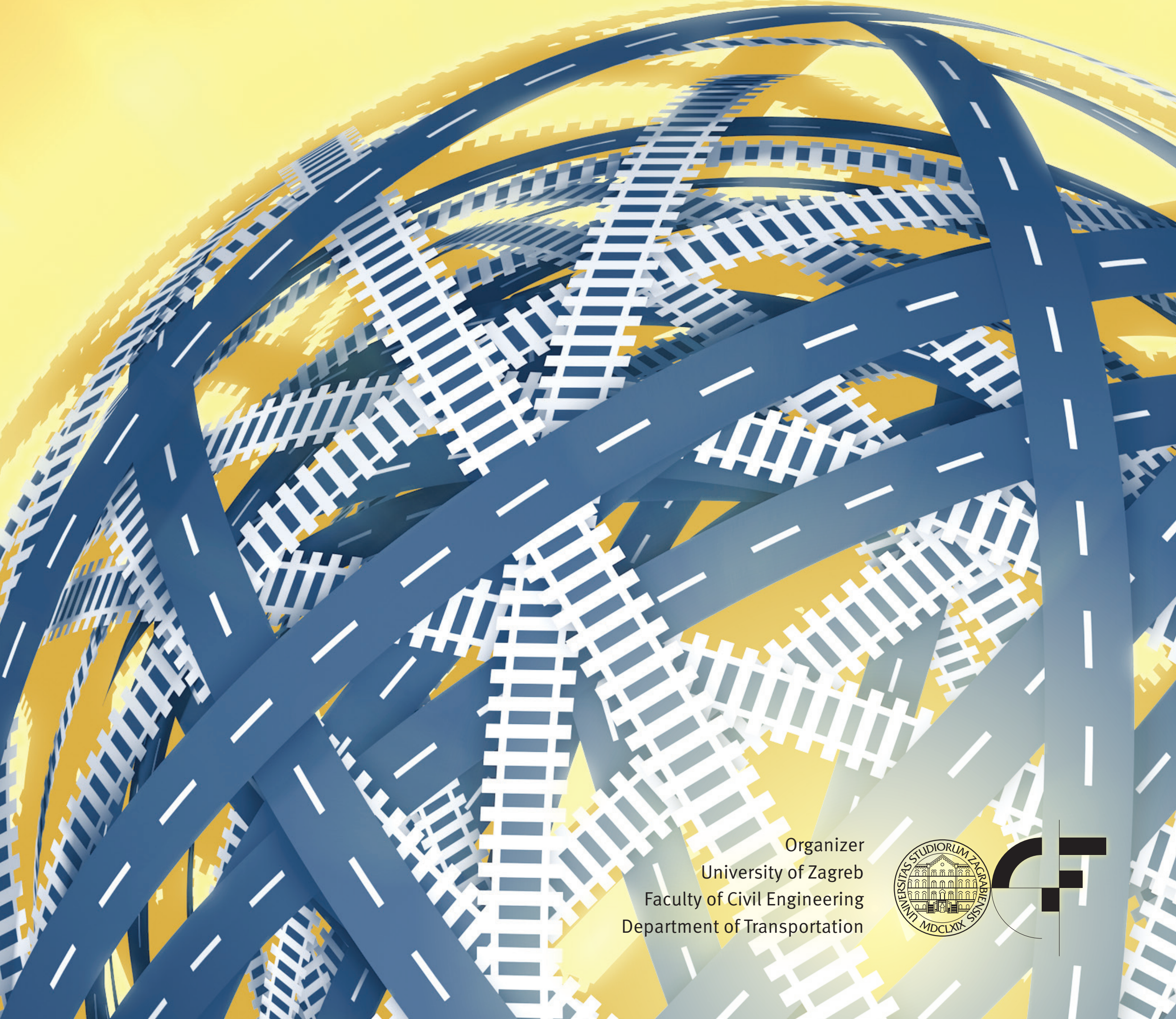
CETRA[2016]

4th International Conference on Road and Rail Infrastructure
23–25 May 2016, Šibenik, Croatia

# Road and Rail Infrastructure IV

Stjepan Lakušić – EDITOR



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# Road and Rail Infrastructure IV

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# DEVELOPING DECISION SUPPORT TOOLS FOR RAIL INFRASTRUCTURE MANAGERS

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## Abstract

European rail infrastructure managers (IMs) are managing ageing rail infrastructure with 95% of the network having been built before 1914. EU transport policy provides the challenge to IMs to increase the productivity of existing rail networks, prioritise renewal and optimise new sections to reduce bottlenecks, increase productivity and achieve a switch from freight transport by road to rail. This needs to be achieved at a time when budgets are restricted whilst improving customer satisfaction and dealing with challenges from natural hazards and extreme weather events which are affecting all of Europe.
In order to deal effectively with this grand challenge, Europe will need to develop methods to manage its rail infrastructure across the single European railway area. Whilst decision support tools are widely applied across, these systems tend to concentrate on only one asset and inherently suffer from the several limitations.
In this paper the European H2020 project Destination Rail that focuses on the development of decision support tool for rail infrastructure managers is presented. Within DESTination RAIL the aim is to provide solutions for a number of problems faced by EU infrastructure managers, such as assessment of existing assets, use of existing databases controlled by an information management system, risk assessment, maintenance and construction techniques for treating rail infrastructure including tracks, earthworks and structures, whole life cycle assessment and impact on the traffic flow. Each of these separate streams are incorporated into the Decision Support Tool which will be the primary exploitable deliverable from the project, and demonstrated on several railway projects across the European network.

*Keywords: decision support tool, maintenance planning, European project, DESTination RAIL*

## 1 Introduction

European rail infrastructure managers (IMs) are managing ageing rail infrastructure with 95% of the network having been built before 1914 [1]. EU transport policy provides the challenge to IMs to increase the productivity of existing rail networks, prioritise renewal and optimise new sections to reduce bottlenecks, increase productivity and achieve a switch from freight transport by road to rail. This needs to be achieved at a time when budgets are restricted whilst improving customer satisfaction and dealing with challenges from natural hazards and extreme weather events which are affecting all of Europe. A number of high profile failures of rail infrastructure have occurred in recent years, with the incidence appearing to increase in response to climate challenges and aging networks amongst other factors, see Figure 1.

a) b)

Figure 1 Recent railway failures: a) Rockfall on Zagreb-Split railway track in Croatia in 2014 [2]; b) Derailment of a Swiss train caused by a rainfall induced landslide, in 2014 near the Swiss Ski resort of St. Moritz [3]

In order to deal effectively with this grand challenge, Europe will need to develop methods to manage its rail infrastructure across the single European railway area. As well as being a significant asset, proper management of the rail infrastructure network is an essential mean in achieving key policies, such as developing the East-West connections, reducing disparity in infrastructure quality between member states, reducing fragmentation along the TEN-T network, reducing greenhouse gas emissions and increasing movement of goods and people. Establishment of a Single European Railway Area (SERA) is seen in the 2011 Transport White Paper as being critical to ensuring long-term competitiveness, dealing with growth, fuel security and decarbonisation in the EU. The European Rail Industry employs 800,000 people and generates a turnover of €73bn [4]. Public investment in Rail is significant, amounting in 2009 to a spending of €26bn on infrastructure. [5] Despite this serious investment growth in passenger numbers is low and the gains in term of modal share of rail remains moderate. Whilst part of this is due to the historical organization of the rail sector across Europe the significant spend of overall budgets on infrastructure maintenance, renewal and development gives a clear indication of the importance of this aspect.

The three-year Horizon 2020 project DESTination Rail, is funded by the European Commission under grant agreement No 636285, through the Innovation and Networks Executive Agency (INEA) under the call MG-2.1-2014, I2I Intelligent Infrastructure. The project started on May 1st 2015. The overall concept and main aims of the project are explained in the following chapters.

## 2 Overall concept of DESTination RAIL project

The aim of DESTination RAIL is to provide solutions for a number of problems faced by EU infrastructure managers. Novel techniques for identifying, analysing and remediating critical rail infrastructure will be developed. These solutions will be implemented using a decision support tool, which allows rail infrastructure managers to make rational investment choices, based on reliable data, see Figure 2. Main aims of the project are:

1) To provide solutions for common infrastructure problems encountered in diverse regions across Europe e.g. bridge scour, slope instability, ballast degradation, rock-falls and failure of switches and crossings.
2) The project will develop management tools based on scientific principles for risk assessment using structural health monitoring (SHM) and other vital data stored in an Information Management System.
3) A decision support tool will be developed to allow decisions on investments for maintenance and new works to be made by Infrastructure Managers (IM's) on the basis of scientific principles.

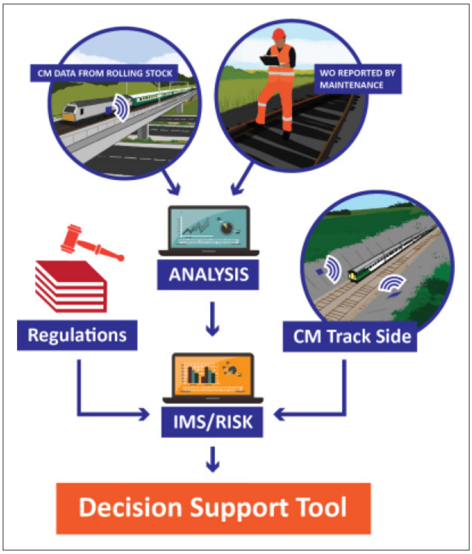


**Figure 2** Integration of all components into Decision Support Tool (DST)

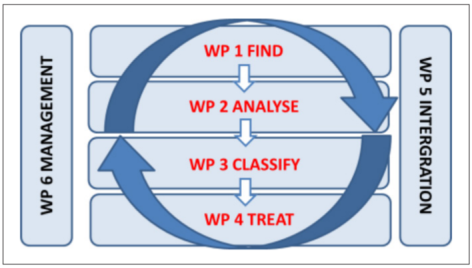


**Figure 3** Project structure [6]

The challenges facing Europe's Infrastructure Managers can be divided into four areas that are addressed directly in the DESTination RAIL project, see Figure 3, through a holistic management tool based on the FACT (Find, Analyse, Classify, Treat) principle:

**Find:** Identifying vulnerable critical assets before failure, knowing how assets are actually performing and the stability of the geological-engineering condition surrounding those assets by improved monitoring techniques, see Figure 4.

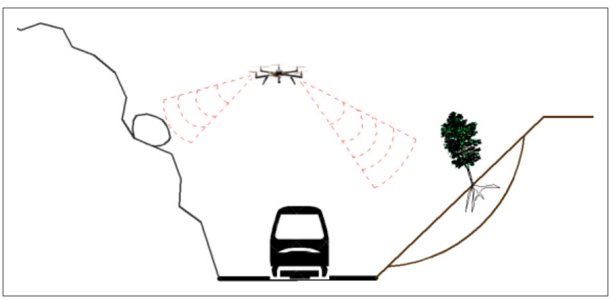

**Figure 4** Drone with high resolution camera to detect high risk areas.

**Analyse:** Having appropriate tools to process this condition monitoring information and data to accurately assess the condition of the asset and the effect of different maintenance on it, see Figure 5. Advanced probabilistic models will be developed and fed by performance statistics which will be used to determine the level of safety of individual assets.

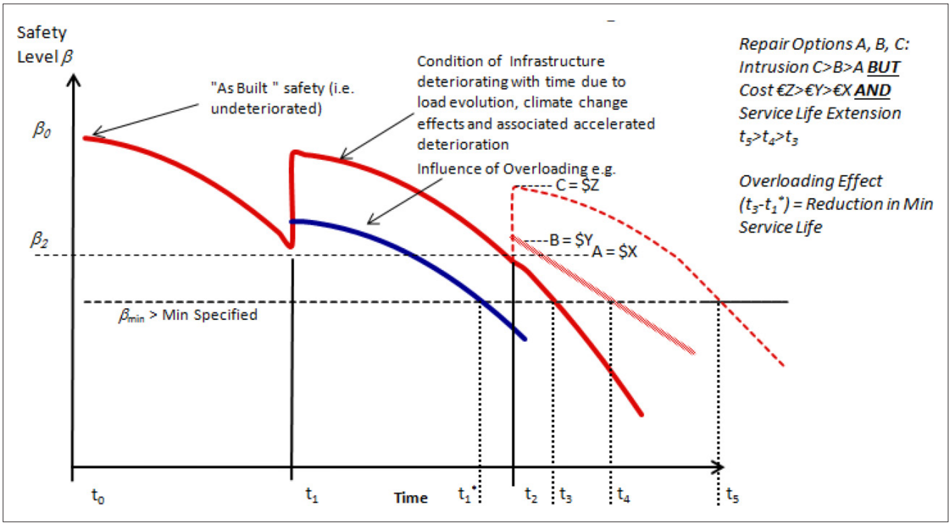


**Figure 5** Probabilistic life cycle optimization model integrating condition monitoring information

**Classify:** Understanding how risks and individual components relate to the overall system, and how changes in the system affect individual components. The performance models will allow a step-change in risk assessment, moving from the current subjective (qualitative) basis to become fundamentally based on quantifiable data. A decision support tool will take risk ratings and assess the impact on the traffic flow and whole life cycle costs of the network.

**Treat:** Conducting maintenance and repairs so the whole network is safe and reliable for users (people and freight) within the restrictions of limited maintenance budgets and the need for increasing sustainability. Novel and innovative maintenance and construction techniques for treating rail infrastructure including tracks, earthworks and structures will be developed and assessed by whole life cycle assessment and impact on the traffic flow.

## 3 Holistic Management Tool

### 3.1 Current situation

At present Infrastructure Managers make safety critical investment decisions based on poor data and an over-reliance on visual assessment. As a consequence their estimates of risk are therefore highly questionable and large-scale failures are happening with increasingly regularity. As the European rail Infrastructure network ages, investment becomes more challenging. As a result reliability and safety are reduced, users perception of these is negative and the policy move to increased use of rail transport is unsuccessful. Whilst decision support tools are widely applied across a range of domains, JRC [7] notes that they tend to work either at a sectoral level (e.g. transportation, or energy etc.) or at an asset level. The first approach is typically undertaken to drive policy, e.g. at a National or European level and thus tends to simplify the consideration of individual assets. In contrast methodologies for assessing certain assets are well defined. In the rail transport sector most IM's are implementing decision support tools on an asset-by-asset basis, for example steep slopes [8] and level crossings [9].

A management system RAILER® EMS, has been developed by the U.S. Army Engineer (ERDC-CERL) as a decision support toolbox for managing defects on tracks. However, these systems tend to concentrate on only one asset (as with the RAILER system) and inherently suffer from the following limitations, which will be addressed in the Destination Rail Project:

1) The data used to perform the risk assessment is mostly inadequate. An over-reliance on visual assessment and guestimates for condition monitoring are the norm rather than the exception.
2) They do not consider the effects of traffic flow.
3) They suffer from a lack of a system wide database of asset condition and performance.
4) They do not account for whole life cycle assessment in a probabilistic manner.

### 3.2 Information Management System

DESTination RAIL has already developed an information management system (IMS) based on the literature study and identified needs through expert interviews [10]. The IMS is designed to hold all the data relating to an individual asset and the network as presented in Figure 6.

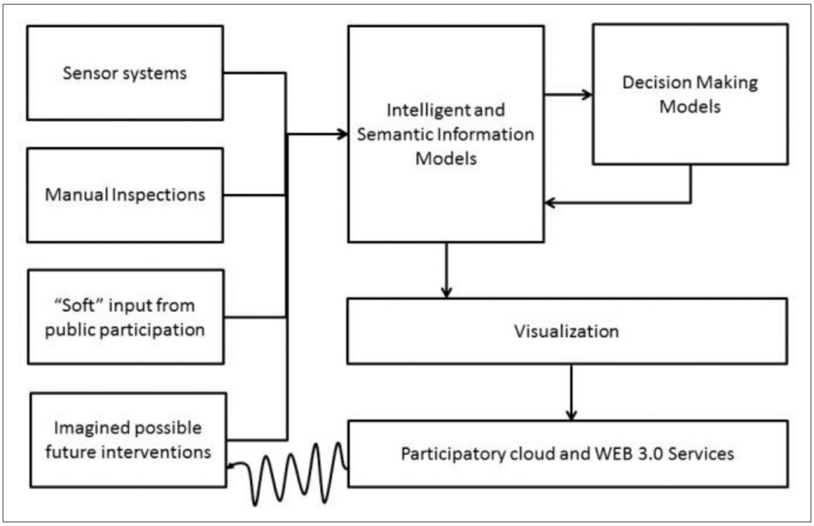


**Figure 6** IMS scheme

Objects in the information model can describe physical entities of the railway infrastructure, such as track or bridge, or conceptual entities related to railway asset management tasks, such as, cause of failure. In addition to representing the physical objects, the information model also represents important attributes of these objects and relationships between the objects. To keep the IMS simple, we have omitted operational details, such as train schedules or railway stocks. IMS is planned as a dynamic model which will adapt changing requirements along its implementation.The IMS will allow to:

- manage the relationships between information items from a diverse range of sources (sensor input streams, manual inspections, risk assessment input parameters, risk assessment outcomes, key performance indicators, etc.)
- keep track of changes within information items throughout the lifecycle of the infrastructure object, and
- aggregate and disaggregate information across different spatial scales (sub-object, complete object, object network) and semantic richness (raw sensor-based data stream to semantically rich information descriptions), and levels of detail.

The development of the information model is based on the knowledge from computer science (system architecture, database architecture, object oriented modelling) and from the domain of infrastructure performance and management.

### 3.3 Risk Assessment and Risk Ranking

Based on the probability of occurrence of the events (e.g. floodwaters deeper than x meters) to which the infrastructure objects will be subjected and the probability of the infrastructure objects providing different levels of service following an event (e.g. due to a flood the road/rail is closed for two days but then reopened without need to execute an intervention, or is closed for two months until it can be rebuilt), risk assessment will be performed. It is particularly challenging to develop such a methodology as infrastructure-related risk due to natural hazards depends on the functioning of all objects in the network simultaneously and the maintenance strategies being followed to allow for an estimate of the amount of downtime expected. It will make use of standard tools, such as event tree and fault tree analysis, as well as the state-of-the-art in network connectivity analysis.
The methodology will be established keeping in mind that the assessment of risk evolves over time and that data collected at different times and in different ways does not always have the same value, especially in non-stationary systems. This means that it will be devised to update past information based on new information, for example to take into consideration the object's exposure to real events.
The methodology developed within this task will provide infrastructure managers with a way to identify the risks related to a single object that is working as part of a network to provide a specific level of service. The risk assessment that results from this methodology will form the basis for the risk ranking, and will therefore help infrastructure managers to allocate their limited resources better. This means instead of focusing just on risk, it will take into consideration the availability of resources to reduce risk, the ability to accept or tolerate risks, the effectiveness or availability of interventions to reduce risk and the residual risks following an intervention. The methodology will allow different interventions to be compared, taking into consideration their relative costs (both direct and indirect).
In addition to this the ranking methodology will also take into consideration options to execute risk reducing interventions on multiple objects simultaneously for lower costs than if the interventions were executed individually.
The methodology will be tested on object and network level case studies, to update a model which considers the deterioration of the infrastructure over time and allows for consideration different hazard scenarios. It will be possible to use the prototype tool to illustrate the impact of different intervention strategies on the long-term risk rating of the objects in the network.

### 3.4 Decision Support Tool

The Decision Support Tool (DST) which is being developed in the project will help infrastructure managers in decision making process in the context of dealing with a number of previously identified and ranked risks. The DST will integrate the outputs from inspection and monitoring, probabilistic reliability modelling, whole life cycle analysis (WLCA) and traffic flow model, and use them under specific process workflows and modules.
The tool will be tested on several scenarios for selected railway sections, meaning different input values for different variables will be used in order to test the defined interrelatedness between different risk factors and the meaningfulness of the outcome of the tool.
The DST should form the basis for the development of 'pre-standard' or benchmark guidelines which can be used by infrastructure managers and stakeholders to support robust development measures which ultimately mitigate multiple risks that are associated with aging railway networks, increased traffic and climate change impacts, along with decreasing ma-

intenance budgets. Beside by integration of WLCA the objective is to develop maintenance and rehabilitation strategies which will minimise their socio-economic and environmental impacts. DST will use intuitive Graphical User Interface features for executing contextual risk management workflows for strategic decision-support, that take on board EU regulations and ISO standards.

## 4 Conclusion

The DESTination RAIL consortium brings together experts from across Europe in the areas of condition monitoring, asset performance, risk assessment and life cycle analysis. The consortium has designers and researchers at the cutting edge of analysing individual assets, based on structural engineering, geotechnics and traffic modelling. A number of infrastructure managers will feed-in industry know-how, provide pilot and demonstration sites and leading infrastructure management researchers will develop the key output, the Decision Support Tool in conjunction with SME's and IM's. At the moment of finalizing this paper the conceptual framework of the decision support tool, risk assessment methods and life cycle cost models are under development as a part of the project.

## Acknowledgement

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