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X-ARA

Cross-asset risk assessment

Risk modelling methodology

Milestone M2.1

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

Milestone report ”M2.1 Risk modelling methodology”

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Executive summary

This report covers the findings concerning the risk framework (Deliverable 1.2), that has been developed in the course of workpackage 1, and the findings concerning the full risk modelling, that has been developed in the course of workpackage 2.

The report covers the topics input data, high-level influence factors and risk modelling. The risk tool that will be developed in X-ARA serves two main purposes: 1) to establish the relative risk across a network. 2) to enable the user to work with "what-if" scenarios to determine the change of the risk according to a scenario that deviates from the baseline scenario. The output of the tool will be a map showing "heat maps" (i.e. a colouring scheme) of the network that visually represents the overall maintenance risk for each section and therefore allows a visual comparison of sections.

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

The assets considered in the risk tool are pavement, structures (bridges and retaining walls), tunnels, road furniture, drainage and geotechnical assets. For each asset category, 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 Three categories are proposed for each high level influencing factor: '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) will be assessed and cumulated on the maintenance section. Following up, for each maintenance section, an overall risk score will be calculated to combine the asset specific risks using different transformation laws.

The next steps to be taken in the project are the implementation of the risk modelling approach into the X-ARA-tool by using the prototype in the course of workpackage 3. In this prototype, the risk matrices and the weighting functions have been developed and adjusted. Transformation laws for combining asset specific risks have been verified and adjusted if necessary. High-level influencing factors have been investigated concerning applicability and consequences.

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. Our approach will 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 resulting model takes into account high-level external variable factors affecting the different assets in an ageing road infrastructure:

Climate Change	Asset performance	Funding/politics
Safety regulations	Network sensitivity	

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 research is related to the 'real world' by the use of a Reference Project drawn upon NRA data, but the output methodology and model are generic and adaptable by different NRAs, under the auspices of CEDR, using their own local data and parameters. The assets themselves as well as 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 guidelines which we will provide.

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, we believe it is necessary to consider 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** needs to be based on real, available and affordable data, and the software is independent of any proprietary database or software platform. Risk-specific effects on safety, operation, and traffic, of high- to low- or non-coordinated maintenance activities are considered, but new construction programmes (schemes) are excluded. A NRA will be 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 can 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 provides a description of the implementation of the risk modelling approach into a prototype using commercially available asset management software.

Development of the risk modelling methodology is the core part of workpackage WP2. As the methodology is described in detail in D1.2+D2.1, the milestone report focuses on the implementation of the prototype.

The risk considered in the report 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 high level influencing factors
- The risk for the road operator to provide users with significantly unsatisfying services after some unexpected 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.

2 X-ARA-prototype

The input data framework, the high level influencing factors, the risk framework and of course the whole risk modelling methodology was implemented into the commercial asset management tool dTIMS™ (version 9.0) to generate a prototype for testing and for quality control of the planned X-ARA tool. dTIMS™ is an open asset management decision support tool, which enables the user to define the database structure as well as calculation procedures individually. Thus, this software was selected to define the X-ARA prototype. For the implementation of the models the following tasks have been carried out in dTIMS™:

- Definition of database structure subject to the input data framework
- Import of prototype data
- Implementation of risk matrixes
- Implementation of calculation procedures
- Definition of reports

Details on the risk matrices and the calculation procedures are to be found in the Deliverable D1.2+D2.2 “Risk framework and modelling specifications” and will not be described in this document.

The commercial software, which has been used for the prototype, provides a graphical, map based user interface that allows the visualisation of the road network, the underlying data and the calculated values (risk per maintenance section).

For the demonstrator, three network sections and their according asset data have been integrated into the database.

The following screenshots give an overview of the dTIMS X-ARA prototype. In the following Figure 1 the database structure with the different tables of the different assets can been seen on the left side (under dTIMS objects). The map shows the prototype network with different types of road.

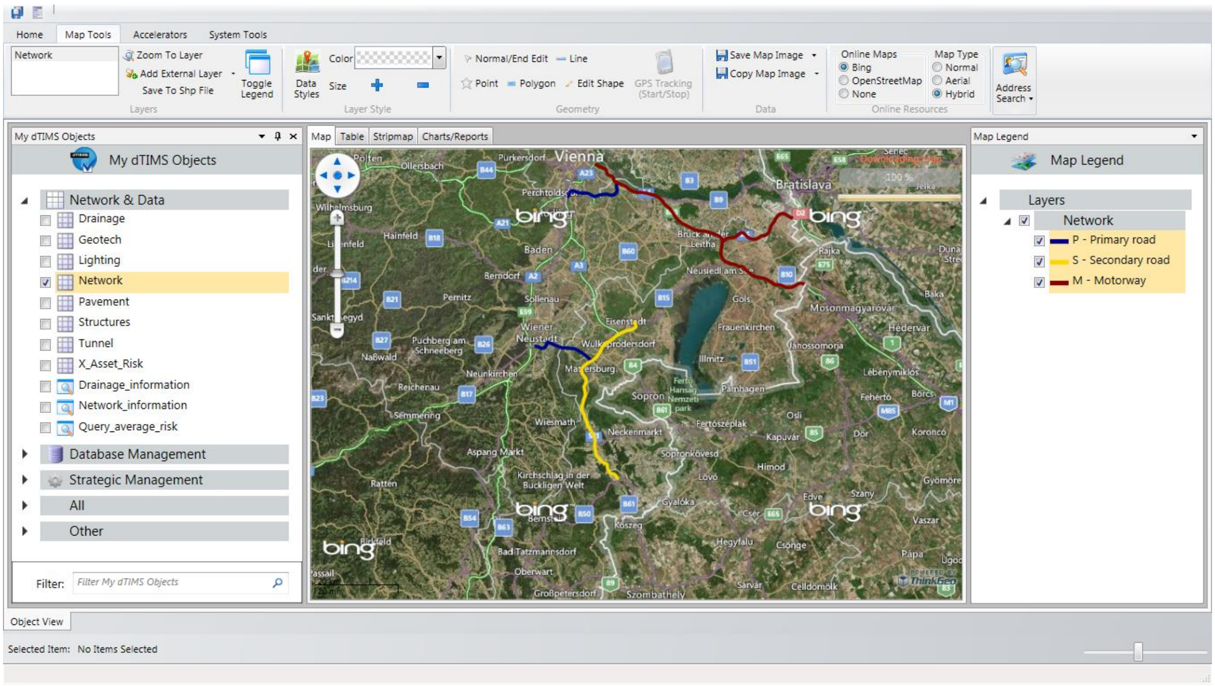

Figure 1: Database structure (dTIMS X-ARA-prototype).

Figure 2 shows the management of data within the system. Each single data set is defined by the location and different attributes, which are used to describe the properties (condition, age, area, etc.) of the selected asset. A list of attributes for each single asset as well as for the network data (maintenance sections) can be taken from the Deliverable D1.2+D2.2 “Risk framework and modelling specifications”.

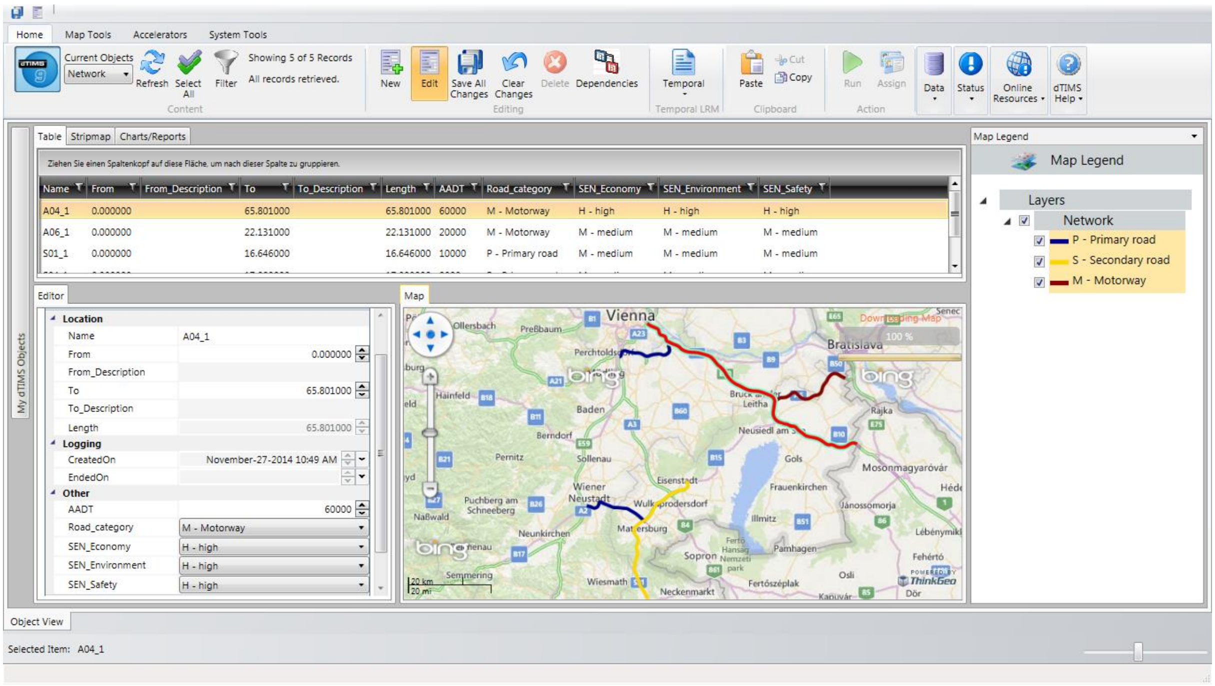

Figure 2: Data management (dTIMS X-ARA-prototype).

The high flexibility of dTIMS enables the user to implement different types of calculations into an algorithm, including formula and cross tab transformations. Cross tab transformations, as seen in the following Figure 3 and Figure 4, have been used to define the risk matrixes, which are described and listed in the Deliverable D1.2+D2.2 “Risk framework and modelling specifications”.

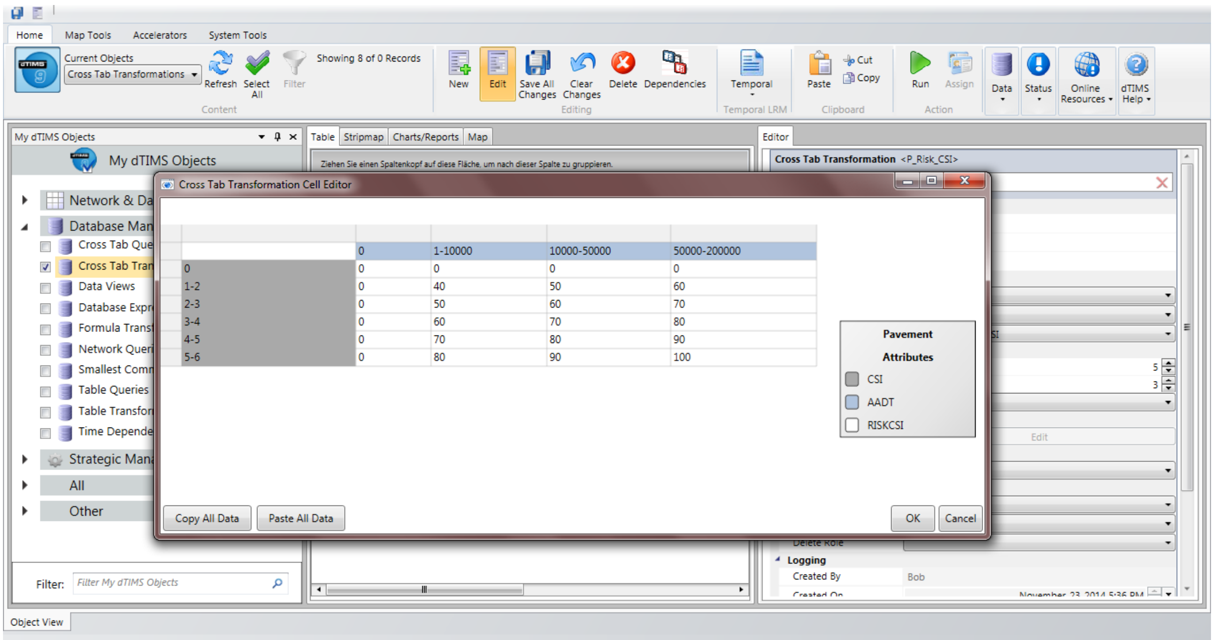

Figure 3: Risk modelling, cross tab transformation CSI (dTIMS X-ARA-prototype).

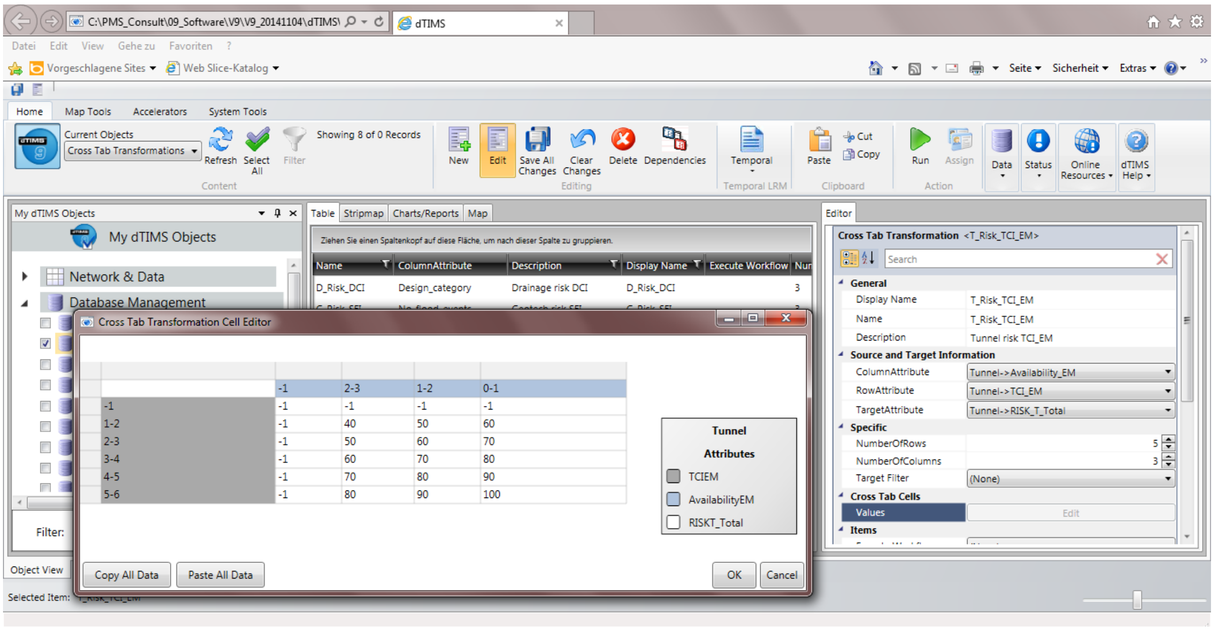

Figure 4: Risk modelling, cross tab transformation TCI (dTIMS X-ARA-prototype)

Use of defined expressions, which can be seen in the following Figure 5, enables to calculate combined parameters like the total risk of the pavements or the structures. In addition, different expressions will be used to calculate the values of the what-if-scenarios. The results of such an calculation will be stored in target attributes, so that the results can be used either for reporting or for any following up calculation (e.g. total risk of the network).

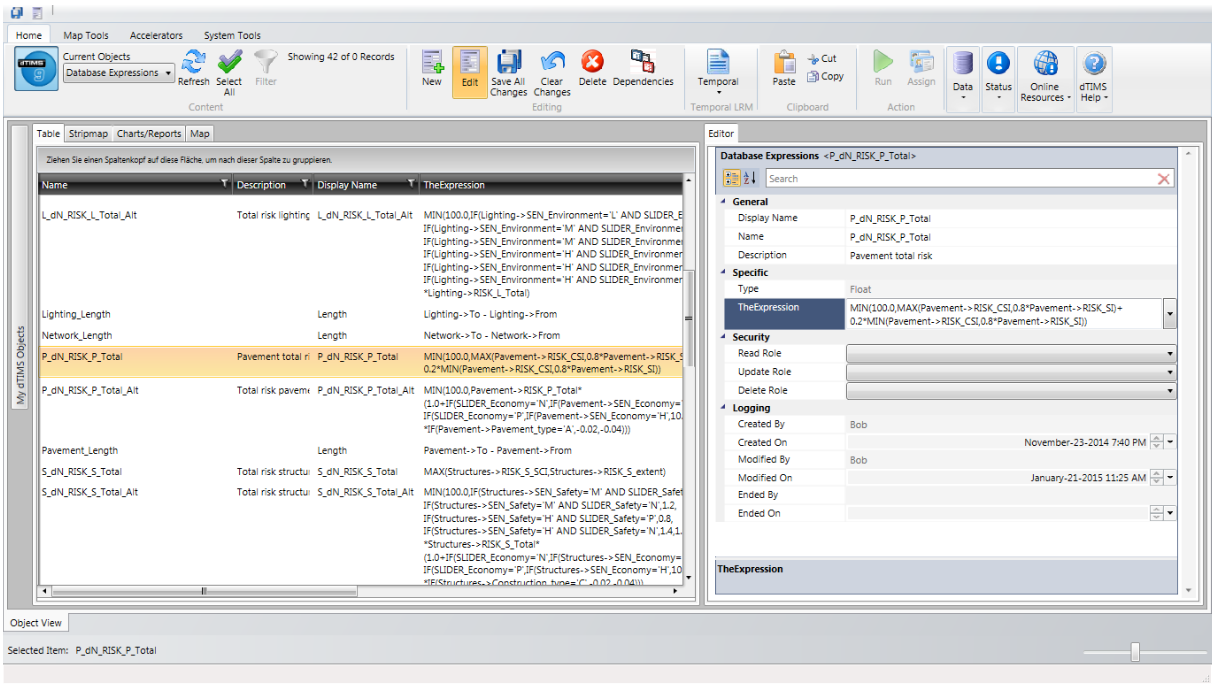

Figure 5: Risk modelling, use of defined expressions (dTIMS X-ARA-prototype)

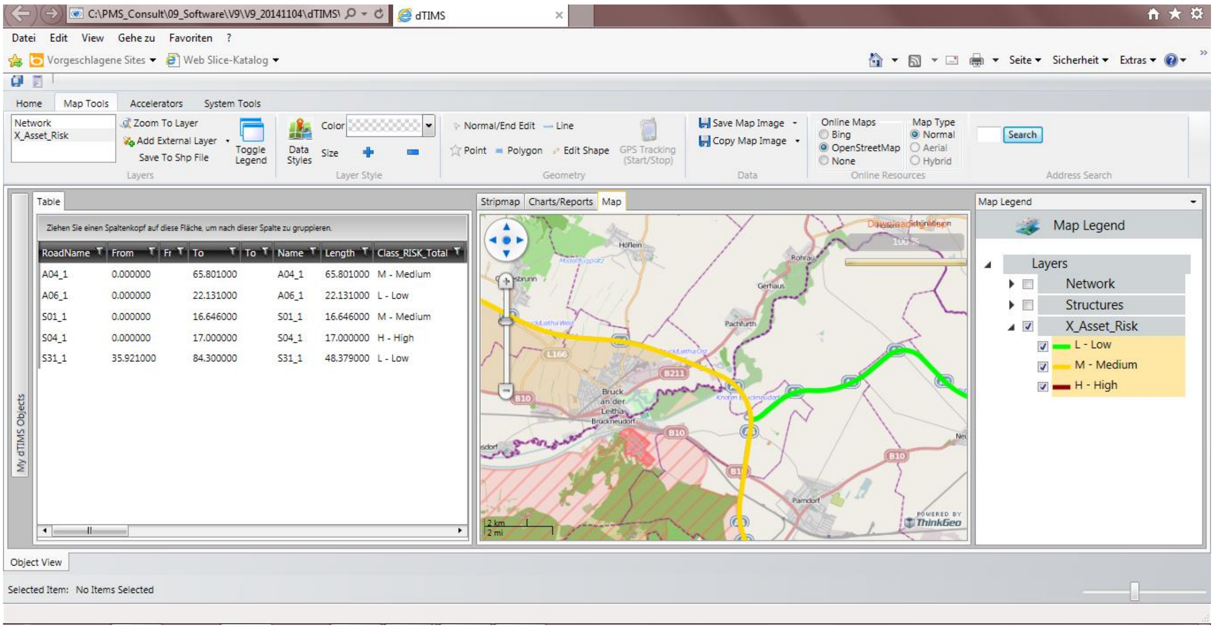

Figure 6: Results (dTIMS X-ARA-prototype)

As an output of the calculation algorithm, which has been implemented into the dTIMS prototype, the asset specific risk on each element (asset) as well as the total risk of each maintenance section (definition see Deliverable D1.2+D2.2 “Risk framework and modelling specifications”) can be displayed in tables and on the map (see Figure 6). A description of the different results can be taken from the following chapter.

3 Results

3.1 Risk quality

The results of the calculation procedure represent the risk quality in 3 different categories and not as an absolute number. As described in Deliverable D1.2+D2.1 “Risk framework and modelling specifications”, the risk scale from 0 to 100 will be subdivided into three qualitative risk categories as follows (see Table 1):

Table 1: Risk classification within X-ARA

Maintenance risk scale	Maintenance risk categories
[0-60)	Low
[60-90)	Medium
[90-100]	High

This scale is unified for all types of risk in the whole project, on asset level as well as on maintenance section or network level. Thus, a comparison of different risks on different assets is possible as well as the combination of asset specific risk to a cross asset risk framework.

3.2 Type of results

Based on this classification the results can be prepared for different purposes and for different end-users (technician, manager, politician or decision maker). Independently from the group of users, the results can be categorized as follows:

- Maintenance section specific results:
  - Risk tables of asset specific risk
  - Risk tables of total (cross asset) risk
  - Risk maps of asset specific risk
  - Risk maps of total (cross asset) risk (example, see Figure 7)

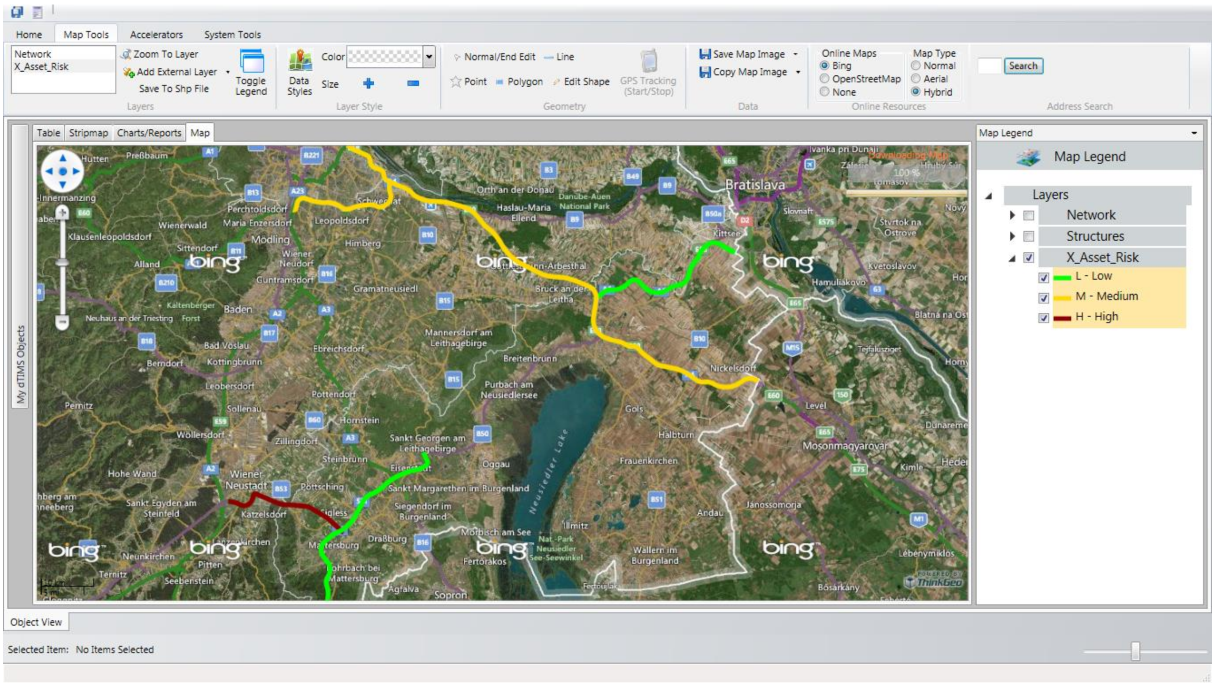

Figure 7: Map with maintenance section total risk categories (dTIMS X-ARA-prototype).

- Network level results:
  - Risk class distribution of asset specific risk
  - Risk class distribution of total (cross asset) risk (see Figure 8)
  - Average risk of asset specific risk
  - Average risk of total (cross asset) risk (see Figure 8)

The results are presented as heat maps as shown in Figure 7. This allows investigating the spatial relation between the different sections. For the network level and the comparison of what-if scenarios, a report with bar charts (see Figure 8) has shown to be helpful.

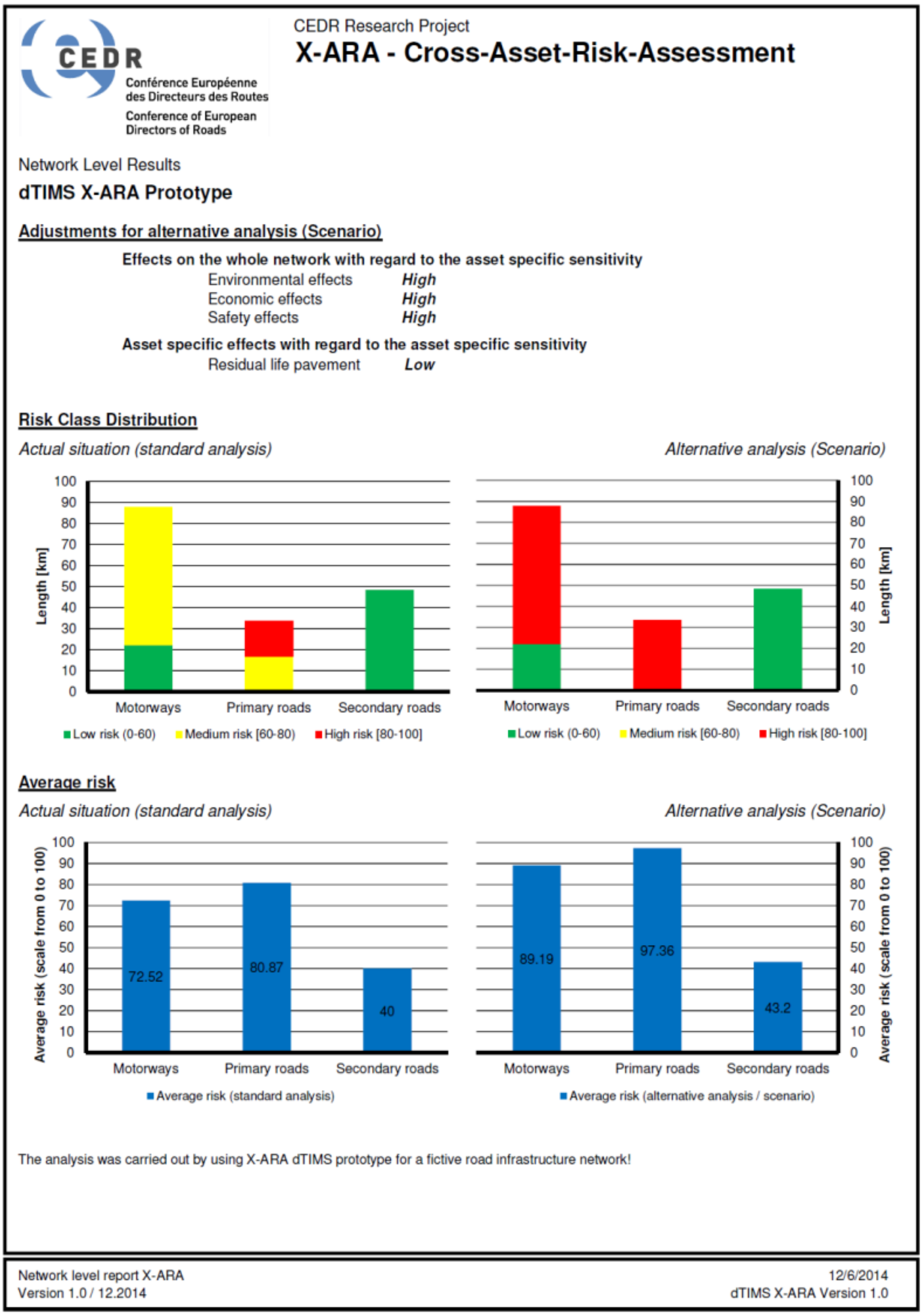

Figure 8: Network level risk reporting (dTIMS X-ARA-prototype).

4 Discussion and Outlook

The implementation of a prototype in commercial asset management software was successful. The software “dTIMS” was used for this. All asset types and their according condition indicators and all high-level influencing factors have been integrated in the prototype. In this prototype, the risk matrices and the weighting functions were studied and adjusted. The transformation laws could be verified and adjusted where necessary. After the prototype has shown to work satisfactorily, the implementation of the standalone X-ARA tool starts in WP3.

A calibration of the risk factors and the underlying models will be carried out within the testing phase of the X-ARA-tool prototype in WP3 and during the practical application of the tool as a part of WP4.

5 Acknowledgement

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6 References

[1] La Torre, F. et. al., COST 354 WP 2 "Selection and assessment of individual performance indicators" – Report, 2007

[2] ESRI Shapefile Technical Description, http://www.esri.com/library/whitepapers/pdfs/shapefile.pdf, retrieved 2014-11-06

[3] EVITA - Effective asset management, Deliverable D3.1- Report on recommended E-KPIs; August 2012

[4] Mian, J.F., Whittlestone, A.P., Patterson, D., and Rudrum, D.M. “A Risk-Based Approach for the Assessment and Management of Infrastructure Assets”, Proceedings of the Asset Management Conference 2011, IET and IAM, 2011

[5] Highways Agency, “Highways Agency standards Volume 1”, SD15/03 and HD43/04.

[6] Highways Agency, “BE11/94 - Volume 3 Highway Structures: Inspection and Maintenance, Section 1 Inspection Part 4”, BD 63/07

[7] ISO 31000: 2009. Risk management. ISO standard, 2009

[8] CEDR road categorization

[9] BE11/94 Bridge inspection standard

[10] Institute of Lighting Professionals. ILP TR22, visual condition guidance, UK, 2012

[11] RVS 13.03.41 – Straßentunnel – Baulich Konstruktive Teile (Road tunnel – constructive elements). FSV, Austrian road research association, Vienna 2013

[12] RVS 13.03.41 – Straßentunnel – Betriebs- und Sicherheitseinrichtungen (Road tunnel – operational and safety equipment). FSV, Austrian road research association, Vienna 2014