic element Composition, e.g. timber, concrete, metal, composites, plastic Post types & mountings Geometry, e.g. height, angle Location data, e.g. road name, section label, start/end chainage, GPS	Video / LiDAR
	Date of Installation, Contract ID, Scheme Acoustic Type – e.g. reflective, absorptive Manufacturer Declared Performance Characteristics Date of Last Inspection Physical Condition Reports Details of Complaints Lodged Dates and details of maintenance Suitable as vehicle restraint system (there are combined systems)	Historical records
Acoustic Ability (also including long-term acoustic performance)	Sound reflection	Current methods are not feasible for measurements on the network level. The measurement of sound reflection is therefore recommended using in-situ techniques
	Airborne Sound Insulation	
	Sound Diffraction (only for added devices on the top of the noise barriers)	
Structural Integrity	*Vibration & Fatigue*	*None identified, no emerging systems for network level identified*
	Resistance to Loads	*None identified, no emerging systems for network level identified*
Safety	Impact from Collison	*None identified.* However, a network level survey may not be necessary. Barriers sufficiently set back from the road or protected by a crash barrier should not be at risk of damage. For those that are at risk, there is just a need to report accidents where contact is made with the barrier.

Table 8: Current and proposed measurement methods to monitor Vehicle Restraint Systems

Property	Characteristic	Recommended measurement method to achieve network level requirement
Inventory	Location	Video, LiDAR
Durability	Presence of damage	Visual inspection from Video
Durability	Presence Corrosion/ Rust	Visual inspection from Video
Structural	Ground Bearing Capacity	Manual inspection (push/pull method, cone penetration test) In-situ (smart technology) measurements
Clearance	Mounting Height	Video, LiDAR
Structural	Fixing Condition	Visual inspection from Video In-situ (smart technology) measurements

5 The work required to achieve monitoring regimes

As shown in the above tables, PREMiUM has identified a number of methods with potential for application in measuring the key characteristics of road equipment, at the network level. However, to implement these will require further work. The areas of further development identified by PREMiUM are summarised in this section. Section 6 proposes a number of research programmes that could be undertaken to support this development.

5.1 Asset Inventory

The requirement for robust inventory is common across all the equipment assets, but many NRAs have incomplete inventory databases. The use of traffic speed video and LiDAR surveys is becoming more widespread, and PREMiUM concluded that their use would be practical to obtain inventory data on road markings and studs, road signs and VRS, and perhaps on noise barriers visible from the road.

However, to implement a reliable and accurate routine high-speed, network level survey for inventory of road equipment, there is a need to:

- Understand the capability of the high speed systems (video/LiDAR)
- Establish realistic performance requirements.
- Develop an ability to test systems being used for the collection of inventory to confirm that the inventory items are accurately located and reported.

In addition, as these methods typically require manual analysis, they may not be practical for network level survey. Thus there could be benefit in the development of automated extraction processes for the identification of road equipment items.

5.2 Road markings and studs

5.2.1 *Night-time Visibility*

A number of traffic speed techniques have reached a stage where they are appropriate to provide information on the night-time visibility of dry road markings (R_L (mcd.m^{-2}.lx^{-1}). These are currently not widely applied for routine assessment. There would be benefit in:

- Investigating the accuracy, precision and consistency of the latest mobile systems, to provide NRAs with robust guidance on the devices and their capability in real-world conditions.
- Undertaking a comparison between dynamic single-line side-mounted retroreflectometers, and the measurement systems which collect information across the full width. This would help understand the advantages and disadvantages of both types of system.
- Developing a better understanding of the capability of systems which offer network level data, but at non-standard geometries. If the data provided by these systems is acceptable for the separation of sound and poorly performing markings, the greater level of practicality provided by non-standard devices could offer significant improvements in the ability to achieve network level assessment. This would open up opportunities for use of new technologies such as LiDAR and imaging systems.
- The investigation should also seek to confirm the capability of systems claiming to assess the condition of road studs. This could help to clarify the performance requirements for road stud assessment at the network level.

5.2.2 *Day-time Visibility*

Although no systems for the direct assessment of day-time visibility were identified, PREMiUM has suggested that the measurement of daytime contrast offers could offer a proxy for this, which would be achievable at the network level. There is a need to:

- Thoroughly test the measurement of daytime contrast through practical trials to assist NRAs in understanding how such data could be accommodated within current or new standards and how to select appropriate systems to apply in network level surveys.

5.2.3 *Wear*

Wear of road markings is currently measured manually, using a scoring system with reference to photographic examples. This can be performed currently either by walking the site or manual analysis of images of the road markings. However, the current subjective assessment based on comparison with images of road markings in various states of wear is unlikely to provide consistent results. Also, there are emerging systems that could be used to automatically analyse image or LiDAR data to achieve this. Thus PREMiUM has recommended:

- A consistent catalogue/guide for the assessment of marking wear is developed (for either manual or automatic analysis).
- To enable automatic analysis, there is a need to further develop the algorithms and validate them using practical trials.

5.2.4 *Skid Resistance*

Although it is theoretically possible to measure the skid resistance of road markings using existing traffic-speed devices, it is impractical at anything but the project level due to the requirement to occupy two lanes and maintain a precise driving line. There are emerging devices that may not be subject to these limitations, and there is also a possibility that a proxy for skid resistance can be developed. It is recommended that

- The potential of emerging traffic speed devices is tested through practical trials.
- An investigation is carried out to determine whether proxy methods would work.

- An investigation is carried out into the application of a prediction model exists.

5.3 Road Signs

5.3.1 *Damage/Loss, Panel Alignment, Orientation, Colour Fade*

PREMIUM did not identify any routine methods at a ready for market level for measurement of these defects. However, existing image collection and analysis methods could be easily implemented to allow analysis from an engineer's desk, reducing the need for on-site inspections and increasing the ability to achieve network level monitoring. It is recommended that:

- The potential for using video images from road sign inventory surveys should be investigated to determine whether manual analysis of these images could be used to monitor and quantify these defects.
- Practical trials with different devices would provide more information and obtain a better understanding of the capability of current systems, and would enable a specification for the minimum technical requirements (image resolution, image quality, positioning system accuracy) for video surveys to be derived.
- A formal manual assessment regime, to use images to quantify condition, could then be developed, including a reporting method (e.g. % of damage).
- For the measurement of orientation LIDAR data can be used to augment image assessment. PREMIUM has identified work in which static LiDAR has been used to quantify orientation. There is potential to mount this on a mobile device and thus offer the potential to provide measurements whilst the vehicle is moving.
- Video data could, in theory, also be used to assess colour fade and should be considered in the above development. This could include investigation of a method to overcome effects of ambient light on the measurements

5.3.2 *Obstruction/ Obscuration*

In contrast with the above, traffic speed methods are currently used for the detection of obstructed road signs. For these inspections a video survey is used in which the images are accurately geographically referenced. Manual assessment of the images is used to identify obscured signs. It is recommended that work continues on the development of measurement systems to convert the emerging methods into routine application, alongside the work undertaken to assess the other aspects of condition discussed above.

5.3.3 *Night-time Visibility*

Emerging traffic speed methods were identified that measure the night-time visibility of road signs using equipment mounted onto vehicles to measure the luminance of the sign in response to a light source. However, no routine use of this equipment was identified. To achieve a network level survey, work will be needed to assist the development and implementation of mobile reflectometers. The work would include:

- Organisation of a large-scale experiment with different mobile devices;
  - Practical trials which assess the performance of individual devices;
  - Practical trials which compare and harmonise the measurements collected by handheld reflectometers with those from mobile reflectometers;
- Provision of guidance to NRAs on the application of high speed systems e.g. defining standards for measurements with mobile reflectometers.
- Investigation of the potential to of determine night-time visibility from LiDAR data, through practical trials and testing.

5.4 Environmental Noise Barriers

5.4.1 *Sound Reflection*

Noise barriers are probably the most difficult equipment asset to monitor at the network level. PREMIUM was not able to identify a method or survey, at a ready for market level, which could be practically applied at the network level for the measurement of sound absorption/reflection of noise barriers. However, a project was identified which was being undertaken to develop a new in-situ procedure for approval testing and quality assurance of the acoustic properties of noise barriers. The procedure developed will not replace current detailed assessment, but it is hoped that the method could provide an overall assessment of the whole barrier in a much shorter time period than current methods. For sound reflection of noise barriers PREMiUM has therefore recommended:

- Investigate the existence of correlation between in-situ and laboratory methods for sound absorption/reflection of different types of noise barriers. This should include comparison between the in-situ ADRIENNE and QUIESST methods for sound absorption/reflection of different types of noise barriers also including the analysis of the frequency spectra.
- The main issue of the investigation should consider the potential for in-situ monitoring using sensors (i.e. intelligent infrastructure). This will require focused development. Once developed, it will need to be trialled on a large scale for different barrier types and different environments.
- Investigate the potential of the new AIT procedure for sound reflection measurements at slow speed and its implementation on a network level, if the EN 1793-5 method cannot be applied.

5.4.2 *Airborne Sound Insulation and sound diffraction*

Currently, there is no routine method that would enable the practical measurement of these properties. PREMiUM did not identify any emerging methods, but recommended that a technology watch continues, to identify emerging methods.

5.5 Vehicle Restraint Systems

5.5.1 *Presence of Damage and rust*

Routine traffic speed visual inspection via a “drive by survey” is commonly used for detection of damaged VRS. This method can be used to identify obvious signs of damages such as damage resulting from vehicle impact. However, small defects are not visible and can be located only by manual visual inspection. Video surveys could be used as an alternative to these visual inspections for the identification of damage. However, this method would only provide significant advantage (i.e. in time and cost) over routine visual inspections (which are carried out as a matter of course) if the damage could be identified automatically. Also, as with routine visual inspections, video surveys cannot be used to detect small defects or defects not visible from the road.

Whilst it was not thought that automatic identification of damage could be achieved within a 3-5 year timeframe, it should be possible to implement video surveys to record the condition of VRS within this timeframe. Therefore PREMiUM recommends that further work be commissioned in order to develop this. The work would include:

- The potential of video and images from the systems used to collect VRS inventory should be investigated to determine whether manual analysis of these images could be used to monitor the presence of damage and corrosion/rust.
- Practical trials with different devices would provide more information and obtain better understanding of capability of current systems and would enable a specification for

the minimum technical requirements (image resolution, positioning system) for video surveys to be derived.
- Develop formal manual assessment regime to use images to identify damage/corrosion – including a reporting method (e.g. % damage).
- Provision of guidance to NRAs on the application of high speed systems e.g. define standards for measurements with image systems
- If manual analysis can be used to determine corrosion from images, then it might also be possible to extract this information automatically. This would require development of automatic analysis algorithms of the video data, and would be a long term objective.

5.5.2 *Mounting Height*

Mounting height is currently measured during a detailed inspection of a barrier's clearance (measured by hand). Alternatively, coarse manual surveys undertaken at traffic speed can identify obvious differences in mounting height. However, PREMiUM has also identified the use of video/LiDAR equipment for the measurement of the mounting height of VRS at traffic-speed. This has been applied in practice using manual methods to analyse the LiDAR data, and there is evidence to suggest that this could be automated.

Although PREMIUM was not able to identify a market ready survey that could be practically applied at the network level for measurement of mounting height of VRS, potential existing methods were identified. The capability of these methods has been demonstrated at the small scale, but there would be benefit in larger scale investigation and assessment. Therefore it was recommended that further work be commissioned, to include:

- Large scale trials of LiDAR and/or video surveys, to provide appropriate data from which mounting height could be extracted
    - Assess the capability to survey at a network level with these systems
    - Assess the capability to measure all barriers the road at traffic speed
    - Ensure a wide and representative range of barrier type, size, and condition are surveyed
    - Assess the repeatability of the data (image quality, LiDAR data repeatability).
- Development of minimum technical specifications for video and LiDAR surveys.
- Development of formal manual assessment regimes to use images to assess height.
- Guidance on the application of high speed systems to this measurement.
- If the accuracy of manual assessment is shown to be acceptable, then seek to determine if this could be automated through algorithm development and testing.

6 Suggested research programmes

It is clear from the above that several technologies exist that have potential to provide condition measurements across road equipment assets. There would be benefit in undertaking research to facilitate the implementation of these existing and emerging technologies within the equipment asset management programme. To draw best value from research programmes it is suggested that the work be grouped by technology type, as shown in Table 9.

Table 9: Measurement technologies and potential characteristic measurements

Technology	Characteristic that can be potentially measured
LiDAR (section 6.2)	Road equipment inventory; road marking night-time visibility and wear; road sign night-time visibility and orientation, VRS mounting height.
Video (section 6.3)	Road equipment inventory; day-time visibility of road markings (contrast), road sign damage/loss, obstruction/obscuration, panel alignment, and orientation; VRS presence of damage, corrosion/rust, and mounting height.
Mobile reflectometer (section 6.4)	Night-time visibility of road markings and studs, day-time visibility of road markings (contrast), night-time visibility of road signs.
Intelligent infrastructure (section 6.5)	Acoustic properties of noise barrier (absorption, insulation, diffraction).

A successful outcome of these research programmes could be the establishment of basic criteria for these measurement technologies as tools to support equipment assessment. These could be drawn upon by NRAs to implement the methods on their network. This would improve the likelihood of NRAs being able to implement a network approach to equipment asset management.

6.1 Programme 0 – Further development/refinement of the PREMiUM approach for equipment assessment across Europe

6.1.1 *Objectives*

The key objectives of this programme would be to assist in the establishment of common requirements for network level understanding of equipment in Europe, drawing on the work undertaken in PREMiUM. The work would

- Confirm the key inventory and key condition requirements proposed in the PREMiUM research.
- Establish outline technical/performance requirements for these inventory and equipment measurements (i.e. the resolution, accuracy) to support the more focussed work of the remaining programmes.
- Publish these using a suitable route.
- Promulgate these to NRAs across Europe.
- Establish the appetite for the proposed approach and the desire to support further development.

6.1.2 *Approach*

The remaining programmes in this section have a strong technical focus, as they seek to investigate practically the capability of technology and then undertake further development to support its use in equipment assessment. The focus of Programme 0 would not be practical or developmental. Programme 0 would build on the work of PREMiUM by proposing initial technical requirements for inventory assessment and equipment measurements and preparing outline requirements documents.

For example, baseline measurement resolutions and accuracy for inventory items would be proposed and collated in an outline technical specification. Peer group

(NRA/researcher/survey developer) review would refine these. The outline specification documents would be published for NRAs so that further challenge and review could be made of the PREMIUM approach. The publication route would need to be decided, taking account of formal standards (CEN/ISO), but noting that the objective would not be to develop formal standards, but to develop specifications that could be used to support network level asset management. This could be followed up by workshops, meetings, webinars etc. to further promulgate the approach and seek consensus across different NRAs. The same approach would be taken to develop (e.g.) resolution and accuracy requirements for the key equipment condition measurements, with similar refinement and promulgation.

The outcome of this programme could be used to provide baseline requirements for the remaining programmes of work, and also to establish the take-up and desire for developing formal specifications for network level equipment assessment.

6.2 Programme 1 – Use of LiDAR for equipment assessment

6.2.1 Objectives

The key objectives of this programme would be to:

- Confirm the capability of LiDAR for the identification of inventory (this is already quite well understood) and for equipment condition assessment (this area is less well understood).
- Establish the performance requirements for LiDAR systems to measure condition and inventory of the various equipment types. This would enable realistic requirements to be established - focussed on the required outcomes, not on the claimed capabilities of commercial systems.
- Establish specifications and methods to check that systems perform as required.
- Determine whether/how automation can be introduced to the assessment of LiDAR data for inventory and equipment condition assessment.

6.2.2 Understanding Capability

A large scale assessment would seek to understand the capability of LiDAR systems using sites located on the network to include a wide range of assets. LiDAR surveys should be carried out in consistent conditions and at a similar time of year (same day would be ideal) to provide LiDAR point cloud data. A “reference” dataset would be established of the assets present on the routes. For inventory this should be obtained using current inventory methods e.g. walked survey, slow driven survey and manual recording of asset, including GPS location, for condition current measurement methods would be used e.g. hand-held retro-reflectometer. The analysis would determine:

- Can each of the assets, identified by the reference survey, be seen in the data?
- Does the data have the potential to be used to provide inventory data for road equipment?
- What level of resolution is needed for the LiDAR data for a human to extract the inventory information needed?
- Can LiDAR data be used to deliver data that correlates with measurements of condition provided by reference methods? It is suggested that capability areas to assess for condition would include: retro-reflectivity of road markings and road signs; wear of road markings; orientation of road signs; mounting height of VRS.
- If so, how accurately might these characteristics be measured?

6.2.3 Specification for LiDAR surveys

Where LiDAR technology is shown to offer the potential to obtain inventory and characteristic measurement data, then there would be benefit in developing specifications for such surveys. The HiSPEQ project (www.hispeq.com) has provided proforma for network level surveys of condition using various methods. This could be used as a template for LiDAR surveys, and would consider technical requirements such as: point cloud density, coverage (e.g. distance 10m from the centre point of each traffic lane to be included), absolute accuracy (e.g. 30mm RMSE), relative accuracy (e.g. 10mm); how the data should be delivered i.e. data format (e.g. LAS 1.2. format); file naming conventions; information to be provided per file etc.

The specification should also state how the accuracy and consistency of the data will be tested (HiSPEQ1:6 in the "HiSPEQ Specification Template Guidance Part1" provides guidance on how to specify Accreditation and Quality Assurance for high speed surveys https://hispeq.com/projectoutput/survey-specifications-and-guidance/).

6.2.4 *Automated extraction processes*

It is anticipated that the focus of the work on understanding capability would primarily apply manual extraction and assessment methods. An automated extraction process would take LiDAR data as input and deliver asset inventory or condition data using algorithms. This will require the following work:

- Research into the development of extraction algorithms. It is suggested that an initial study could rank the anticipated feasibility and performance of automation in each area of application to determine where to focus development work. Development would then be undertaken on the areas with highest potential.
- Test the algorithms using data collected during the capability assessment.
- Determine the performance of the algorithm and improve, where possible.
- Establish the limitation (what can and can't be obtained from automatic asset inventory e.g. only road signs with a face >600cm^2) and determine whether these are acceptable for implementation.

6.3 Programme 2 – Use of imaging for equipment assessment

The research required to develop video technology to measure asset inventory and the characteristics listed in Table 9 would be very similar to that of LiDAR, as summarised in the following sections.

6.3.1 *Objectives*

The key objectives of this programme would be to:

- Confirm the capability of video for the identification of inventory and for equipment condition assessment (these are both reasonably well understood, but objective, consistent, and published data is not widely available).
- Establish the performance requirements for video systems to measure condition and inventory of the various equipment types. This would enable realistic requirements to be established – again focussed on the required outcomes, not on the claimed capabilities of commercial systems.
- Understand and establish how the assessments from video surveys should be reported to support asset management.
- Establish specifications and methods to check that systems perform as required.
- Determine whether/how automation can be introduced to the assessment of image data for inventory and equipment condition assessment.

6.3.2 *Understanding Capability*

Broadly similar to the LiDAR work above, this would undertake a large scale assessment involving different types of imaging systems. Survey providers will need to be commissioned to survey appropriate routes and provide the images collected and, where appropriate, an image viewer. The work would determine the capability of these systems to identify and assess assets, similarly to 6.2.2.

For the assessment of condition it is suggested that capability areas to assess would include: day-time visibility of road markings (contrast); road sign damage/loss, obstruction/obscuration, panel alignment, and orientation; VRS presence of damage, corrosion/rust, and mounting height. The work would establish how accurately these characteristics might be measured.

6.3.3 *Formal manual assessment regime for image analysis*

It will be necessary to establish the assessment regimes required to deliver condition data using images. For example currently sign damage is assessed subjectively, with an inspector recording whether they think that the sign is damaged enough to require maintenance/ replacement. However, there would be benefit in developing a formal manual assessment regime, to enable images to be used to quantify condition, including a reporting method (e.g. the % of damage). This would encourage consistency in the reporting by different inspectors.

More importantly it would allow formal reporting regimes to be established across networks, which would allow NRAs to commission video surveys against a common standard. This would assist in the introduction of these techniques for network level assessment, and would encourage providers to develop commercial survey systems to meet these established requirements.

6.3.4 *Defining a specification for an image survey*

If the use of imaging technology does offer the potential to obtain inventory data, then there is a need to develop a specification for such surveys. Again, the advice given by the HiSPEQ project (www.hispeq.com) would assist in developing the specification. The specification would be expected to include:

- How the images should be locationally referenced to the network.
- The field of view for the images e.g. 270° centred on the carriageway, 270° centred at an angle of 45° to the front of the vehicle, 360°.
- What features should be visible in the images e.g. all on-carriageway features and off-carriageway features within 10m of the highway boundary (and visible from the road).
- The maximum distance the nearest point in each of the images is allowed to be from the survey vehicle.
- Requirements for the effect of survey speed on the resolution, distortion and focus of the images.
- Requirement for vertical objects to appear vertical in the images.
- Requirements for the amount of detail provided on the image e.g. “text on a direction sign should be easily read on an image collected at 40m from the sign”.
- The maximum distance travelled between each image provided.
- How the data should be delivered i.e. image format, file naming conventions, information to be provided per image (location, camera,…).

The specification should also state how the accuracy and consistency of the data will be tested (HiSPEQ1:6 in the “HiSPEQ Specification Template Guidance Part1” provides guidance on how to specify Accreditation and Quality Assurance for high speed surveys https://hispeq.com/projectoutput/survey-specifications-and-guidance/).

6.4 Programme 3 – Use of mobile reflectometers

6.4.1 *Objectives*

The key objectives of this programme would be to:

- Confirm the capability of mobile reflectometers for the assessment of various properties of road markings and signs.
- Establish the performance requirements for these systems. This would enable realistic requirements to be established, focussed on required outcomes. This may include establishing classifications for devices as “network level”.
- Understand and establish how the assessments should be reported to support asset management.
- Establish specifications and methods to check that systems perform as required.
- Determine whether/how automation can be introduced to the assessment of image data for inventory and equipment condition assessment.

6.4.2 *Evaluate available equipment for night-time visibility of road markings*

There are several systems available to measure this property, but there is a lack of understanding of their capability as network level tools. The take up of the tools for routine network level assessment is inconsistent. There is a need to better understand the accuracy, precision and consistency of the latest mobile retro-reflectometer systems, so that guidance could be provided to NRAs on the systems’ capabilities. To enable this, there is a need to understand how the systems perform, leading to development of technical specifications for surveys. A round robin test could be used to assess performance and determine the correlation between different systems. The following is suggested:

- Undertake testing on routes that include representative types of road marking and studs, in environmental conditions that are representative of the conditions of markings/studs found on the network.
- The tests would be carried out in the dry (i.e. summer), supervised by an independent body, by survey providers. A good range of equipment types should be represented, particularly both dynamic single-line side-mounted retro-reflectometers and systems which collect information across the full width. Also, systems that claim to be able to measure road studs. The tests should focus on establishing real-world performance as would be achieved in a network survey, which would include traffic, variation in driving line, etc.
- Assessments would aim to understand the performance in terms of reproducibility (comparison with a fundamental reference), repeatability, fleet consistency (i.e. how the devices compare with each other). It is also suggested that the tests focus on how well systems are able to distinguish poor/good lines as well as the ability to deliver precise measurements of the retro-reflectivity. This would enable the tests to determine if a device is a robust tool for network assessment, but may not be suitable for scheme/project level work.
- Hence provide robust guidance for the NRA on the devices and their capability in real-world conditions, particularly for those devices that offer network level data at non-standard geometries.

6.4.3 *Evaluate measurement of day-time visibility of road markings*

The above practical trials could also include an assessment of the feasibility of measuring day-time visibility using retro-reflectometers, by:

- Collecting “reference” measurements of daytime visibility using:
    - the coefficient of luminance, Q_d and the luminance factor, β of the markings surveyed. Since this requires a slow speed survey and traffic management, it

may be considered sufficient to collect a sample of reference data that is representative of the condition of the road markings on the routes surveyed.
    - A subjective visual survey, from a driven vehicle, recording how visible the markings are from a moving vehicle, travelling at traffic speed. Results should be recorded using a device that can record the position of the data.
- For retro-reflectometers that claim to have potential in this application, calculate the contrast from the retro-reflectometer measurements (i.e. the difference between the retro-reflection value of marking and the retro-reflection value of the pavement) and determine if a correlation exists between the contrast measure and the reference measures.

The results of this trial could then be used to determine the appropriateness of using contrast as a measure of day-time visibility and to understand the potential of current equipment in delivering this measure.

Should it be determined that contrast is appropriate, there will then be a need for NRAs to consider how such data could be accommodated within current or new standards and also to define a specification for these surveys. It is likely that refinement would also be required of the approach to calculate contrast (through further development of algorithms to automatically calculate the contrast measure from retro-reflectivity measurements).

6.4.4 *Development and evaluation of equipment for road signs*

As discussed above, to achieve a network level survey of road signs, it is recommended that work is undertaken to assist the development and implementation of mobile reflectometers. The work needed for this would follow the same broad approach as taken for road markings, and as discussed in section 5.3.3.

6.4.5 *Defining a specification for retro-reflectivity surveys*

As with surveys of asset inventory, we have followed the recommendations of the HiSPEQ project for survey specifications and thus the following will need to be defined:

- How the data should be locationally referenced to the network.
- The accuracy to which the markings or signs should be measured.
- The level of consistency required for the data (i.e. how repeatable the data should be).
- How the data should be reported e.g expected range of values, file naming convention, file formats.

In addition, for road markings, there would also be a need to specify:

- Whether all road markings should be surveyed, or just the lane-delimiting markings
- How the data should be reported e.g. average retro-reflectivity value over a specified reporting length, average retro-reflectivity value per marking.

More guidance on defining a high-speed survey specification can be found in the “HiSPEQ Specification Template Guidance Part1” document (available at https://hispeq.com/projectoutput/survey-specifications-and-guidance/). Section HiSPEQ1:6 of this document also gives guidance on how to specify Accreditation and Quality Assurance for the survey.

6.4.6 *Revisions to standards*

The benefit of establishing the real world requirements and capability for retro-reflectivity measurement will only be realised once the standards for these measurements are revised/updated to accommodate new network level approached. There hence will be a need to assess how network-level retro-reflectivity data for markings or signs could be accommodated within current or new standards and thus whether any revisions are needed. These revisions may allow surveys to be commissioned that enable practical condition assessments to be undertaken using equipment with non-standard geometries, provided they offer good quality data that is correlated with that from devices using the standard geometry.

6.5 *Programme 4 - Intelligent Infrastructure*

6.5.1 ***Objectives***

The key objectives of this programme would be to assist the advancement of in-situ measurement techniques to support routine assessment of condition of equipment assets. It would:

- Confirm the capability of current and emerging sensors, determine where to invest research resources, and support the focussed development of these systems.
- Establish the performance requirements for these systems to help industry focus their own developments.
- Understand and establish how the assessments should be reported to support asset management.

6.5.2 ***Work required***

Given the developments in small, low cost, low power sensing technologies, this is a potentially large area of research, and hence there is a need to understand where and how to focus resources. For equipment PREMiUM has suggested that initial focus could be on

- Sensors that could be applied to (e.g.) measure vibration and movement to support assessment of damage and wear in VRS, signs and noise barriers
- Sensors to continuously monitor traffic noise at a noise barrier, and hence track changes in the ability of the barrier to attenuate noise

It is suggested that research be undertaken to better understand the capability of sensors in these applications, considering items such as fundamental capability, status of development, feasibility of reaching an implementable solution, how the system would fit in with other monitoring methods and on-site technologies etc.

This would lead to a shortlist of development activities, which could be undertaken through direct research (e.g. design bespoke equipment to measure the acoustic properties) or through working with/encouraging the existing sensor industry, for example by embracing the concept of intelligent infrastructure and creating an open platform on the road network that would allow service providers to sell and integrate these types of systems.

Thought will also need to be given to whether the device will automatically feed its data back to a central database, or whether it is more practical for the data to be stored in-situ and manually extracted on a regular basis. Again, this depends on how the NRA would like to implement the intelligent infrastructure approach. In any case, any potential equipment will then need to be thoroughly tested through practical trials to ensure that it meets the requirements for measurement.

7 References

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