CEDR Transnational Road Research Programme

Call 2013: Ageing Infrastructure Management

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X-ARA

Cross-asset risk assessment

Final report

Deliverable D0.3

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CEDR Call 2013: Ageing Infrastructure Management
X-ARA
Cross-asset risk assessment

Final report

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Executive summary

The project X-ARA ("Cross asset risk assessment") has carried out research on how to implement the concept of risk assessment into transport infrastructure asset management.

This final report summarises the work done over a period of two years (04/2014-03/2016). It links together the already produced reports and summarizes their findings.

The project started with a literature review on the topic of risk assessment and management in transport infrastructure. This literature review was complemented by a workshop and a series of interviews where road operators have been asked about three topics: (a) what external factors are currently considered in their asset management work, (b) to what extent risk assessment is currently implemented in their systems and (c) what developments do they expect for the future. The outcomes of the interviews and the workshop have been edited to a series of case studies to allow a comparison of the different approaches.

The definition of maintenance risk in X-ARA has been set as follows: "The maintenance risk is a function of distress probability depending on asset condition or age and the consequences (effects) with respect to the affected stakeholders in the context of asset maintenance management."

With the results of the literature review in mind, the risk framework has been developed. The framework allows calculating the risk for sections of the network (so-called "maintenance sections") on different levels: risk per asset type (pavement, structures, road furniture, drainage, geotechnical assets, tunnels), total risk per maintenance section and total risk of the network. Furthermore, high-level influencing factors have been defined which affect the risk. These are: climate change, funding, safety regulations, sensitivity of the section itself (i.e. functional importance) taking into account also the regional situation (urban, flat or mountainous). Using a length-weighting function, the different extents of the assets are considered. The probability of failure is expressed as current asset performance. Suitable condition indicators have been used for that.

The risk framework has been implemented in two ways:

The first implementation was done using commercial asset management software (dTIMS). This was mainly used during the development of the risk framework as a prototypical implementation. Using commercial software with an already filled database and the easy possibility to implement, modify and optimise calculation procedures was very helpful and speeded the development process. On the other hand it is also a proof that the X-ARA risk framework can be implemented into already existing asset management software.

The second implementation was done in freestanding software, the X-ARA Tool. The tool is able to use the existing CEDR network as a starting point. If the user wants to use his own network ("custom network"), this is possible as well. The X-ARA Tool is available for download together with a demonstration dataset from the X-ARA website (www.x-ara.net). It is accompanied by a user guidance document that explains the functions of the tool and gives advice on the interpretation of results. A programme for dissemination and education of users has been developed.

All reports, presentations, conference papers produced during the project are as well available for download from the project website http://www.x-ara.net.

1 Introduction

1.1 Introduction into the project

The main objective of the project **"X-ARA – Cross-Asset-Risk-Assessment"** is the development of a comprehensive risk assessment framework including a set of guidelines and a practical software tool (**X-ARA risk tool**) for the network level assessment of asset risks and impacts. The approach takes into account the requirements and needs of different stakeholders, considered in an initial desk study, and is focused on delivering a working model fit for use by National Road Administrations around Europe. The project builds on earlier European projects, including aspects of the ERA-NET 2010 Asset Management Programme, as well as drawing on the direct experience of operational asset-managing organisations. The Team comprises a blend of experience from research, academia, private sector experts and asset operators.

The model intends to take into account internal and external factors affecting the different assets in an ageing road infrastructure, such as

Climate Change	Asset performance
Funding/politics	Demand (traffic)
Macro-economic factors	Social factors

To cover these aspects three high level influence factors were defined within the X-ARA model:

- Environment/climate change
- Economy/funding
- Safety/safety regulations

complemented by a factor reflecting the functional importance.

It includes the framework for the necessary input parameters (indicators), the definition of sub-risks and cumulated risks (in form of risk factors) and the procedures to implement the solution on a road infrastructure network. The output methodology and model is generic and adaptable by different NRAs, under the auspices of CEDR, using their own local data and parameters. The assets themselves, as well the economic, geographic and social factors differ in each country so it will always be necessary for each country to calibrate the risk model to its own environment, using the provided guidelines.

X-ARA enables an NRA to execute a risk-based assessment and comparison of different maintenance strategies at a network level, and then 'overlay' the effects of broad influencing factors to assess 'what if' outcomes, in the medium to longer term. To produce a reliable high-level model, it considers a bottom-up approach (using real data) that can be used to measure sub-risks, as well the high-level top-down influences. The **X-ARA risk tool** is based on real, available and affordable data, and the software is independent of any proprietary database or software platform. It considers the risk-specific effects on safety, operation, and traffic, of high- to low- or non-coordinated maintenance activities but does not include new construction programmes (schemes). Hence, a NRA is able to examine a worst case/best case set of scenarios for their own environment and socio/political situation, and consider the implications on funding as well as economic and social outcomes for stakeholders, while meeting the requirements of environmental and other legislation.

X-ARA has the potential to aid a NRA to provide better prognosis of risk against different funding scenarios, and thus will be a powerful tool when juggling ever-reduced budgets against ever-increased demand and uncertainty. It adds real value to existing asset data, is capable of further exploitation across CEDR member countries and gives transnational benefits by providing a common framework for assessing risk which can be configured for each country location.

1.2 Scope of the report

This document gives an overview of the work that has been carried out during the project and gives introduction to the reports and deliverables that have been produced in the course of the project.

As the output of the work packages is fully documented in the already existing deliverables, this report does not cover a specific part of the work. It links together the already produced reports and summarizes their findings.

The report closes with conclusions and an outlook on possible future extensions of the ideas developed in X-ARA.

The following Figure 1 shows the major activities in the project together with the main outputs.

The following sections of the report briefly describe these activities and link to the comprehensive documents produced that hold the detailed results of the activities. All chapters end with coloured charts that contain clickable links to the according documents on the X-ARA website.

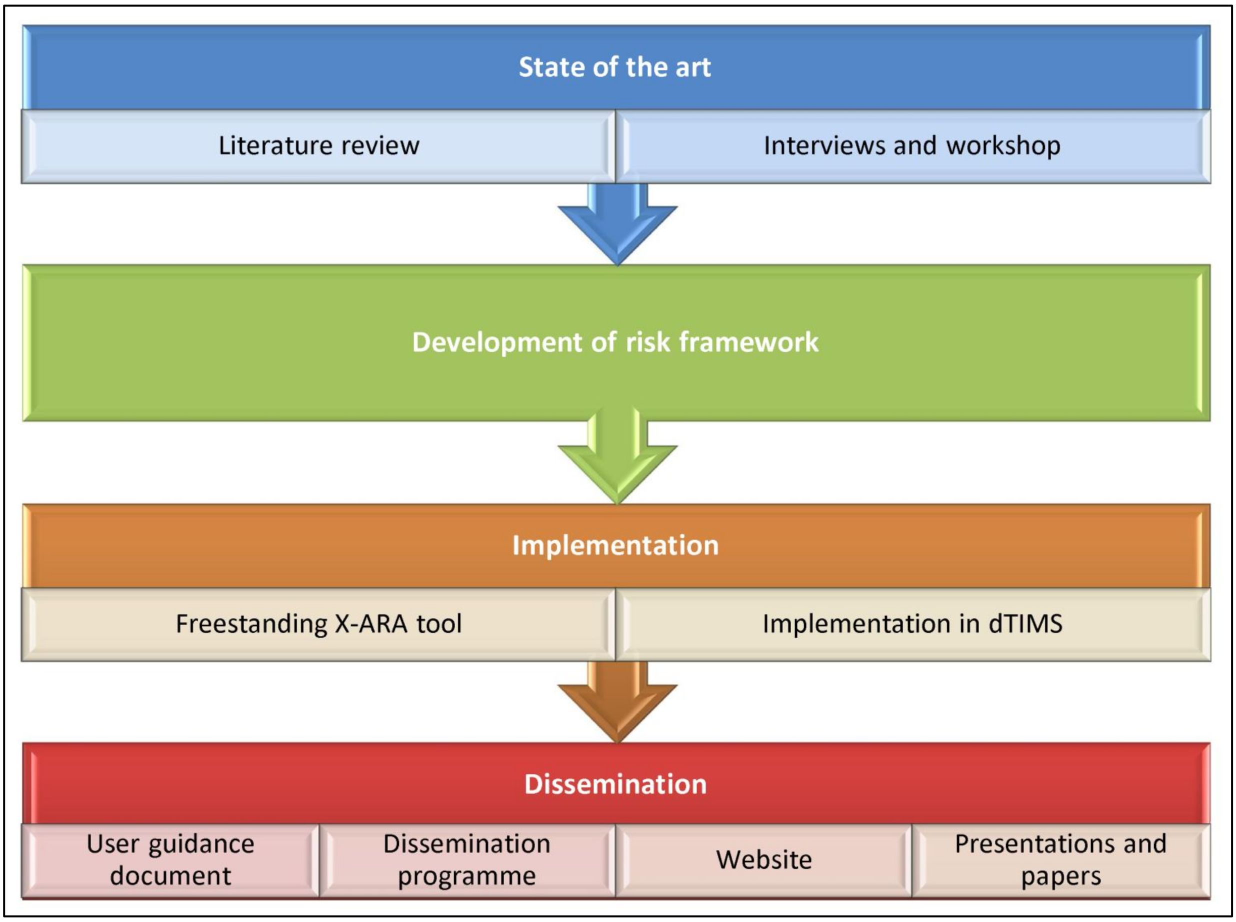

Figure 1: Activities and outputs in the X-ARA project

2 State of the art and desk study

The project started with a literature review on the topic of risk assessment and management in transport infrastructure. The literature review has brought up many definitions of the term "risk", all with slight deviations, but many of them referring to risk as the product of probability of failure multiplied with the consequences of failure.

For the X-ARA project it was decided to follow the definitions:

The maintenance risk is a function of distress probability depending on asset condition or age and the consequences (effects) with respect to the affected stakeholders in the context of asset maintenance management. It is "the risk for the road operator to either perform non-cost-efficient maintenance on his network, or to provide unsatisfying services to the other stakeholders (users, neighbours, society, owner…)."

As not all these "elementary" risks could be developed within the X-ARA project, it was decided to illustrate the approach by considering:

- The risk for the road operator to lose money (too expensive maintenance, excessive loss in asset valuation, etc.) in the short, medium and long terms by applying maintenance strategies which do not adequately anticipate on high level influencing factors

- The risk for the road operator to provide users with significantly unsatisfying services after some improbable event(s).

The same approach could be used to assess other risks (to users or other stakeholders) that the road operator could have to face. It is assumed that these different "elementary" risks could then be merged into a single "overall" risk by a weighted sum. The weights would reflect the relative importance of each risk.

The literature review also showed a common approach to risk management (see Figure 2 below).

Regarding risk management frameworks, many sources suggest a five-step procedure that starts with

1. defining the context, then
2. risk identification,
3. risk analysis,
4. risk evaluation and ends with
5. risk treatment.

Other approaches use a four-step approach where the steps (2) and (3) or (3) and (4) are treated together in some way.

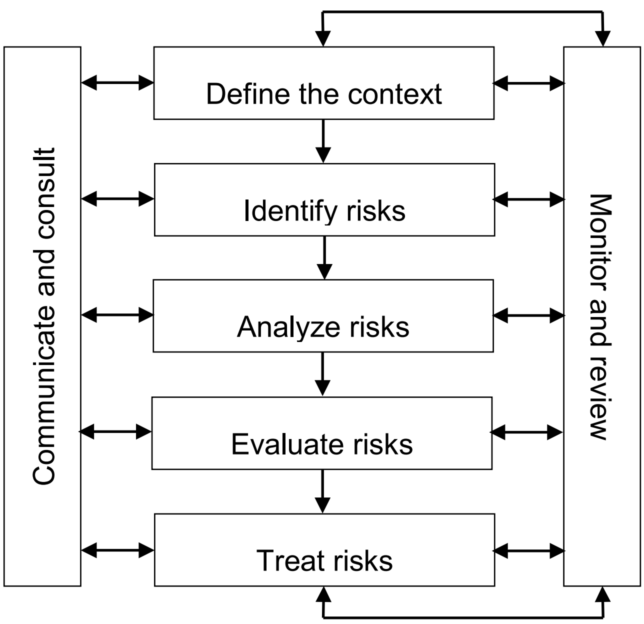

Figure 2: Common approach to risk management in transport infrastructure

This literature review was complemented by a workshop and a series of interviews where road operators have been asked about three topics:

- what external factors are currently considered in their asset management work,
- to what extent risk assessment is currently implemented in their systems and
- what developments do they expect for the future.

The outcomes of the interviews and the workshop have been edited to a series of case studies to allow a comparison of the different approaches.

This procedure was then taken to compare the approaches of different road operators and the how far they got with the implementation of risk management in their asset management processes.

It was found that this straight-forward methodology has not been fully implemented in any of the road operators that have been interviewed. Parts of the risk-assessment framework are implemented at each road operator, although sometimes they are not labelled as such. While for construction projects dedicated risk management procedures are commonly used, in asset management risk assessment is only partly implemented, e.g. for structures or tunnels. In maintenance systems, routine monitoring is often considered sufficient as some form of risk treatment.

External factors are considered to a varying degree. Climate change is considered by some road operators in the form of scenarios that allow a forecast of maintenance and operation cost. Funding is tightly linked to macroeconomic factors, even more if the maintenance budget comes from toll revenues. There is a common feeling that the maintenance budgets are not in danger of a sudden dramatic cut. Regarding demand, a constant conservative growth is largely anticipated with no sudden deviations. Social factors and politics are considered to have a certain influence, however difficult to anticipate.

The availability of data upon which maintenance decisions are taken is considered sufficient for pavements and structures. For these assets, routine monitoring is in place for several years at each interviewed road operator. For street lighting, gullies and drainage there is still some work to do to reach the level of completeness and quality of pavement data, although there are data collection strategies in place to catch up in these areas. What needs improvement is the trust and understanding in the collected data and their central availability.

The report produced concludes with a discussion of the findings of the literature review and the current practice of road operators.

The results of the literature review and the interviews were documented in “D1.1 Desk study” in detail and were the basis for the development of the risk framework (covered in ”D1.2+2.1 Risk Framework”) and the tool that is derived from the framework (“D3.3 X-ARA-Tool”).

D1.1 Desk study

- Literature review
- Interviews and workshop

3 Development of risk framework

This part is the main result of the X-ARA-project as stated in the proposal: The main objective of the project **"X-ARA – Cross-Asset-Risk-Assessment"** is the development of a comprehensive risk assessment framework including a set of guidelines and a practical software tool (**X-ARA risk tool**) for the network level assessment of asset risks and impacts.

At the beginning of the development, some basic definitions were made:

- As the Probability of failure (PoF) is very difficult to determine for transport infrastructure assets (and the aim of the asset management is to avoid a failure of any asset), the Probability of Failure is replaced by a dimensionless condition indicator (see Figure 3). This is also found in the literature and has the advantage that for most assets some form of condition indicator already exists.
- X-ARA uses a data driven approach. The more data about the assets on a maintenance section is available, the more benefit can be made from the risk framework. The availability of condition data varies largely for different asset types. For pavements and structures, most CEDR countries have well-maintained time series of condition data available. For drainage or road furniture, only basic information or no condition data at all may be available. However, a consistent dataset over all assets is the prerequisite for a holistic cross-asset management.
- For the description of the consequences (Consequence of Failure, CoF), suitable measures like Traffic volume or sensitivity to erosion have been chosen.

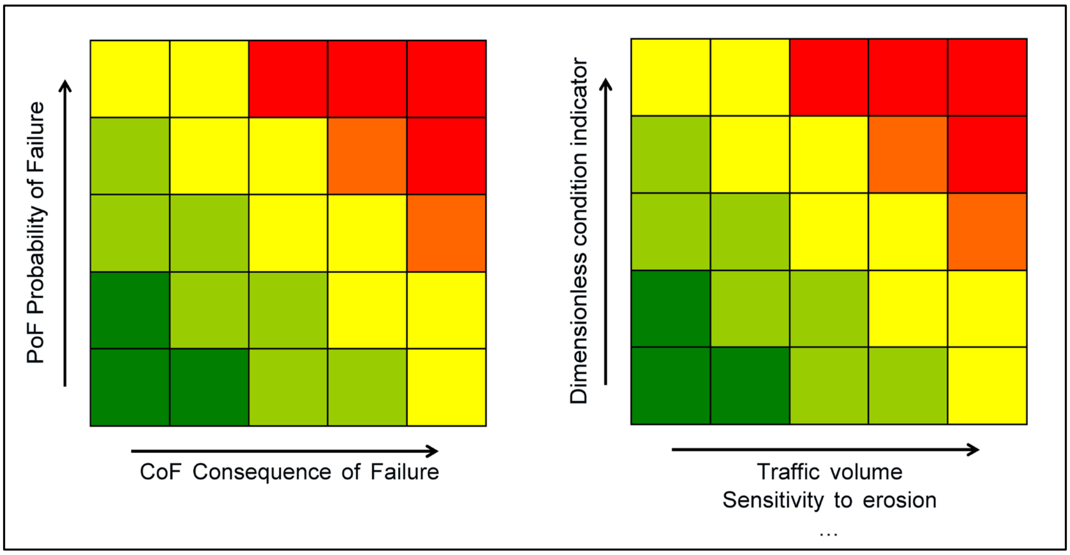

Figure 3: Conventional risk matrix (left), risk matrix used in X-ARA (right)

The risk modelling methodology itself – as the core part of the X-ARA project – covers the following topics:

- Which input-data is needed?
- Which high-level influence factors are considered in the approach?
- How does the risk model work?
- What is the output of the risk calculation?

- How is the maintenance risk defined in general?
- How is the maintenance risk defined for different types of asset?
- What is the output of the risk assessment?

The input data is defined for the underlying network that is structured as maintenance sections that represent homogeneous conditions (number of lanes, type of pavement, traffic volume, etc.).

The asset types considered in the risk tool are

- pavement,
- structures (bridges and retaining walls),
- tunnels,
- road furniture,
- drainage and
- geotechnical assets.

For each asset type, condition indicators have been defined based on literature or common practice.

High level influencing factors have been defined:

- Climate change, that includes all aspects associated to climate change and its consequences;
- Funding, that covers the availability of funding for proper maintenance and
- Safety regulations that allows the introduction of safety related improvements.

These three external factors are complemented by a "functional" high level factor that reflects changes in the functional importance of a road or sub-network.

For each high level influencing factor three categories are proposed: 'positive' to reflect a situation that lowers the asset specific risk; 'standard' to reflect the expected development and 'negative' to reflect a development that increases the asset specific risk. The influencing factors are established for each asset of the network.

The risk for each asset will then be calculated using pre-defined matrices that cover condition of asset and the importance of the asset or – in other words – the consequences of failure of this asset. At first, the risk per each single asset (on object level) is assessed and cumulated on the maintenance section. Following up, for each maintenance section, an overall risk score is calculated to combine the asset specific risks using different transformation laws.

In the Appendix, a worked-out example using a small road network demonstrates the risk calculation approach step-by-step.

D1.2+D2.1

Risk framework

- Network data
- Assets (condition indicators, consequences)
- External influencing factors
- Risk calculation per asset
- Risk accumulation
- Full Example

4 Practical Implementation

The framework that has been developed was implemented in two ways (see Figure 4 below):

The first implementation was done using commercial asset management software (dTIMS). This was mainly used during the development of the risk framework as a prototypical implementation. Using commercial software with an already filled database and the easy possibility to implement, modify and optimise calculation procedures was very helpful and speeded the development process.

On the other hand it is also a proof that the X-ARA risk framework can be implemented into already existing asset management software.

The second implementation was done in freestanding software, the X-ARA Tool (for general workflow see Figure 5). The tool is able to use the existing CEDR network as a starting point. If the user wants to use his own network ("custom network"), this is possible as well. The user needs a geographical representation of the network (a "Shape file", which is the most common file format in today's GIS systems) and imports his network into the tool.

The network is divided into maintenance sections (road sections with homogenous characteristics, e.g. number of lanes, AADT).

Assets are placed on each maintenance section with their according condition indicator.

The baseline risk is calculated

- per asset type
- per maintenance section
- for the total network

By adjusting external influencing factors, what-if scenarios can be explored.

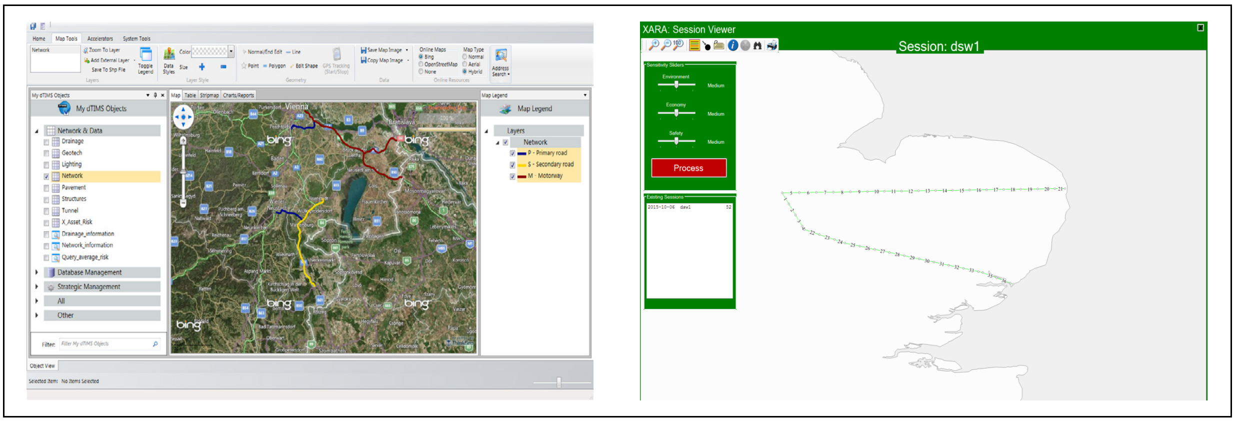

Figure 4: X-ARA prototype in commercial asset management software (left) and X-ARA freestanding software tool (right).

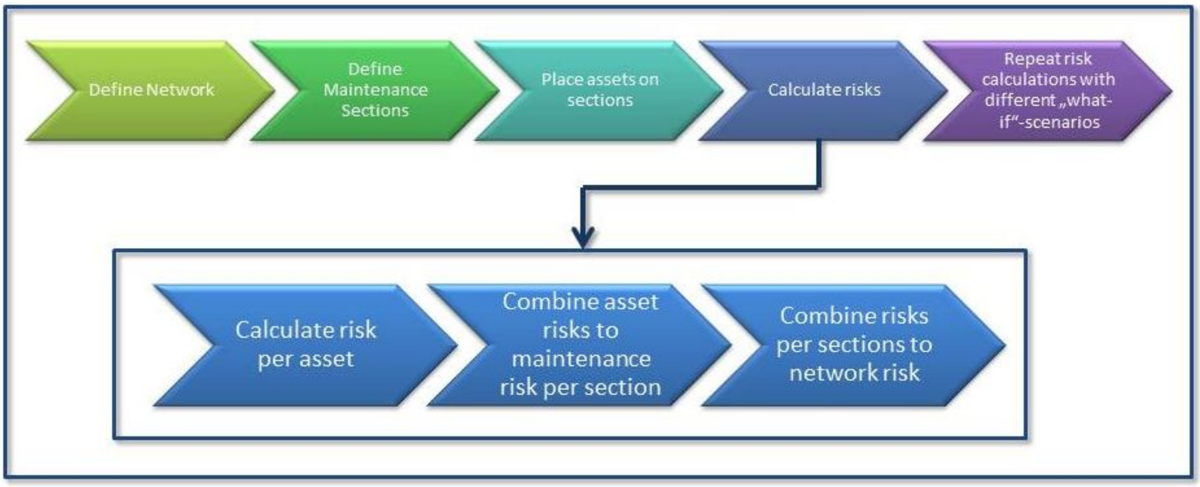

Figure 5: General workflow of the X-ARA tool and workflow of risk calculation

The X-ARA Tool is complemented by a user guide that explains the hardware and software requirements, explains the installation of the tool and gives a detailed description of the functions of the tool including export of results.

The X-ARA Tool is provided as-is, further support is not covered in the project.

D3.3 X-ARA Tool	• Free standing software Tool • Demonstration data set
M2.1 Risk Modelling Methodology	• Description of prototype implementation in commercial asset management software
D4.2 Implementation and User Guidance Document	• Requirements and Installation of the X-ARA Tool • User guide to the features of the X-ARA Tool • Import of Network and Asset data • Export of results • Benefits from the X-ARA Tool

5 Dissemination

The dissemination of the project results started already during the project execution. The general approach of X-ARA has been presented at the EMS D-A-CH meeting (an annual meeting of experts and researchers in the field of infrastructure asset management of the German speaking countries Austria, Germany and Switzerland) in March 2015 in Neuchatel.

Results of the first workpackage (the desk study) were presented at the IABSE conference in Geneva in September 2015. At the IASBE, the risk framework has been presented as well in another session.

The implementation of the risk framework into dTIMS has been presented at the Viagroup European user conference where many users of dTIMS participated (October 2015).

A conference paper has been accepted for the Transport Research Arena (TRA) conference in Warsaw in April 2016, where an overview poster will be presented.

An abstract for the World conference on pavement and asset management (WCPAM 2017) in Milan has been submitted.

All publications and reports produced in the project are hosted at the X-ARA website www.x-ara.net.

The X-ARA Tool together with a demonstration network dataset will be hosted on the X-ARA website as well.

A final demonstration workshop together with the PEB is to be held in May 2016.

D4.1 Dissemination and Education program	• Presentation of risk modelling approach • Presentation of the X-ARA Tool • Practical information on an example
Website www.x-ara.net	• All deliverables • All presentations and conference papers • X-ARA Tool with demo dataset
Presentations and Publications	• Presentation at EMS_D-A-CH (in German) • 2 Papers at IABSE 2015 • 2 Presentations at the IABSE 2015 • Presentation at ViaGroup European User Conference 2015 • 1 Paper at TRA 2016 • 1 Poster at TRA 2016

6 Conclusions

The X-ARA project has successfully demonstrated an approach to implement risk assessment into transport infrastructure asset management. The framework is based on available asset condition data and introduces the concept of risk on the network level.

The approach was practically implemented using commercial asset management software as well as a free standing software tool, the “X-ARA-Tool” developed within the project. Depending on the available resources, a potential user could start to work with the X-ARA tool to explore the concepts developed in X-ARA. To fully exploit the risk assessment approach it would be beneficial to implement the framework into an asset management system already in use as the maintenance planning and condition degradation over time is not implemented in the tool.

The condition indicators defined for each asset type were taken from literature and/or best practice. They can be adapted by the specific user. The sensitivity of the asset to high level influencing factors has to be determined and given as attribute to each asset. This provides the availability to adjust the procedure to the given local situation. Thus each NRA can use the proposed approach and framework using the given experience and the asset management systems currently in use.

The step forward from condition monitoring and derived maintenance strategies to the inclusion of the concept of risk and consequences in the case of failure has the potential to optimize the allocation of maintenance budget.

X-ARA uses a cross-asset management approach based on different asset types on so-called maintenance sections (homogenous road sections) and all asset types contribute to the total risk of a section. The cross-asset consideration is another step to find the most sensitive or vulnerable part of the network.

It has to be kept in mind that the approach is data-driven or even “data hungry” and needs a thorough organisation of network and asset condition data, all location-referenced to an underlying road network. But this is the foundation for all cross-asset management activities and for several asset types (pavements, bridges), time series of condition data is already available at most road operators. From the interviews with the road operators we learned that the status of condition data for other assets like drainage and road furniture is worked on and to be improved soon. This will then make the risk management approach fully exploitable.

7 Acknowledgement

The research presented in this report was carried out as part of the CEDR Transnational Road Research Programme Call 2013. The funding for the research was provided by the national road administrations of Denmark, Germany, Ireland, Netherlands, UK and Slovenia.