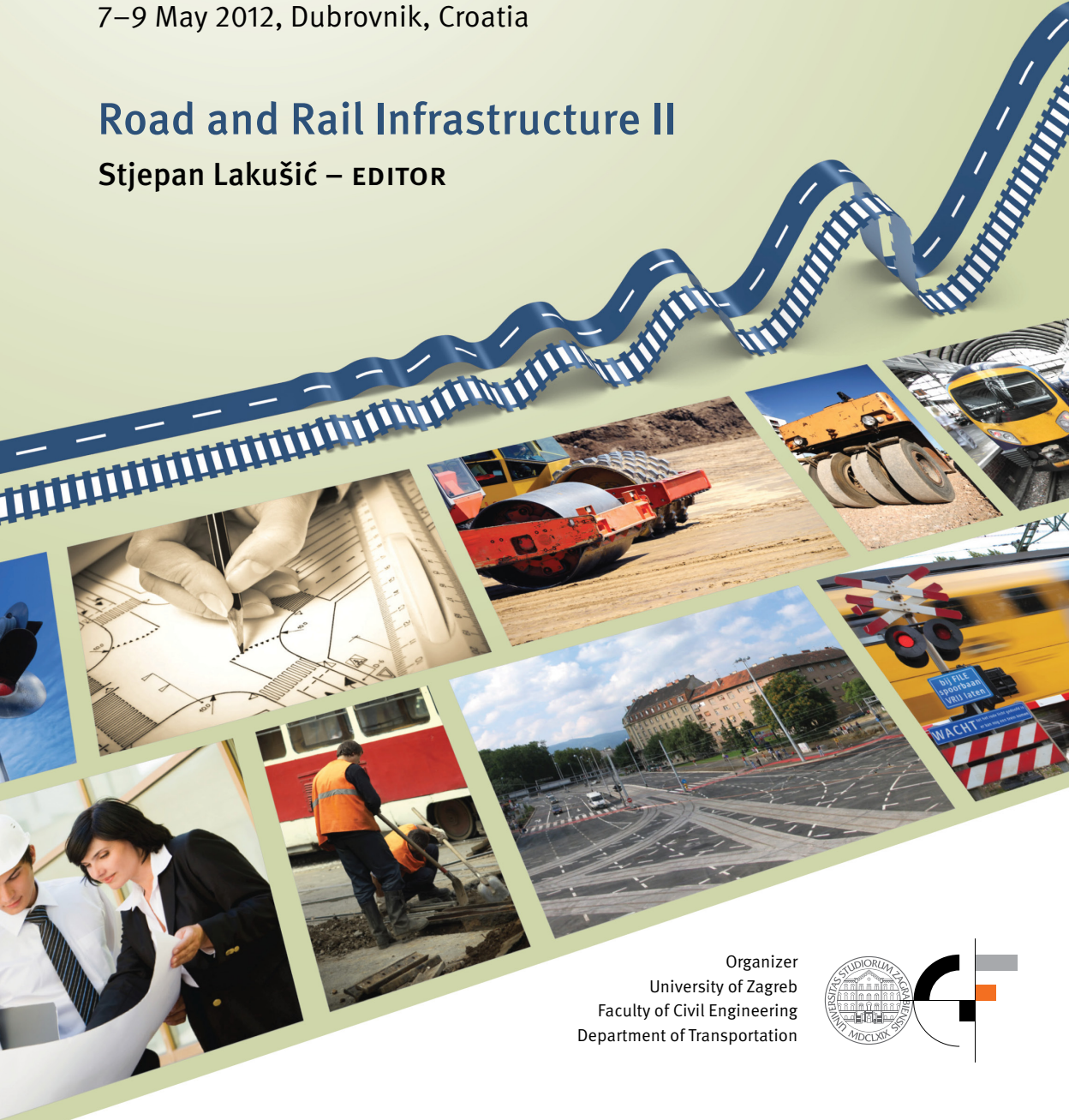


CETRA²⁰¹²

2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

Stjepan Lakušić – EDITOR



Organizer
University of Zagreb
Faculty of Civil Engineering
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SMART MAINTENANCE AND ANALYSIS OF RAILWAY TRANSPORT INFRASTRUCTURE (SMART RAIL)

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Abstract

Europe needs a safe and cost effective transport network to encourage movement of goods and people within the EU and towards major markets in the East. This is central to European transport, economic and environmental policy. Many parts of Europe's rail network were constructed in the mid–19th century, long before the advent of modern construction standards. Historic levels of low investment, poor maintenance strategies and the deleterious effects of climate change (for example scour of bridge foundations due to flooding and rainfall induced landslides) has resulted in critical elements of the rail network such as bridges, tunnels and earthworks being at significant risk of failure. The consequence of failures of major infrastructure elements is severe and can include loss of life, significant replacement costs (typically measured in millions of Euro's) and line closures which can often last for months. The SMART Rail project brings together experts in the areas of highway and railway infrastructure research, SME's and railway authorities who are responsible for the safety of national infrastructure. The goal of the project is to reduce replacement costs, delay and provide environmentally friendly maintenance solutions for ageing infrastructure networks. This will be achieved through the development of state of the art methods to analyze and monitor the existing infrastructure and make realistic scientific assessments of safety. These engineering assessments of current state will be used to design remediation strategies to prolong the life of existing infrastructure in a cost–effective manner with minimal environmental impact. This paper presents the organization, scope of work and project objectives of the SMART Rail project.

Keywords: FP7 project, SMART Rail project, degradation of the railway track, new rehabilitation methods

1 Introduction

Safe and efficient transport infrastructure is a fundamental requirement to facilitate and encourage the movement of goods and people throughout the European Union. There is approximately 215,400 km of rail lines in the EU which represent a significant asset [1]. Many of the rail networks in Eastern Europe and in parts of Western Europe were developed more than 150 years ago. These networks were not built to conform to modern standards and suffer from low levels of investment and in some cases poor maintenance strategies. Replacement costs for civil engineering infrastructure items such as rail track, bridges and tunnels are prohibitive. In the current economic climate it is vital that we maintain and develop our transport network and optimize the use of all resources. [2, 3] It is essential therefore those methods used to

analyse and monitor the existing infrastructure result in realistic scientific assessments of safety which allow the effective programming of remedial works. Thus SMART Rail project brings together experts in the fields of rail and road transport infrastructure, with the aim to develop state of the art inspection; monitoring and assessment techniques which will allow rail operators manage ageing infrastructure networks in a cost-effective and environmentally friendly manner.

2 Existing problems

Several European countries have highly advanced rail networks where the primary areas of concern in relation to infrastructure performance are related to achieving ever higher network speeds. In new member states such as Slovenia, accession states including Croatia and even in some Western European countries with relatively well developed economies, historic lack of investment in rail infrastructure had led to the situation that some elements of the network are in very poor condition. In these countries, parts of the rail infrastructure would be deemed to have reached the end of its service life when analysed using conventional assessment methods. When incidents occur such as structural failures or derailments, it is common practice in certain regions to simply close the line. Because of the lack of viable alternative modes of transport, such drastic action cannot be adopted in most countries.

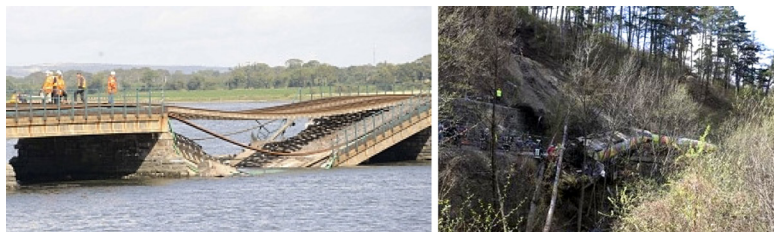


Figure 1 Left: Collapse of Malahide Viaduct on the Belfast–Dublin rail line (August 20th 2009); right: Rainfall induced slope failure at Merano, Italy (April 2010)

Climate change effects are increasing the burden on ageing transport networks with the incidence of infrastructure failure increasing. [4, 5] The construction of the trans-European transport network (TEN-T), which aims to provide interconnection and interoperability of national transport networks within the EU, is seen as vital for the economic competitiveness of the Union and is central to the objectives of achieving balanced and sustainable development. [6, 7] The Cork–Dublin–Belfast rail line in Ireland is one of the 30 TEN-T projects. The Irish railways were amongst the first constructed in Europe, and the 180 m span Malahide viaduct which carries the Dublin–Belfast line just North of Dublin is one of the oldest railway viaducts in the world. In early August 2009 unusual currents developing around one of the piers of the viaduct were reported. A visual inspection was performed on August 18th and no unusual distress to the structure was noted. Three days later the pier collapsed as a local passenger train crossed the viaduct and the Belfast–Dublin express service approached, Fig. 1 (left). The collapse, which was caused by scour of the foundations and was not visible to the inspector, caused the line to be closed for seven months and a repair costs around of €4 million. The scour problem which caused the failure was accelerated by high flows in the estuary caused by recent flooding. [8]

On the 12th of April 2010 a landslide initiated by heavy rainfall, caused the derailment of a train at Merano, in Italy (Figure 1 (right)).

On 31st March 2009, scour caused the failure of a pier on a railway bridge crossing the river Sava in Zagreb during a flood event (Figure 2).



Figure 2 Failure of railway bridge pier in Zagreb, Croatia (31st March 2009)

Climate change effects are having demonstrable effects on ageing infrastructure. These effects create serious safety issues for the European rail network and pose a significant threat that recent improvements in safety could be reversed. Furthermore, significant economic costs could accumulate in the near future unless action is taken to minimise these risks.

3 SMART Rail concept and consortium

In September 2011 SMART Rail project has been launched, funded under theme SST.2011.5.2-6. TPT Cost-effective improvement of rail transport, as a collaborative FP 7 research project. The SMART Rail project brings together experts in the areas of highway and railway infrastructure research, SME's and railway authorities who are responsible for the safety of national infrastructure. Consortium as a whole is given in Table 1.

Table 1 SMART Rail consortium

No	Name	Short name	Country
1	National University of Ireland, Dublin – University College Dublin	NUID–UCD	Ireland
2	Slovenske železnice, d.o.o.	SŽ	Slovenia
3	Forum of European National Highway Research Laboratories	FEHRL	Belgium
4	EURNEX e.V.	EURNEX	Germany
5	Institut IGH d.d.	IGH	Croatia
6	Zavod za gradbeništvo Slovenije	ZAG	Slovenia
7	Roughan O'Donovan Innovative Solutions	RODIS	Ireland
8	Adaptronica sp. z.o.o.	Adaptronica	Poland
9	Technische Universität München	TUM	Germany
10	Instytut Kolejnictwa	IK	Poland
11	The University of Nottingham	UNOTT	United Kingdom
12	HŽ INFRASTRUKTURA d.o.o.	HŽ	Croatia
13	Iarnród Éireann – Irish Rail	IR	Ireland
14	De Montfort University	DMU	United Kingdom
15	University of Twente	UT	The Netherlands

The goal of the project is to reduce replacement costs, delay and provide environmentally friendly maintenance solutions for ageing infrastructure networks. This will be achieved through the development of state of the art methods to analyse and monitor the existing infrastructure and make realistic scientific assessments of safety. These engineering assessments of current

state will be used to design remediation strategies to prolong the life of existing infrastructure in a cost-effective manner with minimal environmental impact.

In order to achieve its stated objectives the SMART Rail project is clearly structured in four content-orientated work packages (WP1-4), two work packages for project management, (one for administrative and one for scientific management, termed WP6 and WP7, respectively) and one for dissemination and exploitation (WP5), as presented in Figure 3. WP's 1-4 address the core issues of measuring the current state of infrastructure (WP1), quantifying its safety (WP2), implementing remediation strategies where required (WP3) and assessing the economic and environmental costs (WP4). The management work packages WP6 and WP7 are led by NUID-UCD (the project coordinator) which has extensive experience of leading framework projects. Central to the implementation of the project will be the SMART Rail advisory board which will have representatives from national rail operators in Slovenia, Croatia, Hungary, Poland and Ireland. The Dissemination work package is led by EURNEX, the European Rail Research Network of Excellence, which comprises 42 scientific institutes in the area of transport, provides an ideal platform for dissemination of the intellectual property generated through the SMART Rail project.

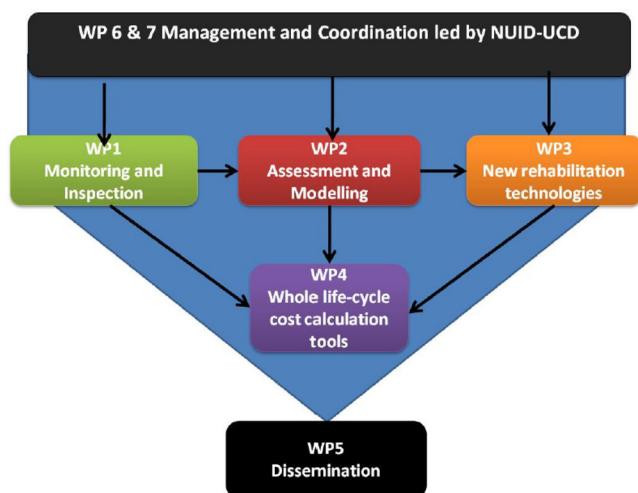


Figure 3 Structure of the SMART Rail project

4 Research topics covered in the project

4.1 Inspection and monitoring

In recent years concentrated research efforts have led to advances in embedded sensor technology and the use of non-destructive test methods including geophysical techniques such as seismic refraction, Ground Penetrating Radar (GPR) and Multiple Analysis of Shear Wave (MASW) are now commonly adopted in practice. The Smart Rail project proposes to

- Use modern ICT networks to collect data from embedded sensor networks and use it to populate statistical data for structural health monitoring models;
- Consider methods to improve the performance of in-situ techniques (specifically the rate of data acquisition);
- Investigate new application of existing techniques and technology – GPR techniques are now routinely used to profile ballast depths [9] and locate services;

- Apply MASW method for establishment of relationships between shear wave velocity, suction and soil strength;
- Develop a bridge weigh-in-motion system for railway bridges which will be capable of separating the dynamic responses of the structure from the train vibration and will thus be able to detect damage in the bridge. [10]

4.2 Assessment

Structural Reliability is an emerging technique for quantifying the safety of structures. In the Smart Rail project a reliability framework will be developed for railway infrastructure. It will encompass not just rail structures (bridges) but all aspects of rail infrastructure such as track susceptible to settlement (derailment risk) and the stability of slopes that might result in landslides onto track. There will be direct links with existing approaches so that probabilistic concepts can be incorporated without the need for a complete overhaul of existing techniques. The main benefit of this type of approach lies in its ability to provide not just a 'snapshot' of the safety of an infrastructural element/network but also to determine how this safety varies as a function of time due to (i) variation in loading, i.e. faster and/or heavier trains (ii) changes in the resistance of a structure due to deterioration or an embankment due to settlement etc. and (iii) the impact of management decisions regarding times of maintenance intervention and the extent of that intervention, both with respect to cost and impact on rail users.

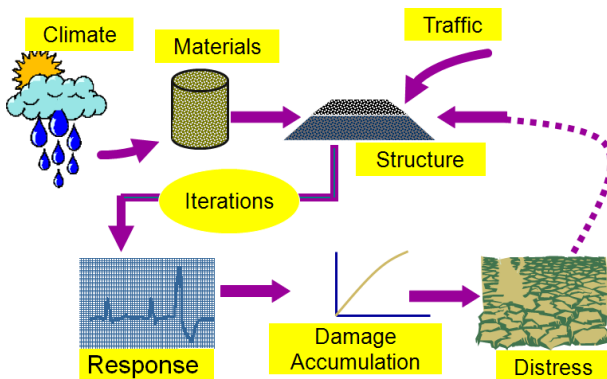


Figure 4 Smart Rail Dynamic Train-Track interaction model will be developed

Improved prediction of differential settlement of the ballast material used in traditional track construction and embedding this in a dynamic train-track interaction model (Figure 4) is at the core of the proposed research. Differential settlement will dynamically excite train suspension systems and this will mean a non-uniform distribution of load along the track. In the first case, it will also mean that some parts of the track are more prone to settlement than others.

4.3 Rehabilitation technologies and construction methods

The SMART Rail project focuses on the 'heavy' civil engineering infrastructure (such as bridges, tunnels, rail track and slopes) associated with ageing rail networks. Each element represents a very high cost item (usually quantified in millions of Euro) and unplanned replacement of any single element would cause unacceptable delays for the network (generally measured in months).

Contributions to advancing the state of the art will be concentrated in the areas of open-track, bridges and tunnels.

4.3.1 Open track

Optimal global track stiffness will be defined to replace the traditional methods whereby sleepers are isolated to measure stiffness or ballast stiffness is measured in-situ or in the laboratory.

In most railway networks in Eastern European countries train speeds in the past have not exceeded 160 km/h, and dynamic loading was generally not accounted for the track stiffness calculation. In-situ measurements from tracks under live train loads where differential settlement has occurred will be collected and dynamic amplifications will be accounted for, as needed.

Drainage systems are critical to the optimal performance of a railway system. The influence of long-term saturation and contamination of ballast layers with mud and small aggregate (known as mucky spots) has a significant effect on ballast/track stiffness, and requires significant remedial works. Methods to prevent the development of this contamination and in general controlling water ingress will be investigated.

4.3.2 Bridges

Consideration of bridge structures will concentrate on methods to:

- Classify structures and define acceptable deflection limits which will depend on the train speed, bridge span and type of the superstructure
- Increase the load bearing capacity of existing railway bridges by the implementation of advanced solutions for the superstructure (composite structure, ballastless track systems, Ultra High Performance Fibre Reinforced Concrete, etc.).
- Evaluation of the distribution of horizontal forces into the superstructure and joints and determination of limit values for longitudinal stiffness.
-

4.3.3 Tunnels

Many existing tunnels have insufficient clearance to allow for electrification. Ballastless track systems offer the opportunity to increase clearance within existing structures. The most effective construction techniques will be determined.

4.4 Cost and Environmental Assessment of railway innovation concepts

Advances in the area of whole life cycle analysis will focus on seven key areas:

- 1 Whole-life costing
- 2 Whole life cycle environmental analyses
- 3 Combined cost and environmental assessment
- 4 Assessment of renovation of the old railway structure
- 5 Holistic approach
- 6 Results and experiences
- 7 Multi-criteria assessment

A Multi-criteria railway revitalization decision tool will be developed as a result of this work. The user friendly tool will enable multi-objective optimization of new concepts for renovation of railway structures by the railway industry. It will allow re-developers to conduct their own analyses and to assess the relative importance of options.

5 Work progress

The SMART Rail concept is to provide a whole life cycle tool which will allow infrastructure operators to optimise the existing, ageing European rail infrastructure and ensure it remains operable into the future. In order to achieve the SMART Rail concept, project has started with the survey on typical problems on existing railways with the focus on older railway infrastructures. Demonstration sites have been selected or are under negotiation process in Croatia, Slovenia and Ireland. In parallel analysis of existing sensor networks and Structural Health Monitoring (SHM) procedures are conducted. Sensors will be embedded in key elements of rail infrastructure demonstration sites. These will collect real-time in-situ measurements of key parameters which will be transmitted via an advanced IT network to provide critical input data. After assessments of current safety have been undertaken environmentally friendly forms of remediation will be undertaken and the effect in terms of SHM will be quantified. Life Cycle Analysis models that will take input from the SHM and identify the most efficient maintenance programmes for each infrastructure operator, considering financial costs and environmental assessment. Those quantifications will be key performance indicators for the SMART Rail project, as the project outcomes in order to achieve primary aims of the project: a reduction of failures of infrastructure elements, such as tunnels, embankments and bridges.

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