Implementation of Advanced Monitoring Techniques in Road Asset Management – Results from the TRIMM project

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Abstract

TRIMM (Tomorrow’s Road Infrastructure Monitoring and Management) is an FP7 project focussed on not yet implemented advanced monitoring techniques, which can provide crucial information to complement existing data for road management. TRIMM covers bridge, pavement and road equipment monitoring techniques. Emphasis is given to how monitoring data can be implemented in asset management systems through indicators. Advances in a range of sensing technologies and information processing now offer a potential for improving practices regarding for example cost efficiency, time and spatial coverage, extent of traffic disruptions, indicator reliability, interpretation of physical processes, reflection of needs regarding functionality and safety, versatility and multi-purpose usage. Finally, this paper present result from the first half of the TRIMM project regarding assessment of added value of monitoring and implementation to optimise benefits provided by monitoring.

Keywords: advanced monitoring techniques; bridge; road; pavement; asset management; cost efficiency; road management.

Résumé

TRIMM est un projet FP7 axé sur les techniques de surveillance avancées qui ne sont pas encore mises en œuvre, qui peut fournir des informations cruciales pour compléter les données existantes. TRIMM couvre les techniques de l'équipement de surveillance des ponts, trottoirs et de la route. L’accent est mis sur la façon dont les données de surveillance peuvent être mises en œuvre dans les systèmes de gestion d'actifs au moyen d'indicateurs. Les progrès dans un éventail de technologies de détection et de traitement de l'information offrent maintenant un potentiel pour la mise en œuvre de nouvelles techniques de surveillance dans la gestion des routes pour soutenir l'évaluation de l'efficacité des coûts, le temps et la couverture spatiale, l'étendue des perturbations de la circulation, la fiabilité de l'indicateur, l'interprétation des processus physiques, reflet des besoins en ce qui concerne la fonctionnalité et la sécurité, la polyvalence et multi usages utilisation, etc. Enfin, le présent document se concentre sur les résultats du projet TRIMM concernant l'évaluation de la valeur ajoutée de la surveillance et de mise en œuvre pour optimiser les avantages offerts par la surveillance.

Mots-clés: techniques avancées de surveillance; ponts; routes; chaussées, la gestion d'actifs, l'optimisation des coûts, la gestion de la route.

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1. Introduction

TRIMM (Acronym for Tomorrow’s Road Infrastructure Monitoring and Management) is an EC FP7 project focussed on not yet implemented advanced infrastructure monitoring techniques, which can provide crucial information to complement existing data and information. TRIMM covers bridge, pavement and road equipment monitoring techniques. Emphasis is given to how these measurements can be implemented in asset management systems through indicators. Finally, TRIMM addresses the problem of how to assess the benefits of using advanced monitoring in order to develop optimised schemes for road asset monitoring. The TRIMM consortium comprise five SME:s, FEHRL and nine institutes in all representing eleven countries in Europe.

The overall purpose of TRIMM is to exploit the potential benefit for asset management hidden in recent advances in asset monitoring. To release this potential benefit a range of activities is included in TRIMM from interpretation of measurements to implementation in road asset management systems. In order to successfully contribute to implementation it is believed that both the technical measurement perspective and the utility oriented asset management perspective need to be incorporated in the TRIMM project.

TRIMM is organised in three work packages: one deal with asset management (WP2), one with monitoring of bridges (WP3) and one with monitoring of roads (WP4). The latter work packages deal with research on monitoring techniques in which aspects are improved such as operational safety, monitoring efficiency, reliability, fundamental descriptions of physical processes and functional descriptions, etc. The work package dealing with asset management is organised for the purpose of supporting the use of collected data and bring in the asset manager perspective. This paper present the TRIMM project with focus on results regarding aspects of asset management, mainly assessment of added value of monitoring and implementation to optimise benefits of the information provided by monitoring.

2. Selection of advanced monitoring techniques included in TRIMM

During the proposal stage, when selecting advanced monitoring techniques to be included in TRIMM, criteria were needed to justify and guide in the decisions. These criteria are of general importance and reflect a number of important aspects. These criteria are related to:

- Measurement techniques: availability of technique (blue sky / close to market), reliability (accuracy, repeatability, reproducibility), data coverage regarding real-time coverage and spatial coverage
- Operational aspects: safe to use, CO₂, traffic disruptions, costs of monitoring
- Implementation effectiveness: multi-purpose use, needs and benefits, complexity of data and principles, implementation barriers
- Administrative: long term consistency, system update and management, costs of data handling

When comparing possible monitoring solutions, it has become obvious that collection of information for efficient road and bridge management require careful planning and organisation. Therefore, the project setup has emphasised work directed towards implementation barriers and the assessment of added value of monitoring.

3. Background to asset management practices and development

An inventory of the needs in road asset management related to monitoring has been carried out aiming at giving a clearer picture for development of road asset management practices and in particular the use of advanced monitoring techniques. As reported in Deliverable 2.5 (Nuijten et al., 2013b) there are national differences in how to organize management of infrastructure assets. Also, collection, quality control, storage and extraction of data need to consider many actors in the process, including procurement interfaces between them. There is also a continuous need for development of parameters and indicators that are better aligned to strategic objectives and stakeholder expectations. Today, road user satisfaction and expectations are often surveyed through questionnaires. However, the group of stakeholders includes not only road managers and road users, but also other members of society as well as organisations involved in design, construction and maintenance. Furthermore, the inventory of needs in the report showed that continuous and undisrupted monitoring of bridges and roads is beneficial to ensure safe and reliable function and may reduce the need for maintenance and
reinvestments. It is, however, beneficial if monitoring data can be related to other data sources describing costs, resource needs and benefits. The ability to predict and model technical parameters and indicators and relate them to physical entities in performance modelling is also beneficial for design and planning purposes. For this purpose, effects of maintenance actions on parameters and indicators need to be estimated. Finally, it was stated that since road infrastructure assets represent vast investments and need to be managed wisely with a long term perspective, better knowledge is required on long term deterioration mechanisms such as the structural condition of bridges and pavements. In this context, non-physical assets such as monitoring data, maintenance history data, and experience also represent values that need to be managed and used in order to maximize long term benefits.

There are a number of barriers to overcome before including monitoring data into road asset management systems. The objective of Task 2.1 has been to overcome those barriers by defining a methodology for how to incorporate new data in condition indicators, which is documented in detail in Deliverable 2.1 (van Kanten Roos, 2013). Then Task 2.2 has investigated the relationships between condition indicators and performance and impact, which is reported in Deliverable 2.2 (Nuijten, 2013a). Deliverable 2.1 (van Kanten Roos, 2013) has provided a list of condition indicators for assets (bridges and pavements), models for condition indicators for bridges and pavements based on data measured by monitoring techniques as well as impact models for appropriate maintenance measures based on monitoring data (through condition indicators). Some of the conclusions stated in the report are:

- Asset management practices for pavements and bridges differ between countries while the same basic principles apply to most. This means that implementation of monitoring information needs to be adapted to national practices (such as existing asset management systems), while the core needs for information remain the same.
- In order to implement monitoring information, all condition indicators need to be related to measurable data in quantitative terms. Such relationships have been developed for a number of pavement condition indicators, comprehensively presented in COST 354. For bridge condition indicators, no such relationships were found. Thus:
  - List of condition indicators and transfer functions for pavements are adopted from COST354
  - List of condition indicators for bridges is proposed:
    - in such a way that the requirement to link the value of condition indicators to measurable data from monitoring is met
    - based on guidelines and recommendations in relevant publicly available literature
  - Transfer functions for calculating values of bridge condition indicators are proposed based on guidelines and recommendations in relevant publicly available literature.
  - Transfer functions for calculating values of bridge condition indicators need to be verified, as no sufficient history data on bridge condition expressed in terms of measurable data were readily available. However, the methodology can be adapted to national practices, where such data exists.
  - Limit values for bridge condition indices at all levels need to be adapted to NRA policy.

TRIMM has been in contact with stakeholders that hold an interest in the implementation of the TRIMM output. Among other actions, a session was organised at the FIRM2013 event. As a result, a number of issues have been raised by the stakeholders. It has been pointed out that validation is a key to the use of monitoring data. Data must make sense and be reliable, otherwise road managers will not move from the relatively safe decisions of today. Data mining is also a large problem. There is already a huge amount of data but there is a need for efficient tools and a systematic approach to its use. The human side of the problem of using monitoring data has also been discussed. Communication between people with different backgrounds and roles is a challenge. The output from monitoring and the presentation of information in asset management must be understood by all people involved from technical experts to managers and planners.

4. Added value of monitoring and implementation in asset management practices

Understanding the potential for exploitation of information from monitoring is a complex task. Added value of monitoring can first of all be discussed from the perspective of who is gaining from the information (assuming publicly owned infrastructure):

- Road users and society, that gain utility from a more reliable and efficient function and suffer from failures to reduce negative impacts (payed by taxes)
Public authorities and road managers, including all levels from strategic planning, network management, program planning, procurement and design (distributing and spending tax money)

Private sector, including consultants and contractors that provide services and products to the above (paid by tax money)

From the long list of categories gaining from monitoring information it is evident that the needs and use of information show a great variation. It could be concluded that the requirements on the delivered information should reflect these needs and strive to provide for multiple use. To understand exactly how added value arise one needs to pin point the difference a piece of information can make in changing decisions that influence each one of the categories. In the TRIMM project this is done qualitatively by describing consequences of introducing new information for decision making and quantitatively by introducing new information in an asset management tool and analyze consequences of the output on decisions made.

Added value of advanced monitoring techniques can also be discussed from a technical perspective. The more advanced techniques may offer, as opposed to traditional monitoring techniques, added value regarding for example:

- improved operational aspects such as cost efficiency, safety of operation, extent of traffic disruptions, ability to scale monitoring to large road networks
- improved data content and quality, for example time and spatial coverage, reliability, robustness and long term consistency
- more fundamental interpretation of physical processes, which allows more relevant condition and performance indicators to be developed and used as well as use of proactive measures to prevent serious damages to appear and limit the need for immediate and unplanned maintenance.

Furthermore, the added value to road management may arise in more objective and systematic decision making processes. Today, road management is highly dependent on subjective experience that may slowly diffuse between different categories of professionals. Objective empirical data can be used in decision making but also form a basis for more general conclusions that contribute to explicit knowledge and be more easily spread for a wider use.

A social cost-benefit analysis (SCBA) method has been developed as described in detail in Deliverable 2.3 (Zouch et al., 2013). Performing an SCBA on associated maintenance strategies within a given appraisal period will highlight the value of different monitoring systems and the added value of selecting adequate parameters to monitor as well as enable the comparison of different monitoring techniques/systems. In order to take into account the uncertainty about the degradation of the asset condition, the policy minimizes not only the immediate costs of maintenance but the discounted, expected cost-to-go on the decision horizon. The resulting maintenance optimization problem is formulated as a stochastic dynamic optimization problem using a Markov decision process (MDP) where the decision parameters are the set condition indicators describing the condition of the asset. The method is made operational in a demonstrator tool with an Excel-based user interface to enable use of arbitrary indicators and models, whereas the actual calculations are being performed by Matlab routines.

5. Presentation of advanced bridge monitoring techniques

The general objective is to advance selected bridge monitoring techniques further towards implementation in maintenance and asset management for cost-effective operation. The common goal in all tasks is therefore to overcome the gaps and barriers in European deployment of innovative bridge monitoring methods to increase availability, structural safety and cost-efficiency. High-Tech SME and industry will benefit from widespread use/needs of different advanced monitoring techniques all over Europe. The involvement of SME and industry ensures further evolution and exploitation of proposed techniques. New technologies are introduced for the assessment of the visual condition of bridges. These will draw on imaging and laser measurements to provide a full record of the structure for the bridge engineer. The current capability will be advanced to identify structural changes within a bridge. In September 2013 when this paper was written, most of the results from field and laboratory were collected but very limited analysis results were available. So far, the preliminary analysis shows that the objectives set in each task are possible to achieve.
The following techniques are investigated:

- Automated 3D Visual Bridge Inspection (Task 3.1) - The method which TRIMM and its partners TRL and LNEC proposes is the use of high-resolution images of bridges as an alternative to on-site visual inspections. TRIMM also investigate the combination of images with laser data, to produce 3D models.

- Traffic Loading and Acoustic Monitoring (Task 3.2) - The methods used by TRIMM partners ZAG, IFSTTAR and CESTEL are long-term bridge weigh-in-motion and acoustic emission as well as non-destructive techniques to monitor development of defects in structural elements of bridges.

- Corrosion Monitoring (Task 3.3) - The method used by IGH and ZAG will be a development corrosion monitoring system using several direct measurements. The challenge is to relate measurements to the real condition of structures and implementation of monitoring results into asset management systems.

- Monitoring of Joints and Bearings (Task 3.4) - The chosen method by partners ZAG and AIT is to monitor modal parameters and calculate influence lines of vehicles passing a bridge with-in-motion (BWIM) system and compare them continuously. The challenge is to eliminate other (environmental) effects on change of structural behavior and to define appropriate performance indicators.

- Integrated Bridge Monitoring Method (Task 3.5) - Measurement systems for static and dynamic bridge response are combined in model updating by TRIMM partners AIT, LNEC and RED Bernard Gmbh. Error propagation techniques are used to evaluate result reliability.

6. Presentation of advanced road monitoring techniques

Similar to monitoring of bridges, data collection is done for most tasks while only preliminary analysis results are available by September 2013. The following techniques are investigated:

- Identification of Potential Water Ponding (Task 4.1) - The method uses joined multi-lane surveys with a combination of methods that identify common features in adjoining lanes. The work is carried out by IFSTTAR and TRL.

- Monitoring Road Inventory (Task 4.2) - During the project an inventory of existing automated inventory equipment has been made and an assessment on the capabilities of methods for road inventory monitoring. Partners in this task are AIT, VTI and Yotta DCL.

- Monitoring Surface Condition (Task 4.3) - This task deals with definition and development of methods for measuring cracking and ravelling and is done by IFSTTAR, TRL and Yotta DCL. One aim of this task is to expand the existing method to work on lower classes of roads and make better use of collected data in order to produce spatial information about the location of defects on the carriageway.

- Monitoring Structural Condition (Task 4.4) - The focus of this task is on the development of tools to measure structural conditions. There are two areas of focus – the measurement and assessment of deflection of pavements at traffic speed on both concrete and local roads with Traffic Speed Deflectometer (TSD, Greenwood) and measurement of the construction using Ground Penetrating Radar (GPR, Roadscanners).

- Monitoring Functionality (Task 4.5) - Today sensors are present in a variety of situations and locations. The challenge in the implementation is within the transformation of such raw data into an indicator with a real significance on road functionality for the road manager. Partners BRRC, VTI and AIT investigates mainly road surface characteristics and ride quality related aspects.

7. Impact and future work

7.1. Impact

The project aims to deliver enhanced methods to monitor roads within the European road network. It will identify, assess and develop tools focussed on improving the assessment of structures and road pavements. The developments will deliver a tangible impact on road asset managers, road engineers, road users and road monitoring equipment developers (including the five SMEs in this project). Regarding the improvement of asset management, TRIMM will develop methods that are capable of continuous assessment of the reliability of bridges and improved assessment pavement condition and performance. Tools will be demonstrated to implement the use of data within asset management systems. The tools will make it possible to better predict when and which preventative maintenance and/or repair measures must be performed. In summary, applying TRIMM monitoring and related maintenance concepts may lead to:

- Postponed replacement of roads and bridges, through extended service life and hence reduced lifetime costs
- More optimum design of construction and maintenance actions with improved links to whole life performance.
- More cost-effective, proactive and preservative maintenance, based on measured condition
- Less traffic annoyance (congestion) because of improved maintenance, less repair work and faster response to maintenance needs
- Increased road safety

The availability of improved monitoring techniques will also provide asset owners with greater ability to more tightly control the management of networks for which responsibility has been devolved under PPP (Public Private Partnership contracts) or performance contracts (such as Design-Build and Design-Build-Operate-Maintain). TRIMM techniques will allow owners to for example specify requirements for asphalt concrete thickness (GPR), bearing capacity over the entire road length (TSD), and surface condition. This in turn will allow closer control to be achieved on contract costs and the required level of performance.

Regarding the impact for developers and SMEs, the development of high tech road infrastructure monitoring and management systems will lead to a demand for highly specialised services in niche markets. Today, this is a scene for SMEs with a potentially world-wide market. The area is a multidisciplinary field for engineers, mathematicians, physicists, IT experts, etc. This project has a strong emphasis on the engagement in promising SMEs, each with a potential to become or stay world-leading in its area.

7.2. Future work and dissemination

TRIMM is ending in November 2014 and is in an intense phase to analyse results and document the work on bridge and road monitoring. The work related to asset management will move on to develop guidelines and recommendations for use of monitoring techniques in road asset management.

This project will disseminate its acquired knowledge using the knowledge transfer procedures and structures of FEHRL and link the project with the Forever Open Road Programme (FOR). A final symposium will be organized and reports will continuously be uploaded to TRIMM website at http://trimm.fehrl.org.

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