FP7 2013 Cooperation Work Programme
Theme 6: Environment (Including Climate Change)

Novel indicators for identifying critical *INFRA*structure at *RISK* from Natural Hazards

Deliverable D8.1

Critical Infrastructure Case Studies

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Executive Summary

The INFRARISK project proposes to develop reliable stress tests on European critical infrastructure which may be exposed to or threatened by natural hazards. The selection of suitable case studies is necessary in order to validate the effectiveness of the tools and methodologies developed in INFRARISK. Specifically, the tools and methodologies developed in WP4, 6 and 7, will be tested on European road and rail case studies. WP4 consists of an overarching methodology for the risk assessment of the network. WP6 involves the development of a stress test framework for the evaluation of the consequences of extreme natural hazard events on an infrastructure network. Finally, WP7 will design and develop a strategic INFRARISK Decision Support Tool (IDST) to ensure that the INFRARISK stress tests and harmonized risk management methods are practically integrated and used under specific process workflows and modules.

This report has been produced based on the work undertaken in *Task 8.1: Case Study Selection* of WP8, *Case Study Simulation,* and describes the INFRARISK project's selected case studies. The objectives of this report are to:

- describe the selected case studies;
- provide an overview of the selection criteria used for the case studies;
- outline the implementation procedures.

The first step in choosing suitable case studies is to define the spatial and temporal extent of the system. It was ensured that the selected case studies cover a wide range of spatial and temporal scales as well as a range of potential hazards and risks. European hazard maps were consulted in order to ensure that a wide range of hazards were possible in the chosen case study regions. Three different hazard scenarios were defined, accounting for cascading events. The first scenario involves the occurrence of an earthquake, triggering a landslide. The second scenario involves the occurrence of a flood, triggering a landslide. The third scenario involves the occurrence of a landslide, triggering a flood. The case studies were therefore chosen ensuring the possibility of such cascading hazard events. Data requirements for the risk assessment as part of WP4, as well as constraints provided by data uncertainties and lack of data were also considered.

The first case study is a road network extending from Florence to Brennero in Italy. The road network is 450 km long and encompasses the A1 and A22 highways. The second case study is a planned rail network, which is currently at design stage and is prioritized for CEF (Connecting Europe Facility) funding. The planned rail network connects the port of Rijeka on the Adriatic/Mediterranean coast of Croatia to Zagreb, the capital of Croatia. As a starting point, a bridge on each network was identified as suitable for a detailed analysis. However, it is noted that additional bridges as well as other components of the network such as tunnels and embankments will also be included in the network analysis.

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1.0 INTRODUCTION

The selection of suitable case studies is necessary in order to validate the effectiveness of the tools and methodologies developed in INFRARISK. Specifically, the tools and methodologies developed in WP4, 6 and 7, will be tested on European road and rail case studies.

WP4, '*Harmonisation'*, is concerned with developing an overarching methodology to ensure that the results produced in WP2 (hazards to which critical infrastructure is exposed), WP3 (hazard curves and vulnerability functions for different events and infrastructure elements) and WP5 (space-time models to analyse the impact of natural hazards on infrastructure that may be location or time dependent) can be used together to identify the risk related to critical infrastructure.

WP6, '*Stress Tests for multi-risk scenarios',* involves the development of a stress test framework for the evaluation of the consequences of extreme natural hazard events on an infrastructure network.

WP7, *'Implementation',* will design and develop a strategic INFRARISK Decision Support Tool (IDST) to ensure that the INFRARISK stress tests and harmonized risk management methods are practically integrated and used under specific process workflows and modules.

The objectives of this report are:

- to describe the selected case studies;
- to provide an overview of the selection criteria used for the case studies;
- to outline the implementation procedures.

It must be ensured that the selected case studies cover a wide range of spatial and temporal scales, potential hazards and risks. Furthermore, the availability of hazard, risk and exposure data must be ensured. Constraints provided by data uncertainties and lack of data must also be considered.

One road network and one rail network are chosen to validate the effectiveness of the methodologies developed in INFRARISK. Both networks are part of the Ten-T core network. These networks form the backbone of the EU's transportation policies within the single market and were agreed at the trialogue between the European Commission, Council and Parliament in May and June 2013. Transport financing under the Connecting Europe Facility (for the period 2014–2020) will also focus on this core transport network, filling in cross-border missing links, removing bottlenecks and making the network smarter.

The selected road network extends from Florence, Italy to Brennero on the Italian-Austrian border. The rail network selected connects the port of Rijeka on the Adriatic/Mediterranean coast of Croatia to Zagreb, the capital of Croatia. These networks will be further described in Section 2.

It is acknowledged that there has been a change in the case studies since the Description of Work was written. This was decided by the consortium after in depth discussions and a preliminary data search suggested that the type of data required by the various work packages to implement their methodologies was unavailable in regions where the hazards under investigation do not occur. The updated choice of case studies was discussed with the advisory board and an agreement was reached that the current approach is acceptable.

2.0 CASE STUDY DESCRIPTION

For the purpose of the INFRARISK project, the types of infrastructure considered are road and rail networks and elements of the same. It is acknowledged that other types of infrastructure can be affected by natural hazards, such as telecommunication lines and service pipes; however, these are beyond the scope of the case studies research in INFRARISK. As such, a European road and rail network on the Ten-T Core Network have been selected as case studies to validate the effectiveness of the tools and methodologies developed in INFRARISK and test the resilience of the network. The Ten-T Core Network Corridors can be seen in Figure 2.1.

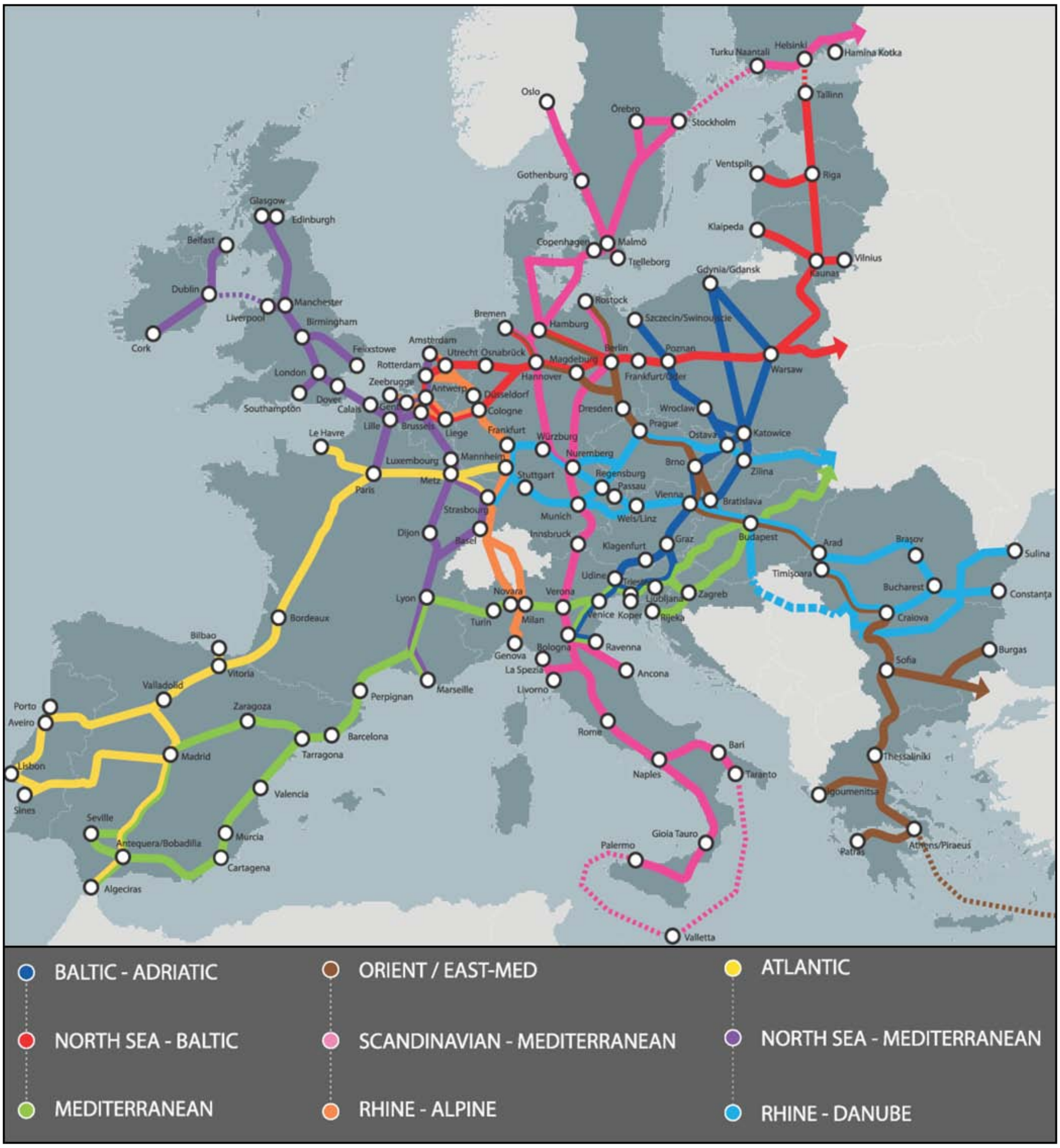


Figure 2.1: TEN-T Core Network

The Ten-T Core network is the second layer of a dual layer approach to the trans-European transport network. The first layer or "Comprehensive Network" considers the five main transport modes, road, rail, inland waterways, maritime and air infrastructure and ensures accessibility for people and goods across all regions within the European Union. The second layer, or "Core Network", Figure 2.1, is made up of the strategically most important parts of the Comprehensive Network, on which project development and implementation will be supported with priority. Multiple factors were considered when selecting the road and rail case studies, which are described in Section 3. A brief description is provided in the following paragraphs.

For the road case study, Figure 2.2, a network in Italy is considered. The network is located on the Mediterranean-Scandinavian corridor (see Figure 2.1), and extends from Florence to Brennero, on the Italian-Austrian border. It is 450 km long and encompasses the A1 and A22 highways. Secondary roads branching off the main highway will also be considered in the analysis in order to model the impact on alternative routes as a result of operational disruptions on the main highways.

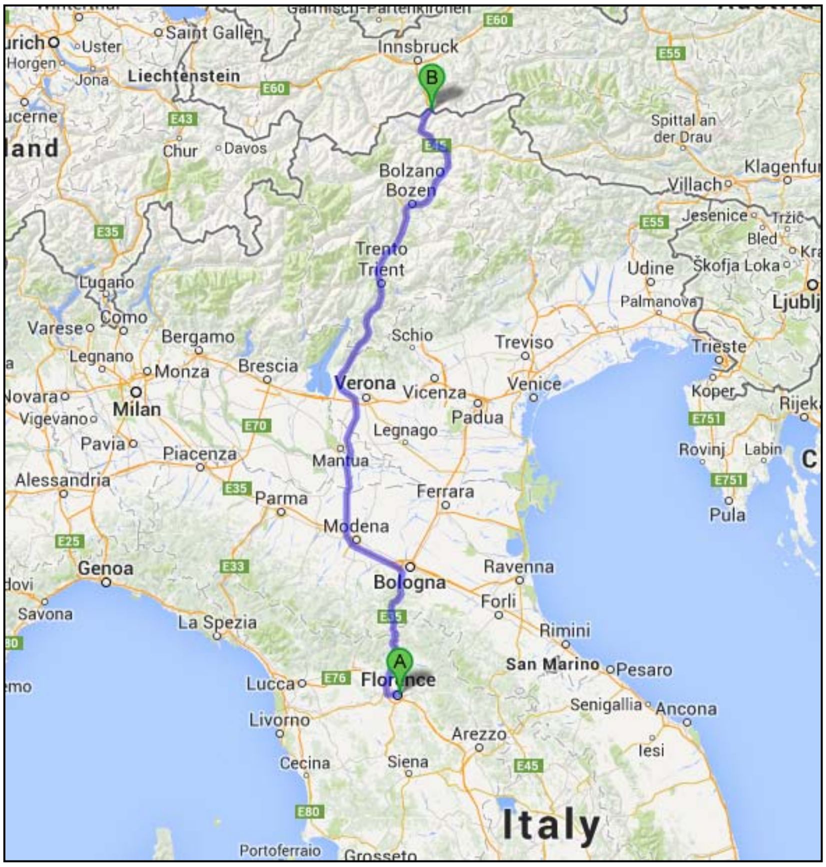


Figure 2.2: Road Case Study

For the rail case study, a planned network in Croatia is considered. The network, Figure 2.3, will extend from Rijeka to Zagreb. Although there is an existing line connecting Rijeka – Zagreb – Budapest, certain parts of it are unsatisfactory and are limiting the performance of the entire line. The best example is a part of the Rijeka – Zagreb line built in the late 19th century through the mountainous region of Gorski Kotar. This section of the line has a large number of curves with radii as small as 275m, which result in a significantly reduced permissible line speed and capacity. For this reason, a new "lowland" section of the line is planned that will allow speeds of up to 200 km/hr. This will increase the rail's goods transportation capacity from 6.2 million net tones/year to over 30 million net tones/year. The project is expected to cost approximately €3 billion and is projected to start in 2015.

The advantage of selecting a case study from a planned network is that the risk assessment of critical infrastructure being undertaken as part of the INFRARISK project is expected to be completed before the new rail line is built. Consequently, the methodologies developed as part of INFRARISK can offer European stakeholders the tools to develop risk mitigation strategies that could be used for real development plans.

It must be emphasized that although efforts have been made to ensure the suitability of these case studies in terms of data availability, certain changes may be made during the course of the project if deemed necessary for their successful implementation. Possible changes may include focusing on a particular section of the chosen case study network where sufficient data is available.

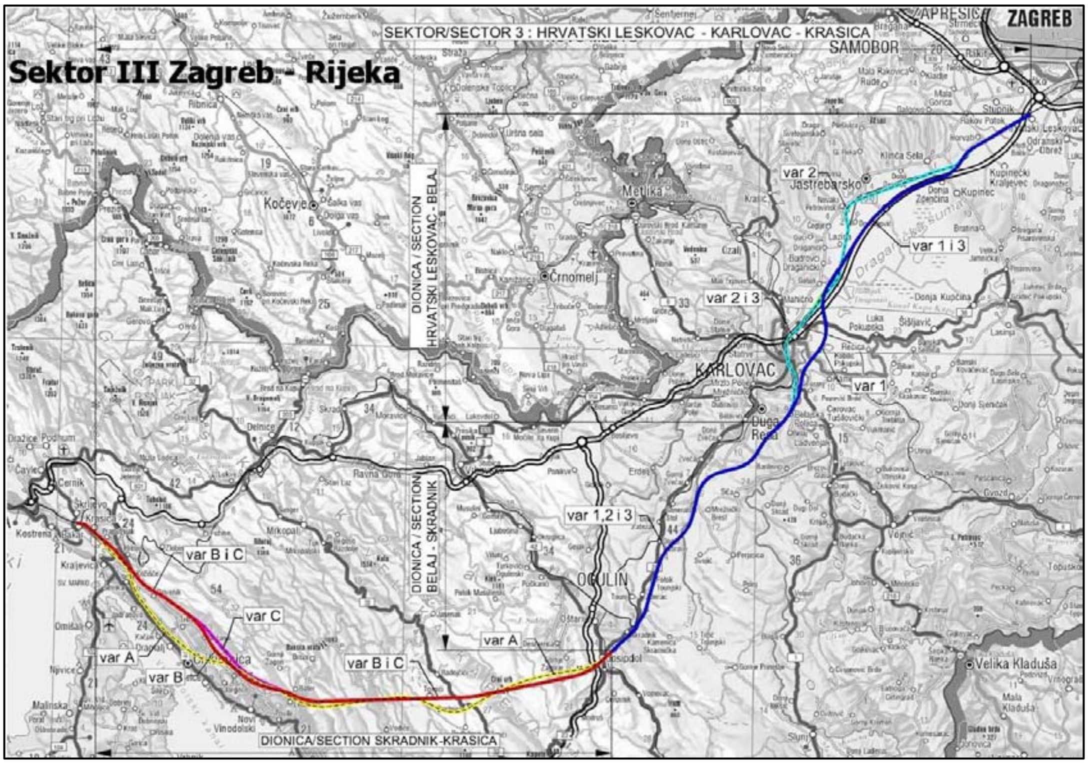


Figure 2.3: Rail Case Study

3.0 SELECTION CRITERIA

The task of selecting the case studies is very important since their successful implementation is necessary to validate the effectiveness of the methodologies and tools developed as part of the INFRARISK project. In order to select suitable case study locations, the requirements of the various work packages were investigated to assess their feasibility. Once the work package requirements were established, potential case study locations throughout Europe were systematically investigated to identify the most suitable locations. The starting point for each case study consists of an in-depth analysis of a local element on each network, which will be followed by the addition of further elements. This section of the report describes the selection criteria adopted in choosing the case study locations. The main factors considered are as follows:

- The critical nature of the infrastructure network.
- The exposure of the network to natural hazards and availability of hazard data.
- The availablity of data on the infrastructure network considered.

3.1 Critical Infrastructure

According to The European Parliament and Council (2008), critical infrastructure is defined as 'an asset, system or part thereof located in Member States which is essential for the maintenance of vital societal functions, health, safety, security, economic or social well-being of people, and the disruption or destruction of which would have a significant impact in a Member State as a result of the failure to maintain those functions'. As mentioned previously, only road and rail infrastructure will be considered as part of the INFRARISK project. The main responsibility of *Task 2.1: Inventory of Critical Infrastructure in the EU* of *WP2 Risk Profiling of Natural Hazards and Infrastructure* was to compile a database of critical European infrastructure. However, in the early stages of the INFRARISK project, it became apparent that it would be very difficult to compile this inventory in the EU due to security restrictions. Given the difficulties associated with identifying critical infrastructure in Europe, for the purpose of the INFRARISK project, it is proposed that critical infrastructure be defined as elements of the Ten-T Core Transport Network such as for example, bridges, tunnels, earthworks and other structures (culverts etc.). This approach is adopted since the Ten-T Core Network has been defined as the most of important parts of the Ten-T network, strategically. Therefore, the first factor considered when selecting the case studies, is that the chosen networks should be part of the Ten-T core network.

3.1.1 Road Case Study

The road case study, Figure 3.1, is a section of the Italian road network extending from Florence to Brennero on the Italian-Austrian border. The proposed case study network connects Florence, Bologna, Modena, Verona, Trento and Brennero. It is located on the Scandinavian-Mediterranean corridor, Figure 2.1, which is considered a crucial axis for the European economy, linking Italy and the Mediterranean to the urban centres of Germany and Northern Europe (European Commission, 2013). From Figure 3.1, it can be seen that this section of road is part of the European Ten-T Core Road Network. While the Florence-Bologna section of the network requires upgrading, it has not been prioritized for Connecting Europe Facility (CEF) funding.

Figure 3.1: TEN-T Road Network

3.1.2 Rail Case Study

The rail case study, Figure 3.2, is a section of the Croatian rail network connecting Rijeka and Zagreb located on the Mediterranean corridor, Figure 2.1, which will link in the south western Mediterranean region up to the Ukrainian border with Hungary, following the coastlines of Spain, France, and crossing the Alps towards the east through Italy, Slovenia and Croatia. The section of the network chosen for the case study is the rail line from the port of Rijeka to Zagreb, a major node on the overall network. Rijeka is the most northern deep-sea port in the Mediterranean and the closest port to the Central European market, therefore, it is considered a critical node on the Ten-T Core Network. From Figure 3.2, it can be seen that the Rijeka-Zagreb section of the corridor requires upgrading, since the existing line cannot meet the current requirements as described in Section 2 of this report. This section of the Ten-T network has been identified as a CEF project and is prioritized for funding.

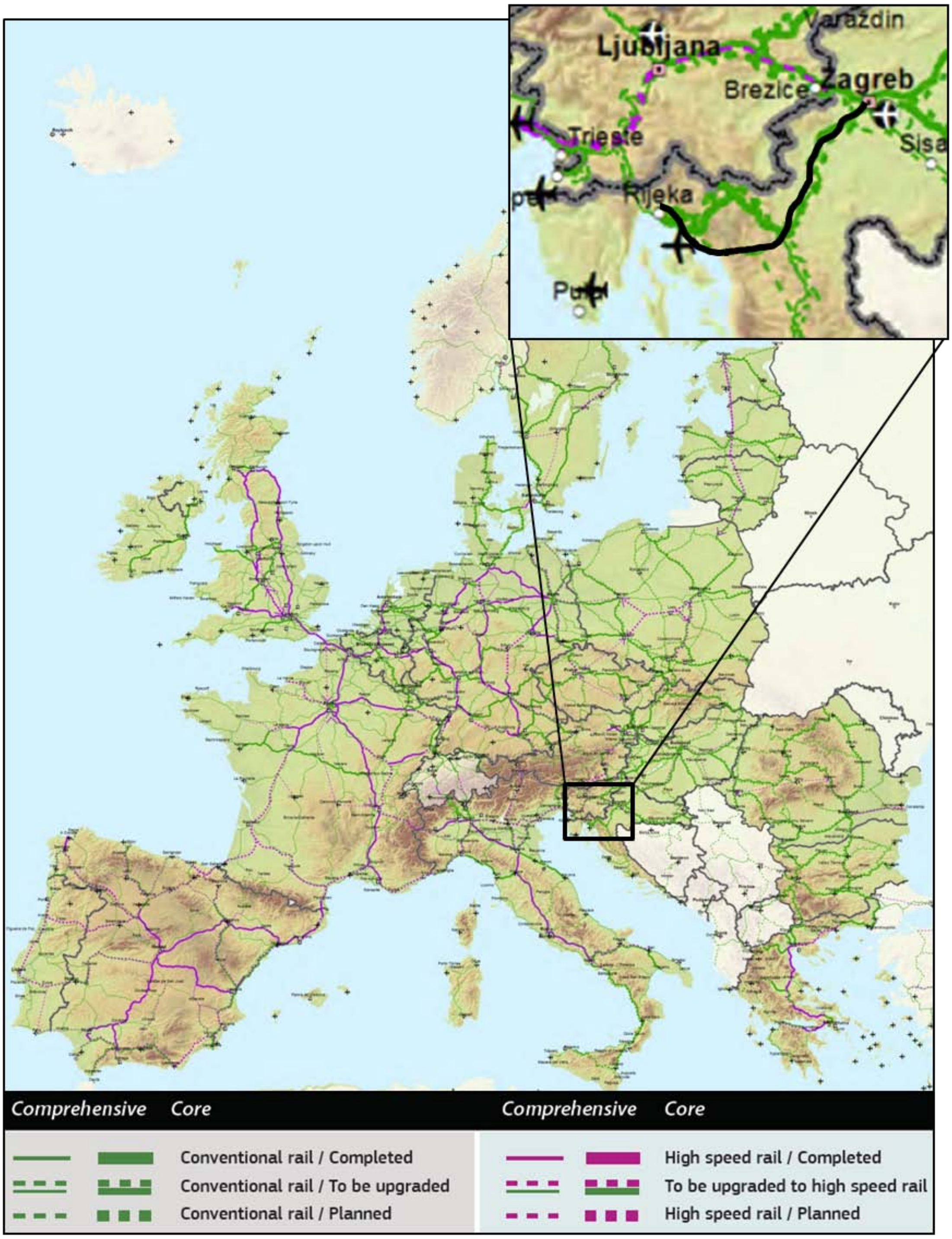


Figure 3.2: TEN-T Rail Network

3.2 Natural Hazard Data

A further factor considered when selecting the case studies is the location of the networks relative to potential sites prone to the natural hazards under investigation in INFRARISK. This is important because a number of work packages require information on hazard levels and their probabilities of exceedance and this information is more readily available in regions where the relevant natural hazards are known to occur. The natural hazards considered in INFRARISK are earthquakes, slope failure, mass movement, and flooding. INFRARISK will also consider cascading hazard events; therefore, the case studies were chosen ensuring the possibility of cascading hazard events such as an earthquake triggering a landslide or a flood triggering a landslide. As a preliminary guide, European seismic hazard maps, landslide susceptibility maps and flood occurrence maps were consulted to identify suitable regions that are susceptible to multiple natural hazards. It is important to note that these maps were only used as a guide for selecting the case studies. It is acknowledged that more detailed and site specific information will be required for the relevant work packages. The hazard maps consulted in order to choose the relevant case studies are identified below.

- Seismic – European Seismic Hazard Map, developed by the FP7 SHARE project (Giardini et al. 2013).
- Landslides – European landslide susceptibility map, developed by the European Landslide Expert Group (Panagos et al. 2012, Günther et al. 2013a, Günther et al. 2013b).
- Flooding – A pan European flood hazard map, developed by The Joint Research Centre, together with the European Centre for Medium-Range Weather forecasts and the University of Bristol (Alfieri et al. 2013).

3.2.1 Seismic Hazard

In terms of the seismic hazard, both the Italian road and Croatian rail case studies pass through high seismic regions. Figure 3.3 shows a European seismic hazard map, developed as part of the FP7 funded SHARE project (Giardini et al. 2013). The uniform seismic hazard map shows the peak ground acceleration (PGA) levels which have a 10% probability of exceedance in 50 years and the case study locations are highlighted.

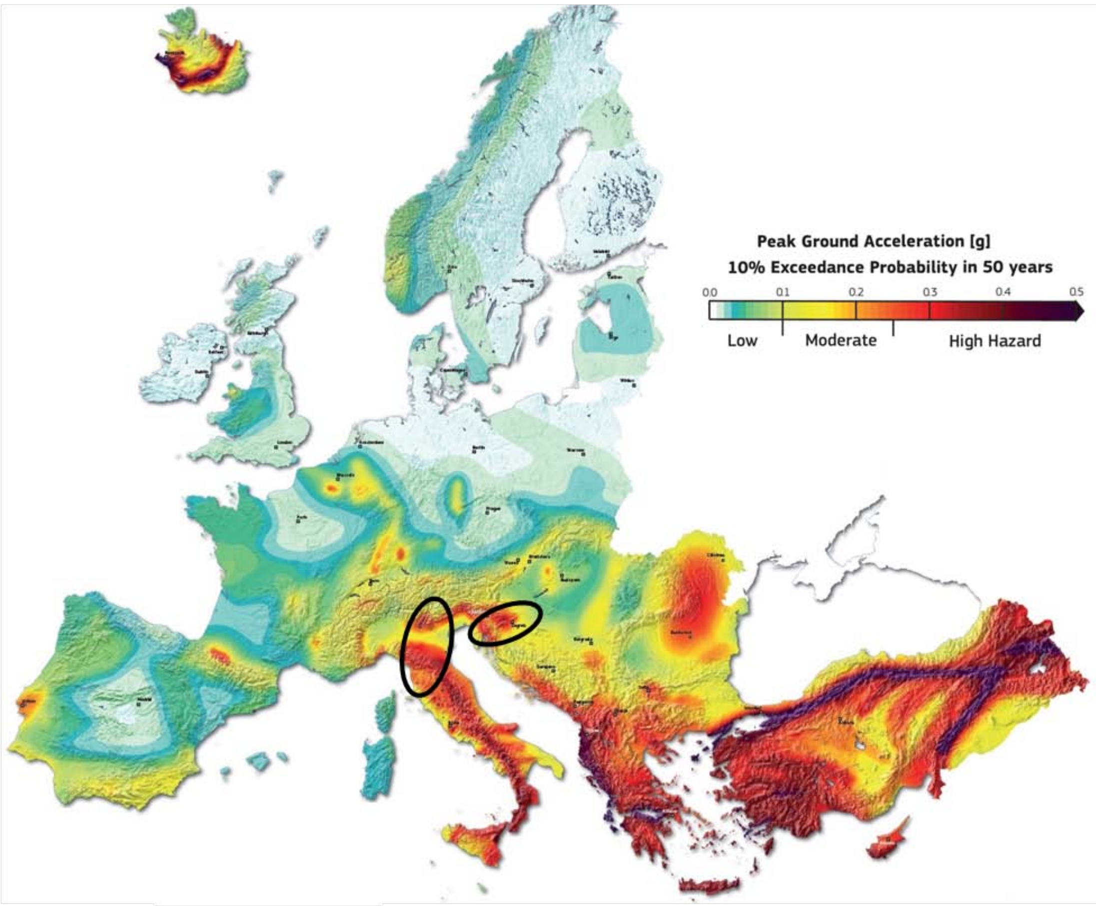


Figure 3.3: European Seismic Hazard Map

From Figure 3.4, it can be seen that the road network under investigation passes through regions that have PGAs ranging from 0.15g to 0.35g. The 2012 Emilia Romagna earthquakes struck the region just north of Bologna, close to the road network under investigation. Two earthquakes struck the region, 9 days apart, with moment magnitudes of 5.8 and 5.9 respectively. Although the earthquakes were considered moderate in magnitude, they caused 27 deaths and widespread damage. However, only a handful of bridges sustained damage during the earthquake, none of which collapsed.

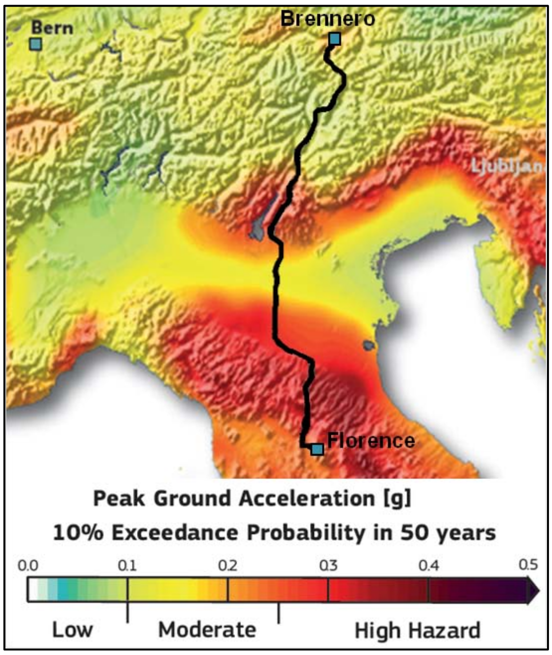


Figure 3.4: Seismic Hazard Map for Road Case study

The rail network, extending from Rijeka to Zagreb, Figure 3.5, passes through regions that have PGAs ranging from 0.15g to 0.3g. The magnitudes and epicenters of historical seismic events relative to the rail network are shown in Figure 3.6 (Herak et al. 1996).

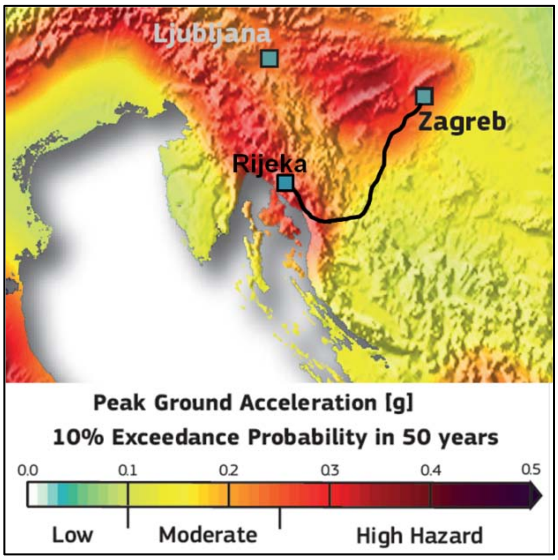


Figure 3.5: Seismic Hazard Map for Rail Case study

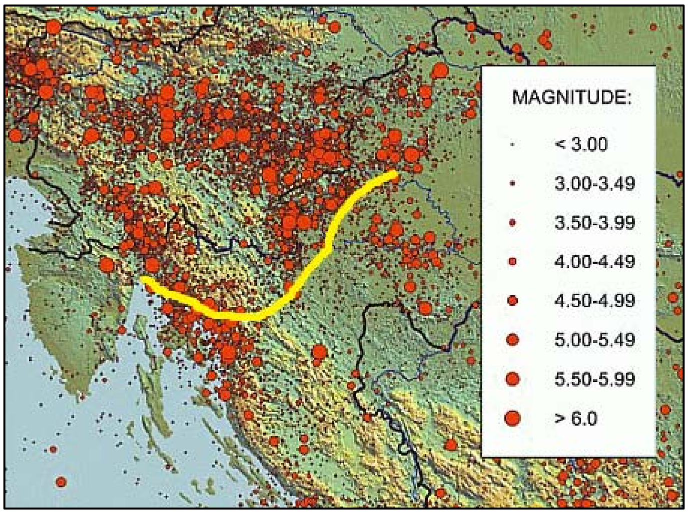


Figure 3.6: Historical Seismic Events relative to rail network

Several significant earthquakes have occurred in Northern Croatia in the past 200 years, most notably the 1880 Zagreb earthquake, which had a moment magnitude of 6.3 and seriously damaged over 500 houses, large buildings, churches and castles (Kozák and Čermák, 2010). As for recent earthquakes, the 1979 earthquake struck the Montenegrin and South Croatian coast with a moment magnitude of 7.0 and caused 136 casualties. Since the affected area was of prime cultural importance, numerous damage reports were produced focusing only on the damage sustained to cultural/heritage objects. Unfortunately, the damage sustained to infrastructure components was largely neglected in the reports (UNESCO 1984, Institute for the Restoration of Dubrovnik 1992).

3.2.2 Landslide Hazard

In terms of landslide hazard, both the road and rail networks of interest are located in regions susceptible to landslides, Figure 3.7, which shows the European landslide susceptibility map developed by the European Landslide Expert Group (Panagos et al. 2012, Günther et al. 2013a, Günther et al. 2013b). This landslide susceptibility map included both rainfall and earthquake triggered landslides. The Italian road network passes through the Apennine and Alpine mountainous regions, where landslide susceptibility is considered very high, as shown in Figure 3.8. In Italy, two different national landslide databases exist. These include the Inventario dei Fenomeni Franosi in Italia (IFFI) database and the Aree Vulnerate Italiane (AVI) database. The IFFI landslide database contains significantly more landslides than the AVI landslide database (485,004 versus 21,159). This is due to the fact that the IFFI database is a geomorphological database containing mainly landslides identified during field work and from analysis of aerial photographs (Trigila et al., 2010). The AVI database is a historical database containing landslide events reported in historical documents and scientific/technical reports (Guzzetti et al., 1994; Guzzetti and Tonelli, 2004). As a consequence it has fewer landslides, however for a significant amount of the recorded events there is information available on additional aspects of the event such as landslide history, triggering factors and consequences (Van der Eeckhaut and Hervás, 2011). As illustrated in Figures 3.7 and 3.9, the Croatian rail network lies in a region that is moderately to highly susceptible to landslides. The planned new section passes through a mountainous karst area of northern Dinaric Alps range with frequent landslide and rock fall occurrences (Arbanas et al., 2012; Roje-Bonacci et al., 2009). Unfortunately, except for the wider Zagreb area, there has been no systematic collection and data processing of landslide and rockfall events in Croatia, and no useful landslide databases can be found for the case study area.

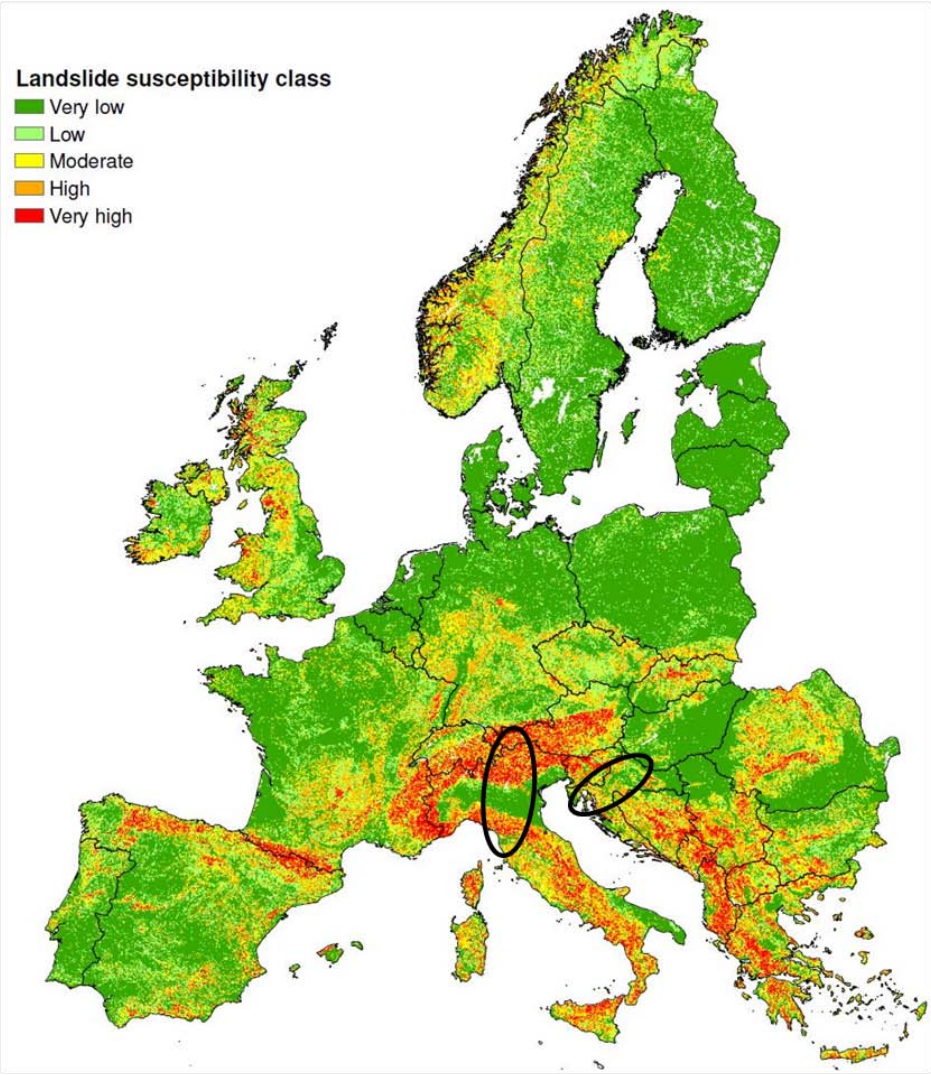


Figure 3.7: European Landslide Susceptibility Map

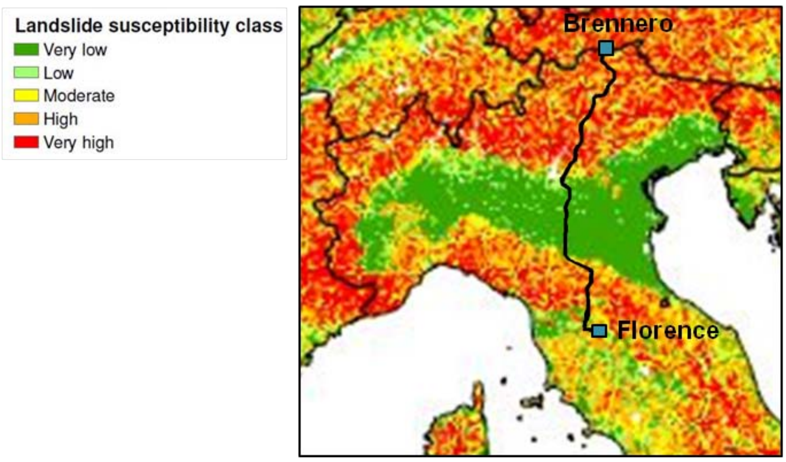


Figure 3.8: Road Network and landslide susceptibility

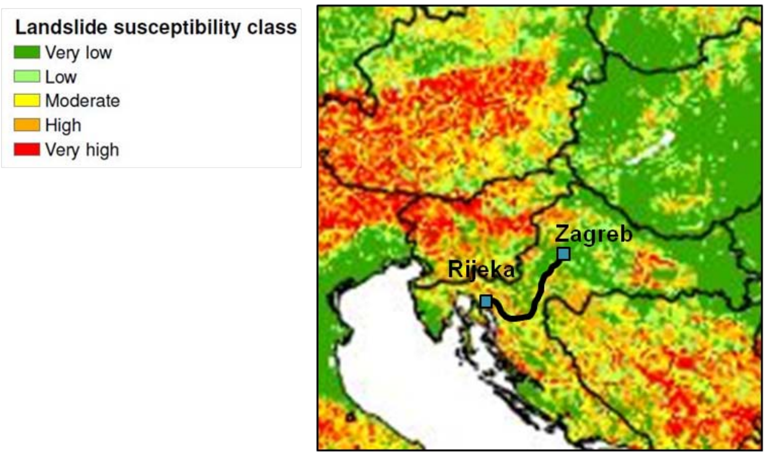


Figure 3.9: Road Network and landslide susceptibility

3.2.3 Flood Hazard

In terms of flood hazard, both case studies pass through regions that are prone to flooding. The hazard maps shown in Figures 3.10 to 3.12, developed by The Joint Research Centre, together with the European Centre for Medium-Range Weather forecasts and the University of Bristol (Alfieri et al. 2013), shows the 100 year flood event in terms of maximum flood depth. It is acknowledged that the Figure 3.1 shows only fluvial and pluvial flood hazard in Europe. This was used only to give a preliminary indication of flood hazard in Europe and alternative flood data will be required for the methodologies developed as part of the project.

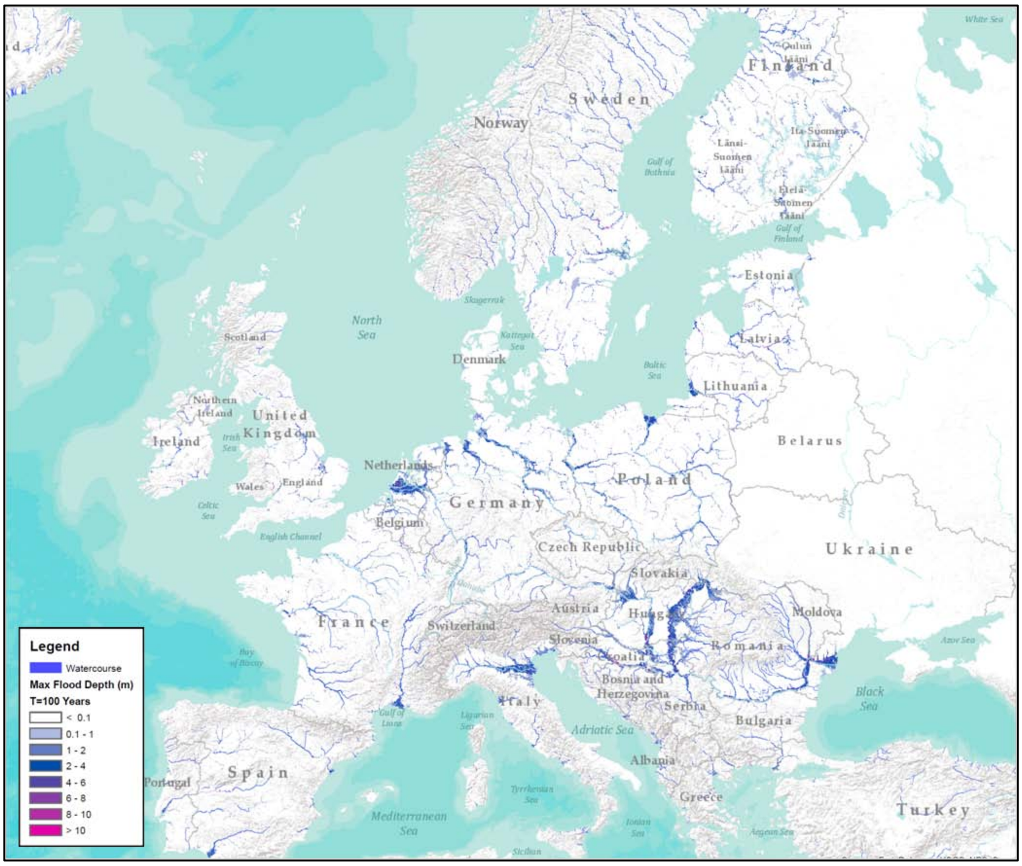


Figure 3.10: European Flood Hazard Map

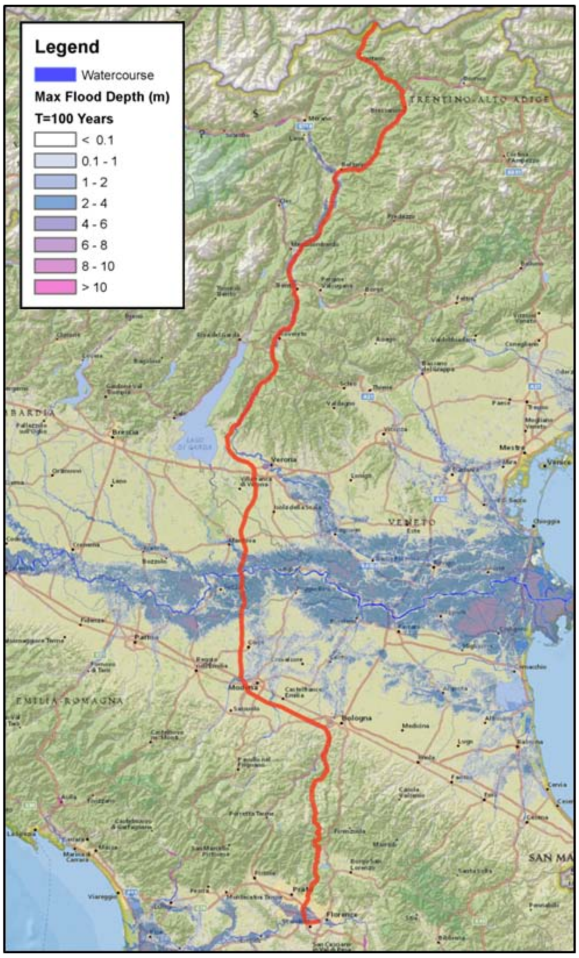


Figure 3.11: Road Network and Flood Hazard

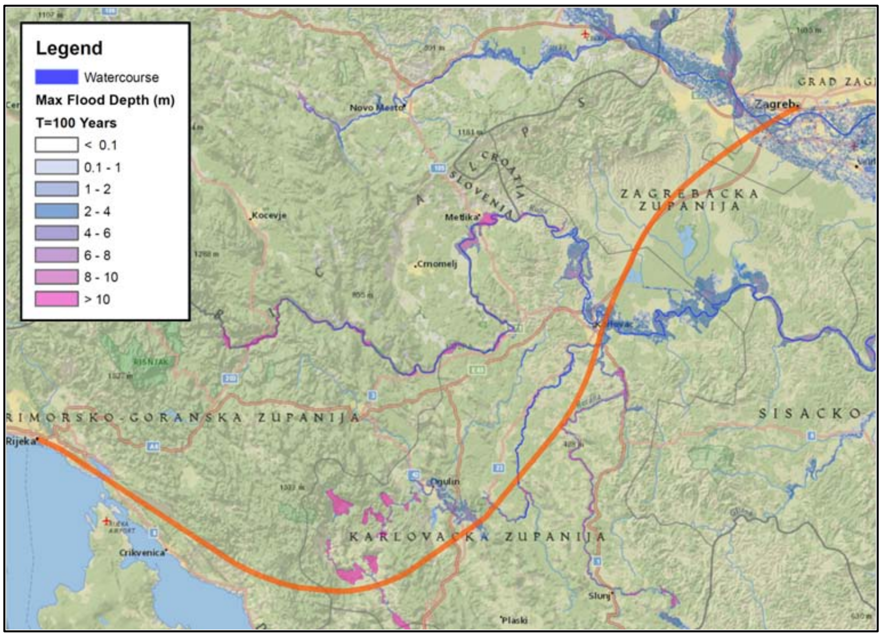


Figure 3.12: Rail Network and Flood Hazard

As illustrated in Figure 3.11, it can be seen that the Italian road network passes through the Po river basin which is susceptible to flooding. Similarly, the area around Florence is prone to flooding, suffering a major flood in 1966 and numerous minor floods over the past number of years. As illustrated in Figure 3.12, it can be seen that the rail line passes through the Kupa river basin which is susceptible to flooding. The rail line is also prone to flooding around the Zagreb region.

3.3 Infrastructure Data

Ultimately, the availability of data required by the various work packages governs the case study locations. Consequently, a list of data requirements was compiled, encompassing all the work package data requirements. A list of the data requirements for the harmonized risk assessment can be found in Appendix A. In addition to hazard data, the main data requirements are related to the infrastructure networks themselves. Similarly, ancillary information such as topographic data, climate records, soil maps and land use/cover maps was sought to maximize the opportunity to optimise the models developed.

In terms of infrastructure information, the required data includes:

- Structural details of components and sub-components of the network (e.g. roads, bridges, tunnels, etc.).
- Structural health of the components.
- Empirical damage data for structural components of the network damaged by past hazard events.
- Traffic flow data for the network.

In terms of the structural details of the network components, various levels of detail are required depending on the type of fragility curves to be derived. Two different approaches will be used to derive the fragility curves for the various components of the networks. The first approach involves identifying relevant fragility functions from the literature. The second approach involves the use of analytical methods to derive new fragility functions for specific network components. If existing fragility functions are selected from previous literature references, it is still necessary to identify the correct typology in order to associate the right fragility functions with the studied components. The SYNER-G database of fragility functions for bridges proposes a taxonomy for the different bridge typologies, based on the following parameters (Crowley et al., 2011):

- Material: Concrete, Masonry, Steel, Wood, Iron, Mixed;
- Secondary Material: RC, Pre-stressed RC, Low/Average/High strength concrete, Unreinforced/Reinforced masonry, Lime/Cement/Mud mortar, etc…;
- Type of superstructure: Girder bridge, Arch bridge, Suspension bridge, Slab bridge;
- Type of deck: Solid slab, Slab with voids, Box Girder, Modern/Ancient arch bridge;
- Deck characteristics: length;
- Deck structural system: Simply supported, Continuous;
- Pier-to-deck connection: Monolithic, Through bearings;
- Type of pier to superstructure connection: Single/Multi column piers;
- Number of columns per pier;
- Type of pier section: Rectangular, Cylindrical, Oblong, Wall-type, Solid/Hollow;
- Height of pier;
- Spans: Single, Multi;
- Span characteristics: number, length;
- Type of connection to the abutments: Free, Monolithic, Through bearings;

- Bridge configuration: Regular, Semi-regular, Irregular;
- Seismicity level: No design level, design level.

Other taxonomies can be found in FEMA (2003), Nielson (2005), Basoz and Kiremidjian (1996) or NIBS (Risk Management Solutions Inc, 1995).

If certain components of the chosen case study networks are not sufficiently covered by existing fragility functions, analytical fragility functions will be developed. For the case of bridge components, the Table 3.1 provides a short summary of the type of input that is required for the development of analytical fragility curves.

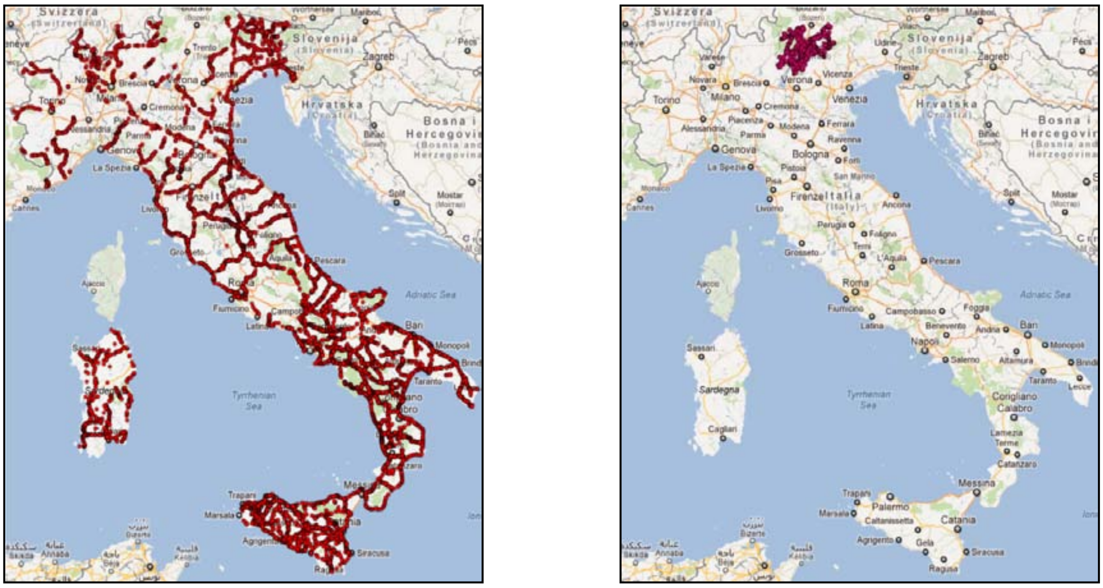
Component	Bridge system	Deck	Piers	Bearings	Abutments
Structural plan (height, length, No. of elements)	X				
Weight		X			
Material		X	X	X	
Section		X	X	X	
Reinforcement		X	X		
Behaviour Concrete			X		
Behaviour Steel			X		
Allowed gap				X	
Max. strength				X	X
Soil type					X
Connection w/ elements		X	X	X	X

Table 3.1 Example of the type of structural data required to model a bridge system

Similar data requirements will be developed for tunnels and embankments, however, bridges will be the most complex objects to model and are therefore were prioritized when choosing the case study locations. It is important to note that although possible sources of data have been identified for both case studies, the availability of data may result in slight changes to the approach adopted for the development of the fragility curves.

3.3.1 Road Network Infrastructure Data

For the road network case study, detailed documentation on a number of representative structures must be acquired through the literature, national and regional administrations as well as major contractors. Ceresa et al. (2012) developed a database of bridge information in terms of position, geometry and structural details for the Italian highway network. While developing the database, Ceresa et al. (2012) identified three sources of data that can be used for the INFRARISK Italian case study. These include the Italian national roads authority (ANAS), the regional roads authority of the province of Trento and Autostrade per L'Italia, the largest concessionaire on the Italian road network. The locations of the bridges included in the three databases mentioned are shown in Figures 3.13 and 3.14 (Ceresa 2013). According to Ceresa (2013), there are approximately 17,000 bridges included in the three databases mentioned, however, structural details were only found for approximately 400 bridges.



(a) ANAS Database Province of Trento Database

Figure 3.13: Italian Infrastructure Databases

Figure 3.14: Autostrade per l'Italia infrastructure database

The Rio Torto Viaduct, shown in Figures 3.15 - 3.17, has been identified as a component of the network suitable for a detailed analysis. The Rio Torto Viaduct is a 13 span reinforced concrete bridge with a total length of 421 m and was built in the late 1950's (Pinto and Mancini, 2008). The viaduct is situated on the A1 highway between Bologna and Florence. Pinto and Mancini (2008) and Di Sarno et al. (2011) have carried out detailed seismic vulnerability assessments of the viaduct in the past, and as such, a significant body of information exists on the structure. Di Sarno et al. (2011) carried out a full scale testing programme on one of the piers, the purpose of which was to investigate the effect of isolation as a retrofit measure. The literature presents extensive structural details of the bridge, including details of the reinforced concrete bridges piers. Finite element models were developed using OpenSEES software, therefore, a certain amount of results are available (e.g. natural frequencies, mode shapes etc.) that could be used to benchmark the model.

Figure 3.15: Rio Torto Viaduct

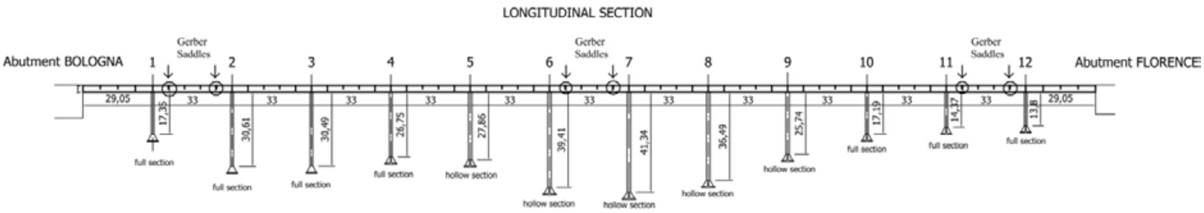


Figure 3.16: Rio Torto Viaduct

Figure 3.17: Rio Torto Viaduct

3.3.2 Rail Network Infrastructure Data

For the Croatian rail case study, structural details must be acquired through the literature, rail operators (*Hrvatske Željeznice Infrastruktura*), national administrations (*Ministry of Transport and Infrastructure*) as well as major designers and contractors (*Institut IGH*). The summary route information, including structural and traffic flow data, as well as some basic structural details for the components on the planned new line can be found in the literature (Lažeta et al. 2008) and documentation from public meetings.

The Rječina rail bridge, shown in Figure 3.18, has been identified as a component of the network suitable for a detailed analysis. This bridge is a component of the existing railway line; however, it will also be part of planned new railway line. The steel bridge has a central span of 35 m (with two other bridges continuing on both sides and supported by the same abutments) and was constructed in 1873. The steel upper deck was replaced in 1946 and renovated in 1962. Since then, it has undergone several repairs, most recently in 2009.

Figure 3.18: Rječina Bridge

Detailed static capacity calculations of the bridge elements have been carried out recently by the University of Zagreb using finite element analysis methods. The extensive structural details of the bridge were obtained from Croatian Railways and will be available for the relevant work packages.

In terms of the structural health of the components, the relevant national and regional authorities will be contacted to establish condition ratings of the bridges under consideration. Although bridge management systems exist in both Croatia and Italy, if suitable information is not available, assumptions may need to be made regarding the structural health of the components based on the age of the component and its exposure level.

Of all the data requirements, empirical damage data caused by natural hazards is the most difficult to gather. This is due to the limited damage incurred by bridges in Europe during past earthquake events. This data requirement is specific to WP5, which will develop space-time models to analyse the impact of natural hazards on the structural behavior of critical infrastructures that may be location or time dependent. For this reason, it is proposed that, should data acquisition be an issue, then the framework developed in WP5 should be tested on a network with available empirical data, not necessarily located in Europe. The framework will be transferable to any network given the availability of sufficient empirical damage data.

Regional authorities and infrastructure owners will be contacted for temporally and spatially referenced data on traffic flow for the chosen infrastructure networks. Depending on the availability of data, it may be necessary to make appropriate assumptions regarding traffic flow based on similar networks.

4.0 IMPLEMENTATION OF CASE STUDIES

As mentioned previously, the tools and methodologies developed in WP4, WP6 and WP7 will be validated using the case studies. WP4 consists of an overarching methodology for the risk assessment of the network. WP6 involves the development of a stress test framework for the evaluation of the consequences of extreme natural hazard events on an infrastructure network. Finally, WP7 will design and develop a strategic INFRARISK Decision Support Tool (IDST) to ensure that the INFRARISK stress tests and harmonized risk management methods are practically integrated and used under specific process workflows and modules.

The first step in implementing the case studies is to define the system. This document provides a preliminary definition of the spatial extent of the case studies. The period of time considered in the assessment must also be defined as the methodologies are developed. Once the spatial and temporal extent of the case studies are defined, relevant information and data must be gathered for the case study networks.

The next step is to identify the hazards to which the network is exposed. For the purpose of the INFRARISK project, three different hazard scenarios were defined, account for cascading events. The first scenario involves the occurrence of an earthquake, triggering a landslide. The second scenario involves the occurrence of a flood, triggering a landslide. The third scenario involves the occurrence of a landslide, triggering a flood if a river was in the path of the landslide. Based on the results of Task 3.1, several low probability high consequence events are identified as suitable for a scenario based risk assessment.

Once the hazard events are identified, a risk analysis is carried out using the methodologies developed in WP3 and WP5. A risk assessment will be carried out at component level (i.e. single structure) and network level. The risk assessment should provide an estimation of consequences including direct and indirect costs as well as occurrence rates.

The stress tests developed as part of WP6 will then be tested on the case study networks in order to predict the response of the system to the stress levels corresponding to the low probability, high consequence events identified in WP3. These stress tests will include optimum physical test scenarios and also management support systems. As part of WP6, an agent based model toolkit will also be developed to simulate how the interconnectivity of different infrastructure systems is affected by extreme hazard events.

Finally, the INFRARISK Decision Support Tool will allow a user to perform the stress tests and harmonized risk assessment on the chosen case study networks. The IDST is aimed at infrastructure owners and managers to support robust development measures which ultimately mitigate multiple risks that are associated with natural hazards and minimize their socio-economic and environmental impacts. The IDST should provide access to scenario simulation results, stress test data, component fragility functions and hazard maps. These shall be accessed using intuitive Graphical User Interface features for executing contextual risk management workflows for strategic decision-support.

It must be noted that certain aspects of the implementation of the case studies may be subject to change with the development of the methodologies produced by WP4, WP5 and WP7. An iterative process will be necessary to practically integrate the stress test and risk assessment methodologies in such a way that they can be applied to the case studies to provide useful results for infrastructure managers and owners.

5.0 CONCLUSION

This report presented the two European infrastructure case studies that have been chosen in order to test the applicability and validate the effectiveness of the tools and methodologies developed as part of the INFRARISK project. It was ensured that the selected case studies cover a wide range of spatial and temporal scales, potential hazards and risks. A preliminary search was carried out to investigate data availability, however, constraints provided by data uncertainties and lack of data must be considered. The first case study is a road network extending from Florence to Brennero in Italy. The road network is 450 km long and encompasses the A1 and A22 highways. The second case study is a planned rail network, which is currently at design stage and is prioritized for CEF funding. The planned rail network connects the port of Rijeka on the Adriatic/Mediterranean coast of Croatia to Zagreb, the capital of Croatia. As a starting point, a bridge on each network was identified as suitable for a detailed analysis. However, it is noted that additional bridges as well as other components of the network such as tunnels and embankments will also be included in the network analysis.

The purpose of this report is to provide an overview of the selection criteria used, describe the infrastructure networks considered and outline the implementation procedures. Ultimately, it must be noted that the availability of the necessary data will govern the successful implementation of the case studies. The partners have carried out a preliminary search for available data and chosen case studies accordingly, however, certain details of the case studies may change based on the availability of data.

The next step requires the leaders of WP8 to coordinate with the leaders of WP2, WP3, WP4, WP5, WP6 and WP7 to establish in more detail the data requirements for each of the methodologies and to contact the relevant organizations in each of the case study countries, as identified in this document. In order to ensure the successful implementation of the case studies, the WP8 leaders must work closely with those partners developing the methodologies to be tested. This will ensure that constraints provided by data uncertainties and lack of data can be identified at an early stage and the methodologies can be adapted to accommodate these constraints.

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APPENDIX A: DATA REQUIREMENTS

WP4 develops an overarching methodology. For WP4 we need all data in a spatial reference system for implementation in GIS. For GIS modelling, the spatial resolution of the data is important. Data needs to be accurate in order to model processes seriously.

1. Infrastructure information:

- 3D Geometry of infrastructure elements, e.g. from bridges
- Cadastral data (buildings, roads, railway water, land use)
- Cities
    - Buildings, best: 3D buildings
    - Building information (parcel, building utilization)
    - Area types (zoning plan/land use): center zone, living zone, industry zone, trade zone, public zone)
    - Population density
- Essential facilities
    - Power plants
    - Airports
    - Harbours
    - Roads
        - Road Vector Data, from cadastral survey If not available: Road Maps, e.g. extracted from national map or road network map
        - Road Classes
        - Tunnel
        - Bridge
        - Light signals
        - Capacity
        - Lanes
        - Types
        - Maximum weight allowed on roads

    - Railways
        - Rail Vector Data, from cadastral survey If not available: Road (Rail?) Maps, e.g. extracted from national map or road (rail?) network map
        - Tunnel
        - Bridge
        - Lanes
        - Type

    - Supply infrastructure
        - Water
        - Power
        - Gas
        - Communication
        - Dams
        - Hospital
        - Education institutions
        - Protective structures (dams, detention basin, slope stabilization)

2. Hazard information:

- Hazard type
- Hazard return period
- Hazard vulnerability
- Hazard Probability of Occurrence Maps in region-wide scale and district (sector)-wide scale
- Hazard Maps in region-wide scale
- Historical hazard data

3. Ancillary data:

- Geometry data:
  - Aerial or Satellite images
  - Digital Elevation Model (DEM), best: LIDAR DEM (high accuracy)
  - Slope, aspect calculation
  - Digital Surface Model (DSM), best: LIDAR DSM
  - National Maps in Vector format

- Geographic data:
  - Agriculture
  - River vector data
  - Lake vector data
  - Soil data
  - Geology data
  - Geomorphological data
  - Tectonics data (plate boundaries)
  - Forest data

- Meteorological data:
  - Precipitation data (from weather station, METEOSAT satellite data, location of weather stations)
  - Temperature data (weather station, METEOSAT satellite data, location of weather stations)
  - (Gauge height data)
  - Wind data (interpolate from weather stations)
  - Climatic data
  - Hydrology data
  - Ground water zones

- Urban space:
  - Population
  - Land cover map (forest, grassland, covered or sealed areas, buildings, roads, lakes, farmland, rivers)
  - land use map (residential, institutional, commercial, recreational, agricultural, other)
  - Areas of interest, industry areas, clusters

- Economic values:
  - economic loss calculation

- Infrastructure:
  - damage calculation, interdependencies calculation, evacuation strategies