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X-ARA

Cross-asset risk assessment

D4.2 - Implementation and User Guidance Document Risk tool X-ARA

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Cross-asset risk assessment

D4.2 – Implementation and User Guidance Document Risk tool X-ARA

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Executive summary

Drawing on experience of assets in our working group and specialist literature, we have clustered knowledge into a tool and checked that the related methodology can work.

This document, developed in the course of Work Package 4 (Deliverable 4.2), provides Users' guidance on how to set-up the tool and run the X-ARA application.

It provides as well to the business operators, i.e. asset manager or decision maker, practical guidance on how to use the application, presenting the benefits that can be derived from using the X-ARA Tool.

It draws on the Draft User Guidance document Risk tool X-ARA (Deliverable 3.2), that has been developed in the course of Work Package 3, and the findings concerning the full risk modelling (Deliverable 2.1), developed in the course of Work Package 2 of the X-ARA project.

This Implementation and User Guidance Document will be the baseline to the trainees who will follow the Education/ Disseminating Program.

1 Introduction

1.1 Introduction to 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 document

The Implementation and User Guidance Document is made of three parts:

- **How to configure the IT Tool**, designed for an IT administrator, as a prerequisite to using the application;
- **How to run the X-ARA application**, to be used by business operators, in particular the asset manager.
  It comprises:
  - Overview of the application;
  - How to log in;
  - How to load a network
  - How to use the Map screen
  - A description of the asset categories and their attributes
  - Exporting/ importing data
  - Session viewers and calculation
  - Results and reporting
- **How to benefit from the X-ARA Tool,** as a guidance of the business operators, i.e. asset manager or decision maker on:
  - what the user might expect as output from the tool;
  - what the tool is able to deliver; and
  - what kind of issues can be dealt with the tool.

  with a focus on workflow and interpretation of results.

2 Configuration of the IT Tool

2.1 Introduction

The X-ARA Risk Tool is a software tool to model and assess the strategic risks facing a highway network and the major assets on it.

The X-ARA Risk Tool is what is known as a “client/server” application in that an executable program carries out the processing of the tool, (“client”), and stores its data in a separate database (“server”). The X-ARA Risk Tool is designed to run on an individual’s PC and therefore both the “client” and “server” parts operate on the same PC.

The X-ARA Risk Tool is a free-standing .NET application compiled as an .exe file. It should be loaded to a directory with its full set of companion files (configuration, etc.).

It makes use of a database to store its data and results, and this is hosted in a local copy of SQL*Server, (by local, it means on the same host PC as the X-ARA Risk Tool), and SQL*Server Express is suitable for use.

A set-up script is provided with the X-ARA Risk Tool to set up the database and its tables, including system attributes. (See “XaraInit.txt”).

Make a copy of the overall application (directory and files) and keep a back-up copy untouched.

2.2 Basic Client Configuration

The X-ARA Risk Tool is a standard .NET executable program file and requires .Net Framework V4.5 on the PC.

The X-ARA Risk Tool “client” should be copied into a discrete, single directory, as it is accompanied by configuration files and two sub-directories Whilst one of the sub-directories is for temporary files used by the X-ARA Risk Tool, the other is the location where the X-ARA Risk Tool expects to find background maps supplied by the user.

The file “Xara_UI.exe.config” is of particular importance as this file configures the executable program, including the database connection strings. The structure and contents of this file are described below.

2.3 Basic Server Configuration

2.3.1 Hardware

Data for the X-ARA Risk Tool is stored in a relational database that is SQL*Server running as a service on the same PC as the executable “client”. Whilst there are many versions of SQL*Server available, the SQL*Server Express 2012 (64bit) is the version recommended for use with the X-ARA Risk Tool (and is the version that the X-ARA Risk Tool has been tested with as the version for the same PC).

The SQL*Server Management Studio 2012 should also be installed in the PC so the user is able to configure SQL*Server for use with the X-ARA Risk Tool. The basic installation of SQL*Server Express 2012 (64bit) and SQL*Server Management Studio 2012 should be

carried out in accordance with the standard installation scripts, etc. supplied by Microsoft and these are not described in this document.

The X-ARA application requires the following hardware configuration to run.
The minimum configuration is published by Microsoft to run Sequel Server Management Studio

The minimum and recommended configurations of the PC are detailed in Table 1 below.

Table 1 : PC configuration

Component	Minimum	Recommended
Central Unit	Intel I5 (64 bits)	Intel I7 (64 bits)
Hard Disk	Depends on the size of the data base	Depends on the size of the data base
RAM Memory	16 Gb	32 Gb
Screen/Video card	17/ 20" screen Display resolution 1280 x 1024 p.	22/ 24" screen Display resolution 1920 x 1080p.
OS	Windows 7 (64 bits)	Windows 8 or 10

Note: hardware is not part of the X-ARA Tool supply and is to be made available by the Client Set-up

The *SQL*Server Management Studio 2012* should be installed so that the user can manage all aspects of the SQL*Server database service using the "Windows Authentication" login – this is a form of login to the database via SQL*Server Management Studio that does not require a user to be registered within the database (see Figure 1 below).

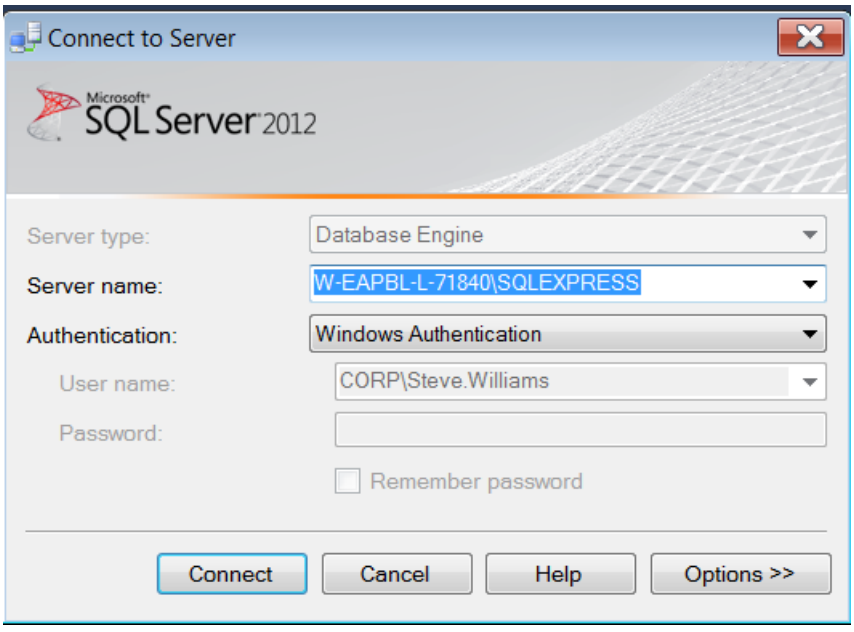


Figure 1 - Example of Login Screen for "Windows Authentication"

Figure 1 above shows:

- Server Type: That SQL*Server Management Studio is being used to manage the SQL*Server database service;
- Server Name: The name of the automatically installed instance of the SQL*Server database service. In this case this is made up of the name of the PC, ("W-EAPBL-L-71840") followed by the term "\SQLExpress";
- Authentication: "Windows Authentication" appears by default;
- User name: Not required/ can leave it blank – the example above shows the legacy of the previous user of this screen for specific user login to the SQL*Server database service;
- Password: Not required – it is only relevant when using a specific user login to the SQL*Server database service;

Once installed, SQL*Server Express normally runs as a service that is automatically started when the PC is started and shuts down when the PC is stopped. SQL*Server Management Studio is an application that interacts with the SQL*Server service to manage the contents of the database. However some actions (as detailed in 2.4.2) will require the user to stop and re-start the SQL*Server service manually and therefore the user must be able to access the "Services" tab in the Windows "Task Manager".

*2.4 Setting Up SQL*Server for the X-ARA Tool*

Two areas of X-ARA Tool specific configuration must be carried out. These are:

- Setting up the X-ARA tables and their contents within the SQL*Server database instance, (do this first);
- Setting up a specific user for the X-ARA Tool to use to log into the SQL*Server database instance, (do this second).

Both are 'one-off' actions.

2.4.1 X-ARA Tables

Having logged into the SQL*Server database instance using SQL*Server Management Studio via the "Windows Authentication", the user should create a new database called "XARA". (Hint: Right click the mouse on "Tables" in "Object Explorer" and select "New").

Having created the blank "XARA" database, then open a "New Query" (the spelling of the XARA database name must be as set out here, without the normal hyphen). Copy and paste the contents of the file supplied with XARA called "XARADatabaseSetup.txt" into the new query window and then run it. ("XARADatabaseSetup.txt" contains all the table build, index build and inserts of the "fixed" data as a series of SQL commands and is a text file so an application like NotePad or Programmers File Editor can open it to enable the user to copy its contents out before pasting it into the query window).

2.4.2 X-ARA User

Following the one-off Windows Authentication to set it at the start, the X-ARA Tool requires a specific user to be set up using SQL*Server Management Studio and that user be granted

specific access rights to X-ARA. In addition the configuration file of the X-ARA Tool needs to be set with details of this specific user.

Having logged into the SQL*Server database instance using SQL*Server Management Studio via the “Windows Authentication” the user should:

- Set-up a new user with a password (Hint: Right click the mouse on “Security”, “Logins” in “Object Explorer” and select “New”).
- Within Security on the XARA database tables, set up the above user to be able to have “SQL user with login” (Hint: Right click the mouse on “Database”, “XARA”, “Security” and click on “New User”). Make user they login with a password;
- Access this new user and check they have database role membership set as in Figure 2. below, resetting them as required. (Hint: click on “Database”, ”XARA”, “Security”, “Users”, “{name of XARA user}” and select the “membership” tab in the window that pops up”).

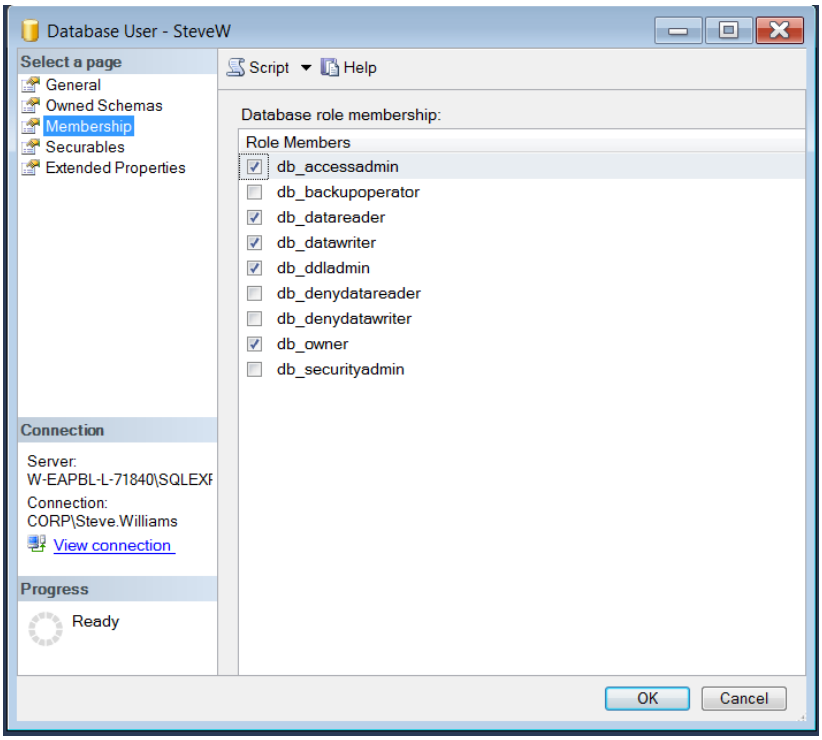


Figure 2 - XARA User Security Settings

(User is SteveW in this example)

The actions to be carried out are the following ones:

One should now exit SQL*Server Management Studio.

The SQL*Server database service now needs to be stopped and restarted. Using “Task Manager” and selecting the tab “Services” and press the “Services” button at the bottom right of the services screen.

Within the new services list screen window find the service “MSSQL$SQLEXPRESS” which should be currently shown as “Started”, (meaning the database service is running), and also be set to “Automatic”, (to automatically start when the PC is started). Right click the mouse on the service “MSSQL$SQLEXPRESS” and select “Stop service”. After the service is

stopped, (shown by services list screen window updating), Right click the mouse on the service “MSSQL$SQLEXPRESS” and select “Start”.

The service should start, (shown by services list screen window updating).

Task Manager can now be closed.

In addition to the above actions using SQL*Server Management Studio and Task Manager, the contents of the X-ARA configuration file “Xara_UI.exe.config” need setting as follows:

- Open “Xara_UI.exe.config” with a suitable text editor that is able to edit XML files, such as Notepad or Programmers File Editor (PFE);
- Within <Xara_UI.My.MySettings> set the **VALUE** of the setting named “DB_IP” as the server name (see login window);
- Within <Xara_UI.My.MySettings> set the **VALUE** of the setting named “DB_Name” as “XARA”;
- Within <Xara_UI.My.MySettings> set the **VALUE** of the setting named “DB_User” as the name of the XARA user established above;
- Within <Xara_UI.My.MySettings> set the **VALUE** of the setting named “DB_Pass” as the password for the XARA user established above.
- Within <Xara_UI.My.MySettings> set the **VALUE** of the setting named “DBConn” as the connection string as follows:

  Provider=sqloledb;Server={server name};Database=XARA;User Id={XARAUser}”;Password={XARAUserPassword};

  where {*server name*} is the server name set in the value of “DB_IP”, {*XARAUser*} is the XARA user name set in the value of “DB_User” and {*XARAUserPassword*} is the password for the XARA user set in “DB_Pass”.

- Save the file.

Do not alter anything else in the configuration file.

If you do, the application may run unpredictably. In that case, un-install the application and start gain the procedure.

An example of the settings used for XARA is shown in Figure 3 below.

```
<userSettings>
    <Xara_UI.My.MySettings>
      <setting name="DB_IP" serializeAs="String">
        <value>W-EAPBL-L-71840\SQLEXPRESS</value>
      </setting>
      <setting name="DB_Name" serializeAs="String">
        <value>XARA</value>
      </setting>
      <setting name="DB_User" serializeAs="String">
        <value>SteveW</value>
      </setting>
      <setting name="DB_Pass" serializeAs="String">
        <value>Isle0fHarris</value>
      </setting>
      <setting name="ShapeTempFolderName" serializeAs="String">
        <value>Temp</value>
      </setting>
      <setting name="MaxSQLString" serializeAs="String">
        <value>30000</value>
      </setting>
      <setting name="BaseMaps" serializeAs="String">
        <value>BaseMaps</value>
      </setting>
      <setting name="DBConn" serializeAs="String">
        <value>Provider=sqloledb;Server=W-EAPBL-L-71840\SQLEXPRESS;Database=XARA;User Id=SteveW;Password=Isle0fHarris;</value>
      </setting>
      <setting name="SliderEnv" serializeAs="String">
        <value>2</value>
      </setting>
      <setting name="SliderEco" serializeAs="String">
        <value>2</value>
      </setting>
      <setting name="SliderSaf" serializeAs="String">
        <value>2</value>
      </setting>
    </Xara_UI.My.MySettings>
  </userSettings>
```

--

Figure 3 - Configuration file example

setting specific to the example are shown in Bold Italic

3 Running the X-ARA application

3.1 Introduction

The X-ARA Risk Tool is a software tool to model and assess the strategic risks facing a highway network and the major assets on it. As such it is intended to be used for examining scenarios of changing economic pressures, environmental factors and alterations to safety regimes, and how they impact as a risk to a highway network. It is not a detailed tool for the asset management of individual carriageways or highway assets.

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 calculation of risk on a road infrastructure network (network and assets). This document relates the model to the ‘real world’ by drawing upon NRA data, but 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 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.

The X-ARA Risk Tool achieves this by enabling a National Roads Authority (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 is necessary to consider a bottom-up approach 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 based on industry standard tools. It considers the risk-specific effects on safety, operation, and traffic, of high- to-low or non-coordinated maintenance activities but excludes new construction programmes (schemes). 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.

The risk considered is "the risk for the road Operator” to either perform a non-cost-efficient maintenance on his network, or to provide unsatisfying services to the other stakeholders (road 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 would 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.

This maintenance risk modelling methodology itself is the core part of X-ARA Risk Tool. Its use is described in detail below and covers the following topics:

- How is the maintenance risk defined in general?
- How to define the maintenance risk for different types (classes) of asset?
- How does the risk model work?
- What will be the output of the risk assessment modelling?

The X-ARA Risk Tool has two main purposes:

- establish the relative maintenance risk across a network, taking into account the asset specific maintenance risk of different types of assets;
- enable the user to run “what-if” scenarios to determine the change of the risk according to a scenario that deviates from the baseline scenario.

3.2 Outline

The workflow when working with the X-ARA Risk tool is illustrated in Figure 4 below.

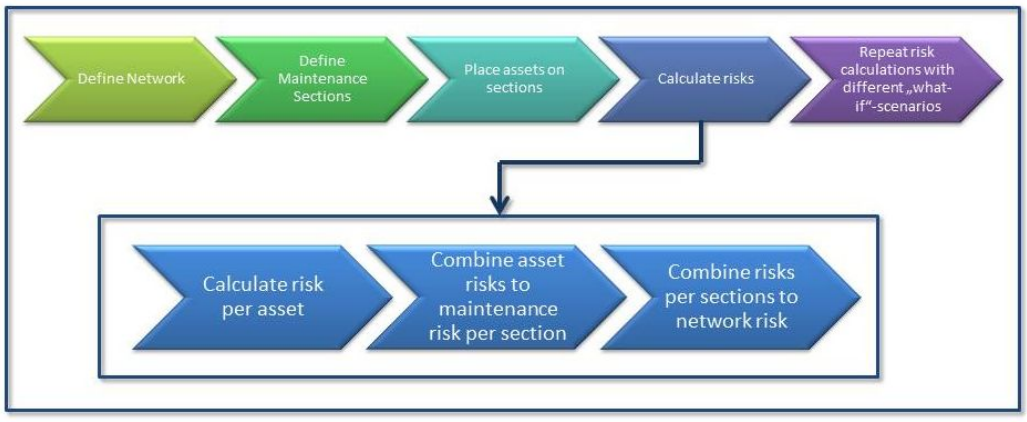


Figure 4 - General workflow of the X-ARA tool and workflow of risk calculation

3.2.1 Network

The first step is to define or load the road network that is to be assessed. All assets are related to the underlying network. The network holds the geometric information of the roads and is needed for the map view.

The X-ARA Risk Tool works based on a network of maintenance sections, and are termed "X-ARA sections" in this document. An X-ARA section can be defined as a section of the road network that has the same general homogeneous conditions (number of lanes, traffic count, sensitivities against different high level influencing factors, etc.). For each X-ARA section (which can be of constant and/or arbitrary length), a number of attributes has to be known. The number of attributes is fixed. These are:

- Unique identifier for each section;
- User measured length of the section;
- Annual Average Daily Traffic (AADT) of the section;
- Average number of lanes of the section;
- Class of the section – Either "Motorway", "Expressway" or "Ordinary Road ".

The user also is able to assign sensitivity factors to each X-ARA section in the range of "Low Sensitivity", "Medium Sensitivity", (the median default value), and "High Sensitivity" and the sensitivity factors are:

- Environmental Sensitivity Factor (EnvSF);
- Economic Sensitivity Factor (EcoSF);
- Safety Sensitivity Factor (SafSF);
- Network Sensitivity Factor (NetSF).

The user also assigns a "Network Situation" value to each X-ARA section of either "Flat", "Mountain" or "Urban", where "Flat" is the default value.

3.2.2 Assets

For the network level approach of X-ARA, a number of asset types (classes) were identified as the most relevant for the calculation of maintenance risk.

Six classes of assets can be assigned to a position along an X-ARA Section and they are:

- Pavement construction – either flexible (asphalt) or rigid (concrete);
- Structure or bridge – either concrete or other material;
- Geotechnical assets;
- Tunnel;
- Road Furniture;
- Drainage.

Each asset has a small number of attributes that are used to define the asset within the X-ARA Risk Tool and are used to determine the base risk of each asset.

The position of an asset is located by the kilometre range along the network section, and not by coordinates, though the asset's position can be set using the GIS mapping tools within the X-ARA Risk tool. It is important to realise that for the purposes of the X-ARA Risk Tool, an asset is not necessarily a single, real world asset but is a contiguous representation of one or more real world assets along a section, where the assets have the same attribution. For example the X-ARA Risk Tool does not model individual lighting points but instead regards them as a "lit section" of the same attributes in the "road furniture" class of assets. Similarly a "Tunnel" class asset is not an individual tunnel bore but represents a set of companion tunnel bores, (either in parallel or in sequence or both), with the same attributes.

The assets do not use attributes specific to a technical measurement of the asset, be it dimension or condition. For example Pavement Construction uses three attributes:

- Material Type: Two possible values of flexible (of bituminous construction) or rigid (of concrete construction) ;
- Comfort and Safety Index: Five possible values ranging from “Very high degree of comfort and safety” to “Very low degree of comfort and safety”;
- Structural Index: Five possible values ranging from “Very Good” to “Very Poor”.

This goes along with the concept of dimensionless indicators that are very common nowadays. If machine based indicators are used, a classification into 5 classes has to be made first. It is up to each user/road Operator to decide how their technical data on assets should be combined and then consistently classified in the asset value ranges of the X-ARA Risk Tool. Advice is given later in this document as to other existing technical documentation for specific asset classes that can guide countries.

3.2.3 Calculation

For the actual risk calculation, a methodology has been worked out. The general approach as well as the details, including an example risk calculation for a small network, are described in the document “D1.2+D2.1 Risk framework and modelling specifications” that is available from the X-ARA website.

Each run of the calculations against an X-ARA network and its assets is called a “session”. For a “session”, the part of the X-ARA Risk Tool that performs the calculations, (referred to as the “CalcEngine”), determines two sets of results for assets, X-ARA sections and the network.

The first is the “initial” set of risks and the second are the determined risks. The initial set are calculated based on the assumption that the overall Economic, Environmental and Safety factors representative of the whole network are set to a neutral value (“Standard”) before applying user-set overall Economic, Environmental and Safety factors representative of the whole network to calculate the determined risks.

The overall Economic, Environmental and Safety factors representative of the whole network can each be either “Negative”(N), “Standard”(S) or “Positive”(P) and are set globally by the user within the tool for each session. It is noted that these values can be reset and re-run in a session, overwriting the session’s determined risks.

The calculation first determines a Base Risk value for each asset using a fixed lookup based on the attributes assigned to each asset, (see section 10 below). It is noted that:

- Pavement Construction has two Base Risks which are separately “influenced” and then combined (see below);
- Both Structures and Tunnels lookup two interim Base Risks but these are combined to be a calculated Base Risk.
- Geotechnical assets, Road Furniture and Drainage have a single Base Risk.

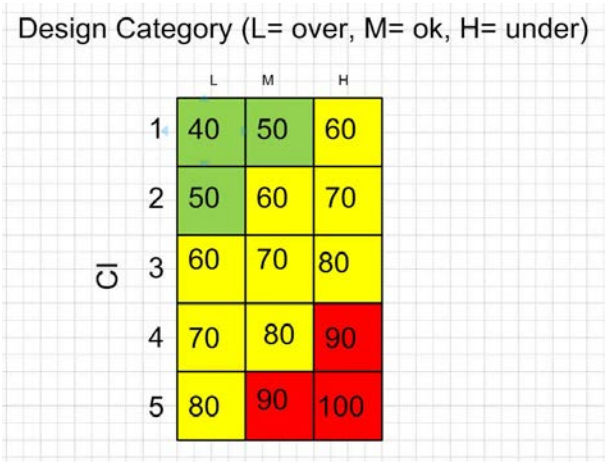


Figure 5 - Base Risk Lookup for Drainage

Each Base Risk is then modified by the influencing factors determined using a fixed lookup from a combination of the value of a Sensitivity Factor for the X-ARA section the asset is on and a user set value of the overall Economic, Environmental and Safety factors representative of the whole network, to make the IFRisk (**Figure 6**).

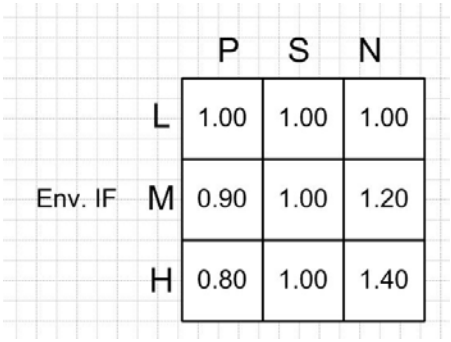


Figure 6 - IF Factor Lookup for Drainage

It should be noted that with the exception of Pavement Construction, each asset class is only influenced by one network section sensitivity factor (either EnvSF, EcoSF or SafSF). For example Tunnels are influenced by the EcoSF whilst road furniture by the SafSF. In the case of Pavement Construction, one Base Risk is influenced by the SafSF and the other by the EcoSF, before they are combined into a single calculated IF Risk.

The IFRisks of each asset class are then length weighted summed (LW) for each X-ARA section. The combined LW IFRisks of each asset class are then combined to give an overall X-ARA section risk. This combination is based on proportionate percentages per asset class, the percentages being set by a lookup based on the X-ARA section's Regional Situation (**Figure 7**).

Asset Type	Regional Situation (Attribute of X-ARA Section)		
	Flat	Mountain	Urban
Pavement	30	35	35
Drainage	10	5	5
Tunnel	15	15	15
Structures	25	30	35
Road Furniture	10	5	5
Geotech	10	10	5
Sum	100	100	100

Figure 7 - Regional Situation Percentages Lookup

If an asset type is not present at a particular section, then its weight is omitted and the weighted sum is scaled accordingly.

The overall X-ARA section Risk is then adjusted by the application of the section's NetSF. Finally the adjusted X-ARA sections risks are length weighted summed to determine a Whole Network Risk.

3.2.4 Results

The CalcEngine "saves" results as follows:

- For each asset:
  - Base risk value(s);
  - IFRisk value; - always neutral as sliders set-up in the X-ARA Tool
  - "Initial" LW risk; - after the sliders have been moved
  - Determined LW Risk.
- For each section:
  - Sum of LW Risk for Pavement Construction ("initial" and determined);
  - Sum of LW Risk for Structure ("initial" and determined);
  - Sum of LW Risk for Geotech ("initial" and determined);
  - Sum of LW Risk for Tunnel ("initial" and determined);
  - Sum of LW Risk for Road Furniture ("initial" and determined);
  - Sum of LW Risk for Drainage ("initial" and determined);
  - Overall X-ARA Section risk ("initial" and determined).
- For the network:
  - "Initial" network risk;
  - "Determined" network risk.

3.2.5 Suggested way of working for entering the Network and Assets

The following workflow is suggested:

- Either create a X-ARA network either from an existing CEDR network shapefile or the user's own network shapefile.
- Use the map screen to select multiple sections and edit the EnvSF, EcoSF, SafSF, NetSF and Regional Situation values.
- Using the map screen, add some assets (if it is a small network or has similar assets spanning whole sections). In case of large network or adding a big number of assets, we recommend to go through the CSV file (Ch. 3.7)
- Export the data to a CSV file.
- Edit the exported CSV file to amend the section attributes or to add assets or delete existing assets.
- Use reporting or re-export to check the data was entered properly and accepted by the XARA Risk Tool

Note: the application sometimes asks you "are you sure you want to do {an operation], e.g. "are you sure you want to create a drainage item".

- Answer "yes" enables
- Answer "no" stops it

3.3 Login

On starting the X-ARA Risk Tool the user is presented with a login screen where they can (**Figure 8**, **Figure 9**):

- Pick their name from the pull down list of users and "login" to start using the X-ARA Risk Tool;

OR

- register themselves as a user of the X-ARA Risk Tool so they can then pick their name from the pull down list of users and press "login" to start using the X-ARA Risk Tool;

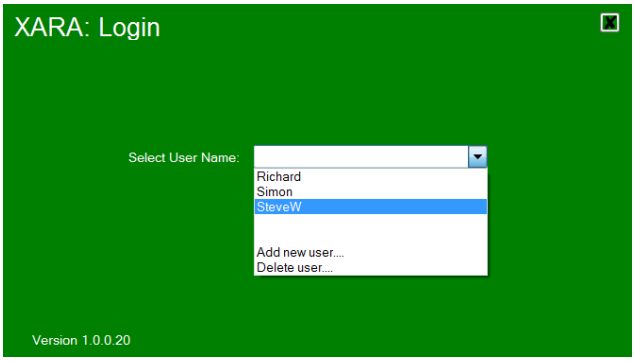


Figure 8 - Login Screen showing pull-down of users and new/delete user

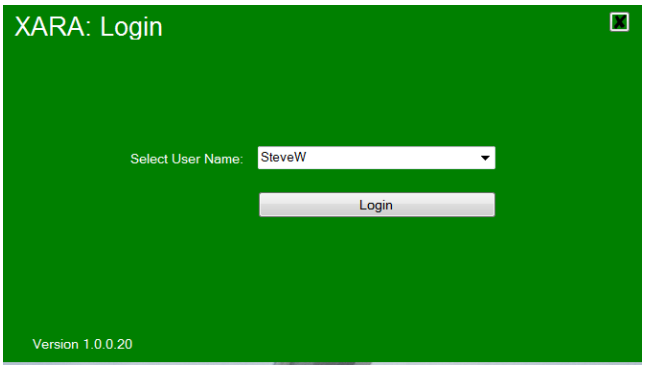


Figure 9 - Login Screen with User selected and Login Button

It is noted that the purpose of this “login” is not for security purposes, (there is no password), but is to identify who loaded what data and who ran which calculation sessions. All data are shared and visible to all users of the same X-ARA Risk Tool on a PC.

In case the application crashes, just start by logging in again.

3.4 Loading a Network

After login the session control screen, (Fig 10 below), is presented to the user, with a list of networks already loaded.

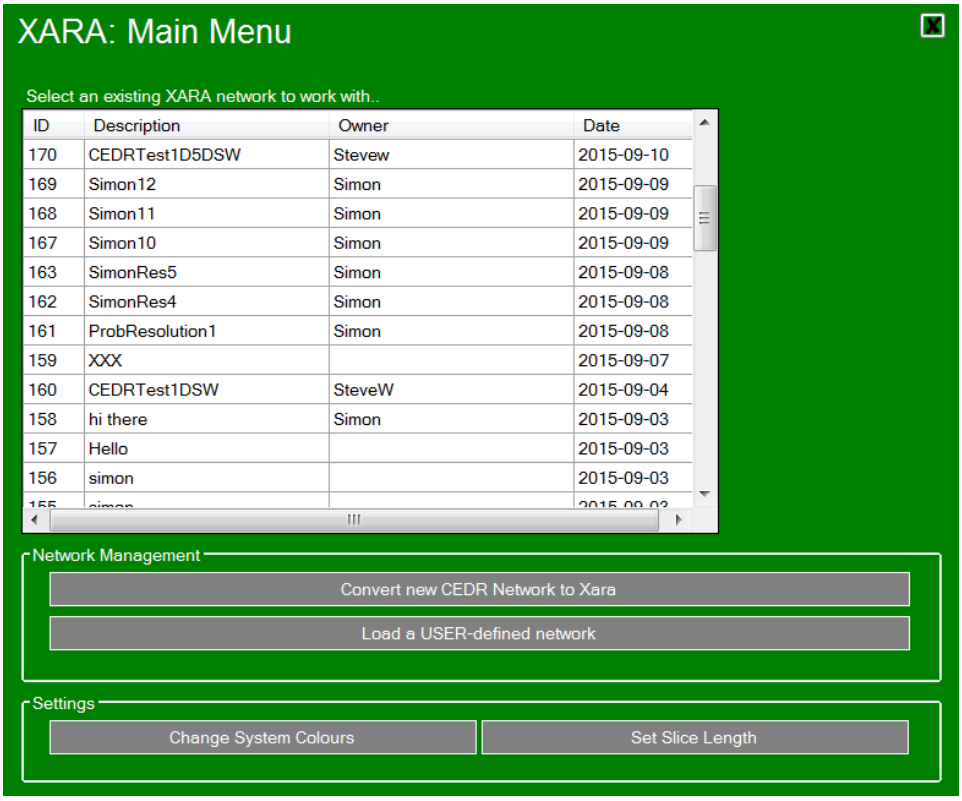


Figure 10 - Main Menu

The user can choose to load a new network, (and implicitly a new session), or to make use of an existing network and session shown in the list box. The user can also revise the network

sub-division length to a new value, the default being 10km, (see below), and can change the background colour for the screens, (I have chosen a middle green colour).

If using an existing network, select and double-click.
To create one, convert a CEDR network to X-ARA or create one from your local file.

Networks are loaded from an ESRI format shapefile which must be a polyline shapefile. Two sources of network are available:

- Created by sub-dividing up a CEDR network into smaller, user-defined lengths ("slices") to form a X-ARA network of X-ARA sections;
- Created from a user defined network where the user section is the X-ARA section;

3.4.1 From CEDR Network

The shapefile for a country's CEDR network can be obtained from CEDR representatives in the NRA, or from the PG Planning Group of CEDR. By default, it is a supplied as a polyline shapefile. The coordinates are in decimal degrees and represent longitude and latitude in the WSG84 projection.

The CEDR network files of the countries participating in the X-ARA project (Denmark, Germany, Ireland, Slovenia, The Netherlands and UK) will be provided with their network files as examples to run the application.

The CEDR network contains the following **attributes** used by the X-ARA Risk Tool:

- CEDR Label (the unique ID of the CEDR Logical Section – the attribute is called "SECREF" in the CEDR shapefile);
- AADT (the attribute is called "AADT" in the CEDR shapefile);
- Road Class (the attribute is called "RoadType" in the CEDR shapefile);
- Number of Lanes (the attribute is called "NoLanes" in the CEDR shapefile);
- User Measured Length (the attribute is called "Length" in the CEDR shapefile).

All other attributes can remain in the CEDR shapefile but are ignored by the X-ARA Risk Tool.

On loading, the CEDR network is sub-divided into a sequence of X-ARA sections, with a user defined length in km, the default value being 10km. Where a CEDR section is not an exact multiple of the user defined length then the CEDR section will be sub-divided into N parts, the first (N-1) X-ARA sections being of the user defined length and the Nth X-ARA section being the remaining length. For example, a 45 km CEDR section sub-divided using a user defined length of 10km will result in fourX-ARA sections of 10km and one of 5km.

After loading the user is asked in a pop-up window to **name the network**.

The resulting X-ARA network will have a unique network identifier (Network UID), creation date and owner, and each X-ARA section within it will have the following attributes:

- X-ARA Label - this is the CEDR label suffixed with "/1" for the first X-ARA section along that CEDR section, suffixed with "/2" for the second, etc.
- CEDR Label of the parent CEDR section (the unique ID of the CEDR Logical)
- AADT
- Road Category
- Number of Lanes

- Measured Length – this is either the user defined sub-division length or the remainder.

The original CEDR network specification had the following definitions for Road Category and these are inherited by X-ARA:

*"**Motorway:** A road of two carriageways, separated by a physical barrier for most of its length. All crossings are normally grade separated. No stopping and usually a minimum speed. Access is generally restricted to certain types of vehicle.*

***Expressway:** A national road or other high-speed road of one or two carriageways, with or without a physical barrier. Has some interaction with the normal network through high-quality interchanges (grade separated, at grade, roundabouts, etc.).*

***Ordinary:** All other roads"*

In 2015 the CEDR definition was changed to:

*"A **motorway** is a road that is part of the TEN-T network that comprises two carriageways, separated by a physical barrier for most of its length. All crossings are normally grade separated. No stopping and usually a minimum speed. Access is generally restricted to certain types of vehicle.*

*A **non-motorway** is a road that is not a motorway but is still a strategic road and is part of the TEN-T network."*

However the X-ARA Risk Tool needs to "create" X-ARA sections in accordance with the original specification. To retain compatibility with post-2015 CEDR network shapefile, the network loader looks at the number of lanes in non-motorway sections and sets the Road Class to "Expressway" where the number of lanes is >= 3.75, otherwise it is an Ordinary road.

3.4.2 From User Supplied Network

The user can also load its own network from an ESRI format polyline shapefile. However the data must pass validation before it will be saved in the database as X-ARA sections. In this case the user sections are not sub-divided so there will be one X-ARA section for each user section. The X-ARA sections will not be saved if the network fails validation, (an "all or nothing" pass strategy).

Each user section must consist of at least two points. These may be in any coordinate system the user wants to use, (i.e. OSGB36 for the UK).

Each user section MUST have the following attributes with the shown field names in the shapefile and only the permitted values:

- Section Reference: This must be a field called "SECREF" and is a character field of up to 20 characters. It must be populated – a null value is not permitted. It is also required to be unique.
- AADT: this must be a field called "AADT" and is a positive long integer;
- Road Category: this must be a field called "RoadType" and must have one of the following values:
  - "Motorway";
  - "Non-Motorway";

  - o “Expressway”;
  - o “Ordinary”.
- Number of Lanes: This must be a field called “NoLanes” and be a positive floating point number.
- Measure Length (in km): This must be a field called “Length” and be a positive floating point number.

The user is expected to create and populate these fields in their shapefile using a suitable GIS (such as ArcView). It is noted that other fields in the user supplied shapefile are ignored.

After loading, the user is asked in a pop-up window to name the network.

3.5 Map Screen

3.5.1 Using the Map Screen

Having either loaded a new network and session, or picked an existing network and session, the user is presented with the following in Figure 11 below. It is from this screen that the user can:

- Make a copy of the network and its asset data;
- Pan and zoom the map;
- Add, remove and render layers;
- Make the ends of the sections visible;
- Label the sections;
- Merge or split sections;
- Move assets on sections;
- Add assets;
- Select sections;
- Search for sections;
- Move to the calculation map screen.

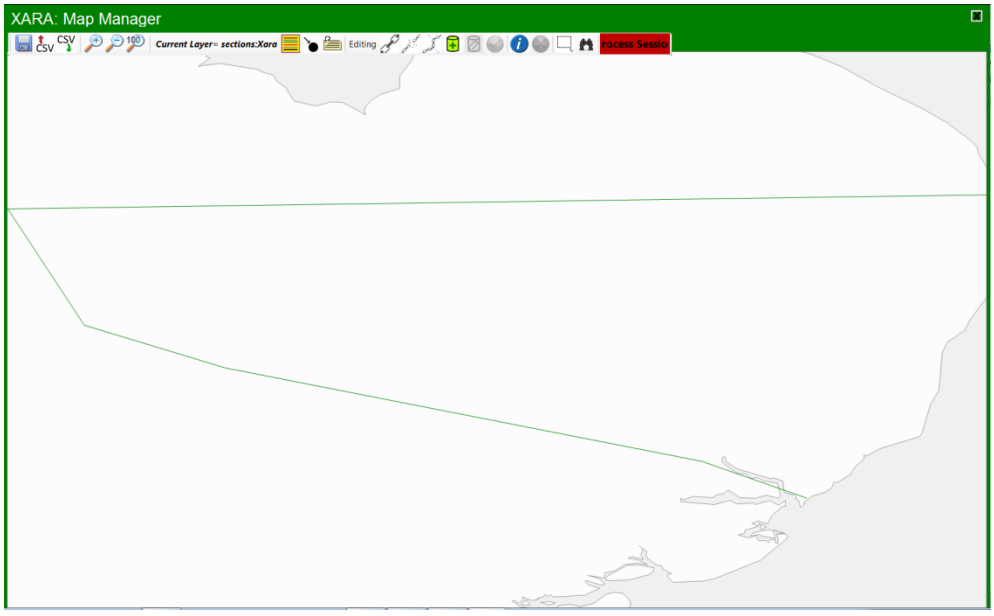


Figure 11 - Map Control Screen

(Please note that the layer and background displayed are for testing purposes, hence their sparsity of rendering).

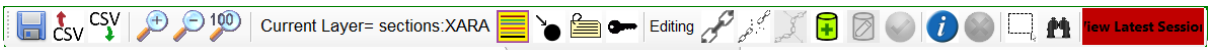


Figure 12 - Map Buttons

The map control buttons across the top (see Fig. 12) are:

- Save As: this allows the user to make a copy of the network and its assets under a new network name;

- Export to CSV:

- Import from CSV:

- Zoom In: pressing the button enlarges the map by a factor of two, around the centre;

Zoom Out: pressing the button reduces the map by a factor of two, around the centre;

- Zoom to Full Extents of Map: pressing the button resets the map to show the full extent of the X-ARA network;

- Currently Active Layer: this only informs the user of which map layer is currently active, that is which layer is affected by edits, etc;
  Asset layer = asset class (pavement, structures…)

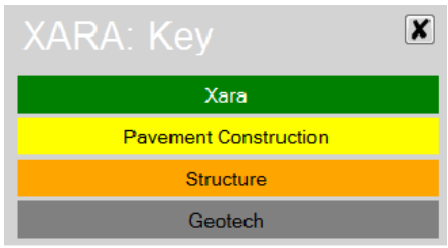
- Layers: this button calls a sub-screen where the user can:
  - Add a map layer; ad-hoc layer can be used to upload a map background
  - Remove a map layers;
  - Make a map layer visible or invisible;
  - Alter the rendering of layers;
  - Select a layer to be active;

- Show Nodes: this button is a toggle control. Pressing it initially marks the end points of each X-ARA section as small circles, and pressing it again unmarks the ends – the

circles are removed. It should be noted that these are referred to as nodes. However they are purely a visual element and have no presence in any of the X-ARA data;

- Show Labels: this button is a toggle control. Pressing it initially marks each section with the UID of the X-ARA section, displayed at the middle of the section. Pressing it again unmarks the labels – the labels are removed. If the X-ARA section rendered at the current display scale is too short for the label to be drawn against it, then the label is omitted. A zoom in usually enables the rendering of the X-ARA section to expand enough to be long enough for the label to be drawn against it.

- Show Key: this button enables the user to display the key to the rendering of the network and assets in the map display. The key is opened:



- Join Sections: this button enables the user to pick two adjacent X-ARA sections and to join them. The user lengths of the joined sections are summed to form the new user length of the new section. The attribution of the first selected section becomes the attribution of the new section and the assets on each joined section transferred to the new section. The joined sections are removed from the network and replaced by the new network. This action cannot be undone;

- Split Section: this button enables the user to split a picked X-ARA section into two parts. The user can either use the GIS pointer to indicate where the X-ARA section occurs or to call a sub-screen where the user can enter a valid kilometrage within the X-ARA section where the split occurs. The two new X-ARA sections inherit the attributes of the split X-ARA section, with new user lengths. Assets are transferred to one or other of the new X-ARA sections by their location on the split X-ARA section. Any asset spanning the split point is in turn split and the parts assigned to the appropriate new X-ARA section. This action cannot be undone;

- Move Asset: this button enables a user to pick an asset and to move it to a new location on the X-ARA section. This can be done visually using the GIS pointer or can call a sub-screen where the user can enter a new kilometrage range for the moved asset. It should be noted that this can be used to stretch or shrink an asset along the X-ARA section;

- Create Asset: this button opens a sub-screen where the user enters a new asset. This is described in section 9.2 below;

- Edit Asset: this button enables the user to select an asset and to then open a sub-screen where attributes of the asset can be amended. Only the attributes whose values affect the selection of the base risk in the calculation can be amended. Note that the edit is “pending” until the “Apply Edit” button is pressed.

  A pop-up window appears asking whether the user wishes to use the map or a form to amend the asset. Using the map enables the user to move and/or resize the asset visually. Using the form enables the user to move and/or resize the asset using chainages, and/or later the attributes of the asset.

- Apply Edits: this button saves any “pending” asset edits;

- Select Section for Info: this button enables the user to select one or more X-ARA sections by using the GIS pointer and to then edit attributes about them in a pop-up sub-window.
  Sequence is as follows:
  - Click on 
  - Click on section
  - Click again on  to show the sub-window with all attributes of the section
  - Repeat as many times as necessary
- Only the following attributes can be edited by the user:
  - EnvSF;
  - EcoSF;
  - SafSF;
  - NetSF;
  - Regional Situation;

- Deselect Sections: this button enables the user to “clear” the selection of X-ARA sections so that none are selected;

- Select sections to edit bulk values: this button enables the user to select several X-ARA sections so that some attributes can edited to the same values on all of them at the same time. The user defines a rectangle to intersect with the sections to be picked.

- Search: this button opens a dialogue box that enables the user to enter the UID of the X-ARA section to be found by the search function. When the X-ARA section is found, the map zooms to the extent of the section.

- View Latest Session: this button opens the session viewer screen from where the calculations are performed, and also where reports are run;

3.5.2 Adding Assets on the Map Screen

Assets can be added using the map screen by the use of the Create Asset button  .

The user presses this button and a window pops up to ask the user to designate the type of asset being added, see **Figure 13** below.

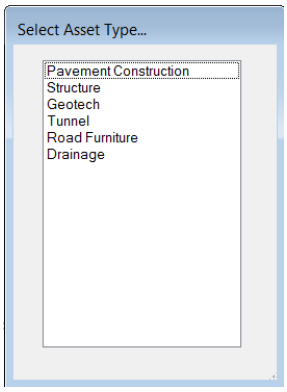


Figure 13 - Select Asset Type

It is noted that this method is used to add the assets one by one interactively and that the "Import from CSV" is used to "bulk-load" asset data, as well as to "bulk-amend" XARA network section data.

On selecting an asset type, the pop-up window disappears and the user is asked to confirm that they wish to add the chosen asset type. If the response to this is yes, then the user picks the XARA section on which the asset is to be created. On picking the XARA section, a pop-up window appears to ask the user whether the user is going to enter the position of the asset either interactively on the map or by using a form based entry, see **Figure 14** below.

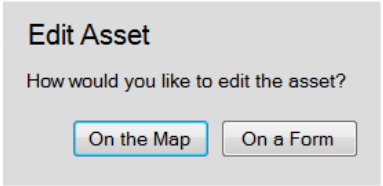


Figure 14 - Edit Asset

Select "On the map" then click where it is on the map

or

Click ‘on a Form” and specify chainage (start/ end)

3.5.2.1 On the Map

By pressing the “On the Map” button, the pop-up window disappears and the user can then digitise the start and end points on the chosen XARA Section, see **Figure 15** below:

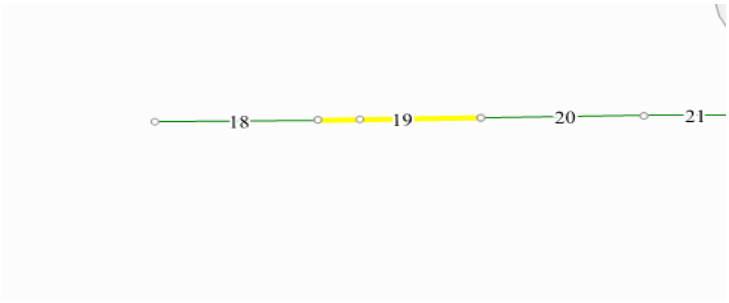


Figure 15 - Add Asset on the Map

In Figure 15 above, the asset is part entered on XARA Section 19, with the start point already picked. On picking the end point a pop-window appears for the user to set the attribute values for the asset, see Figure 16 below:

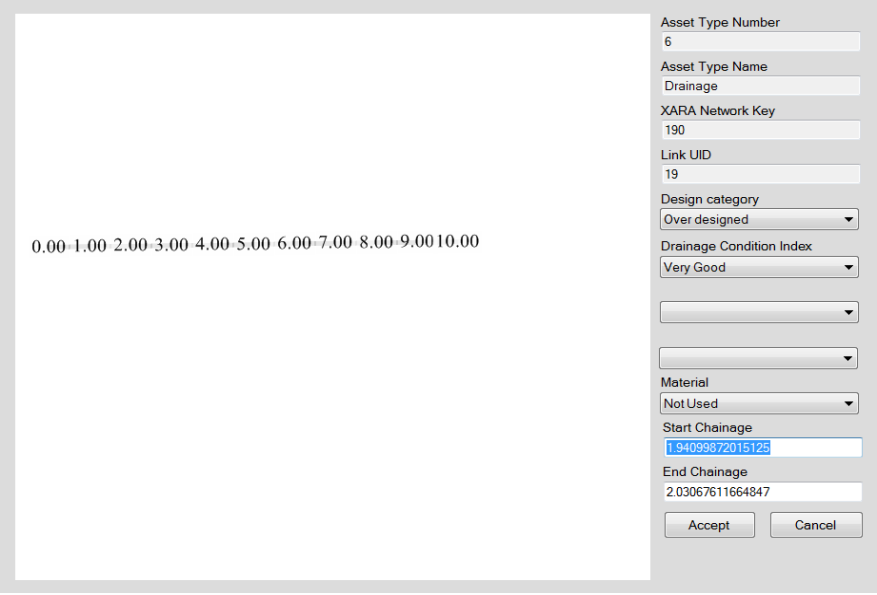


Figure 16 - Asset Update

The illustration to the left of the screen shows the general orientation (North, South, East or West) and starting extremity/ending extremity of the XARA section and is intended to show the user the length and direction of the XARA Section. On the right are the pick boxes, etc where the user should pick the relevant asset’s attributes. In the case shown above, a drainage asset has been designated and the user can set the Design Category and the Drainage Condition Index for the drainage item. The user can also amend the chainage range for the asset. It should be noted that the pick boxes for the asset attributes changes on

this form depending on which asset type is selected. Pressing the “Accept” button saves the asset into the XARA database, whilst “Cancel” stops the entry of the asset.

3.5.2.2 On a Form

When the user presses the “On a Form” button, the Add Asset screen appears (Figure 17):

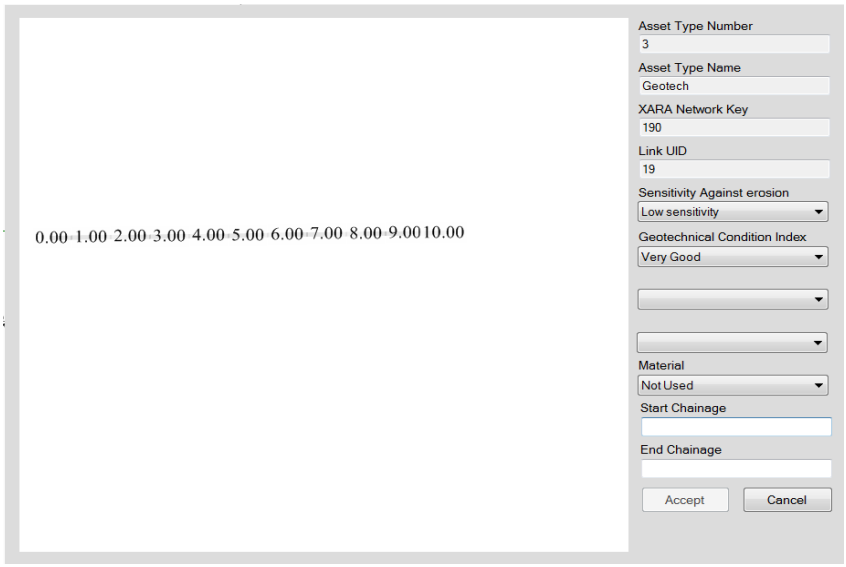


Figure 17 - Add Asset

The illustration to the left of the screen shows the general orientation (North, South, East or West) and starting extremity/ending extremity of the XARA section and is intended to show the user the length and direction of the XARA Section. On the right are the pick boxes, etc. where the user should pick the relevant asset’s attributes. In the case shown above, a geotechnical asset has been designated and the user can set the Sensitivity Against Erosion and the Geotechnical Condition Index for the geotechnical item. The user can also amend the chainage range for the asset. It should be noted that the pick boxes for the asset attributes changes on this form depending on which asset type is selected. Pressing the “Accept” button saves the asset into the XARA database, whilst “Cancel” stops the entry of the asset.

3.6 Assets

3.6.1 Assets and their Attributes

There are six types/ classes of assets which are:

- Pavement Construction;
- Structure;
- Geotechnical assets;
- Tunnel (both structure and equipment);
- Road Furniture;
- Drainage.

Each instance of an asset class does not represent each individual asset, such as individual lighting points. Instead they represent sequences of assets along an X-ARA section that have the same attributes.

3.6.2 Pavement Construction

As the X-ARA tool aims at the network level, no detailed data about layer composition is necessary. Only the general type (asphalt, concrete) is considered. What is more relevant for the risk calculation is the condition of the pavement, as the risk calculated from condition may trigger maintenance measures.

With regard to the data describing the properties of each of two types of pavement construction, two condition indices are used:

- Comfort and safety index (CSI, based on COST354 [1]) to describe the road safety and the riding comfort from the road user point of view;
- Structural condition index (SI, based on COST354 [1]) to describe the structural condition of the pavement construction.

The total traffic AADT categories the effects of maintenance activities to the users as well as to the efforts of the road administrations (higher efforts for maintenance activities on roads with high traffic and lower efforts on roads with lower traffic), but this is also related to the class of road the carriageway is on, (motorway, expressway and ordinary road). Therefore a compound category is used and is derived from the RoadClass and AADT of the X-ARA section the Pavement Asset is located on. The user does not supply this attribute directly.

Within the X-ARA Risk Tool, an asset of the Pavement Construction class has three user definable attributes:

- Material Type;
- Comfort and Safety Index;
- Structural Index.

The material type attribute must be either “Flexible” for asphalt carriageways and “Rigid” for concrete carriageways. For hybrid carriageways, the user should determine the predominant material type based on whether the pavement performs as either a flexible carriageway or a rigid carriageway. It is essential that this determination is consistently applied across the network.

The comfort and safety index attribute must have one of five values and is based on a user assessment of the ride characteristics and resistance to skidding, etc. The values are:

- 1= Very high degree of comfort and safety;
- 2= High degree of comfort and safety;
- 3= Medium or average degree of comfort and safety;
- 4 = Low degree of comfort and safety;
- 5= Very low degree of comfort and safety;

The structural index attribute must have one of five values and is based on a user assessment of the condition of the pavement, both structurally (i.e. deflection under load) and in terms of measurable surface condition characteristics (i.e. rutting, texture depth, etc).

The values are:

- 1= Very good condition;
- 2= Good condition;
- 3= Medium condition;
- 4= Poor condition;
- 5= Very poor condition.

It is noted that a Pavement Construction asset also has an attribute known as “AADT Group”, which is not editable by the user. Instead it is found from a lookup based on the AADT of the X-ARA section the pavement construction asset is on, against the road class of the X-ARA section.

3.6.3 Structure

The approach for the risk assessment for structures is based in principle on the British standard BE11/94 [1]) for bridge inspections, split into two sub-classes based on the predominant construction material of the structurally significant parts of the structure. Two base risks are determined on the basis of having the following indicators:

- Structure condition index (SCI) to describe the total condition of the structure (British scale from 0 to 10, transformed to a scale from 1 to 5 subject to COST354[1])
- Extent of defects (SED) (British classification from A to D, transformed to a scale from 1 to 5 subject to COST354[1])

In the lookup of both base risks, the severity of defects according to British standard BE11/94 [2] has been selected to describe the effects on maintenance actions.

Within the X-ARA Risk Tool, an asset of the Structure class has four user definable attributes:

- Material Type;
- Severity of Defects;
- Sensitivity to Defects (SED);
- Structural Condition Index (SCI).

The material type attribute is either “Concrete” or “All Other”. For a hybrid structure the user should consider the material type of the main structural components of the structure. It is essential that this determination is consistently applied across the network.

Severity of defects attribute considers the urgency with which defects require action and must have one of three values:

- 1= No significant defects or minor defects of non-urgent nature;
- 2= defects to be included in next maintenance programme;
- 3 = Defects where urgent action is needed.

Sensitivity to defects (SED) attribute considers the amount of defects on the structure and must have one of five values:

- 1=No defects;
- 2=Slight < 5% of length or area;
- 3=Moderate, >5 < 10% of length or area;
- 4=High, > 10 < 20% of length or area;

- 5= Very High, > 20% of length or area.

Structural condition index (SCI) attribute considers the condition of most significant defects to the operation of the structure and must have one of five values:

- 1= Very good;
- 2=Good;
- 3= Fair;
- 4=Poor;
- 5= Very poor.

3.6.4 Geotechnical assets

The definition of geotechnical asset is taken from “A Risk-Based Approach for the Assessment and Management of Infrastructure Assets” [5]: “The term 'geotechnical asset' refers to all earthworks (cuttings and embankments) and ground underlying highway”. In principle, the method presented in X-ARA can be extended to other geotechnical assets, but is limited to cuttings and embankments in this project. With regard to COST 354 [1] a condition scale of five condition classes of the geotechnical condition index (GCI) will be recommended for this type of assets as well. GCI is based on the condition assessment procedures used in Highways Agency Drainage Data Management System (HADDMS) [6].

Within the X-ARA Risk Tool, an asset of the Geotech class has two attributes:

- Sensitivity Against Erosion;
- Geotechnical Condition Index (GCI).

Sensitivity against erosion attribute must have one of three values:

- Low sensitivity;
- Medium sensitivity;
- High sensitivity.

Geotechnical condition index (GCI) attribute must have one of five values:

- Very good;
- Good;
- Fair;
- Poor;
- Very Poor.

3.6.5 Tunnel

Tunnels and long underpasses are sensitive elements of the road infrastructure and the functionality of the electro-mechanical equipment is an especially important risk factor in the context of asset management (in particular safety) and thus needs to be assessed beside the structural condition of the tunnel itself.

With regard to the data describing the properties of tunnels, the following information, which are based on the Austrian tunnel standard RVS 13.03.31 [7] and RVS 13.03.41 [8] will be used;

- Tunnel condition index (TCI) to describe the condition of the tunnel structure;
- Age of electro-mechanical equipment to describe the condition of the tunnel equipment.

Because of the complexity, the condition of electro-mechanical assets in tunnels will not be described by standardized condition indices. Furthermore, the condition of this equipment is related to the functionality or to the number of fails within a given time period. Both aspects are usually strongly related to the age of the equipment. Thus, it is possible to use the age instead of a condition index.

With regards to electro-mechanical assets, the availability of spare parts is the indicator, which has the highest impact on the effects, especially to the tunnel operator.

Within the X-ARA Risk Tool, an asset of the Tunnel class has four attributes, the first two assessing the risk to the overall condition of the tunnel asset and the latter two assessing the risk to the tunnel asset's electromechanical infrastructure:

- Tunnel Condition Index;
- Severity of Defects;
- Age of Electromechanical Systems;
- Availability of Spares;

The Tunnel Condition Index (TCI) attribute must be one of five values:

- Very good;
- Good;
- Fair;
- Poor;
- Very Poor.

The Severity of defects attribute must be one of three values:

- 1= No significant defects or minor defects of non-urgent nature;
- 2= defects to be included in next maintenance programme;
- 3 = Defects where urgent action is needed.

The Age of electromechanical systems attribute must be one of five values:

- New < 2 years;
- Young 2 to 5 years;
- Medium 5 to 10 years;
- Old 10 to 15 years;
- Very Old > 15 years.

The Availability of spares attribute must be one of three values:

- 1= Low risk of unavailability;
- 2= Medium risk of unavailability;
- 3=High risk of unavailability.

3.6.6 Road Furniture

Road furniture covers different types of point or linear assets, e.g. street lighting, traffic signs, gantries, vehicle restraint systems (VRS) etc. Because of the different natures of different types of road furniture, the following approach is a general recommendation, which can be adapted or extended to the specific preconditions of different types of road furniture.

For the condition of road furniture no common agreed condition indicator exists, thus the unified scale from COST354 [1] is used to describe the condition of road furniture. It is implicit in this approach that road furniture covers several types of assets simultaneously, such as VRS and lighting.

With regard to the data describing the properties of the road furniture, a road furniture condition index (RFCI), which was defined in the British ILP TR22 guidance [3] (as an adequate example), will be used. In addition three consequence of failure categories, which are also based on TR22 [3], define directly the effect on the users.

Within the X-ARA Risk Tool, an asset of the Road Furniture class has two attributes:

- Road Furniture Condition Index (RFCI) ;
- Consequence of Failure.

The Road furniture condition index attribute must have one of five values:

- Very good;
- Good;
- Fair;
- Poor;
- Very Poor.

The Consequence of failure attribute must be one of three values:

- 1= Low impact;
- 2= Medium impact;
- 3= High impact.

3.6.7 Drainage

For drainage sections, there are two performance indicators, the “drainage condition index” (DCI) and the design category (reflecting how well the drainage section is able to serve its function). Both performance indicators have been developed in the EVITA project [4].

Within the X-ARA Risk Tool, an asset of the drainage class has two attributes:

- Drainage Condition Index;
- Design Category.

The Drainage condition index must have one of five values:

- Very good;
- Good;
- Fair;
- Poor;
- Very Poor.

The design category must have one of three values:

- Over designed - the drainage system has much more capacity than for the amount of water produced in the storm intensity specified in the design requirements;
- Ok designed - the drainage system has the correct capacity than for the amount of water produced in the storm intensity specified in the design requirements;
- Under designed - the drainage system has much less capacity than for the amount of water produced in the storm intensity specified in the design requirements;

3.7 Export to CSV and Import from CSV

3.7.1 Export to CSV

This  enables the user to export all entered details of sections and assets to a CSV file for transfer to another system, such as Excel. (It is noted it exports the details entered by the user, it does not export the results of calculations – see Reports below).

In the CSV file as exported, a section is reported (including a header line to identify the section attributes), followed by any assets on that section, (including a header line for each asset type to identify the asset attributes).

It is organised as follows:

- Section 1
  - Asset type 1 (Pavement)
    - Asset 1
    - Asset 2
    - ……
    - Asset N
  - Asset Type 2 (Structures)
    - Asset 1
    - Asset 2
    - ……
    - Asset N
  - Asset type N (…)
- Section 2
  - Asset type 1 (Pavement)
  - Asset Type 2 (Structures)
  - Asset type N (…)
- Section S

This is illustrated in Figure 18 below (using Excel to view the CSV file):

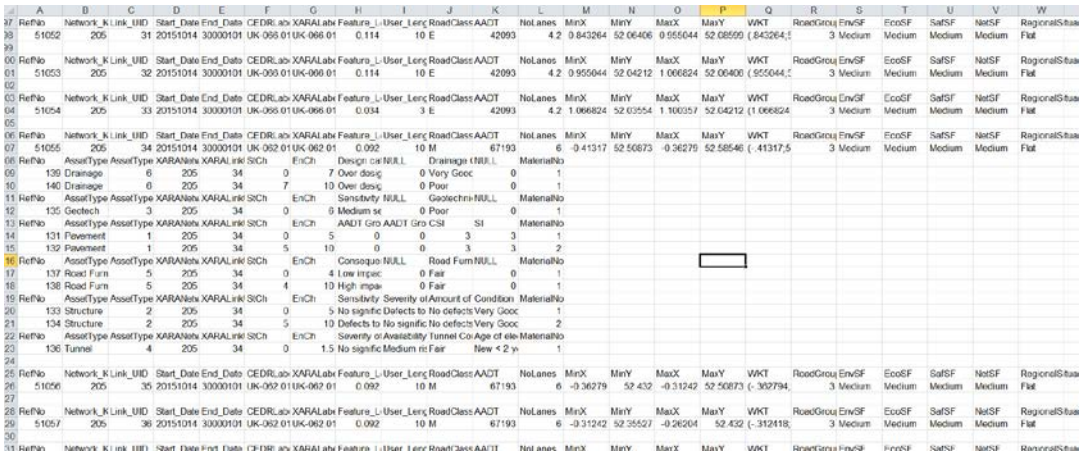


Figure 18 - View CSW file on Excel

3.7.2 Import from CSV

This  enables the user to import a CSV file that can be used to:

- alter some attributes of the Xara section, namely the Environmental Sensitivity Factor (EnvSF), Economic Sensitivity Factor (EcoSF), Safety Sensitivity Factor (SafSF), Network Sensitivity Factor (NetSF) and/or the Regional Situation;
- enter new assets;
- delete existing assets.

A sample CSV file is supplied electronically with this manual that contains examples of entering of new assets and deleting existing assets, and contains examples of all the attribute values used that must be used in an input CSV. It also sets out the “rules” for the way the data are prepared. This file can be used to “Copy and Paste” the required attribute values into the users CSV import file.

Figure 19 below shows a typical X-ARA program directory, (this is V1.0.0.68)

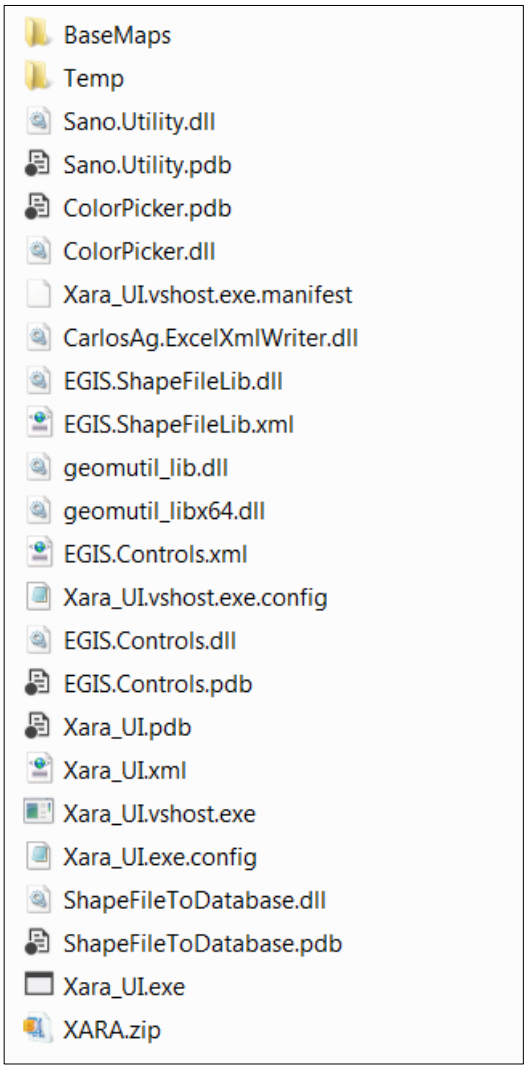


Figure 19 - Content of program directory.

This shows:

- Two directories which are:
  - BaseMaps – to contain any background maps the user wishes to display, in the same coordinate system and projection as the shapefile used to load the XARA network.
  - Temp – a directory where XARA loads working copies of files whilst it is running.

The executable, dll, config and other files that are the suite of files for XARA.

It is noted that the CSV Export produces a file that can be directly imported via the CSV Import.

XARA can be used to export a CSV file of network sections that can be modified with section attribute updates and with assets assigned to those network sections, and then used as an import file back into XARA to make the desired changes.

Figure 20 below shows part of the network data exported (columns A to H are shown, and there are additional data in columns I to W, (assuming Excel is used to view the data). This shows that the sections all belong to the network instance 3, having been loaded into XARA from shapefile previously (Column B).

XARA assigns each a Link_UID which is the user reference for theindividual sections (column C). In Figure 20, Sections 2, 3 and 4 are shown. XARA also assigns each section an absolutely unique internal reference number (RefNo – Column A) - that is never reused even in different network.

RefNo	Network_Key	Link_UID	Start_Date	End_Date	CEDRLabel	XARALabel	Feature_Length
76	3	2	20151019	30000101	UK-062.01	UK-062.01/2	0.092
RefNo	Network_Key	Link_UID	Start_Date	End_Date	CEDRLabel	XARALabel	Feature_Length
77	3	3	20151019	30000101	UK-062.01	UK-062.01/3	0.092
RefNo	Network_Key	Link_UID	Start_Date	End_Date	CEDRLabel	XARALabel	Feature_Length
78	3	4	20151019	30000101	UK-062.01	UK-062.01/4	0.028

Figure 20 - CSV 1.

Normally if one follows the normal data flow of loading the network from shapefile, exporting the sections and then applying updates and assets to the sections before importing the chnages, then the RefNo is of no interest.

However it is of consequence where User B is trying to replicate a network in their XARA instance that has been previously loaded and updated by User A in a different XARA instance. User B will have used the same shapefile to load their XARA instance but the chances are the section will have different RefNo, despite having the same LinkUID. Thus, to use a network update CSV file supplied by User A, User B will have to amend the RefNo in to match the RefNo in their instance of the network as well as ensure the Network_Key and the Link_UID are correct.

RefNo	Network_Key	Link_UID	Start_Date	End_Date	CEDRLabel	XARALabel
75	3	1	20151019	30000101	UK-062.01	UK-062.01/1
RefNo	AssetTypeName	AssetTypeNo	XARANetworkKey	XARALinkUID	StCh	EnCh
	Pavement Construction	1	3	1	0	5
	Pavement Construction	1	3	1	5	10
RefNo	AssetTypeName	AssetTypeNo	XARANetworkKey	XARALinkUID	StCh	EnCh
	Structure	2	3	1	0	5
	Structure	2	3	1	5	10
RefNo	AssetTypeName	AssetTypeNo	XARANetworkKey	XARALinkUID	StCh	EnCh
	Geotech	3	3	1	0	6
RefNo	AssetTypeName	AssetTypeNo	XARANetworkKey	XARALinkUID	StCh	EnCh
	Tunnel	4	3	1	0	1.5
RefNo	AssetTypeName	AssetTypeNo	XARANetworkKey	XARALinkUID	StCh	EnCh
	Road Furniture	5	3	1	0	4
	Road Furniture	5	3	1	4	10

Figure 21 - CSV 2

Figure 21 above shows how assets are associated with their parent network section in the CSV file, (columns A to G are shown and there are other data in columns H to W). This shows a section with a network_key of 3 and a Link_UID of 1 (and a RefNo of 75).

Each asset associated with that section is defined as chainage ranges along that section and therefore each must have the network_key and Link_UID of their parent section in their data. This is the XARANetworkKey (for the section's Network_Key - 3 in this case) and the XARALinkUID (for the section's Link_UID - 1 in this case). Note that the RefNo is not used in this asset to section association.

3.8 Session Viewer and Calculation

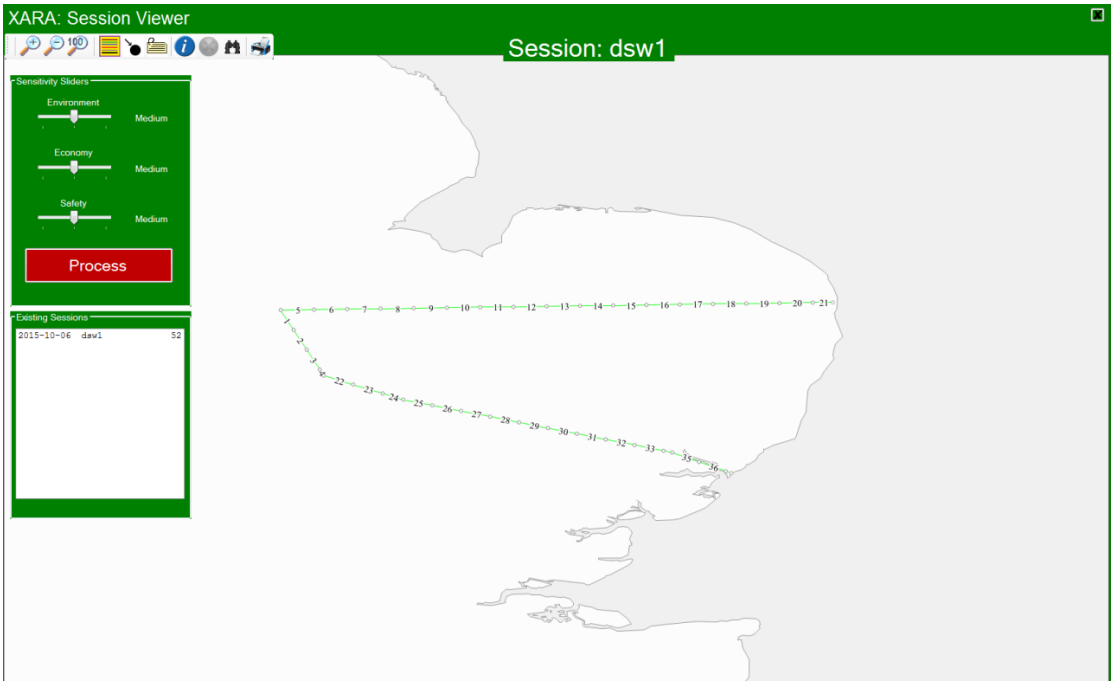


Figure 22 - Session Viewer Screen

This screen is used to:

- Adjust the “sliders” (see below to change the values any of the overall Economic, Environmental or the Safety factors representative of the whole network.
- Initiate the calculation by clicking on the “process’ red key:
  A window appears, requesting to “enter a description of the session”
  Each session is identified with
  - Date;
  - Name of the session (see chapter3.9.1) + number automatically generated by the application
- View the results as a rendering of the network, (using the pan and zoom controls, layer rendering management tools, etc);
- Open the reporting of results sub-screen (using the  icon). See chapter 3.9

The sliders are for the overall Economic, Environmental and Safety factors representative of the whole network and each can have one of three values:

- ‘P’ Positive impact of high level influencing factor and this high level influencing factor leads to a reduction of asset specific risks.
- ‘S’ Standard impact of high level influencing factor = standard set for risk analysis. The influencing factor describes a ‘normal’ or ‘expected’ situation.
- ‘N‘ Negative impact of high level influencing factor and this high level influencing factor leads to an increase of asset specific risks.

The “initial” risk results for the network, for each X-ARA section and each asset are calculated as if all three sliders are set to “Standard”. The user-changed settings are used to determine the risk for the network, for each X-ARA section and each asset.

The initial risk acts as a benchmark against which the results of adjusting the sliders can be viewed and assessed by the user.

The “Process” button starts the calculation of the risks by the “CalcEngine”. Once the calculations are completed, the reporting functions are enabled. In addition:

- a pop-up window appears to report the network risks (determined and initial) directly to the user;
- the X-ARA sections are rendered to show their determined risk result.

The user can adjust the sliders in a session and repeat the calculation process, to then view the changed results.

Certain combinations of sliders states will be integrated to so-called “What-if?--scenarios”. Each scenario will be given an explanatory description.

3.9 Results and Reporting

The following reports shown on Figure 23 below are available once the first sets of results for a session have been calculated. All the reports are output:

- either in a basic tabular format of rows and columns, with column headings and a title to identify the report;
- or in the form of a series of dashboards.

The title includes the date/time of reporting. The reports do not appear on screen but are written to an output file as CSV files that reproduce a column/row format suitable for import by the user into Excel or similar spread sheet tool. The user specifies the name and location of the output file.

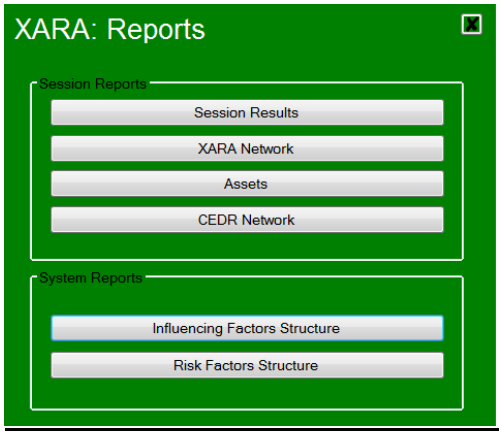


Figure 23 - Reports

The application will request the user

- which folder to create the file in and
- under which name (it suggest a name with date & time that can be overridden)

3.9.1 Session Results – Tabular form

This report shows the overall network results for the current session (or the selected session).

It is organised according to the following columns:

Headers & details

- Name of the session
- Network ID (from main menu)
- Name of Network
- Person who created the network (Network owner)

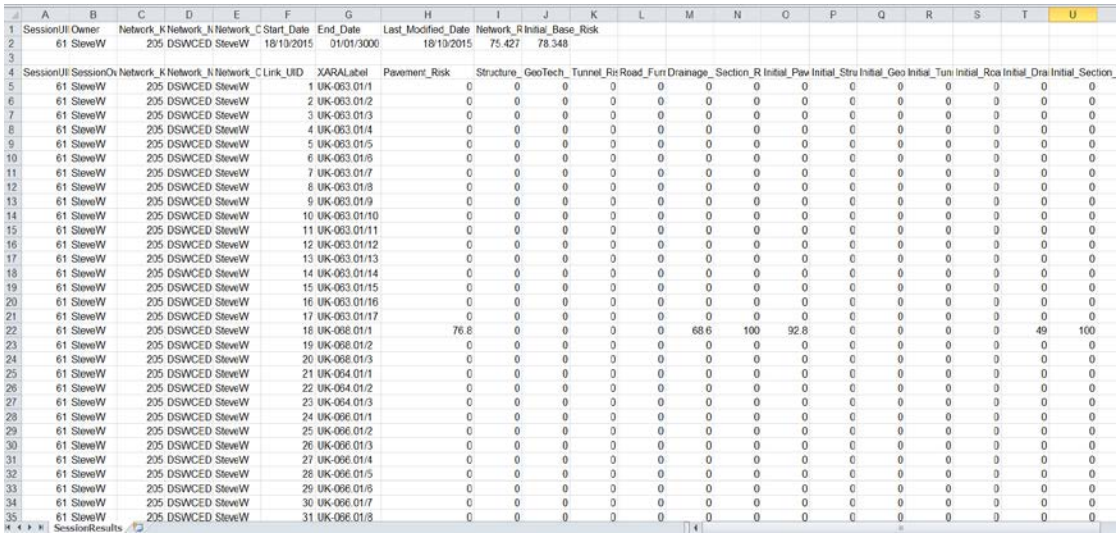
Headers

- Start date (when Network was loaded)
- End date (not to be modified)
- Last modified date
- Network risk (as set with the sliders)
- Initial base risk (neutral position)

Details

- Lines => section par section
  - detail of risks using sliders per asset type of all assets of that section
  - cumulative risk using sliders of all assets on that section
  - detail of risks with neutral sliders per asset type of all assets of that section
  - cumulative risk with neutral sliders of all assets on that section

The results are illustrated on Figure 24 below (using Excel to view the CSV file):



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	SessionUI	Owner	Network_K	Network_N	Network_C	Start_Date	End_Date	Last_Modified_Date	Network_R	Initial_Base_Risk											
2	61	SteveW	205	DSWCED	SteveW	18/10/2015	01/01/3000	18/10/2015	75.427	78.348											
3																					
4	SessionUI	SessionOv	Network_K	Network_N	Network_C	Link_UID	XARALabel	Pavement_Risk	Structure_	GeoTech_	Tunnel_Ris	Road_Furi	Drainage_	Section_R	Initial_Pav	Initial_Stru	Initial_Geo	Initial_Tun	Initial_Roa	Initial_Dra	Initial_Section_
5	61	SteveW	205	DSWCED	SteveW	1	UK-063.01/1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	61	SteveW	205	DSWCED	SteveW	2	UK-063.01/2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	61	SteveW	205	DSWCED	SteveW	3	UK-063.01/3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	61	SteveW	205	DSWCED	SteveW	4	UK-063.01/4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	61	SteveW	205	DSWCED	SteveW	5	UK-063.01/5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	61	SteveW	205	DSWCED	SteveW	6	UK-063.01/6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	61	SteveW	205	DSWCED	SteveW	7	UK-063.01/7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	61	SteveW	205	DSWCED	SteveW	8	UK-063.01/8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	61	SteveW	205	DSWCED	SteveW	9	UK-063.01/9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	61	SteveW	205	DSWCED	SteveW	10	UK-063.01/10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	61	SteveW	205	DSWCED	SteveW	11	UK-063.01/11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	61	SteveW	205	DSWCED	SteveW	12	UK-063.01/12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	61	SteveW	205	DSWCED	SteveW	13	UK-063.01/13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	61	SteveW	205	DSWCED	SteveW	14	UK-063.01/14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	61	SteveW	205	DSWCED	SteveW	15	UK-063.01/15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	61	SteveW	205	DSWCED	SteveW	16	UK-063.01/16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	61	SteveW	205	DSWCED	SteveW	17	UK-063.01/17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	61	SteveW	205	DSWCED	SteveW	18	UK-068.01/1	76.8	0	0	0	0	68.6	100	92.8	0	0	0	0	49	100
23	61	SteveW	205	DSWCED	SteveW	19	UK-068.01/2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	61	SteveW	205	DSWCED	SteveW	20	UK-068.01/3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	61	SteveW	205	DSWCED	SteveW	21	UK-064.01/1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	61	SteveW	205	DSWCED	SteveW	22	UK-064.01/2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	61	SteveW	205	DSWCED	SteveW	23	UK-064.01/3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	61	SteveW	205	DSWCED	SteveW	24	UK-066.01/1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	61	SteveW	205	DSWCED	SteveW	25	UK-066.01/2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	61	SteveW	205	DSWCED	SteveW	26	UK-066.01/3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	61	SteveW	205	DSWCED	SteveW	27	UK-066.01/4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	61	SteveW	205	DSWCED	SteveW	28	UK-066.01/5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	61	SteveW	205	DSWCED	SteveW	29	UK-066.01/6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	61	SteveW	205	DSWCED	SteveW	30	UK-066.01/7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	61	SteveW	205	DSWCED	SteveW	31	UK-066.01/8	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 24 – Example of X-ARA network export as CSV

The first part shows the network result compared to the initial result (sliders set to "Standard"), followed by the detailed results of the individual sections, (please note the part of the test data is reported, hence the lack of assets!).

3.9.2 Session Results – dashboards

The dashboards (see **Figure 36** in chapter 4.5.3) display a network overview.

This includes for each set of parameters (scenario):

- The scenario, indicating the adjustment of the sliders:
  - Effects on the whole network re. asset specific sensitivity (environmental, economic and safety effects)
  - Asset specific effects
- Risk Class distribution chart per Road Category, with a comparison between:
  - Standard analysis (all sliders in neutral position)
  - Scenario (adjusted sliders as described in the above scenario)
- Average Risk per Road Category, with a comparison between:
  - Standard analysis (all sliders in neutral position)
  - Scenario (adjusted sliders as described in the above scenario)

3.9.3 Session Results – coloured map

The coloured map shows directly on the map screen the various sections with a colour code:

- Green = low risk
- Yellow = medium risk
- Red = high risk

There is a possibility to print it through the "print screen" function

3.9.4 X-ARA Network

This reports the data entered about X-ARA sections (without the risk results) for the X-ARA network currently in use in the application.

It is organised according to the following columns:

Headers & details

- Name of the session
- Network ID (from main menu)
- Name of Network
- Person who created the network (Network owner)

Headers

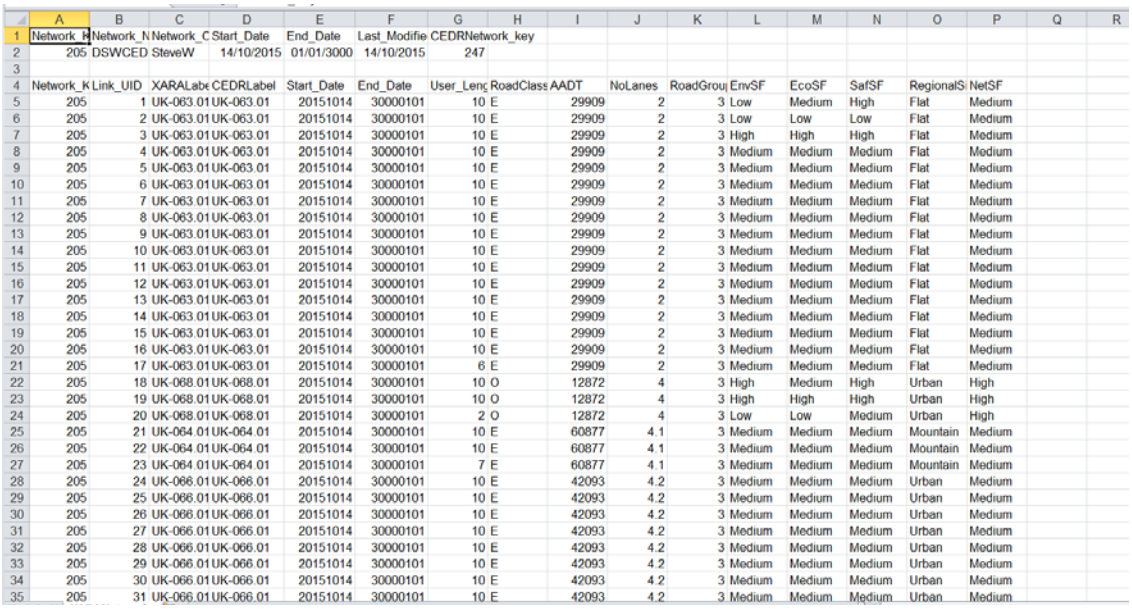
- Start date (when Network was loaded)
- End date (not to be modified)

- Last modified date

Details

- Length (km)
- Road class
- AADT
- Number of lanes
- Road group (automatically generated)
- Sensitivity factors: environmental/ economics/ safety)
- Regional situation (flat, urban, mountainous)
- Network sensitivity factors (high, medium, low)
- ID of the asset (system generated)
- Assset type name (pavement, structure? …)
- Type number
- Network ID
- Section identifier (XARA line UID)
- Start chainage
- End chainage
- Specific attributes of the network - depending on the asset type.

The results are illustrated in Fig 25 below (using Excel to view the CSV file):



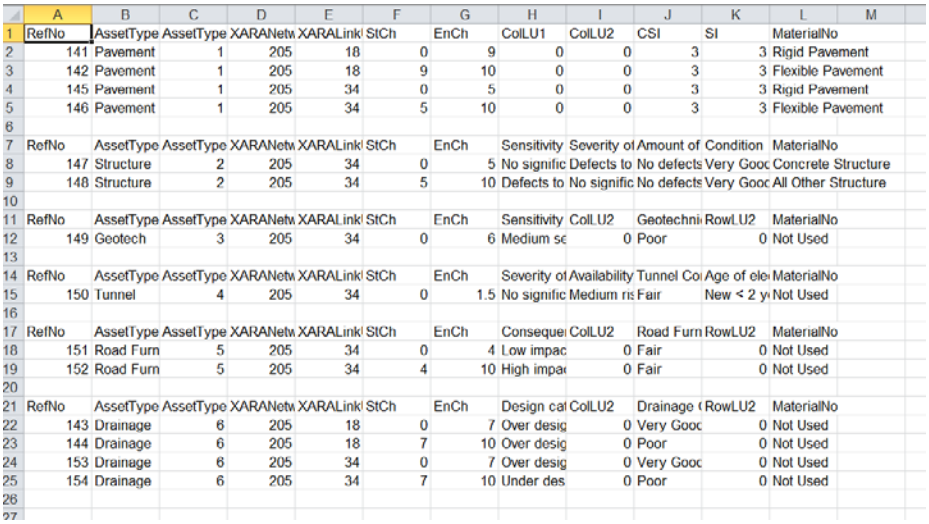
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Network_K	Network_N	Network_C	Start_Date	End_Date	Last_Modifie	CEDRNetwork_key											
2	205	DSWCED	SteveW	14/10/2015	01/01/3000	14/10/2015	247											
3																		
4	Network_K	Link_UID	XARALabe	CEDRLabel	Start_Date	End_Date	User_Lenc	RoadClass	AADT	NoLanes	RoadGrou	EnvSF	EcoSF	SafSF	RegionalS	NetSF		
5	205	1	UK-063.01	UK-063.01	20151014	30000101	10	E	29909	2	3	Low	Medium	High	Flat	Medium		
6	205	2	UK-063.01	UK-063.01	20151014	30000101	10	E	29909	2	3	Low	Low	Low	Flat	Medium		
7	205	3	UK-063.01	UK-063.01	20151014	30000101	10	E	29909	2	3	High	High	High	Flat	Medium		
8	205	4	UK-063.01	UK-063.01	20151014	30000101	10	E	29909	2	3	Medium	Medium	Medium	Flat	Medium		
9	205	5	UK-063.01	UK-063.01	20151014	30000101	10	E	29909	2	3	Medium	Medium	Medium	Flat	Medium		
10	205	6	UK-063.01	UK-063.01	20151014	30000101	10	E	29909	2	3	Medium	Medium	Medium	Flat	Medium		
11	205	7	UK-063.01	UK-063.01	20151014	30000101	10	E	29909	2	3	Medium	Medium	Medium	Flat	Medium		
12	205	8	UK-063.01	UK-063.01	20151014	30000101	10	E	29909	2	3	Medium	Medium	Medium	Flat	Medium		
13	205	9	UK-063.01	UK-063.01	20151014	30000101	10	E	29909	2	3	Medium	Medium	Medium	Flat	Medium		
14	205	10	UK-063.01	UK-063.01	20151014	30000101	10	E	29909	2	3	Medium	Medium	Medium	Flat	Medium		
15	205	11	UK-063.01	UK-063.01	20151014	30000101	10	E	29909	2	3	Medium	Medium	Medium	Flat	Medium		
16	205	12	UK-063.01	UK-063.01	20151014	30000101	10	E	29909	2	3	Medium	Medium	Medium	Flat	Medium		
17	205	13	UK-063.01	UK-063.01	20151014	30000101	10	E	29909	2	3	Medium	Medium	Medium	Flat	Medium		
18	205	14	UK-063.01	UK-063.01	20151014	30000101	10	E	29909	2	3	Medium	Medium	Medium	Flat	Medium		
19	205	15	UK-063.01	UK-063.01	20151014	30000101	10	E	29909	2	3	Medium	Medium	Medium	Flat	Medium		
20	205	16	UK-063.01	UK-063.01	20151014	30000101	10	E	29909	2	3	Medium	Medium	Medium	Flat	Medium		
21	205	17	UK-063.01	UK-063.01	20151014	30000101	6	E	29909	2	3	Medium	Medium	Medium	Flat	Medium		
22	205	18	UK-068.01	UK-068.01	20151014	30000101	10	O	12872	4	3	High	Medium	High	Urban	High		
23	205	19	UK-068.01	UK-068.01	20151014	30000101	10	O	12872	4	3	High	High	High	Urban	High		
24	205	20	UK-068.01	UK-068.01	20151014	30000101	2	O	12872	4	3	Low	Low	Medium	Urban	High		
25	205	21	UK-064.01	UK-064.01	20151014	30000101	10	E	60877	4.1	3	Medium	Medium	Medium	Mountain	Medium		
26	205	22	UK-064.01	UK-064.01	20151014	30000101	10	E	60877	4.1	3	Medium	Medium	Medium	Mountain	Medium		
27	205	23	UK-064.01	UK-064.01	20151014	30000101	7	E	60877	4.1	3	Medium	Medium	Medium	Mountain	Medium		
28	205	24	UK-066.01	UK-066.01	20151014	30000101	10	E	42093	4.2	3	Medium	Medium	Medium	Urban	Medium		
29	205	25	UK-066.01	UK-066.01	20151014	30000101	10	E	42093	4.2	3	Medium	Medium	Medium	Urban	Medium		
30	205	26	UK-066.01	UK-066.01	20151014	30000101	10	E	42093	4.2	3	Medium	Medium	Medium	Urban	Medium		
31	205	27	UK-066.01	UK-066.01	20151014	30000101	10	E	42093	4.2	3	Medium	Medium	Medium	Urban	Medium		
32	205	28	UK-066.01	UK-066.01	20151014	30000101	10	E	42093	4.2	3	Medium	Medium	Medium	Urban	Medium		
33	205	29	UK-066.01	UK-066.01	20151014	30000101	10	E	42093	4.2	3	Medium	Medium	Medium	Urban	Medium		
34	205	30	UK-066.01	UK-066.01	20151014	30000101	10	E	42093	4.2	3	Medium	Medium	Medium	Urban	Medium		
35	205	31	UK-066.01	UK-066.01	20151014	30000101	10	E	42093	4.2	3	Medium	Medium	Medium	Urban	Medium		

Figure 25 – Example of X-ARA network export as CSV

The first part shows the basic network details and is then followed by the sections themselves.

3.9.5 Assets Report

This reports the data entered about assets for the X-ARA network currently in use in the application. The results are illustrated in Fig. 26 below (using Excel to view the CSV file):

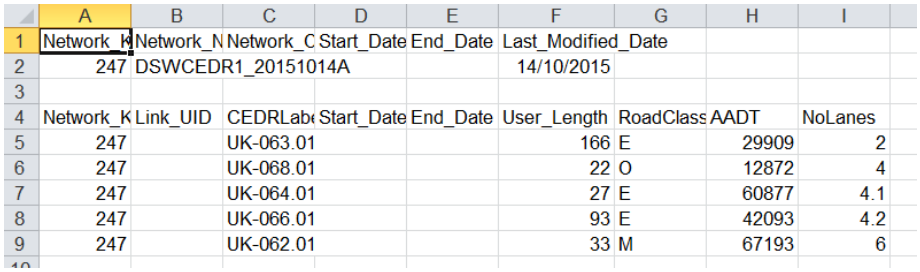


	A	B	C	D	E	F	G	H	I	J	K	L	M
1	RefNo	AssetType	AssetType	XARANetw	XARALink	StCh	EnCh	ColLU1	ColLU2	CSI	SI	MaterialNo	
2	141	Pavement	1	205	18	0	9	0	0	3	3	Rigid Pavement	
3	142	Pavement	1	205	18	9	10	0	0	3	3	Flexible Pavement	
4	145	Pavement	1	205	34	0	5	0	0	3	3	Rigid Pavement	
5	146	Pavement	1	205	34	5	10	0	0	3	3	Flexible Pavement	
6													
7	RefNo	AssetType	AssetType	XARANetw	XARALink	StCh	EnCh	Sensitivity	Severity of	Amount of	Condition	MaterialNo	
8	147	Structure	2	205	34	0	5	No signific	Defects to	No defects	Very Gooc	Concrete Structure	
9	148	Structure	2	205	34	5	10	Defects to	No signific	No defects	Very Gooc	All Other Structure	
10													
11	RefNo	AssetType	AssetType	XARANetw	XARALink	StCh	EnCh	Sensitivity	ColLU2	Geotechni	RowLU2	MaterialNo	
12	149	Geotech	3	205	34	0	6	Medium sc	0	Poor	0	Not Used	
13													
14	RefNo	AssetType	AssetType	XARANetw	XARALink	StCh	EnCh	Severity of	Availability	Tunnel Co	Age of ele	MaterialNo	
15	150	Tunnel	4	205	34	0	1.5	No signific	Medium ris	Fair	New < 2 y	Not Used	
16													
17	RefNo	AssetType	AssetType	XARANetw	XARALink	StCh	EnCh	Consequer	ColLU2	Road Furn	RowLU2	MaterialNo	
18	151	Road Furn	5	205	34	0	4	Low impac	0	Fair	0	Not Used	
19	152	Road Furn	5	205	34	4	10	High impac	0	Fair	0	Not Used	
20													
21	RefNo	AssetType	AssetType	XARANetw	XARALink	StCh	EnCh	Design cat	ColLU2	Drainage (	RowLU2	MaterialNo	
22	143	Drainage	6	205	18	0	7	Over desig	0	Very Gooc	0	Not Used	
23	144	Drainage	6	205	18	7	10	Over desig	0	Poor	0	Not Used	
24	153	Drainage	6	205	34	0	7	Over desig	0	Very Gooc	0	Not Used	
25	154	Drainage	6	205	34	7	10	Under des	0	Poor	0	Not Used	
26													

Figure 26 – Example of Asset report export as CSV

3.9.6 CEDR Sections Report

This reports the data entered about CEDR sections (without the risk results) that are the parents of the X-ARA network currently in use in the application. The results are illustrated in Fig. 27 below (using Excel to view the CSV file):



	A	B	C	D	E	F	G	H	I
1	Network_K	Network_N	Network_C	Start_Date	End_Date	Last_Modified_Date			
2	247	DSWCEDR1_20151014A				14/10/2015			
3									
4	Network_K	Link_UID	CEDRLabe	Start_Date	End_Date	User_Length	RoadClass	AADT	NoLanes
5	247		UK-063.01			166	E	29909	2
6	247		UK-068.01			22	O	12872	4
7	247		UK-064.01			27	E	60877	4.1
8	247		UK-066.01			93	E	42093	4.2
9	247		UK-062.01			33	M	67193	6

Figure 27 – Example of CEDR sections export as CSV

The first part shows the basic CEDR network details and is then followed by the CEDR sections themselves.

3.9.7 Influencing Factors Structure Report

This reports the “fixed” internal values used to determine influencing factors for assets. It is noted that these are set at a system level and are not editable by the user, but are provided for information. The results are illustrated in Figure 28 below (using Excel to view the CSV file):

	A	B	C	D	E	F
1	AssetType	thename	SetNo	ColumnNo	RowNo	InfluencingF
2	1	Pavement	1	1	1	0.95
3	1	Pavement	1	1	2	0.9
4	1	Pavement	1	1	3	0.8
5	1	Pavement	1	2	1	1
6	1	Pavement	1	2	2	1
7	1	Pavement	1	2	3	1
8	1	Pavement	1	3	1	1.05
9	1	Pavement	1	3	2	1.1
10	1	Pavement	1	3	3	1.2
11	1	Pavement	2	1	1	0.9
12	1	Pavement	2	1	2	0.8
13	1	Pavement	2	1	3	0.6
14	1	Pavement	2	2	1	1
15	1	Pavement	2	2	2	1
16	1	Pavement	2	2	3	1
17	1	Pavement	2	3	1	1.1
18	1	Pavement	2	3	2	1.2
19	1	Pavement	2	3	3	1.4
20	1	Pavement	3	1	1	0.95
21	1	Pavement	3	1	2	0.9
22	1	Pavement	3	1	3	0.8
23	1	Pavement	3	2	1	1
24	1	Pavement	3	2	2	1
25	1	Pavement	3	2	3	1
26	1	Pavement	3	3	1	1.05
27	1	Pavement	3	3	2	1.1
28	1	Pavement	3	3	3	1.2
29	2	Structure	1	1	1	0.95
30	2	Structure	1	1	2	0.9
31	2	Structure	1	1	3	0.8
32	2	Structure	1	2	1	1
33	2	Structure	1	2	2	1
34	2	Structure	1	2	3	1

Figure 28 – Example of influencing factors report

3.9.8 Risk Factors Structure Report

This reports the “fixed” internal values used to determine base risk for assets based on the Attribute 1 column/row and Attribute 2 column/row values. It is noted that these are set at a system level and are not editable by the user, but are provided for information.

The results are illustrated Figure 29 below (using Excel to view the CSV file):

	A	B	C	D	E	F
1	AssetType	thename	ArrayNo	ColNo	RowNo	BaseRiskVal
2	1	Pavement	1	1	1	40
3	1	Pavement	1	1	2	50
4	1	Pavement	1	1	3	60
5	1	Pavement	1	1	4	80
6	1	Pavement	1	1	5	90
7	1	Pavement	1	2	1	50
8	1	Pavement	1	2	2	60
9	1	Pavement	1	2	3	75
10	1	Pavement	1	2	4	85
11	1	Pavement	1	2	5	95
12	1	Pavement	1	3	1	60
13	1	Pavement	1	3	2	70
14	1	Pavement	1	3	3	80
15	1	Pavement	1	3	4	90
16	1	Pavement	1	3	5	100
17	1	Pavement	2	1	1	40
18	1	Pavement	2	1	2	50
19	1	Pavement	2	1	3	60
20	1	Pavement	2	1	4	70
21	1	Pavement	2	1	5	80
22	1	Pavement	2	2	1	50
23	1	Pavement	2	2	2	60
24	1	Pavement	2	2	3	70
25	1	Pavement	2	2	4	80
26	1	Pavement	2	2	5	90
27	1	Pavement	2	3	1	60
28	1	Pavement	2	3	2	70
29	1	Pavement	2	3	3	80
30	1	Pavement	2	3	4	90
31	1	Pavement	2	3	5	100
32	2	Structure	1	1	1	10
33	2	Structure	1	1	2	20
34	2	Structure	1	1	3	30

Figure 29 – Example of risk factors structure export as CSV

4 Benefits from the X-ARA Tool

4.1 Introduction

We have developed a **methodology for assessing maintenance risks** on a road network based on literature and experience within the Consortium. This knowledge has been clustered into the X-ARA tool that demonstrates our methodology can work.

This **X-ARA risk tool** enables the user to model his network and its environment in order to:

- establish the relative maintenance risk across the network;
- run 'what-if' scenarios to assess the impact of influencing factors

The maintenance risk considered in X-ARA is the **risk for Road Operators:**

- either to lose money (too expensive maintenance, excessive loss in asset valuation, etc.) by applying maintenance strategies, which do not adequately anticipate on high level influencing factors; or
- to provide users (and other stakeholders) with significantly unsatisfying services.

The risk-specific effects on safety, operation, and traffic, of high-to low or non-coordinated maintenance activities are considered but it excludes new construction programmes (schemes).
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.

This chapter provides practical guidance to business operators, i.e. asset manager or decision maker on:

- what they might expect as output from the tool;
- what the tool is able to deliver; and
- what kind of issues can be dealt with the tool.

It focuses on the workflow and interpretation of results.

4.2 General Workflow

The following Figure 30 shows the general workflow of the X-ARA tool which should help understand the process of risk assessment. The example focuses on the risk calculation and starts with a given network and asset definition.

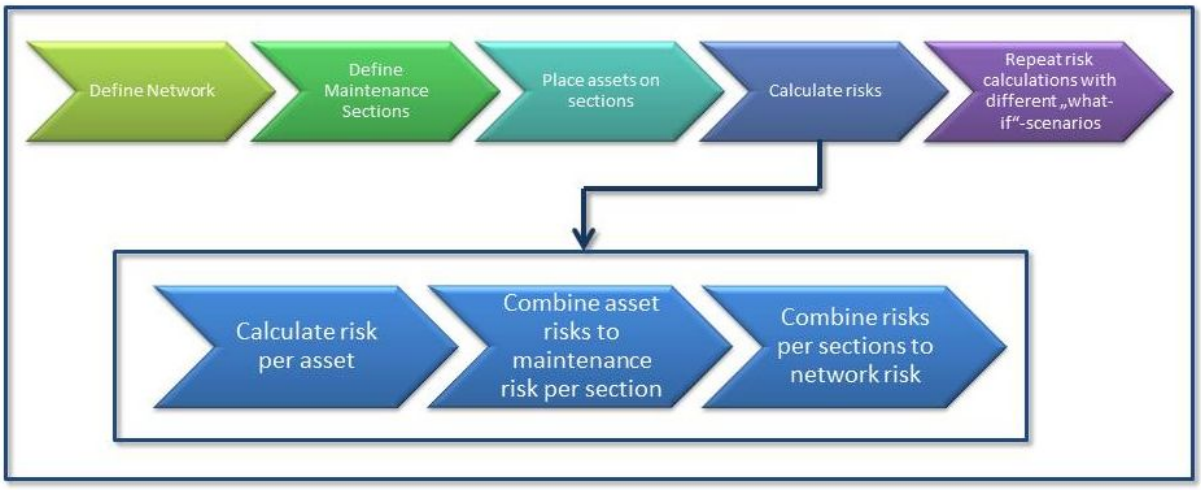


Figure 30: General workflow of the X-ARA tool and workflow of risk calculation

4.3 Inputs to the tool

The input data is defined for the underlying network that is structured as maintenance sections defined as a section of the road network having in general homogeneous conditions (number of lanes, traffic load, sensitivities against different high level influencing factors, etc.).

The sections can be of constant and/or arbitrary length, with a minimum number of attributes (to make the tool work) that depends on the available data set of the Road Operators.

Usually, the maintenance sections will be links between nodes, where the nodes are (main) intersections. Nevertheless, the definition of such maintenance sections (level 1 sectioning) is up to the road administrations and the homogeneous conditions. Number of points on a section is limited to 2500.

For each network section, attributes refer to:

- General description: Name, from-to, length, mapping.
  It is easier to input the related table than keying in assets one by one.
  To check which categories of assets have been input on the network, click on the key on the upper banner.
- Inventory: AADT, Percentage of HGV, Road category, Regional info (flat, mountainous, urban)
- Sensitivity: Climate, Funding, Safety and Network

High level influencing factors have been defined for each asset of the network and investigated concerning applicability and consequences:

- 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 allow 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.

On these sections, the asset categories considered in the risk tool are pavement, structures (bridges and retaining walls), tunnels, road furniture, drainage and geotechnical assets. The basic network elements are visualised in Figure 31.

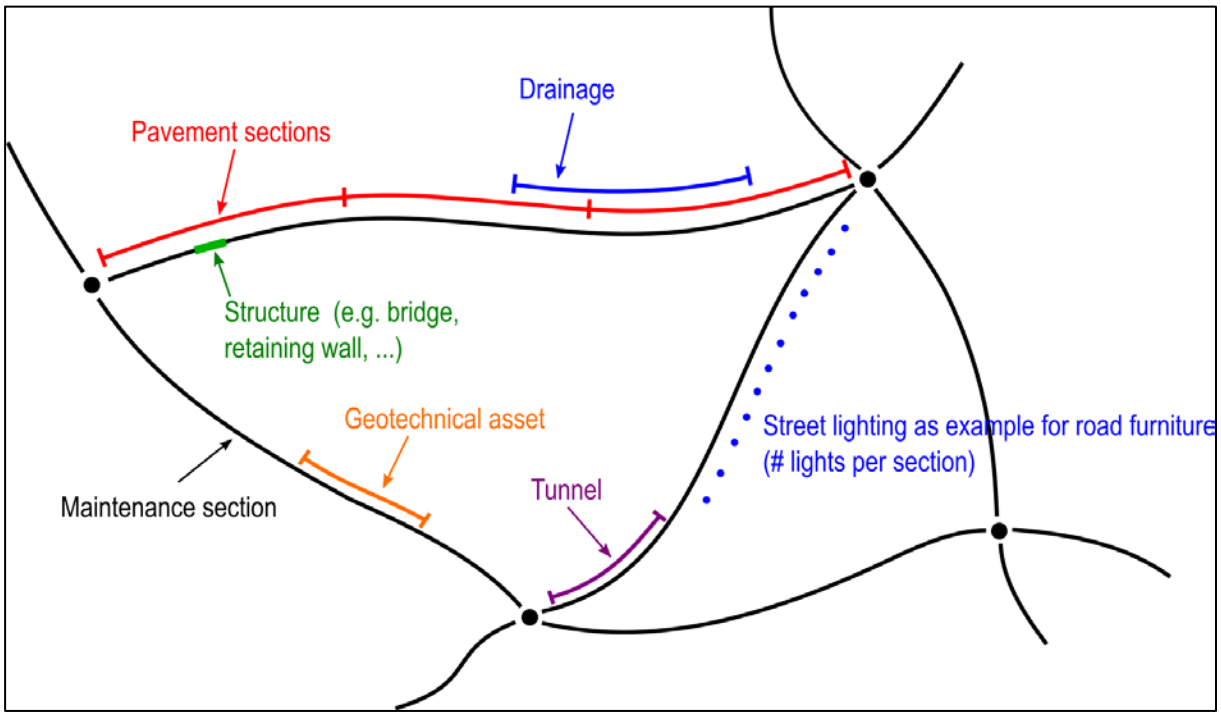


Figure 31: Example of network and asset definitions

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

4.4 Logic of modelling maintenance risk

4.4.1 General

The maintenance risk in the context of asset management is a function of distress probability which depends on:

- asset condition or age
- the consequences with respect to the affected stakeholders; and also
- the type of asset

The general definition of the maintenance risk matrix can be taken from the following **Figure 32** (general example).

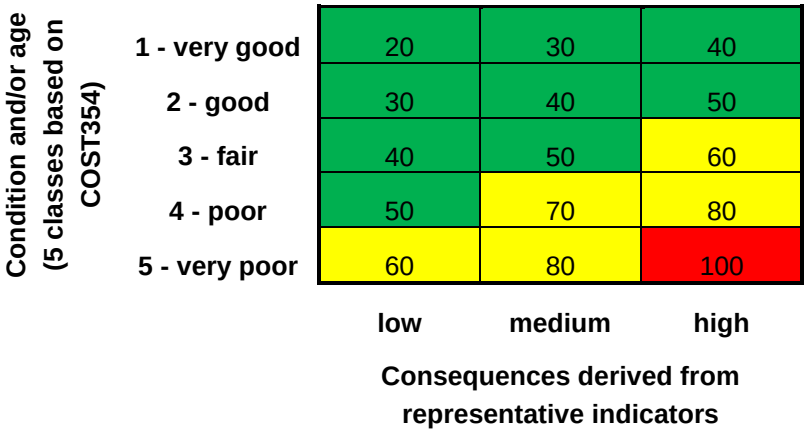


Figure 32: Maintenance risk matrix for X-ARA (general example)

The failure axis is defined by using a scale with 5 condition classes, consistent with the condition scale definition of COST354 [1]) and ENR EVITA [4]. The 5 classes are representing the condition of asset specific properties, where class 1 implies a “very good” condition and class 5 implies a “very poor” condition.
By using a condition scale, the correlation to the failure probability can be made on a quality level, where no asset specific failure distributions, which are usually not available on network level, are necessary. Thereby, a “very good” condition (class 1) means that the failure probability is low in comparison to a “very poor” (class 5) condition, where the failure probability is usually much higher.

The consequence axis is defined in form of at the least 3 categories (low, medium, high), which are either describing the consequences directly or derived by specific indicators (AADT, design category, availability of spare parts, etc.). In many cases direct consequences cannot be calculated because of missing data or underlying information. Thus, it is recommended to use specific indicators, which can be linked to the extension of effects or consequences respectively.

The combination of both, failure (condition) axis and consequences axis leads to a qualitative risk, which is based in the context of X-ARA on a scale from 0 to 100 (rounded off to the integer). Maximum risk that can be displayed is 100 (even if the calculation could lead to a higher value). In principle, this scale is open and can be defined individually. Nevertheless, to avoid misunderstandings and misinterpretations of the output it should be different to the scales and classifications on both axes. To enable a qualitative assessment of the calculated maintenance risk of X-ARA the scale from 0 to 100 will be subdivided into three qualitative risk categories as follows in **Figure 33**:

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

Figure 33: Risk classification within X-ARA

The risk matrices and the weighting functions have been developed and adjusted for each type of asset. Transformation laws for combining asset specific risks have been verified and adjusted if necessary.

The modelling of this generic risk assessment is detailed per asset in Deliverable D3.2:

- Pavements [P]
- Structures (bridges, retaining walls, etc.) [S]
- Road furniture (lighting, safety barriers, etc.) [F]
- Drainage [D]
- Geotechnical assets [G]
- Tunnels (including electro-mechanical equipment) [T]

4.4.2 From asset specific risk to section risk

Asset specific risk is then transformed into maintenance sections using the length weighted average.

Total risk calculation over all types of assets and sub-assets works is based on maintenance sections,

Details are presented in Deliverable D3.2

Table 2: Typical weights asset types

Asset type	Regional situation		
	Flat area	Mountain	Urban
Pavement	30	35	35
Drainage	10	5	5
Tunnel	15	15	15
Structures	25	30	35
Road furniture	10	5	5
Geotechnical assets	10	10	5
Sum	100	100	100

4.4.3 Calculation of total risk on network level

To get an overview of the whole network (network level) it is necessary to combine the maintenance section specific total risk to network level values. This can be either the sum of length of maintenance section in a certain risk category or a length weighted average over all maintenance section.

Details are presented in Deliverable D3.2

Table 3: Network level weighting factor F_{NL}

Network sensitivity	Regional situation		
	Flat area	Mountain	Urban
L	1.00	1.00	1.00
M	1.10	1.20	1.20
H	1.20	1.40	1.40

4.5 Outputs from the tool

4.5.1 Output format

The output of the tool will be provided in three formats: either as a “heat map”, as tables or dashboards.
Whatever the output format, it will enable comparison between:

- Initial risk (all sliders in neutral position)
- Calculated risk (after sliders have been positioned)

Heat map as shown in **Figure 34** provides a **visual overview** of the overall network or part of it.

It is a visual representation (i.e. a colouring scheme) of the overall maintenance risk for each section of the network and therefore allows a visual comparison of sections.

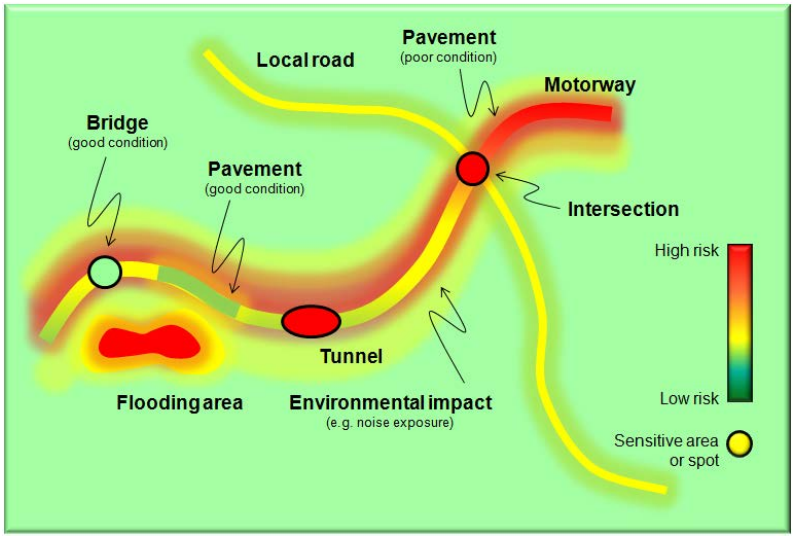


Figure 34: Visualisation of maintenance risk on the network

Additional information like “flooding area” is shown for illustrating influencing factors and depends on availability of GIS representation.

Tables (CSV files) provide **all details of the risk scores** per asset and section (length weighted), but are quite cumbersome to read and do not provide a synthetic view of the network.
Each asset has a unique reference number (generated by the system), which will never be reused if asset is deleted. Assets can be deleted one line by one, by inserting the “DELETE” legend on the first field to be read. Action will take place on first reimporting the CSP

Dashboards provide a **synthetic view** of key sliders of the risks and output of the related scenarios.

4.5.2 Risk quality

The results of calculation procedure represent the risk quality in 3 different categories and not as an absolute number. As described in chapter 4.4 the risk scale from 0 to 100 will be subdivided into three qualitative risk categories(see **Figure 30**):

Maximum risk that can be assessed is 100 (even if the strict calculation could go above 100). Risk rating is rounded off to the integer.

4.5.3 Type of results

Based on this classification the results can be prepared for different purposes and for different end-users (technician, manager, policy or decision maker). Independently from the group of users, the results can be categorised 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 35)

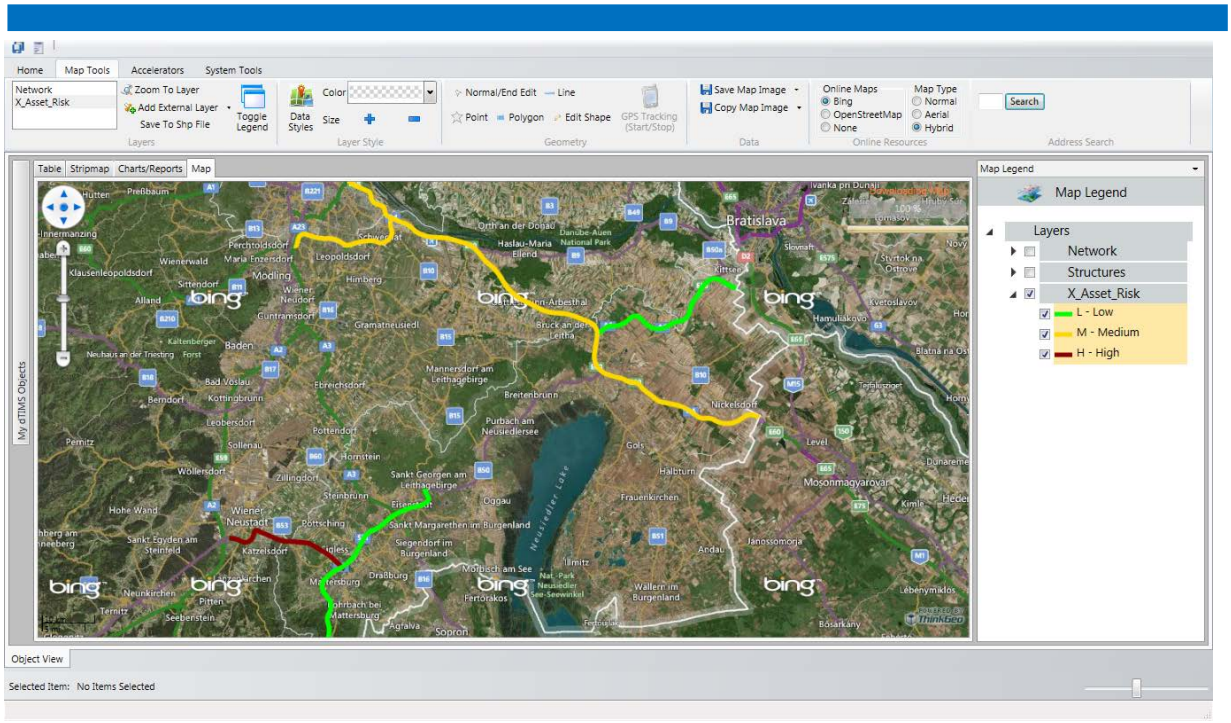


Figure 35: Map with maintenance section risk quality (dTIMS X-ARA-prototype).

- Network level results:
  - Risk class distribution of asset specific risk
  - Risk class distribution of total (cross asset) risk (see **Figure 36**)
  - Average risk of asset specific risk
  - Average risk of total (cross asset) risk (see **Figure 36**)

CEDR Research Project

X-ARA - Cross-Asset-Risk-Assessment

Conférence Européenne des Directeurs des Routes
Conference of European Directors of Roads

Network Level Results

dTIMS X-ARA Prototype

Adjustments for alternative analysis (Scenario)

Effects on the whole network with regard to the asset specific sensitivity

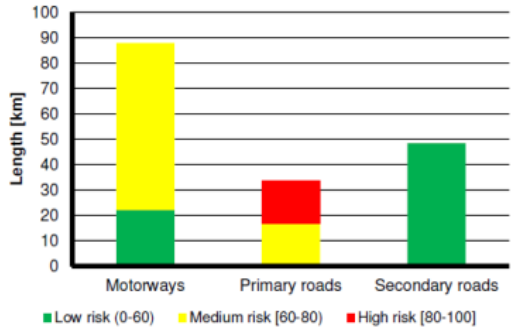
Environmental effects	***High***
Economic effects	***High***
Safety effects	***High***

Asset specific effects with regard to the asset specific sensitivity

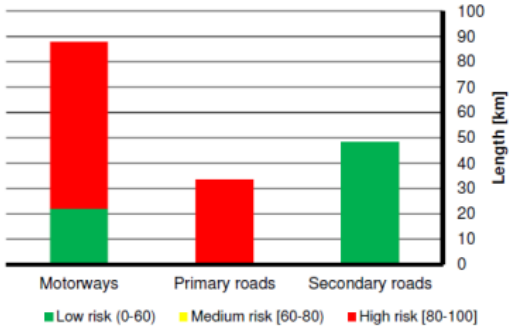
Residual life pavement	***Low***

Risk Class Distribution

Actual situation (standard analysis)

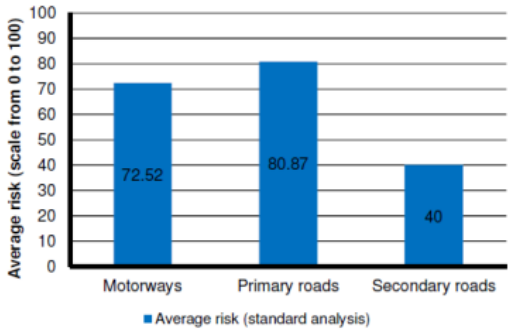


Alternative analysis (Scenario)

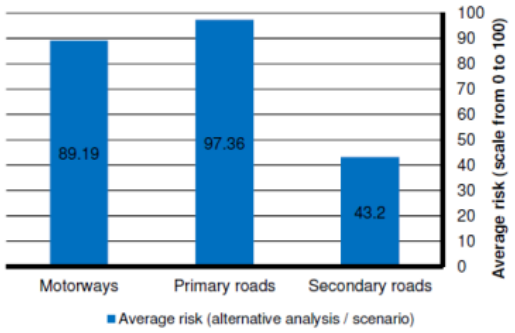


Average risk

Actual situation (standard analysis)



Alternative analysis (Scenario)



The analysis was carried out by using X-ARA dTIMS prototype for a fictive road infrastructure network!

Network level report X-ARA
Version 1.0 / 12.2014

12/6/2014
dTIMS X-ARA Version 1.0

Figure 36: Network level risk reporting (dTIMS X-ARA-prototype).

4.6 Benefits from the project

The main benefits derived from the X-ARA project are:

- the methodology as presented here and developed in Deliverable D3.2, when taken on board by the NRAs
- the use the X-ARA tool, to model the risks related to ageing infrastructure

4.6.1 Methodology

In the course of this project, we made an investigation on the state-of-the-art risk assessment in IAM (Infrastructure Asset Management)

A framework (and Methodology (Deliverable D1.2+D2.1) have been developed, that form the baseline for each motorway or road network.

4.6.2 X-ARA Tool

The Tool (Deliverable D3.2) and Prototype (Deliverable D3.3) were developed.

Depending on the NRA or Asset Manager, it can be used:

- either as a free standing application;
- or as an algorithm in dTIMS (commercial) software, as proof of implementation

4.7 Presentation of results

The X-ARA tool is a macro-economy tool enabling **network level analysis** by identifying the risk areas where to focus on. Its granularity would not be sufficient to trigger repair works on the network.

This guideline document drives 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. These scenarios are run by moving the three sliders in the X-ARA tool.

In practice, the X-ARA tool will enable to:

- identify risk areas on a motorway network, where the Authority should focus on and display in a holistic form that can be easily understood by decision makers;
- compare sections with similar ‘environment’ (e.g. various urban sections as opposed to an urban section vs a mountainous section).

X-ARA can display asset info on a coloured map (with limited number of colours) focusing on the essential.
It can export all results (CSG format) to an external tool including a GIS, where such data can be further processed.

The current X-ARA version enables to display two dashboards:

- the risk class distribution;
- the average risk,

per type of road and for all assets on the whole network.
These are fixed visual reports, and it is not possible at this stage to visualise one given section of the network.

5 Conclusions

X-ARA Tool is a first step towards **understanding how the risk of ageing infrastructure** could be modelled with the objective of **better driving the asset management strategy**.

A number of improvements could be implemented on the current X-ARA Tool:

- Display the same dashboards per asset type and depending on the regional situation (urban, flat, mountainous)
- Interface the X-ARA tool to an Asset management IT-Tool with a full GIS whereby more analysis could be carried out and visualised.
- Print out diagrams beyond screenshots

At this stage, X-ARA focuses on road networks, but a similar methodology with different sets of parameters could be applied to other assets, namely railways, ports, airports…

6 Acknowledgement

The research presented in this deliverable 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.

7 References

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

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