Heroad, Holistic Evaluation of Road Assessment

Pavement condition data and quality procedures

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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. This principle and its overall goals are common for all road managers around Europe. One prerequisite to be able to asses and optimise the costs is that relevant and reliable data is collected from all assets and that effects can be predicted for selected strategies. Since the asset, pavements have a long history of being monitored we have studied the quality approval process for those.

This report summarises different practices that European countries are using to perform quality approval of monitored pavement data and services.

The countries considered for the study were: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Lithuania, Netherlands, Norway, Slovenia, Switzerland, Sweden, and the UK. The study was carried out by analysing results obtained from a consultation with road owners, or road experts in all countries listed. In this study experiences from the standardisation work as well as international experience through PIARC has been consulted.

To conclude Heroad recommend treating data as a very valuable asset that need to have enough resources since it makes up the essential part of a functioning asset management system.

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1 Introduction

Maintenance of roads, including the pavement constitutes a considerable part of the road administration's budget. It is important that available resources are utilized as effective as possible, ensuring that treatments are done on the right sections and at the right time. Consequently, it is important for the road administrations to be able to monitor the condition and degradation of the road network. Road surface condition surveys are therefore conducted regularly.

The data from the surveys supports and constitutes a considerable part of the pavement management systems (PMS) that is necessary for the planning. Data is also used to manage performance of maintenance contracts. The PMS outcome is in turn an important part of the overall use in road assessment procedures.

It is very difficult to measure and describe the complexity of the road surface and its characteristics. To be able to handle this in any kind of comprehensible way at all, the condition of the road surface must be rendered as a number of indicators that satisfy the need for information. Further, it must be technically possible and practically feasible to measure, combine information and calculate adequate indicators. Changing the indicators must occur in a structured and controlled manner so that they will be sustainable and comparable over time. This means being able to determine them at a certain degree of estimated accuracy and define them by a known calculation algorithm.

The road surface has three characteristics that are basic to most of the parameters obtained from survey vehicles: longitudinal and transversal unevenness and friction or estimation of skidding. It must be observed that this is an over-simplification of reality, since a road is actually uneven in all directions as well as friction varying with position. The main purposes of the data are to support pavement management systems, performance control e.g. at new constructions, active monitoring during road construction and maintenance research purposes, e.g. studies of maintenance effects from different actions or budget levels. Figure 1 shows some measureable parameters.

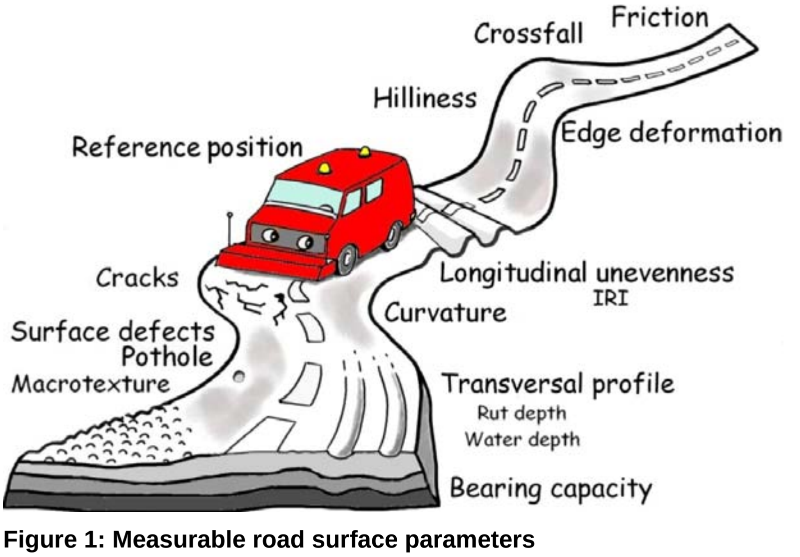

Figure 1: Measurable road surface parameters

2 Quality management and standards

The use of data determines the requirements on necessary quality. The two levels of data usage are the **project level** and the **network level**. Work related to daily operations and support during the construction phase is considered as project level. Data used as support for asset management, which gives information on the current condition status of the entire road network, as well as data used to develop prediction models to be used in the planning of strategies, are regarded as network level data.

For monitoring network condition it is necessary to have a data quality that ensures stability over time and also adequate measures (indicators) with specified documented construction and known accuracy. The network data quality has to be stable over time since it will be used to predict future condition (from models built up by the data). As can be seen in chapter 4 the approval procedure regimes can be very different in Europe´s countries. At least Sweden, Finland, UK and Germany have well developed methods. The method varies between monitoring performed in-house or procured. There are some essential differences in terms of responsibility on how the quality management should be designed depending on if the motoring is done in-house, procured or aimed for project or road network level. As a manufacture of equipment the focus is on sensor control and application control (see below). Implying that the adequate sensors are chosen and valid implantation of indicator calculation is done. As responsible for a road network the focus is on total function control (see below). In this case the goal is to have the required data in time and in a given quality. In this sense the approval procedures and quality checks can be divided into three parts,

1. **Sensor control**

   The accuracy of a sensor e.g. laser sensor

2. **Application control**

   The ability to measure e.g. rut depth

3. **Total function control**

   The ability to deliver the relevant and reliable data in time.

In general **the sensor control** is the main responsibility of the manufacturer (designer and producer of equipment) and the operator (the company offering the measurement services) Regarding the part defined as **application control** it is the operator's main responsibility and finally the user of the data e.g. the road owners and planners should ensure that a total function control is achieved.

The sensor control includes basic calibration according to specification for the sensor type and schemes defined by the manufacturer of the sensor. **The Application control** relies on the sensor control being approved. Total **function control** includes a combination of application control and additional tests. Additional tests include performance of r*eproducibility, i.e.* the accuracy of different equipment of the same type and different operator teams. These tests also include the ability to measure large amounts of road surface characteristics from an extensive road network in order to show the ability to process and delivery large amount of data in the right format, correctly positioned and in time.

There are some essential parts in the quality management that are defined below

Validity	Relevant indicator
Repeatability	Repeatable measurements using individual equipment
Reproducibility	Comparable result measured with same type of equipment but different individuals

This is illustrated in Figure 2. The red circles, yellow stars and blue boxes represent three individuals of the same equipment type. The radius of a circle around the spread of e.g. red circles represents the repeatability. A circle around the spread of all icons (blue, red and yellow) represents the reproducibility, β. Finally the performance of validity is represented by the distance from the centre of all icons to the reference dot, β. The reason to use a reference instead of the true value is that it in practise is almost impossible or at least not cost effective to obtain a true value.

The definition of, and agreement on, a reference is actually essential for successful harmonisation and quality procedure. The reference should, preferably, be more accurate than the tested equipment's and reliable in the sense that it will exist in function for a long time and not be built on a black box principle.

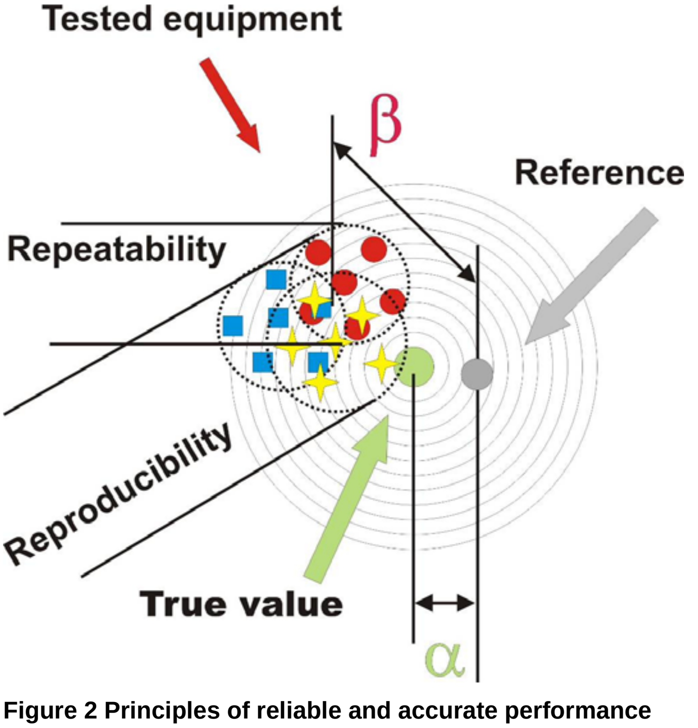

Figure 2 Principles of reliable and accurate performance

3 Requirement on data and methods

There are different requirements on the data depending on the use of it. If we consider the two levels mentioned earlier, project and road network level, we can assume they have different requirements. Contrary to common understanding we believe that it is as important to have high quality and accuracy on the network level data as it is on the project level data. The network data is used to build prediction models on various effects of climate and traffic loads using data for long periods of time. In Sweden the average time for resurfacing is 8 years, and to observe a trend at least three points (3 years of data) are needed. The data has to be treated as a valuable asset and appointed an organised management (Werd, 2003). When there is a sudden change in the condition trend curve one must be sure whether this is due to a new treatment, an actual change in condition or an error in the data, see Figure 3.

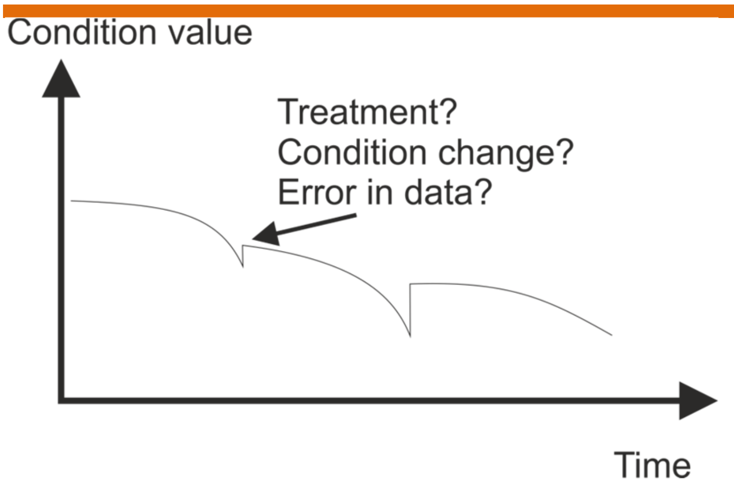

Figure 3 Trend curve with sudden changes

The data has to be adequate and reliable, meaning that it should reflect the aimed purpose (valid) with a known accuracy. It should also be safe to collect for the operator with minimum disturbances (safety as well as flow) to other road users. In addition, it should be safe to collect for the operator. The main stakeholder for network level data is the road manager and owner while the main stakeholder for project level data is the road operator. If data is to be useable, it should be possible to use for regulating performance included in contracts with legal matters also involved.

To conclude data has to be:

- Objective
- Reliable
- Safe to measure /collect
- Sustainable
- Valid

Another requirement, in a European perspective is the possibility to compare between countries and regions (benchmarking) through the use of standards and harmonisation procedures. A common European perspective is getting more and more important.

4 European and national standards

In the following it is important to bear in mind that we are discussing road surface characteristics and parameters that can be collected in safe speed for the sake of asset management.

Standard exist that establish references and common benchmark possibilities as well as to make sure that performance of directives can be followed. There are national standards, European standards (CEN) and International Standards (ISO). In many cases it would be preferable to reference to European standards. The problem with creating common European standards is that many countries have a long history of monitoring and have invested in monitoring devices as well as developing effect and prediction models from years of experience and based on a national standard. Even a simple indicator such as rut depth is difficult to have a European consensus of. Another indicator where it is difficult to agree on a common measurement method is skidding (measurement of friction). Previously 15 methods have been considered as CEN standard. The unevenness indicator IRI (International

Roughness Index) is considered a common standard but UK, France and Germany (constituting a considerable length of the European road network) don't use IRI!
Substantial efforts have been made to investigate the problem over the years such as the PIARC experiment, the EVEN/FILTER (FEHRL Investigation on Longitudinal and Transverse Evenness of Roads) project which made comparisons between profilometers and evenness indicators and the Tyrosafe (Tyre and Road Surface Optimisation for Skid resistance and Further Effects) coordinated support action that investigated the possibilities to develop harmonised approaches for the key safety and environmental properties related to tyre and road surface interaction. HERMES (**H**armonisation of **E**uropean **R**outine and Research **M**easuring **E**quipment for **S**kid Resistance of Roads) was another initiative that was organised by FEHRL (Forum of European Highway Research Laboratories) trying to establish a European International Friction Index (EFI). Regarding the environmental indicators relating to tyre/pavement interaction such as noise and rolling resistance an initiative called MIRIAM (Models for rolling resistance In Road Infrastructure Asset Management Systems) is on-going. The objectives are to harmonise indicators and methods in order to provide a sustainable and environmentally friendly road infrastructure.

5 Quality Assurance Regimes

Quality Assurance (QA) regimes and calibration processes check that devices providing data for road management are working and providing accurate measurement data. More advanced regimes include "certification" or "accreditation". These are organisation/management systems which, amongst other things, control the types of equipment used and

Figure 4: Quality Assurance Regimes (illustration)

ensures that only independently approved contractors and equipment will be used.

Certification and Accreditation covers the whole process, from measuring a pavement property, all the way to delivering data to the customer. All countries that responded to the consultation carried out in HeRoad calibrate their measurement systems against manufacturers' recommendations, using standards such as ISO 9001. However, only five countries claimed to run "accreditation processes". This is summarised in Table 1.

The ISO 9001standard can be described as an organization method. This method can be certified by a certification body. This certification body will be "accredited" for this certification procedure and the requirements to proceed to this certification are described in the ISO17021 standard. An accreditation is granted by an official organization (such as BELAC in Belgium or UKAS in UK). The ISO17025 standard is a specific accreditation for the laboratories. The accreditation is a testimonial of the technical competency of laboratories for tests and calibrations. The main difference between ISO9001 and ISO17025 is the integration of technical requirements in the ISO17025

Table 1: Data quality regimes implemented

Country	**Data quality regime**
Austria	Use of accredited test laboratories and institutes, standardized measurement procedures, e.g. for skid resistance monthly recalibration of RoadSTAR device
Belgium	Measurement protocols exist and they include calibration by independent and competent organisation and round Robin test are organised. The AWV is ISO9001 certified and an ISO17025 accreditation is planned.
Finland	Devices subjected to an accreditation test.
Germany	Regular comparison tests are carried out by BASt, which is an independent organisation for this.
Ireland	SCRIM and FWD devices take part in UK accreditation trials. Other devices are checked by the contractor
Lithuania	Measurement devices are regularly calibrated, some have QA regime in place
Netherlands	Quality control measurements: ISO9001
Slovenia	Measurement devices are regularly calibrated, some have QA regime in place
Sweden	Devices subjected to an accreditation test, which happens every 4 years. Within this period, the contractor is not allowed to modify the system. They are also required to carry out repeat surveys on 5% of the data collected.
UK	All survey devices must be accredited before starting any survey work. They are then subjected to regular QA regimes, to ensure consistency in the data delivered. This applies for all network types.

It was found that the UK and Sweden employ an in depth approach to accreditation and QA processes for their network level condition surveys. We have made these the subject of case studies in the following chapter.

6 Case studies on quality approval procedures

6.1 UK Accreditation

Skid resistance is measured routinely on the Primary road network in the UK at traffic speed using SCRIM devices. Pavement deflection is measured on a project level by either FWD or Deflectograph. Routine traffic-speed surveys to measure other aspects of pavement condition are known as TRACS (TRAffic-speed Condition Survey) on the English Primary Road network and SCANNER (Surface Condition Assessment of the National Network of Roads) surveys on the other road networks in England. Similar surveys are commissioned within the other countries in the UK e.g. SCANNER surveys are used on all road networks in Wales and Scotland.

Any of these measurement devices wanting to survey the UK road network must first pass an accreditation test. The purpose of the accreditation testing is to ensure that the survey equipment is capable of measuring and reporting the defined parameters consistently under carefully controlled conditions. The accreditation testing is carried out at a number of different levels:

- Site tests compare the individual parameter(s) measured by the survey equipment against those measured by a reference method.
- Network tests assess the operational capabilities of the survey equipment (and survey crews) on one or more routes located on the public road network.

Sites are specifically chosen to provide a range of levels of pavement condition over which to assess the machines. For example, an accreditation test for a SCRIM device will require it to survey sites consisting of different pavement surfacings and differing skid resistance, whilst an FWD will be expected to survey lengths with differing construction and pavement stiffness.

Any accredited survey device should be capable of reporting data that is both reproducible and also repeatable. Whilst repeatability can be tested by assessing data collected during repeat surveys, reference data is required to test reproducibility. For many pavement condition measurements reference data can be obtained by taking measurements with specialist reference devices e.g. 2m straight edge for rutting, or a slow speed reference profiler for ride quality. However, it is not possible to define an absolute value for skid resistance, nor for pavement deflection. Rather, at any particular time, the “correct” result can only be estimated. Therefore, for SCRIM, FWD and Deflectograph devices the accreditation is undertaken by testing a set of machines for consistency, whereas for TRACS and SCANNER the survey devices are tested individually against a set of reference data.

The tests are supervised by an independent auditor who issues an accreditation certificate to all successful devices. The devices are then required to undergo and pass re-accreditation testing every 12 months (3 months for TRACS).

6.1.1 UK Quality Assurance (QA)

The purpose of QA is to ensure that the survey equipment remains able to produce consistent and reliable results throughout the year, between the re-accreditation testing. In order to provide comprehensive quality assurance for accredited surveys of the UK road network, QA is provided by a combination of 'first party' QA, operated by the contractor and 'third party' Audit, provided by an independent auditor.

In the first party QA the contractor applies an on-going Quality Assurance regime covering all aspects of the accredited surveys, including:

- vehicle operation and maintenance
- driver and operative training and instruction
- survey operation and record keeping
- data recording, processing, and analysis
- delivery of survey results.

The auditor monitors these internal QA processes to ensure they are of suitable quality and are correctly implemented.

The third party QA is a process where additional surveys are carried out to check the consistency of the data. This includes contractor's repeat surveys (CRS) and auditor's repeat surveys (ARS).

The contractor's repeat surveys (CRS) are used demonstrate the repeatability of the survey equipment. Originally, CRS were carried out by requiring the contractor to deliver repeat surveys of ~5% of the network that they had surveyed - similar to the process currently used in Sweden (Table 1). However, it was found that the repeat survey would often have been carried out within a matter of days of the original survey. This prevented slow deterioration in the equipment being identified. Also, there were often large gaps in time between each CRS and thus, when issues were identified with the data, this would lead to doubt being cast on the quality of a large amount of delivered data. Therefore, the CRS process was enhanced so that the survey contractor is now required to carry out checks based on four levels:

- Contractor's Calibration Site;
- Primary Reference Sites;
- Secondary Reference Sites;
- Daily Test Sites.

The survey contractors use the Contractor's Calibration Site to regularly calibrate the survey equipment and to monitor long term data trends. One or more Primary Reference Sites are established, which test the satisfactory operation of the equipment and these must be surveyed at least once a month. Secondary Reference Sites are similar but must be surveyed at least once a week and Daily Test Sites are used to check the equipment on every day that it is being used to survey. Specific requirements are laid down for each type of site and the contractor is required to obtain approval from the auditor for sites that they choose. The contractor is required to keep the data from any surveys of these QA sites and the auditor may request to see it at any time. In addition, results from tests carried out on the data from Secondary and Calibration sites must be sent to the auditor each time such a site is surveyed. Both data and test results from Primary sites must be sent to the auditor. The frequent nature of these repeat surveys and the fact that the same sites are repeatedly surveyed enable issues with the survey equipment, or data delivered, to be identified promptly. Gradual degradation in data quality can also be identified using the data from the Calibration Site.

In the auditor's repeat surveys (ARS) the auditor carries out repeat surveys by selecting a site and repeating the survey carried out by the contractor, but using an independent survey vehicle. The data from this independent survey will then be compared to that delivered by the contractor and the auditor will determine if the assessment has been successful and if any further action is required.

In 2011 a further QA check was introduced for UK SCANNER surveys where the auditor is provided with all of the survey data collected by the contractors, at regular intervals during the year (this amounts to over 100,000km of data each year). The auditor maintains a national database of SCANNER data against which the current survey data is loaded. The auditor can then make statistical comparisons against previous year's data to identify deterioration in the measurements.

6.1.2 Survey Specification

One of the benefits of the UK system appears to be the provision of a well defined technical specification for each condition survey type. For example, the SCANNER specification is published and can be found at http://www.pcis.org.uk/index.php?p=6/8/0/list,0,58, whilst the specifications for FWD and Deflectographs are defined in the Highways Agency's Design Manual for Roads and Bridges (DMRB) and can be found at http://www.dft.gov.uk/ha/standards/dmrb/vol7/section3/hd2908.pdf. The specification for SCRIM devices is both in the DMRB (http://www.dft.gov.uk/ha/standards/dmrb/vol7/section3/hd2804.pdf) and has also been published as a British Standard, BS7941-1. The review has found that it is much more difficult to find out the requirements for other countries.

The published specifications are both technical and also result specifications for raw data. The fact that any survey equipment manufacturer in the world can view these specifications and find out what technical requirements are needed to be able to survey road networks in the UK, opens up the market to anyone capable of building a device to these specifications. This increases the competition within the survey equipment market. For example, there are currently four SCANNER suppliers in the UK, running 12 vehicles between them. This competition has the benefit that it significantly reduces the costs to road owners for commissioning the surveys. The availability of the specifications also allows road owners in other countries to adopt similar requirements for their condition surveys, for example, a device is currently being accredited against the SCANNER specification in the UK, for surveys in China, and the profile survey in New Zealand specifies the SCANNER requirement. It also allows individuals to determine whether devices, accredited for use in other countries, could deliver raw data that fit the requirements to be used to calculate the parameters used in their country. Having access to such other devices could potentially reduce the risk of non-availability of data and could also help clear any survey backlog present in their system.

6.2 Swedish Accreditation

The Swedish Transport Administration (STA) has, since 1987 used data from road surface surveys collected by survey vehicles as the basis for maintenance and management on paved roads. Today, this constitutes a substantial amount of the data input supplied to the PMS (Pavement Management System) used by the STA. Apart from being sufficiently accurate, the data is expected to be comparable over time and between different parts of the country. Road surface surveys performed by survey vehicles are also being used to an increasingly greater extent for project control of contracted works (project level surveys). Accuracy and comparability are important with respect to these surveys as well. Simpler types of survey equipment are also used for project control.

If there are several types of equipment available on the market, the question naturally arises as to whether they are equivalent. Do these relatively complex and technically sophisticated survey systems deliver comparable data? The comparability either between different types of equipment or between different units of a particular type of equipment must be possible to test. It must furthermore be possible to test this during the procurement process as well as throughout a contract period as a ~~spot~~ random sample test or if the equipment is changed.

Similarly, it should also be possible to check the less sophisticated types of survey devices. Corresponding means of quality control are also needed when evaluating developments.
The service to monitor road surface condition on the Swedish state owned and paved road network has been outsourced since 1996. The service is accomplished through a procurement process. Companies are asked to give a quotation provision of the service for a four year period. Two companies can be approved and share the service (responsible for one bigger road network and one smaller).
Before being able to take part and give an offer, in the extensive comparison tests, the company must be approved. For example, besides being a proven sound firm, there are other requirements e.g. they need for having access to at least two comparable measuring vehicles. When approved on the initial requirements the company is qualified to take part in the procurement process.
In short the Swedish Road Administration has the following quality management control steps:

- In conjunction with procurement of the monitoring service
- Continuously during the contracted period
- Repeated tests done during measurement for performance control of special projects
- A specific procedure to manage renewed test during the contract period if the system has changed

Procurement tests
Includes the following

- Qualified to take part? A number of requirements has to be fulfilled before a company and their system can take part in the following tests
- Comparisons tests on special test sections against reference devices
- Object performance control (Project level)
- Extensive road network measurements, [1].

Procurement tests have been done 4 times, 1997, 2000, 2004 and 2009, in Sweden. The same procedures have been used once in Finland.

Controls during the contracted period
When assigned to a contract for a four year period there are data quality controls applied during that period as well. Five percent (5 %) of what has been measured in the production has to be re-measured. An evaluation is then done to check whether the data is comparable within certain limits or not, if data is not comparable the company will not get paid.
Each maintenance object should be measured and approved according to rules in the document [2]. This includes that the object has to be measured at least three times within an accepted variance.
A special scheme has been set up to regulate what changes can be accepted before a renewed test must be done. E.g. if a computer must be changed, software has been updated or, e.g. due to a collision, the system has to be repaired a process starts to decide if a test is necessary and how comprehensive it has to be.

6.2.1 Comparison tests

Comparison tests are carried out at three levels: Project level surveys, Road network surveys and Object performance sections.

Project level surveys

As mentioned earlier the quality management is divided into three levels: sensor control, application control and total function control.

The sensors control is not tested in the Swedish QA method. Instead it is left to the survey company (client) to make sure that an approved calibration test is carried out. Instead the comparison tests are aimed at controlling that the data is valid and repeatable including the survey vehicle, software implementation and operator. A number of test sections are selected on real roads, with a length of around 1000 m. They are selected to test a certain parameter e.g. rut depth. The goal is to have sections with low, medium and high values. Each of them should be as homogenous as possible. To minimize the costs the aim is also to combine sections for different parameters. Each of the test sections are then measured with a reference method. The reference methods are presented, to the clients in advance, in order to have them accepted by all parts. The test sections have a well-defined start and end as well as a painted guide line in the left wheel track. This guide line is to help the operator of the equipment to manoeuvre the equipment along the test section to have a consistent lateral position.

Since it might need road closures at the tests and to avoid differences in road wear the tests are concentrated to be carried out during a week with all clients. All test sections are measured by the reference close in time to the tests. The clients are required to measure each test section a number of times. Five times per three speeds (30, 50 and 70 km/h if possible) i.e. there will be 15 repeated runs per client on a test section.

The results are analysed to give quantitative values for repeatability, speed dependence and the level of equality with reference data, see Figure 2.

Road network surveys

This includes extensive measurements of road networks. Four networks are selected, A, B, C and D. Each of the equipment does a complete measurement of each network once and then re-measures 20 % of route A, B and C. The operators are required to switch equipment for the repeat survey (to do those tests the client need two sets of equipment's and operators). Finally each equipment measures route D five times. Approximately this will lead to more than 1500 km of measurement kilometers per client. All measured parameters are controlled in sections of 400 m.

The mandatory data to collect in Sweden today are:

- Three longitudinal profiles (0.1 meter)
- Transverse profile (1 meter)
- Rut depth, max, left and right (20 meter)
- IRI, left and right (20 meter)
- Macrotexture, MPD in three tracks (1 meter)
- Megatexture, two tracks (1 meter)
- Curvature, Hilliness (20 meter),
- Crossfall (1 meter)

  Digital images (20 meter

Object performance sections

Routinely each resurfaced or new laid surface has to be measured according to requirements in [2] in Sweden. The requirements are set, among other things, to ensure a reliable measurement result. This is done by demanding at least three repeated runs. The results from the runs must be within a certain limited variation. If the variation is too high a new fourth measurement has to be done. In the procurement process the participants have to measure 2 objects.

The requirements, to make a bid, are presented in the STA documents [1] and [2]. In conjunction with each new procurement additional requirements are released as well.

[1] Vägnätsmätning, Metodbeskrivning VVMB 121, 2009 (road network requirements)
[2] Objektmätning, Metodbeskrivning VVMB 122, 2009 (object level requirements)

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7 Conclusions and recommendations

To conclude Heroad recommends treating condition data as a very valuable asset and that sufficient resources are provided to manage the data since it makes up the essential part of a well-functioning asset management system.

To reach a trans-European asset management framework the measurements need to be standardised or at least harmonised. This can only be achieved by first agreeing on common indicators, requirements how they shall be measured and finally how they can be quality approved. A number of initiatives has been conducted, are on-going or proposed, to harmonise indicators. Very little has been done to have common European quality approval procedures. The internal data quality control in an organisation is important as well. Is the data from the right spot, i.e. correctly positioned? When data from different databases is combined, how reliably can it be synchronised? How are outliers treated, are there systematic errors etc. Questions like this have to be solved in a common procedure as well. Heroad therefore recommends putting efforts on developing a common European quality assurance concept including selection of reference methods to be used in the process.

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