Heroad, Holistic Evaluation of Road Assessment

Equipment performance assessment

Deliverable Nr 3.1

September 2012

VTI, Sweden

TRL, UK

BRRC, Belgium

FEHRL, Belgium

ZAG, Slovenia

AIT, Austria

This project was initiated by ERA-NET ROAD.

Project Nr. 09/16771-39

Project acronym: Heroad

Project title:

Holistic Evaluation of Road Assessment

Deliverable 3.1 – Equipment performance assessment

Due date of deliverable: 31.12.2012

Actual submission date: 29.09.2012

Start date of project: 01.01.2011 End date of project: 31.12.2012

Author(s) this deliverable:

Christophe Casse, BRRC, Belgium

Carl Van Geem, BRRC, Belgium

Version: Final

Executive summary

To manage the road network, road managers and operators have to consider existing policies such as the requirement to keep the network in good condition, and to deliver this condition at minimum whole life cost. However, the condition should also meet the expectations of stakeholders. The management process has to optimise the total costs for society, whilst minimizing the effects of given condition levels on safety, reliability, environmental impact, economics and sustainability. *Heroad* will investigate the holistic process (the combination of individual components, levels of assessment and the inclusion of a life cycle perspective) to incorporate also new challenges in the asset management.

HEROAD has focused on developing a clear understanding of the performance and behaviour of individual assets and how this understanding can then be used to benefit asset management across Europe.

This deliverable takes the equipment part into account. The aim of the work was to bring to the common denominator information from different sources:

- International or European research projects dealing with similar topics.
- Interviews with road operators and experts.

In general the equipment is not part of an integrated management process. Few references are available regarding management techniques for the different assets included in the equipment category. Therefore we mainly concentrated our efforts in the interviews and data collection on current practices in the different countries listed in chapter 4.

Another view is related to the stakeholders. We envisaged different stakeholders' expectations and how the current techniques from the NRAs were in line with these, in order to describe, where possible, technical indicators. The results are available in chapter 5.

Visual inspection is still the most important type of condition monitoring given the ease to perform these and the minimum investment needed to carry out. A key point related to the visual inspection is the training of the inspectors, this is also crucial when it is outsourced to a contractor. We see a clear trend for automatization and traffic speed measurement devices.

The frequency is related to the nature of the network and the expected service life of the different assets. From the study, a service life may vary from 3 to 12 years for the same equipment following the country. This may lead to significant different inspection frequencies.

Data Management is a key success factor therefore good practices include the development of a methodology for data collection and maintenance. The on-line access to these data's is mentioned as an improvement possibility, as the automatization of the data collection on-site. Another improvement is based on the interactions between contractors in charge of maintenance or inspection and these central databases.

Central databases are mainly used (e.g. for UK, Slovenia, Lithuania). These often cover the highways and primary road networks. For secondary networks and networks operated by local authorities, the data are often stored on a case by case methodology.

Different levels of data are available, from raw measurements from inspection devices to the analysed and tuned data. The level of detail may be restricted to some operators: For example, the engineers in charge of the network management will only have access to the shaped data. The data collection methodology can be described in a guide, as for the Slovenian Road Data Bank (Methodology of collection and maintenance).

Service lives are set and evolution models are used, for example by the RWS in The Netherlands. Another approach may consist in taking other inputs into account - rather than technical indicators of the equipment condition, triggers for maintenance can also be used: A significant increase in the number of calls by technical personnel of the Road Administration

or by users (complaints), a significant increase of the number of maintenance interventions or repairs by the “care team” (whose task is to intervene rapidly when a major technical problem has been identified) or for VMS or other electronic equipment: electronic parts of the system may become expensive or difficult to find, which implies that it is getting time to replace the whole system.

Recommendations may include:

- Further research on service life and evolution models for specific types of equipment combined with a cost – benefit approach in order to evaluate if an asset management program based on these laws will bring benefits versus the present approach based on network inspections and fixed term maintenance or replacement
- Promote other sources of information for the management, such as number of complaints, feedbacks from road users or other stakeholders
- Formalization of the inspection techniques: what are the qualification criteria requested for contractors or own personnel performing asset evaluation. This evaluation may be executed while performing a maintenance operation (such as a structure assessment when a bulb replacement is planned) and one activity should not jeopardize the other.
- Use of traffic speed investigation technique such as video inventory compilation, assets’ geo- localisation and combined with post-processing activities.

List of Tables

Table of content

1 Introduction

"ERA-NET ROAD – Coordination and Implementation of Road Research in Europe" was a Coordination Action funded by the 6th Framework Programme of the EC. The partners in ERA-NET ROAD (ENR) were United Kingdom, Finland, Netherlands, Sweden, Germany, Norway, Switzerland, Austria, Poland, Slovenia and Denmark (www.eranetroad.org). Within the framework of ENR this joint research project was initiated. The funding National Road Administrations (NRA) in this joint research projects are Belgium, Switzerland, Germany, Denmark, Finland, France, Ireland (Eire), Lithuania, The Netherlands, Norway, Slovenia, Sweden and United Kingdom.

To manage the road network, road managers and operators have to consider existing policies such as the requirement to keep the network in good condition, and to deliver this condition at minimum whole life cost. However, the condition should also meet the expectations of stakeholders. The management process has to optimise the total costs for society, whilst minimizing the effects of given condition levels on safety, reliability, environmental impact, economics and sustainability. This principle and its overall goals are equal for all road managers around Europe. *Heroad* will investigate the holistic process (the combination of individual components, levels of assessment and the inclusion of a life cycle perspective) to incorporate also new challenges in the asset management. This includes

- Looking at data collection, assessment and reporting regimes
- Especially considering new challenges (climate change, traffic configuration, new materials, LCC and the focus on road users' expectations)
- Identify and assess the key technical components of these regimes and then determine whether they are good practice or not
- Identifying and describe indicators at different assessment levels (for road operators complicated technical parameters are okay, for decision makers and public more understandable indicators that could be built from combination of technical parameters are needed).

This document is a deliverable reporting the outcomes from the work on assessment of equipment in the Heroad project.

1.2 Aim of HEROAD

HEROAD has focused on developing a clear understanding of the performance and behaviour of individual assets and how this understanding can then be used to benefit asset management across Europe. In the area of equipment, the focus of the work was to:

- Bring available information about the equipment performance in countries contributing to the EraNet Road/CEDR "Asset Management" programme, collected with questionnaires and interviews, to a common denominator.
- Identify and assess the parameters, models and criteria used for managing the condition and performance of equipment. Determine what parameters are being monitored and how, how data quality and consistency is controlled. Consider how the processes could be improved, whether road users' opinions are considered and what the effect of the sensitivity and quality of the data is.

- Determine how these could be used to develop common evaluation tools, through the identification and development of comparable condition assessment parameters.

- As a result of the above, identify good practices and determine how these could be taken forward for use in management systems and/or within cross asset management systems.

Throughout the project we have concentrated on the requirements of Road Managers, keeping in mind the objective of providing useful, straightforward, tools that can be implemented in practice.

2 Methodology

Equipment may also be defined as road furniture and in some cases as inventory. In the case of Heroad we have called it equipment and have concentrated on road signs, lighting, markings, restraint systems and noise barriers and finally VMS (Variable Message Signs) and other technologies.

The aim of the work was to bring to the common denominator information from different sources:

- International or European research projects dealing with similar topics.
- Interviews with road operators and experts.

The equipment is not usually part of an integrated management process. Few references are available regarding management techniques for the different assets included in the equipment category. Therefore we mainly concentrated our efforts in the interviews and data collection on current practices in the different countries listed in chapter 4.

A second angle of view is related to the stakeholders. We envisaged different stakeholders' expectations and how the current techniques form the NRAs were in line with these in order to describe, where possible, technical indicators. The results are available in chapter 5.

3 Inventory, Data management and Case Studies

Data from ten countries were gathered by the partners from interviews with experts and authorities representatives: France, Eire, Austria, Belgium (Flemish Region for pavements and equipment and Walloon Region for the structures), Germany, Lithuania, Slovenia, United Kingdom, Sweden and Nordic Countries. The list of interviewees is available in appendix B. For The Netherlands, we have collected data from a case study for PIARC Technical Committee D1-Wg 1 from July 2011 [12].

The answers to the questions have not been easy to receive either because there is no simple answer or the right expert was not available. Another reason can be that not much information can really be given since there are a lack of methods and procedures. See Appendix A. From UK, Belgium and Lithuania there are complete information given.

3.1 Inventory of equipment

Inventory covers the inspections and the management related issues for different equipment. The data gathered in the different questionnaires are the base of the following findings.

3.1.1 Main findings

Inspections are carried out and are often classified as safety and service inspections. During safety inspections, damage and failures that might have a short term impact are inventoried. The service inspections are organised on a lower frequency. Some countries have defined programs and others use a mix of defined and “at random” inspections.

Road equipment inventory can be collected at traffic speed; however its condition is usually carried out with slow speed or stationary surveys.

The inspections are mostly visual assessments. A Mobile Road Survey Laboratory is also used (e.g. in Lithuania) and the pictures are stored in a central database (LAKIS)

Internal guidelines are developed in order to carry out the inventory; we can mention the ones of Asfinag.

The teams performing the inspections can be either contractors or personnel from the road authorities.

The following chapters will cover the different assets for which data were gathered during the interviews.

3.1.2 Road Signs

Table 1: Road signs - Data Collection per country

Country	Inspection frequency	Monitoring system
United Kingdom	Regular inspections but also a 2 year inspection for performance and relevance.	Described in a standard [2]
Sweden	N/A	Mainly visual inspection and sometimes maybe hand-held instrument There are guidelines (minimum values for the retro-reflectivity) for when the signs should be replaced
Slovenia	Video inspection every two years coupled with contractors' daily surveys	Reflectivity is measured
Lithuania	Visual inspections are performed at a frequency based on the road category (daily for motorways, twice a week for national roads and once a week for regional roads)	Mainly based on visual inspections, A Mobile Road Survey Laboratory is used
France		Traffic speed data collection based on images Renewal based on expected service life (7-12 years)
Eire	Condition monitored every year on motorways	Manual data collection
Germany	N/A	N/A
Austria	Regular inspections on a random sample (Asfinag guidelines)	Reference documents are available [5] Presence and retro-reflectivity
Belgium	Three year life expectancy	Visual inspections

The inspections cover mostly:

- the visual performance based on different aspects such as peeling, loss of legend, information correctness,
- the structural integrity (rust, damages, foundation) and
- the retro-reflectivity.

The expected service life ranges from 3 to 12 years.

In Belgium, a central database has been developed to hold inventories of all the road signs of the Flemish road network (national, regional and communities roads). This was based on video inspections. The challenge is to keep this database up-to-date and use the collected information for management goals.

3.1.3 Lighting

Table 2: Lighting - Data Collection per country

Country	Inspection frequency	Monitoring system
United Kingdom	N/A	Described in a standard [3]
Sweden	N/A	Visual inspection. A mobile instrument which measures the illuminance of the lighting installation and the brightness of the road surface is under development.
Slovenia	N/A	N/A
Lithuania	Visual inspections are performed at a frequency based on the road category (daily for motorways, twice a week for national roads and once a week for regional roads)	N/A
France	N/A	Traffic speed data collection based on illuminance
Eire	N/A	N/A
Germany	N/A	N/A
Austria	Regular inspections on a random sample (Asfinag guidelines)	Reference documents are available [5] Presence and correct function
Belgium	Visual inspections are carried out when a bulb replacement is performed	

The lighting is not always inspected with scheduled programs, ASCAM findings show that inspections are done irregularly and the time between visual inspections is dependent on type of street and luminaire. The maintenance (bulb replacement) is sometimes used as an inspection opportunity in order to monitor the condition of the lighting equipment: structural integrity, electrical conformance, presence of rust (paint or coating condition,…)

The expected service life is around two years.

3.1.4 Markings

Table 3: Markings - Data Collection per country

Country	Inspection frequency	Monitoring system
United Kingdom	Visual inspections are performed during frequent safety inspections on all road networks.	Traffic speed survey has been tested.
Sweden	Contractors are performing control measurements on a yearly basis on randomly selected sections	Mobile monitoring of retro-reflectivity. A Road marking Management system (RMMS) is being developed [4]
Slovenia	N/A	Reflectivity is measured
Lithuania	Visual inspections are performed at a frequency based on the road category (daily for motorways, twice a week for national roads and once a week for regional roads)	N/A
France	N/A	Traffic speed data collection based on retro-reflectivity
Eire	Contracts mention a minimum service of life of three years but a 5 year life is achievable. Cyclical maintenance is carried out, an extreme intervention level is also defined	Investigations are carried out for automated measurement of line marking condition coupled and maintenance policies (vs. cyclical)
Germany	N/A	N/A
Austria	Regular inspections on a random sample (Asfinag guidelines)	Reference documents are available [5] Presence and retro-reflectivity
Belgium	From one to six year life expectancy (paint : one year, thermoplastic : three years, shaped marking : six years) [6]	Visual inspections are now performed and automated inspections are investigated in the Flemish Region. Test sections are used to analyse the behaviour of markings types in the Walloon Region.

The retro-reflectivity is the key parameter. The frequency may vary from one country to another. Other parameters are: wet and dry retro-reflectivity, luminance coefficient and friction

For example, in the Flemish Region (Belgium), the 100% service level is the conformity to the initial specifications that meet the EU norms. This conformity is reached by using the appropriate material / equipment. Following the type of material used, the expected lifetime will vary between 1, 3 or 6 years. After this initial conformity, all equipment is monitored but no measures are taken to evaluate the service level evolution. The aim of the monitoring is simply to follow up whether the expected lifetime is respected on site or not (e.g. the same type of road markings will not last as long on a heavily trafficked ring road around a city as on a less trafficked motorway with few entrances). Therefore it’s not possible now to provide an evolution law describing the decrease of performance versus time. In the near future, mobile equipment (a mobile retroreflectometer) will be used to measure systematically (probably once a year on the whole network) the roadmarking’s properties: reflection (reflectometer) and the whiteness. The network will be monitored on a yearly basis

For Sweden, yearly inspections are performed on randomly chosen road sections. The functional (e.g. retro-reflectivity) and design (width, thickness, length and interdistance for intermittent markings) requirements are assessed during these inspections.

Road Markings Management Systems (RMMS) are developed in the Nordic countries.

Traffic speed assessment is often mentioned as a future tool in order to assess the performance of markings. Traffic speed survey has been tested in UK with an Ecodyn on an annual basis but is not considered as ‘best value for money”, further development is needed for traffic speed survey. In France, this technique brought better results, maybe due to the absence of road studs. Some authorities in France replace the markings systematically after x years but the use of Ecodyn showed that much later replacements were possible, with the advantage to provide supporting evidence with the measurement.

3.1.5 Restraint systems and noise barriers

Table 4: Restraint Systems - Data Collection per country

Country	Inspection frequency	Monitoring system
United Kingdom	Based on two levels : safety and service inspections	Safety inspections (visual)
Sweden	Roadside, median and bridge barriers are the three categories of barriers in Sweden. They are registered in the Batman (bridge database) or National road data bank.	Wire barriers and other concrete barriers are not inspected regularly. There is a need to know what type the barrier is and how old it is but this is not organised. The bridge barriers are inspected regularly according to rules in the Batman system.
Slovenia	N/A	N/A
Lithuania	Visual inspections are performed at a frequency based on the road category (daily for motorways, twice a week for national roads and once a week for regional roads)	N/A
France	N/A	N/A
Eire	N/A	N/A
Germany	N/A	N/A
Austria	Regular inspections on a random sample (Asfinag guidelines)	Reference documents are available [5] Presence and condition Expected service life of 5 years (as well as delineator posts)
Belgium	Visual inspections during weekly inspection	N/A

Safety inspections are carried out and the restraint system are visually assessed: integrity, damages, presence of retro-reflectors, etc.

In Sweden a work has started to organise inventory of barriers. Since new built barriers need to be type approved but old barriers aren’t, there exists a need to record this.

Noise barriers are not often mentioned as equipment concerned by the inspections. They are present in the inventory but the questionnaires didn’t demonstrate a specific management.

The expected service life, for example in Austria, is set to five years.

3.1.6 VMS and other technologies

Table 5: VMS and other technologies - Data Collection per country

Country	Inspection frequency / Logging	Monitoring system
United Kingdom	Fault logging	Remote monitoring systems (RMS) and Urban Traffic Control (UTC) Described in a standard [1]
Sweden	N/A	Automatic supervision and visual inspection (seldom)
Slovenia	N/A	N/A
Lithuania	Visual inspections are performed at a frequency based on the road category (daily for motorways, twice a week for national roads and once a week for regional roads)	N/A
France	N/A	N/A
Eire	N/A	N/A
Germany	N/A	N/A
Austria	Regular inspections on a random sample (Asfinag guidelines)	Reference documents are available [5] Presence and correct function
Belgium	N/A	Online monitoring by the management centre of the Flemish road authority

The inspections for VMS cover the following aspects: functionality (testing), calibration of various sensors, need for cleaning

Traffic monitoring cameras and emergency phones are marginally mentioned as making part of the inventory.

The challenges for the future are related to the expansion of new technologies on the network: traffic control posts that will deal with vehicle weighing, plate number recognition, etc.

3.1.7 Conclusions

From all the data gathered and analysed, we can draw some conclusions for the types of inspections that are performed and their frequency.

Visual inspection is still the most important type given the ease to perform these and requires the minimum investment to carry out. A key point related to the visual inspection is the training of the inspectors, this is also crucial when it is outsourced to a contractor. We see a clear trend for automation and traffic speed measurement devices.

The frequency is related to the nature of the network and the expected service life of the different assets. From the study, a service life may vary from 3 to 12 years for the same equipment following the country. This may lead to significant different inspection frequencies.

3.2 Data management for the equipment

3.2.1 Introduction

Data management is a key point in order to assure a good follow-up to the inspections performed on site, e.g. visual inspections, or remotely, e.g. fault logging for Variable Message Signs. Therefore this chapter will concentrate on the existence of databases, their relations and their availability.

3.2.2 Data management

Table 6: Data management - per country

Country	Findings
United Kingdom	Inventory data (detailing location and, if relevant, dimensions of road equipment) for the motorway and primary road network is stored on a central database. Condition data for this network is stored by the contractors responsible for operating and maintaining the equipment. For other road networks, the data will be stored by each local authority in the country. Staff in the Highways Agency and maintaining agents have access to inventory data on the motorway and primary road network. Only relevant personnel would be able to access the systems for condition recording. Relevant personnel in the Local Authorities would have access to the data for the other road networks.
Sweden	Data has until now been gathered but not collected in a common database. The TRA has just recently started a project where the data on road markings is to be included in the databases for road maintenance (VUH) and for road condition measurements (VYM). The data should be linked geographically to the road network via the network model used by TRA. Data to be gathered in VUH: Road number, road type, road section, type (centreline, edge line, etc.), material (thermoplastic, spray plastic, paint, etc.), intermittence (broken, continuous), line width, age, design (plane, profiled), surfacing (asphalt, surface treatment, etc.), speed limit, salting (yes/no) Parallel work is on-going to inventory road barriers, type, length and probably condition etc. This will be collected in Batman (The bridge management system, [10] or/and the national road databank, NVDB [11])
Slovenia	The data is stored in a central database, named the Road Data Bank, that pavement engineers can access on request (in some cases they gain remote access, in others the requested information is sent to them by the Road Data Bank managers). They only have access to the analysed data, not to raw measurements made by the traffic speed devices. Some past data are usable, but many times not reliable enough. Data are collected by engineers, contractors on-site and sent to responsible for preparing and filling data into Road Data Bank. Automation of this process would be a huge improvement.

Lithuania	Data from implemented project is used, which has been collected during visual inspection. Pictures captured with Mobile Road Survey Laboratory are also used. The data is stored on a central database, named “LAKIS”. Employees of Lithuanian Road Administration can access this data. Also this data can be accessed by subordinate bodies and other institutions on request (in some cases they gain remote access, in others the requested information is sent to them by ”LAKIS’’ managers). They only have access to the analysed data, not to raw measurements made by the traffic speed devices.
France	There’s a database for road marking retro-reflectivity (mainly national roads), some motorway concessionaire have their own databases that they populate regularly, some local authorities also, use of GIS. Stakeholders, maintaining agents for the national road network have access to these data.
Eire	N/A
Germany	N/A
Austria	Collected data are compiled into an internal database Access : ASFINAG, Ministry of Transport, Innovation and technology
Belgium	The inspection results are stored locally in the 5 regional road divisions for all the subsequent equipment. An IRR project is launched and in development. It is an Inspection, Inventory and Reporting tool where all the monitoring data will be centralised Road signs [7] : a web tool is developed where all the road signs are registered (http://www.mobielvlaanderen.be/verkeersbordendatabank/index.php)

3.2.3 Conclusions

Data Management is a key success factor, good practices include the development of a methodology for data collection and maintenance. The on-line access to these data is mentioned as an improvement possibility, as is the automation of the data collection on-site. Another improvement is based on the interactions between contractors in charge of maintenance or inspection and these central databases.

Central databases are mainly used (e.g. for UK, Slovenia, Lithuania). These often cover the highways and primary road networks. For secondary networks and networks operated by local authorities, the data are often stored on a case by case methodology.

Different levels of data are available, from raw measurements from inspection devices to the analysed and tuned data. The level of detail may be restricted to some operators: for example, the engineers in charge of the network management will only have access to the shaped data. The data collection methodology can be described in a guide, as for the Slovenian Road Data Bank (Methodology of collection and maintenance).

Service life is set and evolution models are used, for example by the RWS in The Netherlands. Another approach may consist of taking other inputs into account: rather than technical indicators of the equipment condition, triggers for maintenance can also be used: A significant increase in the number of calls by technical personnel of the Road Administration or by users (complaints), a significant increase of the number of maintenance interventions or repairs by the “care team” (whose task is to intervene rapidly when a major technical problem has been identified) or for VMS or other electronic equipment: electronic parts of the system may become expensive or difficult to find, which implies that it is getting time to replace the whole system.

3.3 Case studies

This chapter will describe specific cases worth to be mentioned: best/good practices, success stories.

3.3.1 Belgium – Flemish Region – Lighting

An example is given for lighting management compared to a technical indicator: the visibility distance. An interview was conducted with the Flemish authority. Different levels were proposed for some equipment based on the optimum (100%) distance. The proposed levels were not found appropriate by the interviewees. The condition assessment is performed on a case by case methodology: does the equipment still deliver a sufficient performance? The visibility and legibility levels are not used in Belgium. The Flemish regional government decided recently to reduce road lighting at night and the road administration worked out a plan for the implementation of this decision. As a consequence of the reduction of lighting, a higher reflection is required from the road markings (since the beginning of 2011) and for the reflectors on the road side. This illustrates well that the introduction of environmental criteria has to be integrated in asset management as a whole.

The Highways Agency Carbon Account evaluates the environmental footprint of the Highways Agency activities. From the results of this analysis, some measures were identified for the reduction of carbon emission. Switching off the lighting at night reduces energy consumption. Amongst other measures reducing traffic congestion itself, better real-time information to road users about traffic jams occurring on the road network leads to better traffic fluidity and hence less carbon emissions ([13] Richards, Kerwick-Chrisp 2010). The communication to road users can be increased by better use of VMS or information broadcasted by radio and distributed on the internet

Regarding the maintenance strategy, rather than technical indicators of the state of the equipment, triggers for maintenance could be based on: a significant increase of the number of calls by technical personnel of the Road Administration or by users (complaints), a significant increase of maintenance interventions or repairs by the “care team” (whose task is to intervene rapidly when a major technical problem has been identified). For VMS or other electronic equipment: electronic parts of the system may become expensive or difficult to find, which implies that it is getting time to replace the whole system.

3.3.2 Other cases

No other case was proposed by the interviewees.

4 Equipment: the stakeholders, their Expectations and ideal measurements

The holistic approach should cover the different aspects related to all equipment and to the different stakeholders. These stakeholders will have different expectations on the different aspects that each type of equipment is supposed to cover. A matrix was therefore developed in order to determine these expectations for the following aspects: availability, safety, environment, durability, economy.

A core matrix was developed during the first HeRoad workshop. Then a specific matrix for each asset was built by each WP leader and submitted for review to the WP partners.

The different expectations are classified following these terms. The PIARC terminology, if available, has been used as the reference for their definitions.

Availability: this term is also related to accessibility as defined in the PIARC terminology: "A measure, generally in terms of time period, of the capability of the road network of allowing penetration into an activity area or a measure, generally in terms of time period, of obtaining a service or a connection with an activity". The PIARC terminology doesn't provide a definition for availability, we propose the following: "the existence of an item with the assumption that its condition is adequate to its function (as designed or as expected in the present situation)"

Safety: no definition found in the PIARC terminology. This could be defined as "Relative freedom from danger, risk, or threat of harm, injury, or loss to personnel and/or property, whether caused deliberately or by accident."[1]

Environment: this large concept is maybe better defined with the concept of environmental impact, as defined in the ISO14001 norm. "An environmental impact is a change to the environment. Such change can be positive or negative. Environmental impacts are caused by environmental aspects"

Durability: the PIARC terminology doesn't include this term. We propose the following: "ability to resist wear, decay", "Assurance or probability that an equipment, machine, or material will have a relatively long continuous useful life, without requiring an inordinate degree of maintenance".

Economy: All the aspects related to the financial area.

[1] Taken from www.businessdictionary.com

4.1 Expectations, per issue

4.1.1 Stakeholder expectations – availability

Stakeholder	**User (commercial and private)**	**Owner/Operator**	**Neighbours**
Availability *What the stakeholder expects*	Users expect that the necessary equipment for an efficient and safe trip are present	The owner shall maintain a minimum level of service at minimal cost (maintenance/repairs)	Presence of equipment shouldn't interfere with the quality of living (global environment) or should be available, present in order to improve it.
Availability *What is ideal measurement practice?*	• The amount of delays (hours) caused by maintenance • The ability to predict the accuracy to which maintenance interventions occur in time and duration • How well the information regarding road works, and associated delays etc., reaches the users	• If operators' income is affected by network availability or amount of delay due to equipment maintenance, the *amount of delays (hours) caused by this maintenance*. • If there is a risk of being sued if the emergency services can't get to where they need or if there is an economic impact : quantification of possible loss	• Hindrance due to equipment is difficult to quantify and is related to an assessment of the quality of life • Presence and efficiency of equipment designed to reduce the hindrance is related to its design and condition (e.g. : noise barriers)

4.1.2 Stakeholder expectations – service quality

Service Quality *What the stakeholder expects*	The users expect the equipment to meet their own criteria. There may be a discrepancy between the owner's objective and user's perception.	The owner expects any in-place equipment to fulfil, in an optimal way, the objectives for which the equipment was selected. In other words, was the right equipment implemented at the right place? Support to the users for safety and/or traffic fluidity.	N/A
Service Quality *What is the ideal measurement practice*?	• Visible signs and markings : presence • Accuracy and readability of VMS messages • Adequate signalisation, non-equivocal signs and messages is difficult to measure, can be assessed with an on-site inspection	• These requirements are dependent on how the owner/operator operates their contracts. If we assume that they have user or service quality requirements built in, then these might contain all of those listed in the users' requirements : initial performance is often described in the specifications • Thresholds specified may differ from user requirements in certain circumstances	• Level of noise (hindrance limiting equipment) • Level of lighting (hindrance due to the equipment)

4.1.3 Stakeholder expectations - safety

Stakeholder	User (commercial and private)	Owner/Operator	Neighbours
Safety *What the stakeholders expect*	The users expect the equipment to have a positive impact on their trip's safety. The equipment should not be hazardous obstacles.	Owner wants to provide equipment that will prevent accidents from occurring, or minimise the damage and injury if accidents do occur. Owner wants to optimise the use of forgiving equipment by selecting the best location following the risks. Balance between benefits and investment costs is crucial.	Safety from the neighbour's point of view may be considered as indirect and related to a specific interest. A shop owner wants safe access for his customers, an individual wants a safe street for his relatives, a school wants a safe area near its entrance for the pupils. Thus, the neighbours expect provision of equipment that prevents vehicles from leaving the carriageway, where there is high risk that this may happen.
Safety *What is the ideal measure-ment practice?*	• Length of network equipped with lighting and restraint systems • Length of network equipped with VMS giving instructions about the road and/or traffic condition • Length of network equipped with "motor biker friendly" markings	• Measurements/monitoring that prevents from jeopardising safety on roads (e.g. Remote control of lighting) • Measurements/monitoring that prevents from causing traffic safety problems, such as icing	As for the entire road network, nothing specific for equipment.

4.1.4 Stakeholder expectations - environment

Stakeholder	User (commercial and private)	Owner/Operator	Neighbours
Environmental Impact *What the stakeholders expect*	Users are increasingly "environment" minded. The road equipment can have a positive impact on the travel time (VMS messages…). This will have a positive impact on the emissions (less fuel used)	Less emissions = less costs for curative measures	Less emissions and nuisances can be achieved with appropriate equipment.
Environmental Impact *What is the ideal measure-ment practice?*	• Time for the home-work daily trip… •	• Monitoring of traffic speed on strategic sections • Monitoring of noise, weather data and pollutants level	• Pass by noise, particulates, CO_2 levels, other harmful gases.

4.1.5 Stakeholder expectations - durability

Stakeholder	User (commercial and private)	Owner/Operator	Neighbours
Durability *What the stakeholder expects*	Users expect the equipment to be continuously present and to be constant in its performance	Lifetime expectance should be predictable.	Durability of the equipment will limit the nuisance
Durability *What is the ideal measure-ment practice?*	• Days of service unavailability	• Measurements/monitoring that will prevent from premature deterioration, and will deliver parameters from which durability could be calculated. • Visual inspections that predict deterioration problems	N/A

4.1.6 Stakeholder expectations - economy

Stakeholder	User (commercial and private)	Owner/Operator	Neighbours
Economy (cost) - what the stakeholder expects	VMS can limit the time spent in traffic jams Total costs for the society (accidents…) may be reduced due to safer and efficient restraint barriers (e.g. for motor bikers), safer poles (frangible), presence of road markings.	The owners expect to incur a level of cost for maintenance and asset management (including survey costs). They expect the whole life costs to be minimal, or at least sensible. They also expect to minimise costs incurred by accidents, whether for liability claims, or clear up etc.	Neighbourhood can be impacted if the equipment needs in energy and maintenance increase, resulting in potential extra taxes to cope for the electricity bills (lightings) and maintenance. The equipment can also have a negative impact on estate value (landscape…)
Economy (cost) - Ideal measurement practice	• maintenance work shall not incur costs arising from detours and delays • Percentage of the road network equipped with efficient and safer equipment	• Measurements/monitoring shall provide information that will optimise expenditures on maintenance of equipment	

4.2 Expectations, per equipment

4.2.1 Road Signs

Users expect that the road signs will contribute to a safe and quick trip, whatever the moment of the day or of the year and whatever the type of user (motor bikers, car drivers, Lorries). Therefore the road signs will have an impact based on the correctness and up-to-date information that they bring. The information carried by the road sign shall be delivered in a consistent way and shall not be altered during the year (season impact: luminosity, weather) or the daytime/night time conditions.

Owners shall meet the expectations from the different users based on the directives coming from the other authorities. Moreover, the economics will impact the strategies for the maintenance and replacement of the road signs.

Inspections of the road signs' condition is then a must but should also be combined with the pertinence and adequacy of the global signalisation on users' itineraries. "The right type of sign at the right place".

4.2.2 Lighting

Lighting can have a significant impact on the safety but also on the user's comfort. Users could then expect that the lighting is present on all the roads and is lit during the night but also in adverse weather (fog, heavy rain…). Of course this is not achievable given the nature of the road network and the related economics. A minimal expectation is then the availability of lighting if the absence of it leads to a risk increase.

Owners need to evaluate the adequacy of lighting in terms of presence and in terms of use. Case studies were discussed in chapter 4 where the lighting usage is evaluated. New technologies also bring improvement on the energy efficiency (LED technology) and on the durability.

Inspections and measurements are important and should be coupled with the safety needs related to the position of the equipment (black spot? critical situation possibly leading to dangerous behaviours).

4.2.3 Markings

The discussion on markings is quite similar to road signs regarding the users' and owners' expectations.

Developments are available regarding traffic speed inspections. Ecodyn is used to measure the retro-reflectivity of road markings (lines) and other companies propose new developments, such as Ramboll RMT (Road Markings Tester) offering the ability to collect data such as retro-reflectivity in the dry/wet, luminance coefficient, friction, thickness, and width/length/gap/design. However, these technologies are not ready for immediate use and are currently being assessed for suitability for use and value for money, in a number of countries.

4.2.4 VMS and other technologies

Users expect that the variable messages are readable and updated promptly when road circumstances change. The messages have to be clear and the options (detour, lane selection, speed limit being compulsory or advised) should be unambiguous. Whether a sign is helpful and unambiguous is a very subjective thing and would be difficult to measure.

Owners are confronted with the high cost of the equipment and the challenge to communicate clearly and on-time the information coming from the network sensors and other sources.

4.2.5 Restraint Systems

Users expect the restraint systems to be efficient and not lead to aggravated injuries.

Restraint systems have to comply with legal requirement and specific standards. The compliance is achieved by the selection of appropriate restraint system and a conform implementation. There is no verification of the restraint capacity during the service life if the restraint system is not damaged.

5 Conclusions and recommendations

Given the specific context of equipment and its limited lifecycle, possibly ranging from 1 year (for markings or signs) to 10 years (for barriers etc.), the equipment asset is rarely integrated in a fully integrated asset management system. Moreover, the equipment is often qualified with a binary condition: working or not working. Therefore, we will present a number of recommendations coming from good practices or case studies mentioned in the interviews but also from reflections of the consortium members.

Recommendations include:

- Further research on service life and evolution models for specific equipment combined with a cost – benefit approach in order to evaluate if an asset management program based on these laws will bring benefits versus the present approach based on network inspections and fixed term maintenance or replacement,
- Promote other sources of information for the management, such as number of complaints, feedbacks from road users or other stakeholders,
- Formalization of the inspection techniques: what are the qualification criteria's requested for contractors or own personnel performing asset evaluation. This evaluation may be executed while performing a maintenance operation (such as a structure assessment when a bulb replacement is planned) and one activity should not jeopardize the other,
- Use of traffic speed investigation technique such as video inventory compilation, assets' geo- localisation and combined with post-processing activities.

6 Sources

[1] DESIGN MANUAL FOR ROADS AND BRIDGES, Volume 8 Section 1, Part 2 TD 24/97, All-Purpose Trunk Roads Inspection and Maintenance of Traffic Signals and Associated Equipment, August 1997

[2] DESIGN MANUAL FOR ROADS AND BRIDGES, Volume 8 Section 2, Part 2 TD 24/97, All-Purpose Trunk Roads Inspection and Maintenance of Traffic Signals and Associated Equipment, August 1997

[3] DESIGN MANUAL FOR ROADS AND BRIDGES, Volume 8 Section 3, Part 2 TD 24/97, All-Purpose Trunk Roads Inspection and Maintenance of Traffic Signals and Associated Equipment, August 1997

[4] RMMS model, VTI Notat 21A-2009

[5] ASFINAG reference documents for data collection: Basic requirements in RVS 08.23.xx and RVS 05.03.xx and RVS 05.04.xx series, Road signs: RVS 08.23.0, Delineator posts: RVS 08.23.02, RVS 08.23.03, Retroreflectors for delineator posts: RVS 08.23.04, Road restraint systems: RVS 08.23.05, RVS 08.23.06, Traffic lights: RVS 08.23.07, RVS 05.04.33, Road markings: 05.03.12

[6] Code de bonne pratique pour l'exécution des marquages routiers, Recommandations, R79/07, CRR

[7] http://www.mobielvlaanderen.be/verkeersbordendatabank/index.php

[8] ASCAM, Deliverable No.4 - Inventory Road Equipment Management practices, March 2012, Era-Net Road

[9] Mouvement Communal, 02/2009, pp63-81, Dossier éclairage public.

[10] https://batman.vv.se/batman/logon/logon.aspx?url=https://batman.vv.se/batman/

[11] http://www22.vv.se/nvdb2_templates/default____36975.aspx
[12] Asset Management Methods in The Netherlands, Case study for PIARC Technical Committee D1 - WG 1, Management of Road Infrastructure Assets, July 21st 2011
[13] Richard, G. and Kerwick-Chrisp, D. (2010), Highways Agency Carbon (Ac)counting, 6th Highway Asset Management Conference, London, 26th January 2010.

Appendix A. HEROAD Questionnaire – Questions related to Structural Assessment

A.1 Guidance for Pavement Interviewers

The European road network consists of a wide range of assets, such as pavements, structures, tunnels, signs and other road equipment, which has led to a large number of approaches being proposed to model the behaviour of the assets, and the use of many different parameters. Work within the HeRoad project is focussing on developing a clear understanding of the performance and behaviour of individual assets and how this understanding can then be used to benefit asset management across Europe. The first stage of this work involved identifying and assessing the parameters, models and criteria used for managing the condition and performance of assets in countries contributing to the Asset Management call. Table below lists these countries and responsible HeRoad partner to obtain information from individual countries.

Country	Partner responsible for obtaining information
Austria Germany Switzerland	AIT
Belgium	BRRC
The Netherlands	FEHRL
France Ireland UK	TRL
Denmark Finland Norway Sweden	VTI
Lithuania Slovenia	ZAG

A.2 Questions

A list of questions has been compiled, to provide guidance for the interviews. Additional information that may also be relevant for the project was also appreciated.

The questions have been divided into 3 sets: “Pavement Performance”, “Performance of Structures”, and “Performance of Road Equipment”. This set of questions covers the assessment of pavements.

Prior to interviewing, a literature search has been carried out, along with a review of previous relevant research and this has been used to answer as many of the questions as possible..

A.3 Performance of Equipment

3.5	Road Equipment	
	Question	**More information for Question**
3.5.1	What kind of equipment can be found on each road network type	Road markings, Road studs (cat's eyes), Delineator posts, Barriers, Wires, Fixed signs, Variable message signs (VMS), infrastructure related to communication service, Road lighting. Should other equipment be mentioned?
3.5.2	Length and types of roads equipped with lighting, VMS and communication infrastructure,	What length of the motorway network has lighting, VMS etc.

6.1	Current Inventory	
	Question	**More information for Question**
6.1.1	How is data collection organised and realised on each equipment type?	What approach is used to measure the condition of road equipment? If the approach is varying following the road category, it should be noted. Are there automated equipment giving a direct feedback on the service level conformity
6.1.2	Which parameters are used for assessment on each equipment?	
6.1.3	How often are they measured or evaluated?	It's interesting to know if an evolution model is used or developed to model the asset's condition and determine when an evaluation should be carried on or whether the model predicts an acceptable condition.
6.1.4	Which parameters are classified as primary and	

	why?	
6.1.5	What about the other parameters, why are they considered as secondary or not as important?	
6.1.6	What other parameters could be measured? Why aren't they measured now?	In order to meet uncovered expectations or future challenges (costs reductions, less human resources due to budget cuts, …)
6.1.7	Road Signs, traffic lights	How are they managed (inventory, inspection, decision, ...).
6.1.8	What is the expected service life time of each of the equipment	The expected service life time or road markings may be much shorter than the expected service life time of fixed signs or road lighting. This may have an influence on the maintenance policies for each of the equipment (immediate replacement after a short life time versus regular maintenance over decades).
6.1.9	What are the typical maintenance operations on each of the equipment that can be expected to be executed sometime during the life time of the equipment	Are there intermediate maintenance operations that can be programmed in order to preserve the equipment for rapid degradation or is the only available maintenance option simply the replacement of the equipment?
6.1.10	Are there other criteria than the current condition of the equipment that can play a role in the decision making on management?	E.g. is safety for the road users (expressed in number of accidents for instance) a criterion that can influence the replacement of equipment on an earlier moment in its service life than at the "end of life" from a purely technical condition point of view? What's the trend? Sometimes the lighting is seen as "nice to have" but not as necessary for safety as initially thought. Some NRA's have decided to limit or avoid replacing the lighting for sustainability reasons. Is it the case? If yes, on which grounds are the decisions taken (safety statistical figures, inspections, other means…)? Are the VMS seen as a good solution and what's the decision process?

6.2	**Data Management**	
	Question	**More information for Question**
6.2.1	Describe the way the data collected are organised and stored	It's also interesting to know if the data collected in the past are "usable" in order to develop evolution laws. If these laws exist, how were they obtained?

6.2.2	Who has access to these data?	
6.2.3	Which improvements could be carried out for the storage and accessibility?	In order to meet the future needs and strategies
6.2.4	How are these data used on budget level and on the project level?	Evolution laws are perhaps available, these may be used for budget evaluations, is it the case? If yes, how? If no, what are the issues that prevent this?
6.2.5	How are these data verified and validated?	Validation : includes also the predictions of potentially used models
6.2.6	Is the methodology for collecting and managing data described in a quality management system or a comparable management system? (certification, accreditation, …)	
6.2.7	Are there improvements foreseen in order to meet new challenges or to comply with new strategic plans?	

6.3	**Varia**	
	Topic	**More information**
6.3.1	Case Studies	Provide if possible a case study based on one equipment
6.3.2	Environmental impacts : how are they measured / assessed for each equipment	
6.3.3	What future challenges	
6.3.4	“new technologies	it would be nice to know whether there are any plans for traffic speed surveys of road equipment, for example measuring the luminance of street lamps, or whether the lights are instrumented to report when they are failing etc.

Findings:

The following table shows the level of input received from the different interviews. The green colour indicates that the data's received include answers to almost all the questions from the questionnaire. Orange indicates that the information collected is insufficient to draw conclusions. Yellow is an intermediate situation indicating that the data's are available with a certain degree of incompleteness or uncertainty.

Table 7 : Data collected with the interviews

Country	Inventory	Data Management	Case studies, Challenges, new technologies
United Kingdom			
Sweden			
Slovenia			
Lithuania			
France			
Eire			
Austria			
Belgium			

Appendix B. Experts consulted to answer pavements questions and literature reviewed

Country	Partner responsible	Experts consulted/Literature reviewed
Austria	AIT	Christian Krall, ASFINAG
Germany	AIT	Karen Scharnigg, BASt
Belgium	BRRC	BRRC experts Margo Briessinck, Senior Advisor, Vlaamse Overheid, Agentschap Wegen en Verkeer, Mobiliteit en Openbare Werken - Afdeling Wegenbouwkunde, Erik De Bisschop, Verkeerskundig Ingenieur, Vlaamse overheid, Agentschap Wegen en Verkeer, Expertise Verkeer en Telematica Pierre Gilles – Inspecteur - SPW
France	TRL	Jean Iaquinta, TRL, carried out literature review and interviews JI to complete
Ireland	TRL	Brian Fern, TRL, carried out literature review and interviews Albert Daly, NRA,… BF to complete
UK	TRL	Emma Benbow carried out literature review (Internal experts consulted (TRL): Geoff Crabb External experts: Dave Johnson Transport For London, Ray Privett Portsmouth County Council
Sweden	VTI	Anita Ihs, Leif Sjögren, Jan Wenäll and Sven Olof Lundquist
Lithuania	ZAG	Arunas Rutka, Deputy Head of Long-term Planning Division, Lithuanian Road Administration
Slovenia	ZAG	Aleš Žnidarič, Darko Kokot External expert: Anton Švigelj, Slovenian Roads Agency