OUTCOMES OF PROJECT AND OVERVIEW OF WORK

The European Commission FP7 project entitled "*Tomorrow's Road Infrastructure Monitoring and Management*" (TRIMM), which has run from 1st December 2011 to 31st November 2014, has contributed to road asset management decision-making by improving the means of collection and use of information on road asset condition, maintenance needs and end user service.

TRIMM has developed monitoring tools for the assessment of bridge conditions, which help to detect structural damage at an early stage and set optimal maintenance actions. The techniques developed help to assess the bridge visual condition, corrosion progress, cracking activity, functionality of joints and bearings, as well as the integrity of major load-bearing elements.

The project has enhanced the monitoring of road functionality by making 24/7 real-time 'low-quality' ride quality measurements with normal vehicles. It has also looked at existing methods of monitoring the surface and structural condition of pavements and implementing them in new ways.

Emphasis has also been given to how measurements can be implemented in asset management systems through relating them to an accepted set of condition indices. TRIMM has also addressed the problem of how to assess the benefits from the introduction of advanced monitoring, by prototyping methods for making business cases, thereby enabling more efficient and economical road asset operations. The overall purpose has been to highlight and assess the potential benefit for asset management through recent advances in asset monitoring.

Here we summarise the work carried out to produce these findings under the three technical Work Packages (WPs) during the 36 months of the project.

Asset Management (WP 2)

This WP focuses on the implementation of monitoring data in asset management systems. Emphasis was given to relating monitoring data to an accepted, consistent and complete set of technical, condition and performance (or impact) indicators and transfer functions between them. The main key to the implementation of monitoring lies in the National Road Administrations (NRAs), through up-front consideration of which performance indicators or impact indicators they will actually be able to handle in their existing management system, or which indicators are relevant to the stakeholders they need to cater for.

TRIMM has also addressed the problem of how to assess the benefits from the introduction of advanced monitoring, by prototyping methods for making business cases and societal cost benefit analyses, thereby enabling more efficient and economical road asset operations. TRIMM has pointed out, in this respect, that the effect of the maintenance measures on the related indicators is important information which needs to be quantified. These methods can enable NRAs to weigh up different monitoring alternatives and express the outcome in monetary terms. This WP has recognised that whether or not monitoring systems are favorable may not only be a monetary decision. NRAs have to keep in mind that optimising asset management by using monitoring data may require considerable changes, such as the organisational structure of the NRA or the adaptation of the time scale considered in service contracts. The overall purpose has been to highlight and assess the potential benefit for asset management through recent advances in asset monitoring.

Advanced Bridge Monitoring Techniques (WP 3)

Monitoring techniques for the assessment of bridge conditions were developed to provide an improved basis for maintenance planning. Bridge condition was considered from three aspects:

- Visual condition
- Mechanical condition
- Electrochemical degradation

The visual condition of a bridge is assessed by experienced bridge inspectors. TRIMM has developed a camera-based system which creates a 2D visual model of the bridge. This tool allows the inspection to be performed off-site, comparing visual conditions to past visual models to examine defect development, and the evaluation of the condition by different inspectors. The camera-based system enables the reproducible detection of visible defects like cracks, spalling, colouring as an indicator of corrosion and water leakages. Tests of the system at different bridges concluded that the camera-based system is suitable for concrete bridges, but not for steel structures.

The mechanical condition of bridges can be examined using monitoring techniques that were advanced within TRIMM. They can detect cracking activity, functionality of joints and bearings and integrity of major load-bearing elements. Cracking activity is monitored using the *Acoustic Emission technique.* It is possible to determine the location of active damage zones using sufficient sensor density. At the present state of research, the damage level can be evaluated using Acoustic Emission during controlled load tests, whereas qualitative evaluation of cracking activity is provided during normal bridge operation. Monitoring the *functionality of joints and bearings* was tested using two techniques: the measurement of influence lines and of resonant frequencies. Both methods were able to detect the presence of movement restriction at joints and bearings. Positive detection triggers the recommendation to perform a special inspection that validates the measurement findings. The inspection is also used for the planning of timely repair, to avoid consecutive structural damage produced by restricted bridge movements. TRIMM has monitored the *integrity of main load-bearing elements* using a model-updating technique. The main aspects of the development were the handling of indicator uncertainties and automated continuous operation. The technique detects pre-defined damage scenarios, such as partial loss of pre-stressing forces or the reduction of cable stiffness. The probability that a certain damage scenario should occur is evaluated continuously. In the case of positive damage detection, a recommendation to perform the targeted inspection of the identified damage area is triggered to validate monitoring results and plan repair actions.

The electrochemical degradation of bridges is induced by corrosion processes. TRIMM has tested different measurement techniques and recommended a combination of electrical resistance (ER) and multi depth sensors as the most effective technique for the early detection of corrosion. Criteria for corrosion condition assessment were defined based on measured corrosion rates. The condition can reach five levels ranging from 1 (very good) to 5 (very poor). A very good condition represents the state before the corrosion process initiates, whereas a very poor condition represents the point of appearance of the first cracks in a concrete surface. The acquired monitoring data enable prediction of future development of reinforcement loss.

Advanced Road Monitoring Techniques (WP 4)

The investigation focused on the application of existing technologies to new areas of pavement infrastructure monitoring. Work focused on the following three areas:

- Pavement Surface Monitoring
- Pavement Structure Monitoring
- Road Inventory

Pavement Surface Monitoring

This was investigated in two ways; via dedicated survey vehicles, and via information collected from probe vehicles that need no specialist equipment installed.

Regarding data collected from probe vehicles, the approach draws on the use of measurements provided from a vehicle CANBus and data provided by smartphones. Test drives were carried out with such vehicles and data collected from these devices. Questionnaires were also used to get views from road users on road quality. A simplified KPI for "ride comfort" arises from longitudinal unevenness, determined by estimating a "weighted longitudinal profile" from CANBus data in test vehicles. Results show that poor ride quality can be detected, though some erroneous classifications were found on roads with medium evenness. The investigation into using smartphones to collect condition data provided observations indicating it might be a promising technique.

With regard to dedicated survey vehicles, research concentrated on the detection of cracking, raveling and water ponding. The investigations into cracking and raveling concentrated on transferring the application of existing techniques from strategic networks to a 'local road' environment. With suitable adjustments to account for the different road environments encountered at a local level, cracking and raveling can be detected therein. Work on water ponding on roads developed a method for modelling a whole carriageway and the movement and behaviour of water on that carriageway. It was shown that with sufficient information about the geometry and profile of a road, it is possible to obtain qualitative agreement between the model and manual observation of a road in heavy rain.

Pavement Structure Monitoring

Traffic Speed Deflectometer (TSD) surveys have shown to be suitable for investigating the structural strength of 'local roads', in addition to the current application of TSD surveys strategic road networks. It should be possible to design a lighter version of a TSD, yet still obtain a deflection response that is comparable to existing static methods (i.e. Deflectograph).

The TRIMM project assessed the use of Ground-penetrating radar (GPR), in particular for the measurement of layer thickness without the need to collect reference calibration cores. Several methods have been assessed, with the result being that Wide Angle Reflection and Refraction provides accurate thickness information. The results obtained showed a very high accuracy compared with drill core reference data, representing a substantial improvement compared to the commonly used techniques. However, the configuration does require the use of two high frequency (2GHz) horn antennas and a modern high resolution GPR unit to guarantee the needed data accuracy for the proposed dual receiver calculations. Also, data interpretation still must be done by a skilled GPR operator, and is not ‘automated’, and only applies to the first pavement layer. Additional studies are needed to expand the calculation to the underlying layers.

Road Inventory

Road operators from across the EU were interviewed on the current state of road inventory in their nations. Emerging technologies are perceived as expensive and of doubtful accuracy, however most showed interest in incorporating such technologies for data collection. The work provides a summary of recent round robin tests carried out in the EU for devices designed to measure retro-reflectivity of road signs. For dry road makings, mobile devices show accuracies in the range of static hand devices. For wet road markings, the uncertainties increase.

An equipment evaluation for several devices measuring road inventory was carried out in three different areas in Vienna. Areas included a densely built-up urban, a suburban and a rural area. Information on roadside inventory was collected and compared against a manual reference. For each inventory and area type, an evaluation of spatial accuracy and completeness of detection was carried out. Traffic signs, masts and poles and hydrants are detected to a high percentage in all areas. Gullies and manholes are often located in the parking lane and therefore covered by parked vehicles, making them invisible to the cameras of the survey vehicle. Spatial accuracies of <=1m are possible most of the time, though use of control points allows for improvement. Generally, inventory mapping using automation and traffic speed vehicles was much quicker and safer for all personnel.

For more information, visit http://trimm.fehrl.org or contact the Project Coordinator at robert.karlsson@vti.se. TRIMM is also present as a Linked In group that you can join called “*Tomorrow’s Road Infrastructure Monitoring & Management*”.

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