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

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

## Deliverable D9.4

## Business Plan (BP including TIP)

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| **Primary Author** | Mark Tucker, Julie Clarke/Roughan & O' Donovan Limited (ROD), Miguel Segarra/Dragados S.A (DSA) |
| **WP** | 9 |
| **Submission Date** | 30/11/2016 |
| **Primary Reviewer** | Ken Gavin/Gavin & Doherty Geosolutions (GDG) |
| **Dissemination Level** | RE |

**This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 603960.**

# Project Information

**Project Duration:** 1/10/2013 - 30/09/2016

**Project Coordinator:** Professor Eugene O' Brien
Roughan & O' Donovan Limited
eugene.obrien@rod.ie

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

**Call Topic:** Env.2013.6.4-4 Towards Stress Testing of Critical Infrastructure Against Natural Hazards-FP7-ENV-2013-two stage.

**Project Website:** www.infrarisk-fp7.eu

**Partners:**

Roughan & O' Donovan Limited, Ireland

Eidgenössische Technische Hochschule Zürich, Switzerland.

Dragados SA, Spain.

Gavin and Doherty Geosolutions Ltd., Ireland.

Probabilistic Solutions Consult and Training BV, Netherlands.

Agencia Estatal Consejo Superior de Investigaciones Científicas, Spain.

University College London, United Kingdom.

PSJ, Netherlands.

Stiftelsen SINTEF, Norway.

Ritchey Consulting AB, Sweden.

University of Southampton (IT Innovation Centre), United Kingdom.

# Document Information

| Version | Date | Description | Primary Author |
|---|---|---|---|
| Rev01 | 30/10/2015 | Draft for review DSA | Mark Tucker |
| Rev02 | 03/03/2016 | Draft for partner input and comment | Mark Tucker, Miguel Segarra |
| Rev03 | 14/11/2016 | Draft for partner input and comment | Mark Tucker, Miguel Segarra, Julie Clarke |
| Rev04 | 24/11/2016 | Draft for internal review | Mark Tucker, Miguel Segarra, Julie Clarke |
| Rev05 | 28/11/2016 | Partner review | Ken Gavin |

# Executive Summary

The INFRARISK project has developed a business plan to identify and formulate an exploitation strategy for the key project outcomes and findings. These relate to the stress testing of critical road and rail infrastructure, with the goal of improving their resilience to extreme natural hazard events. In this report, the exploitable results of the INFRARISK project are identified and described according to a technological implementation plan. The intellectual property right issues that may arise due to the exploitation of these items are identified and a plan to exploit the project results is proposed. A plan for conducting a market analysis is also outlined in this report and a market strategy is proposed. In addition, financial planning is proposed for the period beyond completion of the project.

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# 1.0 INTRODUCTION

The focus of the INFRARISK project is on the development of reliable stress tests for critical European road and rail infrastructure due to extreme natural hazard events. To do so, a stress test framework has been proposed (van Gelder and van Erp, 2016), which can be used to evaluate the potential losses associated with low probability, high consequnece natural hazard events according to an overarching risk assessment methodology (Hackl et al., 2016). The approach has been demonstrated in the project for two European case study networks (Clarke et al., 2016). Alongside these methodologies, the INFRARISK project has developed online tools, which include an INFRARISK Decision Support Tool (IDST) (Melas and Sabeur, 2016) and a knowledge base (Roman et al., 2016).

To disseminate the outputs of the INFRARISK project to critical infrastructure managers and owners, a variety of dissemination activities have been undertaken, including a conference event (Jimenez and Garcia Fernandez, 2016), publications, and a dedicated training course (Connolly and Clarke, 2016). To facilitate the successful exploitation of the project results, a Business Plan (BP) has been developed, which specifies an operational framework for the implementation of the key project outputs, as described in this report.

The main components of the BP consist of the following:

- An evaluation of the INFRARISK consortium in terms of the core strengths and competencies.
- A Technological Implementation Plan (TIP) to identify and analyse the exploitable results of the project.
- A post-project plan in relation to the legal and business agreements amongst consortium members, including the regulation of Intellectual Property Rights (IPR).
- A market analysis and marketing strategy.
- Final planning that provides an estimate of the associated resources, the break-even point and the potential return on investment.

# 2.0 INFRARISK CONSORTIUM

## 2.1 Consortium Overview

The INFRARISK consortium consists of a multi-disciplinary consortium of eleven partners from seven European countries: Ireland, the Netherlands, Spain, Switzerland, Norway, Sweden and the United Kingdom. These consortium members include research institutes, higher education institutes, small and medium-sized enterprises (SMEs) and a large enterprise. The consortium members bring together expertise in the areas of risk assessment, transport infrastructure, hazard assessment, structural and geotechnical engineering, problem solving in relation to security and societal challenges, as well as software and database development.

The INFRARISK consortium consists of a well-balanced mix of partners; five of the partners are academic partners, who bring state-of-the-art research to the project. The remaining six partners are industry partners that offer their expertise to maximise the impact of the INFRARISK research outputs.

The various tasks in the INFRARISK project were distributed amongst the consortium partners based on their respective areas of expertise. Table 2.1 provides a summary of the consortium partners, their country of origin and the organisation type. A more detailed description of the consortium members and their role within the INFRARISK project is provided in Appendix A.

| **Partner Name (Short Name)** | **Country** | **Organisation Type** |
|---|---|---|
| Roughan & O' Donovan Ltd. (ROD) *Project Coordinator* | Ireland | SME |
| Eidgenössische Technische Hochschule Zurich (ETHZ) | Switzerland | Higher Education Institute |
| Dragados SA (DSA) | Spain | Large Enterprise |
| Gavin & Doherty Geosolutions Ltd. (GDG) | Ireland | SME |
| Probabilistic Solutions Consult and Training (PSCT) | Netherlands | SME |
| Agencia Estatal Consejo Superior de Investigaciones Científicas (CSIC) | Spain | Research Institute |
| University College London (UCL) | United Kingdom | Higher Education Institution |
| Peter Prak Leonard (PSJ) | Netherlands | SME |
| Stiftelsen Sintef (SINTEF) | Norway | Research Institute |
| Ritchey Consulting AB (RCAB) | Sweden | SME |
| University of Southampton (IT Innovation) | United Kingdom | Higher Education Institution |

**Table 2.1:** INFRARISK consortium members

## 2.2 Strength and Core Competencies

The INFRARISK consortium consists of an effective partnership that offers a unique opportunity to facilitate the assessment of existing infrastructure to ensure the protection of critical road and rail transport networks from the impacts of extreme natural hazard events.

The breadth of the expertise available in the INFRARISK consortium facilitates the realisation of this goal through the availability of hazard experts, risk analysts, geotechnical and structural engineering specialists, uncertainty modellers, infrastructure managers, stress testing experts and implementation experts, as outlined in Figure 2.1.

Partners such as ROD, GDG, Dragados and PSJ provide invaluable practical expertise from both a design and assessment perspective of road and rail infrastructure. Hazard identification and risk analysis can be dealt with in an integrated way based on the combined effort of UCL, CSIC, GDG, ROD, ETHZ, RCAB and PSCT. Impacts on the road and rail networks can be assessed by UCL, according to traffic and agent-based modelling, and also by ETHZ according to the development of restoration models. Implementation of the risk assessment and stress test procedures is being provided by IT Innovation, through the development of a web-based tool that demonstrates the methodologies developed.

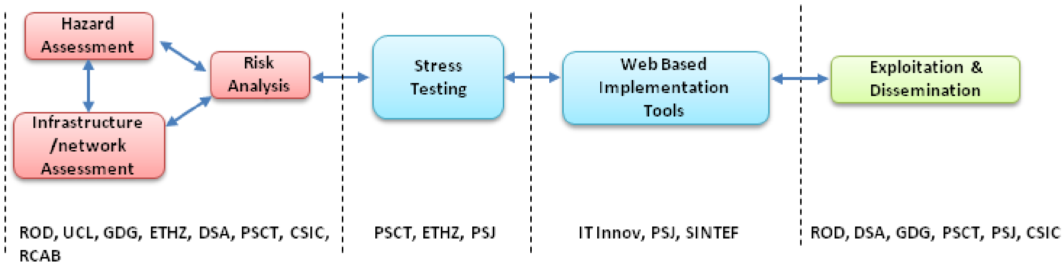


**Figure 2.1:** Partner value chain

The strengths of the consortium were identified as follows:

- Heterogeneity of the consortium, covering most of the value/supply chain;
- A strong balance between research and innovation capability versus industrial knowledge and application experience;
- Participation of partners with national and international presence;
- Participation of partners with experience in R&D projects;
- A balanced distribution of the effort relative to the complexities of the research activity.

## 2.3 Potential Weaknesses

The INFRARISK consortium was also critically assessed in terms of the potential weaknesses in relation to the exploitation of the research outputs. The consortium weaknesses were identified as follows:

- Distribution of collaborating partners across Europe, which may impede the ability to continue research activities or to promote joint initiatives for exploitation;
- The lack of relevant information relating to critical infrastructures, hazard assessment, etc.;
- The presence of a multidisciplinary consortium where partners possess specific expertise in a particular area of research activity and which may impede future collaborations;
- The geographically specific nature of risk quantifications, the associated hazards and the differences in perception to risk, which may produce heterogeneous information;
- The possibility of communication difficulties between the consortium members due to speciality differences between the partners across disciplines (e.g. certain partners may be unfamiliar with IT phrases and procedures).

## 2.4 Governance and Legal Issues

The basis of the legal and governance issues within the consortium is contained in the project Consortium Agreement dated 29/10/2013, which came into effect following agreement of the particulars by all partners. This document is based on the DESCA Simplified FP7 model agreement with some minor modifications. This document outlines the conditions relating to: partner responsibilities, liabilities; governance structure, financial provisions, legal issues, IPR and access rights.

The conditions of engagement between the between the partners and commission are contained in the Grant Agreement (no. 603960), signed by European Commission on the 23/10/2013.

# 3.0 TECHNOLOGICAL IMPLEMENTATION PLAN (TIP)

## 3.1 Introduction

The potentially exploitable results of the INFRARISK project were identified by each consortium partner. Each item was subsequently analysed in terms of the potential for exploitation (IPR, exploitation strategy, market demand, etc.).

## 3.2 Exploitable Results Identification

To identify the potentially exploitable aspects of the INFRARISK project, a template was circulated to all project partners, as outlined in Appendix B. For each exploitable result of the project identified, a description of the results and the level of expected exploitation potential were specified, as outlined in Table 3.1.

| Exploitable Result No. | Exploitable Result | Description of Project Result(s) | Partner Responsible | Estimated Exploitation Potential |
|---|---|---|---|---|
| 1 | Fragility curves for shallow rainfall-triggered landslides | Methodology for developing fragility curves for shallow rainfall-triggered landslides on earthworks on transport networks. The fragility curves were developed using probabilistic slope stability calculation. | GDG | Medium |
| 2 | GIS Knowledge Base | A technical infrastructure for the GIS Knowledge Base has been set up based on DataGraft, a cloud-based service portal for data transformations and data access developed by SINTEF that allows users to upload, transform and query data about infrastructure components and natural disaster events. A Web portal has been set up at https://infrarisk.datagraft.net/ to show samples of the collected data. | SINTEF | Medium |
| 3 | INFRARISK Vocabulary | A set of agreed and shared data models for infrastructure components and natural disaster events. A Resource Description Framework (RDF) representation of the vocabulary was developed and is available via http://vocabs.datagraft.net/infrarisk. | SINTEF | Medium |
| 4 | Approach to assess low probability seismic hazard | A methodological approach to assess low probability seismic hazard. | CSIC | Medium |
| 5 | Methodology to evaluate infrastructure related risk due to natural hazards | A methodology to be used to assess infrastructure related risks due to natural hazards. The methodology is to be used in all situations, e.g. different hazards, different consequences, different team expertise, different levels of computer support, and different amounts of time available. | ETHZ | High |
| 6 | Bayesian Network model for cost estimations for different infrastructure disruptions | A modelling procedure based on a Bayesian Network to estimate the levels of societal costs of different types and degrees of natural hazards on transportation infrastructure, given specific infrastructure information for a given area. | RCAB | Low - Medium |

| Exploitable Result No. | Exploitable Result | Description of Project Result(s) | Partner Responsible | Estimated Exploitation Potential |
|---|---|---|---|---|
| 7 | Stress Test Framework | A stress test framework, in which infrastructure managers have tools to: 1) generate a stress test scenario, 2) generate a spatial hazard map, 3) generate a probability map via conditional fragility curves, 4) select the damage state scenarios from the resulting probability map, 5) estimate the outcome metric given the selected damage state scenarios of the system, 6) evaluate the outcome metric for which a novel criterion has been developed in INFRARISK. | PSCT | High |
| 8 | Proof of concept stress tests performed for two European case studies | A systematic application of the methodologies proposed in the INFRARISK project to two existing networks along the TEN-T European road and rail networks. | ROD | High |
| 9 | ORT application for Croatian Rail Study | An example of the method was developed to carry out a first assessment to set priorities (critical network sections, critical hazards etc.) for any infrastructure manager. | PSJ | Medium |

**Table 3.1:** Exploitable results identification

## 3.3 Exploitable Results Analysis

Following compilation of the exploitable results identification, as outlined in Table 3.1, the Intellectual Property Rights (IPR) and the exploitation claims related to each of the potential results were subsequently identified. To do so, Section 2 in the template provided in Appendix B was completed by all partners. This was used to identify the various IPR issues associated with each Exploitable Result.

From this analysis a list of partners associated with each Exploitable Result was prepared, as outlined in Table 3.2.

| Exploitable Result No. | Exploitable Result | Partners contributing to the generation of the Exploitable Result |
|---|---|---|
| 1 | Methodology for developing fragility curves for shallow rainfall-triggered landslides. | GDG |
| 2 | GIS Knowledge Base. | SINTEF |
| 3 | INFRARISK vocabulary. | SINTEF, GDG, ROD, DSA, UCL, CSIC |
| 4 | Approach to assess low probability seismic hazard. | CSIC |
| 5 | Methodology to evaluate infrastructure related risk due to natural hazards. | ETHZ |
| 6 | Bayesian Network model for cost estimations for different infrastructure disruptions. | RCAB, ROD, UCL, ETHZ, GDG, DSA, Brian Bell (AB Chairman) |
| 7 | Stress Test Framework. | PSCT, ETHZ, ROD |
| 8 | Proof of concept stress tests performed for two European case studies. | ROD, UCL, CSIC, DSA, GDG, ETHZ |
| 9 | ORT application. | PSJ, ROD, GDG, ETHZ, PSCT, DSA |

**Table 3.2:** Exploitable results analysis

### *3.3.1 Intellectual Property Rights (IPR) Management*

To anticipate any eventualities or conflicts, the Consortium Agreement addressed specific patent issues, which have been agreed among the project partners. In cases where issues are not covered by the Consortium Agreement, the default EU IPR guidelines are applicable (http://ec.europa.eu/research/participants/data/ref/fp7/89593/ipr_en.pdf).

New knowledge developed during the project (foreground) has been shared by those directly involved in the development of this material. All consortium partners are allowed to access this foreground information under the agreed conditions. The interests of the industrial partners were given priority in order to enhance exploitation of project results.

In relation to new knowledge developed during the project (foreground), the following conditions apply:

- Each partner has ownership of their development, i.e. foreground, and protection of their current knowledge, tools, software, etc.;
- Each partner has the right to exploit the knowledge outside the consortium;
- Any partner can join an activity with another partner as long as it is permitted by the IPR conditions;
- Partners can exploit specific IPR of their own and IPR of other partners only subject to an agreement being in place with the IPR owner;
- This document encourages partners to look for synergies with other partners for the definition of new business opportunities, commercialisation of results and other activities relevant for the benefit of the consortium.

Table 3.3 was subsequently completed by the project partners in relation to the identified exploitable results, which provided information on the following:

(i) Type of exploitation

(ii) IPR measures

(iii) Access rights

It is important to note that it is intended that the IPR will be more explicitly defined where required in the future.

| Exploitable project result | Type of exploitation | Timetable, commercial or any other use | IPR measures taken or intended | Owner & Other Beneficiary(s) involved |
|---|---|---|---|---|
| 1 | Possible use of methodology in commercial or future R&D projects. | End September 2016 onwards | N/A at present | GDG (owner) |
| 2 & 3[1] | SINTEF targets specific opportunities for applying the DataGraft in solving real life needs, and also targets specific R&D funding opportunities that will allow future developments and maintenance of DataGraft. DataGraft will be further developed in euBusinessGraph and EW-Shopp. | End September 2016 – 2019 | N/A at present | SINTEF (owner) |
| 4 | Use of methodology in commercial or future R&D projects. | End September 2016 onwards | N/A at present | CSIC (owner) |
| 5 | To be used for research purposes in the development of future methodologies for detailed situations. | End October 2016 onwards | Software tools developed for individual infrastructure managers The rights associated with these will depend on those involved. | ETHZ & those involved (Owner) |
| 6 | Possible use of methodology in commercial or future R&D projects. | End September 2016 onwards | N/A at present | RCAB (owner), ETHZ (rights) |
| 7 | Possible use of methodology in commercial or | End September 2016 | N/A at present | PSCT |

[1] Note – these results have been combined as they are complimentary.

 

| Exploitable project result | Type of exploitation | Timetable, commercial or any other use | IPR measures taken or intended | Owner & Other Beneficiary(s) involved |
|---|---|---|---|---|
| | future R&D projects. | onwards | | |
| 8 | Possible use of methodology in commercial or future R&D projects. | End September 2016 onwards | N/A at present | ROD (owner), UCL, CSIC, DSA, GDG, ETHZ |
| 9 | Commercial exploitation | End September 2016 onwards | Amendments to the ORT-application for the Croatian Case Study Rail due to specifications from end-users | PSJ (owner), ETHZ, ROD (Rights). It should be noted that the software of ORT 'as such' is owned by PSJ; only an application within ORT was made for Infrarisk).<br><br>DSA and its concessionaire (operator) company would be interested in the use of commercial versions of tools applying the INFRARISK methodology to assess the risks of the infrastructure management by them. |

**Table 3.3:** Exploitable results analysis

### 3.3.2 *Exploitable Results Planning*

The INFRARISK consortium members subsequently completed Sections 3 to 5 of the template provided in Appendix B. A full list and details of all exploitable results are presented, as outlined in Tables 3.4 to 3.11.

| **Exploitable result no.** |
|---|
| 1 - Methodology for developing fragility curves for shallow rainfall-triggered landslides. |
| **Description (objectives and goals)** |
| Fragility curves are a versatile vulnerability assessment tool with increasing usage in risk assessments for large networks. This will enable the inclusion of rainfall-triggered landslides, a very common hazard on a transport network, in any future risk assessment and risk management process. |
| **Degree of development** |
| Methodology developed and demonstrated on a test slope, also used in the Croatian Rail case study in INFRARISK. A TRL level of 5 has been reached (technology developed and demonstrated in relevant environment), which is the initial planned level and this is expected to be the highest level TRL applicable. |
| **Intellectual Property Rights (IPRs)** |
| None at present. |
| **Target customers and competitors in the market** |
| The target market is limited to the number of major road and rail network managers in Europe (and elsewhere) who would potentially be interested in employing this methodology. However the size of the risk assessment projects undertaken by each of these entities is quite large given that they operate on a national or a regional basis, rendering each individual application a clear success. A considerable number of research organizations and R&D companies are involved in developing landslide risk assessments. However, as vulnerability analysis is one of the least developed steps in the risk assessment process, the number of entities looking at vulnerability of earthworks is not considered very large. To the best of the author's knowledge, there are no similar fragility curve results available from other sources. Any potential collaboration in future will be carried out in line with EC recommendations and good practice. |
| **Benefits and barriers** |
| Fragility curves are a method of assessing the asset's vulnerability, a sub-process of the risk analysis. The methodology uses the probabilistic techniques based on slope stability calculations and thus provides fully objective vulnerability results. This represents a significant advantage over current subjectively derived vulnerability indices used for this purpose. Equally, while these curves are widely developed and used for some network elements such as bridges, there is a much smaller volume of solutions for engineered slopes. Additionally, most of the fragility curves developed for slopes address the seismically-triggered landslides, and to date there are no fragility curves for rainfall-triggered landslides that are ready to be used in multi-hazard risk assessments of transport networks. The result fills the gap in market where there are currently no fragility curves for rainfall-triggered landslides that are ready to be used in multi-hazard risk assessments of transport networks. Barriers include the availability of the necessary date. End users interested in implementation of this methodology imply they have taken the precursory steps in data gathering |

| |
|---|
| and objective hazard assessment. |
| **Exploitation route** |
| Disseminating successful examples of application of the methodology to real life network sections |
| **Other (specify)** |
| GDG might seek to further develop and refine this methodology in future. This will be done using internal investments. Also, possibility is for the methodology to be further developed as a part of commercial or research project. |

**Table 3.4:** Detailed planning – exploitable result no. 1

| **Exploitable result no.** |
|---|
| 2 & 3 - GIS Knowledge Base and INFRARISK Vocabulary |
| **Description (objectives and goals)** |
| The GIS Knowledge Base (KB) infrastructure applies techniques from the emerging field of Linked Open Data (LOD)[2] which uses the semantic standards Resource Description Framework (RDF)[3] for representing data on the Web and SPARQL[4] to query the data. INFRARISK has developed a Resource Description Framework Schema (RDFS)[5] for infrastructure components and events that can be used to formally represent and exchange data between Web applications. An RDF representation can be accessed via http://vocabs.datagraft.net/infrarisk. The KB, which is a cloud-based platform for provisioning, transforming, querying data about infrastructure components and natural disaster events. DataGraft started with the goal to provide new tools and approaches for faster and lower-cost publication, reusing open data and making them available as linked open data in the Resource Description Framework (RDF) format, thereby enriching the semantic Web. The lifecycle for the creation and provisioning of (linked) open data typically involves raw data cleaning, transformation, and preparation (most often from tabular formats), mapping to standard linked data ontology and generating a semantic RDF graph. The resulting semantic graph is then stored in a triple store, where applications can easily access and query the data. Conceptually, this process is rather straightforward; however, such an integrated workflow is not commonly implemented. What is needed is an integrated platform for effective and efficient data publication and reuse. At the very core, this means automating the open data publication process to a significant extent – in order to increase the speed and lower its cost. DataGraft is the one-stop-shop for hosted data management. It provides powerful data transformation capabilities, including sharing, repeatability and reuse (through its Grafterizer tool), while at the same time allowing reliable data access for data workers to manage and visualize their data in a simple, effective, and efficient way. Opportunities include; (Partly) Open-source model, Underuse of Linked Data technologies in such similar products in the market and Distributed data trans-formation model, that can be used for big data. The GIS Knowledge Base represents a usable demonstrator that shows the application and benefits of DataGraft, and will be used as a showcase in the acquisition of future research and development projects. The knowledge base can also be made available for use by other European projects. The vocabulary has the potential to become a standard vocabulary for interexchange of data on the Web about infrastructure components and natural hazards. |

[2] https://www.w3.org/standards/semanticweb/data
[3] https://www.w3.org/TR/2014/REC-rdf11-concepts-20140225/
[4] https://www.w3.org/TR/rdf-sparql-query/
[5] https://www.w3.org/TR/2014/REC-rdf-schema-20140225/

| **Degree of development** |
|---|
| DataGraft is being developed as a large scale prototype (TRL5) that is tested in use case pilots in the EU projects DaPaaS, INFRARISK and proDatamarket. DataGraft will be further developed in euBusinessGraph and EW-Shopp with the goal of reaching TRL6 (large scale environment with expected performance) and TRL7 (operational environment at pre-commercial scale). DataGraft will be further developed in euBusinessGraph and EW-Shopp with the goal of reaching TRL6 (large scale environment with expected performance) and TRL7 (operational environment at pre-commercial scale). TRL6 during the next 24 months with marketability (TRL7) during months 24-30. |
| **Intellectual Property Rights (IPRs)** |
| None at present |
| **Target customers and competitors in the market** |
| SINTEF has established (and will continue to establish) bilateral contacts with Norwegian industry for the potential use of DataGraft technologies in different domains. The H2020 programme for 2016-2017 is of high relevance for SINTEF as another opportunity to reuse its INFRARISK results and the data management expertise acquired during the project. SINTEF successfully targeted the "ICT-14-2016-2017: Big Data PPP: cross-sectorial and cross-lingual data integration and experimentation call to apply and further extend DataGraft as a technology for cost-effective data management. As with all software developments, competing solutions may start to provide the differentiating features. |
| **Benefits and barriers** |
| Benefits include; One integrated portal includes hosting, data management, open-data publishing; Cost effective; RDF export support; Executable transformations; Possibility to compile and distribute trans-formations services; Some barriers include; User quotas due to being a free service, for inputs size, transformation complexity and hosted data; DataGraft is an integrated prototype, with support that cannot equal enterprise level support; Less feature-rich compared to other market products (e.g. suggestions for transformations similar to Trifacta). |
| **Exploitation route** |
| SINTEF will coordinate a new H2020 project euBusinessGraph (Enabling the European Business Graph for Innovative Data Products and Services) and participate in a new H2020 project EW-Shopp (Supporting Event and Weather-based Data Analytics and Marketing along the Shopper Journey) where DataGraft will be further developed as a core service in the respective platforms for euBusinessGraph and EW-Shopp. To further exploit the results of INFRARISK, SINTEF targets specific opportunities for applying the DataGraft in solving real life needs, and also targets specific R&D funding opportunities that will allow future developments and maintenance of DataGraft. To ensure continuity of the DataGraft service, SINTEF already facilitated the transfer of the DataGraft operations to the proDataMarket project (http://prodatamarket.eu/) which SINTEF is coordinating. |
| **Other (specify)** |
| N/A |

**Table 3.5:** Detailed planning – exploitable result no. 2&3

| **Exploitable result no.** |
| --- |
| 4 - Approach to assess low probability seismic hazard |
| **Description (objectives and goals)** |
| A methodological approach to assess low probability seismic hazard. Usually, only the standard procedures for hazards assessment are available or the results provided. The developed procedure within INFRARISK deals specifically with low probability hazard assessment and also its application and implementation for different situations (linearly distributed systems or other types of infrastructure or critical facilities). The developed approach can be adapted and tailored to different situations and applications regarding natural hazards (earthquakes) and its effects on critical infrastructure. |
| **Degree of development** |
| The methodology is ready to use in its current format. Specific studies, analysis, and evaluations of seismic hazards will require an adaptation tailored to the particular needs of end-users. The expected results were achieved in due time within the life time of the project as it was applied as expected and planned. Extensive testing and sensitivity analysis were performed during the development stages. The methodology is ready-to-use and to be implemented with an adaptation to specific cases and needs. |
| **Intellectual Property Rights (IPRs)** |
| None at present. |
| **Target customers and competitors in the market** |
| Infrastructure companies (Energy, Transportation, Water, etc) assessing natural hazards (earthquakes) and their effects on critical infrastructure. |
| **Benefits and barriers** |
| No similar systematic approaches are available that can be adapted to the specific needs or applications of infrastructure managers, operators or regulators to assess low probability seismic hazard in a straightforward way and which are capable of considering different scenarios chosen and analysed by the end-user. |
| **Exploitation route** |
| Primarily through dissemination activities. |
| **Other (specify)** |
| |

**Table 3.6:** Detailed planning – exploitable result no. 4

| **Exploitable result no.** |
|---|
| 5 - Methodology to evaluate infrastructure related risk due to natural hazards. |
| **Description (objectives and goals)** |
| A methodology to assess infrastructure related risks due to natural hazards. The methodology is to be used in all situations, e.g. different hazards, different consequences, different team expertise, different levels of computer support, and different amounts of time available. The use of the methodology will ensure a much more comprehensive over view of the risk related to infrastructure than would result from many, if not all, of the existing methodologies. It also can be used by regulators to help define stress tests to be run by infrastructure managers. The proposed methodology is new in that it is the only such methodology developed for infrastructure managers at this level. Other methodologies are either higher levels and deal with all risks for all situations, or lower levels dealing with specific risks for specific situations. Unique characteristics of the proposed methodologies include the establishment of the classification of events, the consideration of spatial and temporal risks. |
| **Degree of development** |
| The methodology is complete and has been illustrated by using it to evaluate the infrastructure related risks with a road network due to heavy rainfall that could lead to both flooding and landslides in the region of Chur Switzerland. Work will continue on the development of the approach beyond the project. The methodology was tested by using it to estimate infrastructure related risks in three situations; 1) the road related risks due to heavy rainfall that may trigger flooding and landslides in the region of Chur Switzerland; 2) the road related risks due to earthquakes in the region of Bologna, Italy, and 3) the rail related risks due to flooding in Croatia. In all cases the methodology proved itself to be useful in helping infrastructure managers assess their risks. The methodology is ready to be implemented. For use in specific situations, however, detailed discussions with infrastructure managers need to take place before software can be developed to enable them to systematically conduct their risk assessments. First work in this direction is currently underway with the Irish Railways. Discussions are planned following a dissemination event in the beginning of 2017. |
| **Intellectual Property Rights (IPRs)** |
| None at present though software tools developed for individual infrastructure managers to enable the implementation of the methodology in specific circumstances are being developed. The rights associated with these will depend on those involved. |
| **Target customers and competitors in the market** |
| The methodology will benefit the infrastructure managers who use it to set up risk assessment methodologies for their specific cases. It may also be used by regulatory agencies to establish stress tests for infrastructure managers. There are no patent rights on the methodology. Software developed for individual owners will have the rights negotiated at appropriate times. This methodology can be used by infrastructure managers in the sectors of road, rail, water distribution, gas distribution and electricity distribution. In each case, however, specific situations need to be identified that need to be analyzed. For each of these situations specific instances of the proposed methodology need to be developed, complete with computer support tools if necessary. Assuming 5 infrastructure sectors and 27 countries in Europe, there are at least 135 potential infrastructure managers who can use the methodology. If one takes into consideration that each country has many infrastructure managers in each area at lower organizational level, e.g. state, city and county level, there are easily > 1000 potential infrastructure managers who could use the methodology. |

| **Benefits and barriers** |
|---|
| Before the development of this methodology there was no systematic methodology that could be used for all situations. Most methodologies were focused on specific hazard or specific consequences and often had preferred methods to be implemented, leaving infrastructure managers in the situation that many of the methodologies were not useful for their situations. The new methodology provides all infrastructure managers a systematic way to evaluate their risks regardless of the situations in which they find themselves. This helps to eliminate much confusion about where to start in the process, and it paves the way for the development of appropriate detailed methodologies for specific situations. The methodology will serve as a foundation for future work for many years. It is reasonable to believe with active efforts of partners that it could help in the development of many detailed methodologies. A potential barrier is to the exploitation and use of the methodology is that there are many other companies and research institutions that are seeking to develop specific risk assessment methodologies. Collaborations with them will be sought out when appropriate. |
| **Exploitation route** |
| The ETHZ plans to exploit the results of the INFRARISK project by developing detailed methodologies that are suitable for use in specific infrastructure sectors in specific situations. No commercial applications are planned but may emerge depending on the agreements established with interested infrastructure managers. Mainly through dissemination activities; One in Switzerland at the beginning of 2017 where Swiss infrastructure managers will be invited. Upcoming conferences, including the International Forum on Engineering Decision making in Stoss, Switzerland in December 2016. Individual discussions with Pro-rail, the UIC, Irish Rail and the region of Chur. Following these more will be planned. Holding dissemination events and seeking direct meetings with specific groups of key stakeholders in the rail, road, water distribution, electricity and gas sectors. |
| **Other (specify)** |
| Develop a detailed methodology and appropriate computerized support to allow the yearly assessment of infrastructure related risks. |

**Table 3.7:** Detailed planning – exploitable result no. 5

| **Exploitable result no.** |
|---|
| 6 - Bayesian Network model for cost estimations for different infrastructure disruptions |
| **Description (objectives and goals)** |
| A modelling procedure based on a Bayesian Network to estimate the levels of societal costs of different types and degrees of natural hazards on transportation infrastructure, given specific infrastructure information for a given area. |
| **Degree of development** |
| The modelling procedure – in the form of a proof-of-concept – was delivered to WP 4 one month before the end of the project. It consists of a computer-aided Bayesian Network model and a process report describing the model and its development. The internal work and proof-of-concept assessment process was completed in September 2016. Further feedback from other sources will be determined by the WP manager. It would be quite advantageous to test the modelling procedure for a specific site with a "real" infrastructure manager group. Currently the methodology |

| |
|---|
| is at TRL 3: Analytical and experimental characteristic proof of concept. |
| **Intellectual Property Rights (IPRs)** |
| None at present. |
| **Target customers and competitors in the market** |
| Infrastructure managers |
| **Benefits and barriers** |
| The methodology allows infrastructure managers to develop a tailor-made assessment tool for their assets, thus identifying the weak points in infrastructure networks that may need attention. There are numerous tools and methodologies, based on expert opinion. Delphi panels etc. available. |
| **Exploitation route** |
| Mainly through dissemination activities or working alongside INFRARISK partners in future ventures |
| **Other (specify)** |
| |

**Table 3.8:** Detailed planning – exploitable result no. 6

| |
|---|
| **Exploitable result no.** |
| 7 - Stress Test Framework |
| **Description (objectives and goals)** |
| A stress test framework, in which infrastructure managers have tools how to: 1. Generate a stress scenario; 2. Generate a spatial hazard map, with help of physical models; 3. Generate a Probability Map via conditional fragility curves; 4. Select the Damage state scenarios from the resulting probability map. Because of the huge number of possible scenario's, clever algorithms have been developed in INFRARISK, which are ready to use; 5. Estimate the Outcome Metric, given the selected damage state scenario's of the system; 6. Evaluate the outcome metric, for which a novel criterion has been developed in INFRARISK. |
| **Degree of development** |
| The methodology has been developed and is ready to use in its current state to other case studies. The methodology is assumed to have a TRL of 6 (System/subsystem model or prototype demonstration in a relevant environment) as a representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. The developed methodology and tools are ready to use, but for specific case studies, tailor made fine tuning is still necessary. |
| **Intellectual Property Rights (IPRs)** |
| None at present |
| **Target customers and competitors in the market** |
| Stakeholders interested in stress testing their networks/assets |

| **Benefits and barriers** |
|---|
| There was no integral approach how to perform stress tests before the start of the Infrarisk project. The developed procedure in Infrarisk provides a structured approach and gives tools how to deal with the computational burden of large infrastructural networks, as well as how to deal with decision making for infrastructural managers under uncertain outcome metrics, amongst others. There are no similar products/services on the market, which are able to deal computationally with large infrastructural networks and to deal with decision making under uncertainty with a full Bayesian paradigm. |
| **Exploitation route** |
| Primarily through dissemination such as ; Publication in journals and conferences and newsletters and video tutorials; Journal of Infrastructure Systems (ASCE-ascelibrary.org/journal/jitse4); International Journal of Critical Infrastructure Protection (http://www.journals.elsevier.com/international-journal-of-critical-infrastructure-protection); Infrastructure Complexity, a Springer Open journal; Structure and Infrastructure Engineering (www.tandfonline.com/toc/nsie20/current) |
| **Other (specify)** |
| |

**Table 3.9:** Detailed planning – exploitable result no. 7

| **Exploitable result no.** |
|---|
| 8 - Proof of concept stress tests performed for two European case studies. |
| **Description (objectives and goals)** |
| Development and application of the methodologies developed in the INFRARISK project and their application to existing and planned road and rail networks to quantify the potential losses associated with extreme natural hazard events, such as earthquakes, floods and landslides. |
| **Degree of development** |
| These applications would need to be tailored to the specific types of infrastructure and hazards considered. |
| **Intellectual Property Rights (IPRs)** |
| The INFRARISK consortium members developed the basis of many of the methodologies that were applied to the case studies. However, these were further developed and directly applied by ROD in conjunction with CSIC, PSCT, DSA, PSJ and UCL. |
| **Target customers and competitors in the market** |
| Target customers are infrastructure managers and owners. |
| **Benefits and barriers** |
| Quantification of the potential losses, including monetary losses due to repair costs, travel disruption and associated economic losses, for distributed road and rail networks due to extreme natural hazard scenarios. |

| |
|---|
| A possibly barrier is the lack of availability of data. |
| **Exploitation route** |
| Dissemination activities. |
| **Other (specify)** |
| |

**Table 3.10:** Detailed planning – exploitable result no. 8

| **Exploitable Result no.** |
|---|
| 9 - ORT Application |
| **Description (objectives and goals)** |
| A product consisting of an Objective ranking tool (ORT) application to assess vulnerable rail or road sections to the impact of natural hazards. |
| **Degree of development** |
| The product is currently ready to use in its current application of the INFRARISK case studies. |
| **Intellectual Property Rights (IPRs)** |
| In future use/development of the application, it should be noted that PSJ developed the ORT-software while the Consortium developed the ORT-application for the Croatian Case study Rail. |
| **Target customers and competitors in the market** |
| Organisations/stakeholders in road and rail sector. As such there is a potential target market of 50-100 infrastructure managers within Europe. For the application itself there are no competitors. |
| **Benefits and barriers** |
| The application has the benefit that it can facilitate a rapid assessment of the most critical rail or road sections. The method is dependant of expert opinion so stakeholder participation is critical. There are also numerous methods available which use expert opinion to prioritise criteria/actions etc. |
| **Exploitation route** |
| Through dissemination activities, working with other INFRARISK partners or through commercial use by PSJ of the software itself. |
| **Other (specify)** |
| |

**Table 3.11:** Detailed planning – exploitable result no. 9

## 4.0 POST-INFRARISK PARTNER COOPERATION

Upon completion of the INFRARISK project, partner obligations as per the Grant Agreement will remain. Subject to the conditions of the Consortium Agreement, new agreements amongst project partners may need to be implemented for further collaboration.

In the case of intellectual property (IP), new agreements may need to be put in place, subject to the conditions of the existing Consortium Agreement. For example, in the case of co-ownership of the IP, a potentially exclusive and in any case long term licensing agreement may have to be alternatively sought to secure access to any required technology and freedom to operate on the market. Other considerations may include the extent to which the rights on the IP being commercialised by the company are or can be registered and, therefore, efficiently prevent the entry to the market of potential copycats. If the IP cannot be registered, how a technological advantage will anyway be maintained in the future is a key point to consider. This can be linked for instance to a very strong governance policy in terms of file management inside the company and restriction of know-how access to a very limited group of people (e.g. funders and the top management team with shareholder agreements in place).

Contracts secured or planned with external contractors, researchers, integrators or suppliers should be clearly identified and a policy should be in place for developing strategic relationships with those external stakeholders. The scope and framework of any technical partnerships should be clearly defined. Access to key IP needed for future product developments should be secured, while too restrictive and locking-in alliances should be avoided. Setting out the global partnership scheme chosen for the company in the business plan will provide a clear vision and roadmap in terms of collaborations and will help to clarify any potential uncertainties.

# 5.0 MARKET ANALYSIS AND STRATEGY

The objective of the INFRARISK project was to develop a stress test framework for critical European road and rail infrastructure due to extreme natural hazard events. Based on the outcomes of the project, it is anticipated that the project partners, in particular the SMEs involved in the consortium, may wish to exploit the results commercially. In order to do this, having identified the exploitable results, a market analysis will be undertaken based on the identified exploitable results. In addition, a detailed strategy will be developed to facilitate market uptake of the outputs. It is expected that this market analysis will take place after completion of the project by those partner/partners who wish to further exploit the results. The following sections provide a brief outline of the pertinent aspects of the market analysis and strategy that should take place.

## 5.1 Market Analysis

### *5.1.1 Sector Description*

This section provides an in depth analysis of the sector in which the various services provided by the consortium partners operates. These are different for each partner as the areas of expertise is different for each partner and also, SMEs are typically more focused on the commercial market. This analysis should include, but not necessarily be limited to,

- Market size, e.g. how big is the sector?
- Market trends, e.g. can any important changes in this sector be perceived? What are the general sector trends?
- Market forecasts, e.g. a PESTLE analysis or similar may be required. For example, what are the political, economic, social, technological, legislative or environmental changes that could affect business in the medium or long term?
- Market growth, e.g. what is the potential for growth in the market?
- Risk and mitigation analysis.

### *5.1.2 Potential Customer Analysis*

An analysis should be carried out highlighting the various potential customers. The main features of should consider:

- The target market, e.g. how desirable is the sector for new, local entrants and from other EU areas?
- Purchaser trends;
- Risk and mitigation analysis.

### *5.1.3 Competition Analysis*

To commercially exploit the results in a successful manner, competitor awareness is important, as well as the knowledge of competitor strengths and weaknesses (i.e. partners should profile their competition). As such, a detailed analysis should be carried out to ascertain who the direct competition is for each partner. Some of the issues to be addressed include:

- An analysis of published data;

- The number of companies operating in the same sector;
- The most important competitors;
- Competitor strengths and weaknesses;
- Your competitive advantage over competitors;
- Means by which to increase the competitiveness of the service or product provided;
- The pricing policies of competitors and how these may affect sales strategies;
- The estimated market share of competitors;
- The benefits of your service/produce to potential clients/customers over competitors;
- A risk and mitigation analysis.

## 5.2 Marketing Strategy

### *5.2.1 Price Strategy*

Project partners should provide detailed pricing information for the services/products provided in order to maximise the gross margin/profitability of the company, including a risk and mitigation analysis.

### *5.2.2 Sales Strategy*

Partners should describe the main composition, qualification and features of the sales policy and compared them with the competition, in order to analyse and propose additional advantages, including a risk and mitigation analysis.

### *5.2.3 Dissemination Strategy*

The dissemination strategy plays a vital role in addressing the means by which the exploitable results have been made known to the public/customers/stakeholders (i.e. the Client). Client awareness is critical to the successful exploitation of the project. The principles of the dissemination strategy from a consortium perspective are highlighted in INFRARISK Deliverable D9.1 (Jimenez and Garcia-Fernandez, 2014). However individual partners may have their own dissemination activity/strategy planned which is specific to the service/product they wish to exploit, including a risk and mitigation analysis.

### *5.2.4 Training Strategy*

In addition to the dissemination of the INFRARISK project results, the training strategy plays a vital role in the dissemination of knowledge to potential clients. The principles of the training strategy from a consortium perspective are highlighted in the sample training videos described in INFRARISK Deliverable D9.5 (Connolly and Clarke, 2016). The training strategy was addressed by considering the following:

- The target audience;
- The type of knowledge to be disseminated;
- The format of the training;
- Risk and mitigation analysis.

## 6.0 FINANCIAL PLANNING

This section provides a description of methods that should be adopted by project partners in terms of financial planning to commercial the exploitable results of the INFRARISK project.

### 6.1 Investment Plan

A detailed analysis should be conducted of the investment that will be required to commercialise the exploitable results. The issues to be addressed include:

- What financial resources will be needed?
- What physical resources will be needed?
- What human resources will be needed?
- What financing method will be required?
- What is the break-even point?

### 6.2 Account Forecasting

A three year projection for the exploitable results should also be prepared to consider the following aspects:

- What will the estimated revenue in years 1 - 5 be?
- What are the incurred costs over the first few years of activity?
- What is the return on Investment?

### 6.3 Risk Assessment

A risk assessment should also be carried out to assess the foreseeable risks that may exist in the commercialisation of the results and how these risks are to be dealt with. Factors considered in this analysis should include:

- Internal risks, e.g. acceptance of service within the market;
- External risks, e.g. changes in market demand;
- Expected risks associated with the implementation of the result;
- Methods to manage and deal these risks.

# 7.0 CONCLUSION

This report has described a business plan, which includes a Technological Implementation Plan (TIP), to identify and analyse the exploitable results of the INFRARISK project. The core aspects of the business plan include an evaluation of the INFRARISK consortium in terms of the core strengths and competencies, a post-project plan in relation to the legal and business agreements amongst consortium members, aspects of market analysis, marketing strategy and financial planning to be considered in the future. The business plan described herein provides a framework to facilitate the exploitation of the INFRARISK research and proposed methodologies, which have the potential to be employed by the next generation of infrastructure managers and owners to improve the resilience of critical road and rail infrastructure against natural hazards.

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# APPENDIX A: INFRARISK PARTNER DESCRIPTIONS

**Roughan & O' Donovan Ltd. (ROD)**

ROD is an SME based in Dublin, Ireland, comprising approximately 120 staff, which is recognised as one of the leading civil engineering consultancies in Ireland, having been involved in projects with a combined value of €3 billion in recent years. Areas of ROD's expertise include bridges, transportation, environmental (including geotechnics and hydrology), and building structures. All of ROD's technical staff members are university qualified and almost 20% hold a Masters or a PhD.

The subsidiary company, Roughan & O'Donovan Innovative Solutions (ROD-IS), was established in 2009. ROD-IS is the part of the ROD group of companies that focuses on the latest research developments in advanced structural design and assessment. ROD-IS staff have developed software and published extensively on probabilistic approaches for bridge safety assessment, structural health monitoring, bridge dynamics, bridge traffic loading and bridge weigh-in-motion. In addition to providing specialist consultancy services, ROD-IS is deeply involved in European research and development projects through participation in a number of European Union 7th Framework (FP7), European Horizon 2020, and CEDR funded Projects. ROD-IS is led by a collaboration of Roughan & O'Donovan Ltd., Prof. Eugene OBrien (University College Dublin) and Prof. Alan O'Connor (Trinity College Dublin), bringing together over thirty years of research in bridge and structural engineering in the fields of loading, design and assessment.

ROD acted as project coordinator for the INFRARISK project. In addition, ROD led technical work package 8, in which two European case studies were conducted to demonstrate the systematic application of the methodologies developed in the project to existing road and rail transport networks. As an SME with extensive experience in the design and construction management of transport infrastructure, ROD applied their technical knowledge of civil engineering structures, as well as the research capabilities of ROD-IS. ROD's position within industry also facilitates the exploitation of the INFRARISK results, according to the development of a training course and a business plan.

**Eidgenössische Technische Hochschule Zurich (ETHZ)**

ETHZ is a science, technology, engineering and mathematics university located in Zürich, Switzerland. ETHZ is currently ranked as the 5th best university in the world in engineering, science and technology according to the QS World University Rankings. The Institute for Construction and Infrastructure Management (IBI) at ETHZ forms part of the Department of Civil, Environmental and Geomatic Engineering. One of the focuses of this department is to improve the management of infrastructure.

The IBI at ETHZ is well connected with other research laboratories and with infrastructure stakeholders, such as SBB in Switzerland, RFF in France, FEDRO in Switzerland. In addition, the IBI is well connected to those who are currently developing state-of-the-art computerised management systems. The IBI has extensive experience of participation in EU, national, and international projects, and have partnered with prominent academic and leading industrial players, such as IFSTTAR, KU Leuven and TU Delft.

Within the INFRARISK project the IBI at ETHZ was responsible for the development of a methodology to be used to assess infrastructure related risks due to natural hazards. The proposed methodology is adaptable to various natural hazards, consequences and available resources.

**Dragados SA (DSA)**

DSA belongs to the ACS Group and has been one of the leading multi-national contractors worldwide for over 70 years, and currently operates in more than 50 countries. In 2011, DSA had a turnover of €2,290 million and 5711 employees. The company has extensive experience in research projects in Spain and throughout Europe in fields such as infrastructure, building, construction processes, health and safety and environmental impact.

DSA delivers all type of infrastructure, including roads, rail, ports, tunnels, bridges, dams, buildings, etc. but the main interest of the company in the INFRARISK project has been in the area of linear transport infrastructures. DSA owns one of the largest concessionaire (operator) companies in the world and, therefore, commercial versions of the tools deployed in INFRARISK are of significant interest to DSA, which can be applied to their infrastructure assets. Additionally, from both a design and construction point of view, DSA sees added value in applying the methodologies developed in the INFRARISK project to for improving the resilience of new and existing infrastructure and to assist in more informed and better investment decisions regarding maintenance and repair activities.

DSA contributed their technical and practical expertise in relation to infrastructure within the INFRARISK project. In particular, DSA provided expertise in the areas of hazard assessment for infrastructure elements and network vulnerability assessment. The final dissemination conference for INFRARISK was also hosted by DSA in their headquarters in Madrid, Spain.

**Gavin & Doherty Geosolutions Ltd. (GDG)**

GDG is a specialist geotechnical engineering consultancy, based in Ireland, providing innovative geotechnical solutions across a broad range of civil engineering sectors. GDG was founded in 2011 by Dr. Paul Doherty and Prof. Kenneth Gavin. GDG is very active in EU cross-collaboration research projects, serving as a partner or project coordinator in a number of EU funded projects, mostly focusing on infrastructure risk (FP7 SmartRAIL, FP7 RAIN, FP7 LeanWIND, H2020 DestinationRAIL, etc.). GDG successfully collaborates with a number of national transport infrastructure managers, both as a part of these research projects and in other commercial projects, having a first-hand opportunity to present the exploitable results to the primary category of end-users.

With a strong background in geomechanics and applied geotechnical research, GDG brings together state-of-the-art research and direct industry experience, and is in a position to offer a unique engineering service, delivering the most progressive, reliable, and efficient geotechnical designs across a wide variety of situations. Over 70% of company’s technical staff is either MSc or PhD qualified. GDG is actively involved in a range of international infrastructure projects including harbours/marinas, offshore oil/gas installations, onshore and offshore windfarms, commercial structures and basements. GDG’s principal areas of expertise are Infrastructure, Renewables, Structures, Offshore and Research & Development.

GDG acted as leaders for work package 2 in the INFRARISK project, which developed a sample database of critical infrastructure in Europe and an online knowledge base. In addition, GDG contributed to the development of methods for the assessment of network vulnerability, particularly relating to earthworks. Furthermore, GDG analysed the impact of climate change on critical transport infrastructure, focusing on engineered slopes along an existing rail network.

**Probabilistic Solutions Consult and Training (PSCT)**

PSCT is an SME, founded in 2006, that provides consultancy services focused on statistical modelling and risk assessment for risk profiling of assets. Risk profiles have been developed by PSCT for a wide range of applications, such as rail yards based on geometrical and socio-economic properties and risk profiling of inventory and other current assets of Dutch pharmacies.

PSCT employs advanced statistical models for estimating and assessing high-dimensional datasets. Modelling adaptive measures to reduce flood risk under uncertain climate change has been a recent project of PSCT for the Dutch Ministry of Environment. PSCT provided in the past an in-house course for the Dutch energy company NUON on stress testing for traffic light systems and PSCT was involved in evaluating adaptive measures to reduce flood risk under uncertain climate change for the Dutch Ministry of Environment.

PSCT was responsible for developing the stress test framework for infrastructure networks due to extreme natural hazards in the INFRARISK project. In addition, PSCT proposed a decision making theory that can be used to determine the optimal interventions to be taken by infrastructure managers to improve the resilience of distributed infrastructure networks. PSCT also investigated and fitted wavelets, and linear hydrodynamic models of temporal and spatial fluctuations of environmetric cycles, such as river discharge cycles. Furthermore, PSCT modelled occurrence probabilities of extreme events with novel extreme value distributions.

**Agencia Estatal Consejo Superior de Investigaciones Científicas (CSIC)**

CSIC (Spanish National Research Council) is Spain's largest public research institution, and ranks third among Europe's largest research organization. CSIC is under the responsibility of Spain's Ministry of Economy and Competitiveness through the Secretary of State for Research, Development and Innovation, and plays a key role in scientific and technological policy in Spain and worldwide. According to its Statute (Article 4), CSIC has 4 main missions: *to foster multidisciplinary scientific and technological research, Knowledge transfer to industry and society, Education and training of scientific and technical staff, Creation of Technology Based Companies*. CSIC has 10,940 employees, including 3,764 researchers. CSIC has 123 Institutes spread across the country and covering different areas of Science and Technology. CSIC produces 20% of the national scientific output (more than 12.000 ISI paper in 2014). CSIC remains the leading patent filer among research bodies in Spain with more than 180 patent requests published in 2014.

CSIC is a major player in the development of the European research area and therefore a significant contributor to the European integration process. Within the 7th Framework Programme CSIC has signed 723 actions (including 97 coordinated by CSIC and 47 ERC projects). As to the number of projects, CSIC is listed the 1st organisation in Spain and the 6th in Europe in the 7th Framework Programme, with a total FP7 contribution of over 263 million euros (E-CORDA). Within the first Work Programme of H2020 (2014-2015), CSIC has actively participated in different calls, having special success in some programmes, such as Research Infrastructures, ERC and Marie Curie Actions, as well as in the Societal Challenges of "Food Security, Sustainable Agriculture and Forestry". The Institute of Geosciences at CSIC has extensive expertise in earthquake hazard and risk modelling, as well as engineering seismology. In addition, CSIC has experience of developing educational materials, outreach activities and training in relation to scientific communication strategies. The Institute of Geosciences at CSIC has been involved in several European projects, including DG-ECHO UPStrat-MAFA, FP7 KNOW-4-DRR and the EC-FP4 project SERGISAI, whereby the use of GIS and AI techniques for seismic risk scenarios were pioneered.

Within the INFRARISK project, CSIC was responsible for developing a methodology for the assessment of low probability seismic hazard for linearly distributed infrastructure and a procedure for its implementation in the INFRARISK IDST tool. CSIC also acted as work package leaders for the project dissemination and exploitation activities.

**University College London (UCL)**

UCL is a higher research institution that employs 4,078 academic research staff in over 50 departments and institutes and has two decades worth of experience in the EU Framework Programmes. UCL is currently involved in 370 FP7 projects and is ranked 3rd in the UK and 9th in Europe in terms of the amount of FP7 funding awarded.

UCL is represented in INFRARISK by the highly interdisciplinary Department of Civil, Environmental and Geomatic Engineering (CEGE) which is amongst the top four UK civil engineering departments and has a reputation for research excellence, ranking 5$^{th}$ in the last UK Research Assessment Exercise (RAE). The CEGE at UCL have expertise in the areas of seismic and flooding vulnerability assessment for existing structures, and were previously involved in the EU FP7 projects: NIKER and PERPETUATE. In addition, UCL have expertise in the areas of space-time modelling and network analysis, including data acquisition, management and representation for large and complex spatial dataset.

In the INFRARISK project, UCL acted as leaders for work package 3, in which hazard assessment methods and network vulnerability assessment methods were proposed that could be employed as part of multi risk analysis scenarios. UCL also lead work package 5 in the INFRARISK project, which developed space-time models to analyse the impact of natural hazards on spatially and temporally varying infrastructure networks.

**Peter Prak Leonard (PSJ)**

PSJ is an SME consisting of a single employee based in the Netherlands, which was established in 2009. PSJ has experience in the field of integral safety and security management, as well as vital infrastructure protection at strategic and tactical levels.

PSJ provides consulting services in relation to the development of security concepts, decision support and ranking using the Objective Ranking Tool (ORT). In addition, PSJ provides training and conducted research and development activities. Some of PSJ's clients include governments (national, regional and local), infrastructure managers (rail, road, and water), public transport operators, universities, museums and commercial enterprises. Based on over 20 years of industrial experience, PSJ develops security concepts for risks to critical infrastructures, as well as terrorism threats, crowd control and management, as well as project and program management.

In the INFRARISK project, PSJ contributed to the case studies, through application of the ORT as a decision-making and ranking tool. In addition, PSJ was involved in the development of a dedicated training course for infrastructure managers and owners.

**Stiftelsen Sintef (SINTEF)**

SINTEF, Scandinavia's largest independent research organisation, is a non-profit research foundation whose overall vision is "technology for a better society". Smarter and more effective ways to work with data, as explored in INFRARISK, is an area of research that aligns well with its overall vision. SINTEF has the ambition to become an internationally leading research organisation in the field of applied research in big data management.

SINTEF ICT is in the business of acquiring and executing national and international research and development (R&D) projects and providing expertise and consultancy services in different scientific areas. More specifically, in the context of the INFRARISK project's business exploitation plans, SINTEF ICT has provided and plans to continue to provide research and innovation expertise in the fields of data management and Linked Data. SINTEF operates in the contract-based R&D market. The SINTEF group that was involved in the project mainly targets public R&D funding (e.g. from Norwegian Research Council, European Com-mission), but also acquires bilateral contracts with industry, particularly the Norwegian industry in the area of Big Data, cloud computing and Internet of Things.

Since SINTEF is a contract-based and not-for-profit research organization, the INFRARISK impact creation activities will primarily be focused on using and further extending the DataGraft platform in existing and future projects in which SINTEF will be involved. DataGraft is cloud-based service portal for data transformations and data access. It provides powerful data transformation capabilities, including sharing, repeatability and reuse, while at the same time allowing reliable data access for data workers to manage and visualize their data in a simple, effective, and efficient way. DataGraft was used as the technical infrastructure for the development of the INFRARISK GIS Knowledge Base that allows you to upload, transform and query data about infrastructure components and natural disaster events. DataGraft applies techniques from the emerging field of Linked Open Data (LOD)[6] which uses the semantic standards Resource Description Framework (RDF)[7] for representing data on the Web and SPARQL[8] to query the data. For the GIS Knowledge Base SINTEF developed a Resource Description Framework Schema (RDFS)[9] for infrastructure components and events to formally represent and exchange data between Web applications. The GIS Knowledge Base represents a usable demonstrator that shows the application and benefits of DataGraft, and will be used as a showcase in the acquisition of future research and development projects. Furthermore, SINTEF has led the development of the INFRARISK vocabulary; a set of agreed and shared data models for infrastructure components and natural disaster events. SINTEF will reuse this vocabulary in various DataGraft-related tutorials, and will consider the possibility to standardize the vocabulary.

[6] https://www.w3.org/standards/semanticweb/data
[7] https://www.w3.org/TR/2014/REC-rdf11-concepts-20140225/
[8] https://www.w3.org/TR/rdf-sparql-query/
[9] https://www.w3.org/TR/2014/REC-rdf-schema-20140225/

**Ritchey Consulting AB (RCAB)**

RCAB is world leading in the use of computer-aided General Morphological Analysis (GMA) for problem structuring and decision support modelling, particularly in relation to complex, multi-stakeholder societal problem areas, also known as “wicked problems”. RCAB’s main role is to work with project participants and other subject matter specialists in the problem structuring and conceptual modelling of these complex problem areas, and then to build methodological tools that can later be used by the project and the end-users.

Since 1995 RCAB has applied GMA to more than 100 projects in the areas of infrastructure vulnerability and resilience, technology innovation/foresight, emergency management and civil preparedness, rescue services, transportation, environment, crime prevention and migration/immigration. These include the FP7 project CPSI (Changing Perceptions of Security and Interventions ), a project for EDM, Kobe entitled ‘Modelling Multi-Hazard Disaster Reduction Strategies’, as well as development of Sweden’s National Risk and Vulnerability Assessment Program.

In the INFRARISK project, RCAB applied GMA 1) to develop among the project participants a common conceptual framework (and terminology) for the project’s total problem space; 2) to discuss and make recommendations about the bounding of this problem space (e.g. as concerns types of events, hazards, infrastructure elements, networks and consequences of disruptions); and 3) to make an initial hypothesis about how this information can potentially be used to structure the overarching methodology to be developed in WP4 concerning inputs, throughputs and outputs.

**University of Southampton (IT Innovation)**

The IT Innovation Centre is the applied research centre at Electronics and Computer Science, Faculty of Physical Sciences and Engineering. It has more than 25 years of research experience in complex systems using advanced work flow optimisation theories and processes in leading national and international research programmes. The team of over 35 research staff has a wide range of experience in academia, industry, commerce, and public sectors.

An international leader in applied research, the IT Innovation Centre works on a wide range of research initiatives involving: secure service-oriented systems, future internets, smart cities, big data analytics, artificial intelligence, information discovery, risk management and critical decision support. IT Innovation has a substantial track record in the development of interoperable information systems based on generic data fusion and modelling frameworks for risks, safety and security management with advanced situation awareness.

IT Innovation acted as leaders for work package 7 in the INFRARISK project, which developed a strategic INFRARISK Decision Support Tool to ensure that the methodologies developed in the project as part of the stress test framework were practically integrated and used under specific process workflows and modules.

## APPENDIX B: EXPLOITABLE PROJECT RESULTS TEMPLATE

| 1. Results Description | | | |
|---|---|---|---|
| WP No: | Result No: | Title: | Date: |
| Output | ☐ Product<br>☐ Service<br>☐ Process/methodology<br>☐ Other | | |
| Description of the Result | | | |
| Market Niche | | | |
| Value proposition | | | |
| Unique selling point (differentiating factors, competitive advantages) | | | |
| State of development at present date and indicate final state of development by end of project | | | |
| Performed trials and achieved results at present date | | | |
| Expected level of development for the result (TRL) | | | |
| Expected time for marketability | | | |
| Has this result the potential to be exploited in the consortium | ☐ Yes<br>☐ No<br>☐ Don't Know<br><br>If yes indicate exploitation potential -☐ low ☐ Medium ☐ High | | |

| 2: IPR | |
|---|---|
| Exploitable Result No. | |
| Exploitable Result Description | |
| Contributors | |
| Background declaration | |
| Protection Plans | ☐Internal know-how<br>☐Patent (to be applied, applied, granted)<br>☐License agreement ( in progress, reached)<br>☐Registered design<br>☐Exclusive rights ( under discussion, granted)<br>☐Trademark , copyright, etc. |
| Expected foreground (who will do what?) | |
| External partners required for development | |
| Actual Foreground | |

## 3. Dissemination Strategy

- Define all main industry segments ( Key Stakeholders (KSHs));
- Identify major companies/organisations within each segment;
- Define target number for each KSH;
- Define dissemination actions ( who, what, when);
- Describe direct approach to be taken;
- E-communications;
- Participation in events;
- Workshops organisation;
- Other;
- Define KPI to measure the effectiveness of those actions.

| | | |
|---|---|---|
| Dissemination limitations (according to IPR) | | |
| KSH 1 | Key message | |
| Insert KSH | Target Number | |
| | Dissemination Actions description and date (planned and carried out) | |
| KSH2 | Key message | |
| | Target Number | |
| | Dissemination Actions description and date (planned and carried out) | |
| KSH3 | Key message | |
| | Target Number | |
| | Dissemination Actions description and date (planned and carried out) | |
| Etc.... | | |

<table>
<tr><th colspan="3">4. Exploitation Strategy</th></tr>
<tr><td>Legal form for result exploitation and Governance Policy</td><td colspan="2"></td></tr>
<tr><td>Exploitation claims (for each partner or for the Joint Venture)</td><td colspan="2"></td></tr>
<tr><td>NON contributing INFRARISK partners</td><td colspan="2"></td></tr>
<tr><td>External (non INFRARISK) partners required for marketing, commercialisation?</td><td colspan="2"></td></tr>
<tr><td>Source of financing required after project</td><td colspan="2"></td></tr>
<tr><td>Target market size</td><td colspan="2"></td></tr>
<tr><td>Competitors / allies</td><td colspan="2"></td></tr>
<tr><td>Business model</td><td colspan="2">Define product/service positioning and customers engagement<br>☐Direct sales<br>☐Open distribution<br>☐Consultancy service<br>☐Operation fees<br>☐Joined investment/revenues with clients<br>☐Turn-key<br>☐Enabling technology (for subsequent product, service,etc.)<br>☐Training<br>☐Other -<br>Canvas (or similar) business model to filled.</td></tr>
<tr><td>Marketing strategy</td><td colspan="2"></td></tr>
<tr><td rowspan="2">Barriers</td><td>Barriers</td><td>Measure to overcome</td></tr>
<tr><td>☐Legal / regulation<br>☐Technology barriers<br>☐Environmental barriers<br>☐Other</td><td>☐xxx<br>☐xxx<br>☐xxx<br>☐xxxx</td></tr>
<tr><td>Contribution to standards</td><td colspan="2"></td></tr>
</table>

| 5. Risks assessment | |
|---|---|
| • Identify potential risks which might prevent a successful ER development or market uptake and the necessary risk mitigation / avoidance strategies<br>• Select from Risks list and/or add new ones. | |
| Risk | Mitigation strategy |
| | |
| | |
| | |
| | |
| | |

 