ISSMGE TC304-TF3

INTERNATIONAL STATE OF THE ART REPORT

on

Integration of

Geotechnical Risk Management

and

Project Risk Management

PART 1 – REPORT

FINAL

Version 2

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Disclaimers

This report with its appendices reflects the individual views of the reporters on the application and integration of geotechnical risk management in project risk management in their countries. This information is likely to be incomplete and aims to present a general state of the art overview.

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PART 1 page

PREFACE

This international state of the art report on the application and integration geotechnical risk management and project risk management has been provided by Technical Committee 304, Task Force 3 (TC304-TF3) of the International Society of Soil Mechanics and Geotechnical Engineering (ISSMGE).

The TC304-TF3 objective is contributing to the application and integration of geotechnical risk management (GeoRM) in project risk management (ProjectRM), by sharing and evaluating existing international knowledge and lessons. This may support geotechnical professionals, as well as project, contract, cost, safety, quality, and other managers, with managing engineering and construction project risks, with geotechnical risk drivers, in an effective and cost-efficient way. Moreover, also for researchers the collected data, analyses and conclusions may be useful for their geotechnical and project risk management research.

In total ten countries participated in this research. These are, in alphabetical order, Austria, China, Czech Republic, Finland, Germany, Japan, Netherlands, Sweden, Switzerland and United Kingdom.
TC304-TF 3 representatives of these ten countries participated in the research, by delivering country reports that served as foundation for this state of the art report.

The reporter is very grateful to these ISSMGE TC304-TF3 representatives. Without their commitment and results, this state of the art report simply could not be developed. Therefore, in alphabetical order by first names, Hongwei Huang, Joost van der Schrier, Lars Olsson, Leena Korkiala-Tanttu, Olga Spackova, Paul Cools, Paul Maliphant, and Tadashi Hashimoto, many thanks to you and your teams!

In total 10 country reports have been summarized and analysed in this state of the art report, which is some 5 % of the total number of countries in the world. Eight of these ten countries (80%) are European, which are mainly located in northern and central Europe. The remaining two countries, China and Japan, are located in East-Asia. Therefore, five of the seven continents are not represented and additional research, including in particular countries of the “missing” continents is highly welcome.

Moreover, despite or perhaps because of the applied research methodology, including a survey with brief case studies, some inherent and unconscious subjectivity of the reporter may have entered the research analyses and conclusions. Therefore, practitioners and researchers, including MSc and PhD students, are warmly challenged to reconsider the data, analyses and conclusions of this report. Any comments, publications, as well as additional research, is expected to contribute to our collective and yet limited knowledge base about the application and integration of project and geotechnical risk management, in the heat of practice of civil engineering and construction projects.

Martin van Staveren
Breda, Netherlands, November 2013

EXECUTIVE SUMMARY

This international state of the art report on the *application and integration* of geotechnical risk management and project risk management has been provided by Technical Committee 403, Task Force 3 (TC304-TF3) of the International Society of Soil Mechanics and Geotechnical Engineering (ISSMGE).

The TC304-TF3 *objective* is contributing to more application and integration of geotechnical risk management (GeoRM) in project risk management (ProjectRM). Evaluating and sharing existing international knowledge, practices, and recommendation, as presented in this report, may contribute to this objective.

A variety of professionals in the engineering and construction industry is the *target audience*. The report objective is supporting geotechnical professionals, as well as project, contract, cost, safety, quality, and other managers in understanding the possibilities and limitations of ProjectRM and GeoRM applications in different countries and cultures. These professionals may apply the content of this report for managing their geotechnical and project risks in an effective and cost-efficient way. This can be done during all project phases. The experiences from other countries can serve as inspiration for improving the application of ProjectRM and GeoRM in one´s own construction projects. Moreover, researchers may be interested to use the collected data, analyses, and conclusions of this report for their geotechnical and project risk management research.

In total *ten country reports* have been summarized and analysed in this state of the art report, which represents some 5 % of the total number of countries in the world. Eight of these ten countries are European, which are mainly located in northern and central Europe. The two remaining countries are located in East-Asia. The report consists of two parts. Part 1, which is this report, includes the summarized and analysed data that is provided by ten country reports. These country reports are presented in their original form in Part 2.

Despite several inherent *research limitations*, this report may provide valuable first steps for (1) identifying the status of applying ProjectRM and GeoRM, (2) highlighting their potential benefits for contributing to project successes, and (3) presenting ways how to stimulate and improve ProjectRM, GeoRM, and in particular their integrated application, for achieving effective and cost-efficient risk management results in civil engineering and construction projects.

Regarding risk management *definitions*, in the majority of seven out of the ten countries (70 %) no specific, widely accepted, or official ProjectRM definitions are in use. In the remaining three countries ProjectRM definitions are slightly different, with a different origin. In even eight out of the ten countries no specific and unified GeoRM definitions are in use. In one country GeoRM is not specifically defined, because it is considered an overall part of project risk management.

With regard to *risk management codes, standards, guidelines, and processes*, it can be concluded that seven out of the ten countries mentioned the use of ISO-based standards, guidelines, and processes. The remaining three countries report their own ProjectRM codes, standards, regulations, and guidelines. These are focusing in particular on safety during development and operation of constructions, or integrate risk management within project management standards. Contrary, seven out of the ten countries report that there are no GeoRM codes, standards, guidelines, and processes that would be broadly used. In the remaining three countries a few specific GeoRM guidelines and processes are available and in use.

Considering the *types of projects* in which risk management is applied, five out of ten countries report explicitly that standardized ProjectRM is not applied in all construction projects. Only one country reports that GeoRM is applied in all projects, yet not always exactly following the standards. In other words, GeoRM application is not yet standard in 90% of the ten countries. If applied, ProjectRM as well as GeoRM seem to be most common in underground constructions (e.g. tunnels, subway stations), major highways, and generally in large infrastructure projects. In the remaining types of projects ProjectRM and GeoRM seem to be applied in a minority of the countries.

Regarding the *project phases* in which risk management is applied, five out of ten countries report explicitly that standardized ProjectRM and GeoRM are not applied consistently in all project phases. If applied, then ProjectRM and GeoRM seem to be most common in the design phases, during tendering / contracting, and in the construction phase. GeoRM seems to be applied to a lesser extent during the design and tendering / contracting phases than ProjectRM. However, regarding the feasibility phase, a few more countries reported GeoRM application than ProjectRM application. Nevertheless, this report reveals that ProjectRM and GeoRM seems by far not yet applied in all phases of engineering and construction projects, as all project risk management theories do recommend.

Considering the *results* of applying risk management, from the ten country reports in total 12 different results of applying ProjectRM have been derived. From applying GeoRM in total 10 results have been derived. The results present a rather wide scatter of ProjectRM and GeoRM benefits. Partly, GeoRM benefits are similar to the reported ProjectRM benefits. Examples are avoiding cost and time overruns, providing a sustainable and safe design, reduction of conflicts, and timely awareness and management of project risks.

Moreover, from the country reports it was not always clear whether the reported ProjectRM and GeoRM results were *real* results derived from practice, or merely anticipated or *wishful thinking* results. A number of countries made explicit statements about the scarcity of risk management results. ProjectRM and GeoRM successes seem quite difficult to find and are not readily available. Nevertheless, some ProjectRM and GeoRM success examples were provided by six participating countries. The ProjectRM and GeoRM benefits in the examples are evaluated qualitatively, rather than quantitatively. Successes were not expressed in figures of the usual performance indicators for project success, such as cost, time, safety, and quality.

Hurdles for applying ProjectRM and GeoRM, as well as *solutions* for overcoming these hurdles, have been classified in three types: (1) hurdles and solutions that are primarily caused by the structure of (project) organizations (Os), (2) those primarily caused by the culture of these organizations (Oc), and (3) hurdles and solutions primarily caused by technical causes (T). Causes of organizational structure and culture seem often closely coupled. From the ten country reports in total 18 different hurdles for applying ProjectRM and in total 20 different solutions for overcoming these hurdles have been derived. For applying GeoRM, in total 17 different hurdles and 19 different solutions for overcoming the hurdles became visible.

Regarding ProjectRM and GeoRM *integration*, this seems only the case in the two Scandinavian countries. In the remaining eight countries the degree of integration seems to vary on the full spectrum of even no risk management application at all towards fully integrated and applied ProjectRM and GeoRM in projects of certain clients.

Considering the contribution of GeoRM to ProjectRM, from the country reports in total ten different *contributions* of GeoRM to ProjectRM have been derived. Examples are managing the crucial role of geotechnical uncertainties that have a major influence on construction projects, increasing the safety during the works and of the final constructions, and combining systematic gathering of geotechnical information with construction performance and costs, for improving know-how and fostering learning. However, all of the identified contributions of GeoRM to ProjectRM are rather general and qualitative, evidence-based and quantitative evaluation of the benefits expressed in money, time, safety records, and so on was not provided.

With regard to the *ways of communication* of geotechnical risk to non-geotechnical persons, specific attention has been given to cultural elements, language issues, and the so-called fear factor of risk communication. This reveals that geotechnical risk communication to non-geotechnical engineers and managers, as well as to the public, is far from easy. In total ten ways of GeoRM communication to non-geotechnical persons have been retrieved from the country reports. Five suggestions for GeoRM communication have the public as target, the other five focuses on project teams with non-geotechnical engineers and managers. Six of the ten communication suggestions are proposed by one single country. This allows considerable learning opportunities for the other nine countries.

Considering *lessons* from *other sectors* for more and improved ProjectRM and GeoRM application, five out of the ten participating countries suggested seven sectors outside the construction industry where valuable lessons for more effective and cost-efficient GeoRM can be found. These are the mechanical, space, insurance, chemical, nuclear, financial services, and the consulting industry. Therefore, outside the construction sector, there seems a wealth of proven methods, techniques, tools and approaches that can be used for developing well-integrated ProjectRM and GeoRM. This may save a lot of time, energy, and money, because it avoids reinventing the wheel.

This brings us to three *main conclusions* on integrating GeoRM and ProjectRM: (1) in theory there are no objections for a full integration of GeoRM and ProjectRM, (2) the awareness of the need for and potential benefits of such an integration is growing, and (3) the complete application and integration of both types of risk management, for providing full support of realizing project success in practice, has still a lot of room for improvement.

Finally, the ten country reports delivered in total 19 *recommendations* for integrating GeoRM and ProjectRM. Similar to the ProjectRM and GeoRM hurdles and solutions, all of these recommendations have been classified in three types: (1) recommendations that are primarily realized by changes in the organization structure of (project) organizations (Os) involved in construction projects, (2) those primarily realized by changing the culture within these organizations (Oc), and (3) recommendations primarily involving technical measures (T).

In total 13 out of the 19 recommendations (68 %) are organizational of origin, of which 9 are structural and 4 are cultural. In total six technical recommendations have been identified.

In summary, the *top six recommendations* for more application and integrating GeoRM and ProjectRM are:

1. Provide education and training on GeoRM and ProjectRM and make it part of the curricula.
2. Identify and communicate success stories of integrating GeoRM and ProjectRM for achieving project objectives within time and budget.
3. Provide short courses and tools for non-geotechnical risk managers about the need and benefits of integrating GeoRM in ProjectRM.
4. Teach geotechnical professionals how to communicate the effects of geotechnical risks in the language of non-geotechnical engineers, managers, and the public.
5. Improve the know-how of GeoRM and ProjectRM by evidence-based learning from finished projects, in particular by systematic evaluation of the effectiveness and cost-efficiency of applied risk remediation actions.
6. Provide standards for RM processes in public investments projects that would be broadly accepted by the community.

Remarkably, five of these six recommendations are classified as an Os (Organization structure) type. This aligns with the identified ProjectRM and GeoRM hurdles, which are mainly of a similar organizational type.

However, the data reveals also that there seems a tendency to solve *organizational problems* with merely *technical solutions*, rather than with organizational solutions. In other words, a lot of technical solutions were raised for solving merely organizational problems. This seems to reflect what engineers have been trained to do and also highlights, perhaps, a gap in (post-graduate) engineering education. It should be a point of attention, when one is trying to reduce ProjectRM and GeoRM hurdles for (further and deeper) integrating both types of risk management.

Finally and in conclusion, during all activities *the main objective of application and integrating ProjectRM and GeoRM* should be kept in mind: contributing to project success, by developing effective and cost-efficient risk management practices for civil engineering and construction projects, of any project type, in any project phase, at any project location in the world.

INTRODUCTION

TC304-TF3 objective and target audience

Over the last years, geotechnical risk management and project risk management developed rapidly. Geotechnical risk management (GeoRM) aims to control geotechnical risk, while project risk management (ProjectRM) aims to control project risk. Both types of risk management apply cyclic and common steps of (1) setting objectives, (2) identifying risks, (3) classifying risks, (4) remediating risks, by preventive and / or corrective risk control measures, (5) evaluating the effectiveness and efficiency of risk remediation measures and (6) reporting the results of the risk management process to the next project phase. However, in day-to-day practices of realizing construction projects, including project phases such as feasibility, design, contracting and construction, both complementary types of risk management seem often partly or separately applied, if applied at all.

This incomplete application and separated positioning of GeoRM and ProjectRM within organizations may avoid catching all potential risk management benefits, in terms of improved safety and quality, cost and time savings, and strengthening of reputations. In addition, potential synergies of scale and learning of risk management remain unused. This results into the following *TC304-TF3 objective*:

Contributing to the integration of GeoRM in ProjectRM,
by sharing and evaluating existing international knowledge and lessons.

By summarizing, analysing, and presenting the TC304-TF3 knowledge and lessons in this international state of the art report, geotechnical professionals and managers can be motivated and supported by explicitly managing their geotechnical and project risks. Figure 1.1 shows the current and targeted positioning of GeoRM and ProjectRM.

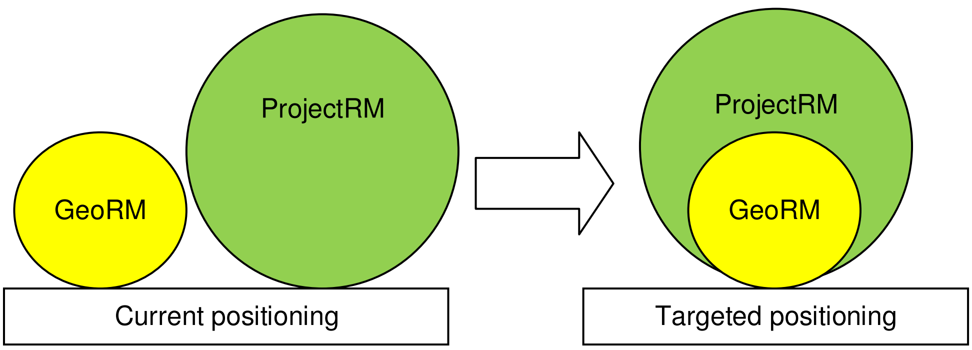

Figure 1.1. Current and targeted positioning of GeoRM and ProjectRM

A variety of professionals in the engineering and construction industry forms the *target audience*. The report objective is to support geotechnical professionals, as well as project, contract, cost, safety, quality, and other managers. These professionals may apply the content of this report for managing their geotechnical and project risks in an effective and cost-efficient way. This can be done during all project phases. Moreover, researchers may be interested to use the collected data, analyses, and conclusions of this report their geotechnical and project risk management research.

TC304-TF3 research approach
The targeted result of TC304-TF3 is an *International State of the Art Report* on the integration of GeoRM in ProjectRM. However, given the unavoidable time constrains of the TF3 members, we needed to bring the report expectations (back) to a realistic and feasible level. Therefore, inevitably, this international state-of-the-art report:

- Is not based on an entirely objective scientific approach
- Is not a complete reflection of the situation in each country considered
- Involves a limited number of countries
- Involves a limited number of experiences

Nevertheless, from data submitted by ten different countries the international state of the art report is expected to provide at least some valuable information on:

- The status of ProjectRM in different sorts of project
- The status of GeoRM in different sorts of project
- Differences in ProjectRM definitions and practices
- Differences in GeoRM definitions and practices
- Expected and realized ProjectRM benefits
- Expected and realized GeoRM benefits
- The level of integration of GeoRM in ProjectRM
- Expected and realized benefits of GeoRM in ProjectRM integration
- Hurdles of GeoRM in ProjectRM integration
- Solutions for GeoRM in ProjectRM integration
- How geotechnical engineering may empower GeoRM
- How GeoRM may empower geotechnical engineering
- How GeoRM may empower ProjectRM
- How ProjectRM may empower GeoRM

As far as known, this type of information is currently quite limited, if existing at all. Therefore, despite the inevitable constrains of the targeted international state of the art report, it is assumed that it may provide a considerable lot of valuable knowledge for the international geotechnical and project management community. It may give insights in how geotechnical engineering, when applying GeoRM processes, may directly contribute to ProjectRM, and indirectly contribute to successful engineering and construction projects to the benefits of our societies. Therefore, any contribution of anyone representing any country has been welcomed.

In total ten countries participated in this research, which is some 5 % of the total number of countries in the world. Eight of these ten countries (80%) are European. These are mainly located in northern and central Europe and are in alphabetical order Austria, Czech Republic, Finland, Germany, Netherlands, Sweden, Switzerland, and United Kingdom. The remaining two countries, China and Japan, are located in East-Asia. Therefore, five of the seven continents are not represented. Nevertheless, as far as known, similar reports on the integration of GeoRM and ProjectRM with an international perspective are not available.

TC304-TF3 research methodology and limitations

Because of the presented research objective and approach, the research methodology included data collection by a survey that is supported by brief case studies, if available. The survey included the following six questions and sub-questions:

1. State of art of Project Risk Management (ProjectRM)
1.1 How is ProjectRM defined?
1.2 Which ProjectRM guidelines, standards, and processes are used?
1.3 In which kind of projects is ProjectRM applied?
1.4 In which project phases is ProjectRM applied?
1.5 What are the results of applying ProjectRM? Bring in examples
1.6 What are hurdles for applying ProjectRM?
1.7 What are solutions for overcoming ProjectRM hurdles?

2. State of art of Geotechnical Risk Management (GeoRM)
1.1 How is GeoRM defined?
1.2 Which GeoRM guidelines, standards, and processes are used?
1.3 In which kind of projects is GeoRM applied?
1.4 In which project phases is GeoRM applied?
1.5 What are the results of applying GeoRM?
1.6 What are hurdles for applying GeoRM?
1.7 What are solutions for overcoming GeoRM hurdles?

3. Integration of GeoRM and ProjectRM
3.1 What is the status of GeoRM-Project RM integration?
3.2 How contributes GeoRM to Project RM?
3.3 How is GeoRM communicated to non-geotechnical persons?
3.4 What are ProjectRM lessons from other industries for GeoRM?

4 What are the main conclusions on integrating GeoRM and ProjectRM?

5 What are the main recommendations on integrating GeoRM and ProjectRM?

6 What are the references?

These questions have been submitted in a pre-set country report format. The representatives of the participating countries have been asked to use this format for providing their answers.

Inevitably, these answers are influenced by the inherent subjective interpretations and views of the country representatives and reporters. For instance, answers of all reporters will be affected by the way how they understood the question, by their nature of answering (some tend to be more brief in their answers than others), by their background (e.g. whether they are more active in tunnelling projects or in other types of projects) and by many other factors. So it is for example likely that some of the reporters are not aware of application of ProjectRM in bridge projects in their country, because they have no experience in this field.

In this report, quantitative weights of answers are presented in percentages. These are retrieved from the number of the ten participating countries that provided similar answers in their country reports. However, because of the inevitable subjectivities and incompleteness of the answers, these percentages should not be interpreted as completely objective evidence, but rather as indicators of general trends.

Furthermore, it is appropriate to mention the fact that four of the countries (Austria, Czech Republic, Germany, and Switzerland) have the same reporter and three of these (Austria, Germany, and Switzerland) were even included in one report. This confirms the presented biases, as these reports do not reflect the situation in the countries entirely objectively.

Regarding the role of language, this report, as well as all the country reports, has been written in English, which is not the mother language of most of the participants. Within the summary tables in this report, the language and expressions of the country reports have been maintained as much as possible, for reasons of traceability.

Within this state of the art report, all data provided by the ten country reports have been summarized and analysed by using the method of data triangulation (Patton 1997, Yin 2003). This type of triangulation involved comparing the variety of answers on the same question, as presented in the ten country reports. Answers that could be considered as more or less similar have been clustered in one answer. Of each question, the summarized results are presented in tables. Based on each table, some main conclusions have been made. Also here, inevitably some bias of the reporter has been influenced the results, which should be considered as indicators of trends, rather than as entirely objective evidence.

Within this report, identified hurdles for applying ProjectRM and GeoRM, as well as the proposed solutions for overcoming them, have been classified in three types: (1) hurdles/solutions that are primarily related to the structure of (project) organizations (Os) involved in construction projects, (2) those primarily related to the culture of these organizations (Oc), and (3) hurdles/solutions of a technical nature (T). This subdivision is based on the risk management implementation approach as developed by van Staveren (2009).

The structure of (project) organizations (Os) involves the *formal* part of organizations, including distribution of tasks, responsibilities, authorization, and so on. Examples of hurdles with these causes are poor organization of risk management responsibilities and a poor project evaluation, which results in a lack of evidence of risk management effectiveness.

The culture of a (project) organization (Oc) represents the *informal* part of organizations, including the mind-sets, attitudes, and behaviour of groups or teams of people working on shared goals. Examples are mental attitudes that risk management is equivalent to bureaucracy or that risk management delays the process of projects. Obviously, organizational structure and organizational culture are inter-related and inter-dependent.

Examples of hurdles for ProjectRM and GeoRM with *technical* causes (T) are a lack of appropriate risk management methods and tools.

Despite all mentioned research limitations, this report may provide valuable first steps for (1) identifying the status of GeoRM and ProjectRM, (2) highlighting its potential benefits for contributing to civil engineering and construction project successes, and (3) presenting ways how to improve ProjectRM, GeoRM, and in particular their integration, for achieving effective and cost-efficient risk management results in projects.

How to read this report

The International State of the Art Report on the integration of GeoRM in ProjectRM consists of 2 parts Part 1, which is this report, includes the summarized and analysed that is provided by ten country reports. These country reports are presented in their original form in Part 2.

For reasons of traceability and user-friendliness, the numbers of the chapters and sections in this state of the art report correspond with those in the country reports. Moreover, all summarized data has been presented in tables.

Chapter 1 and Chapter 2 present the summary, analyses and main conclusions of the state of the art of Project Risk Management (ProjectRM) and Geotechnical Risk Management (GeoRM). Chapter 3 presents similar information about the integration of ProjectRM and GeoRM. Finally Chapter 4 and Chapter 5 present the summaries, analyses, and main conclusions of respectively the conclusions and recommendations of the ten countries on integrating GeoRM and ProjectRM.

1 STATE OF THE ART OF PROJECT RISK MANAGEMENT (PROJECTRM)

1.1 How is ProjectRM defined?

Country	Summaries of ProjectRM definitions
Austria	No broadly accepted ProjectRM definition.
China	ProjectRM is defined as all activities and measures for dealing with technical risks for managing a project.
Czech Republic	There is no definition of ProjectRM that is generally used in the Czech construction industry.
Finland	While ProjectRM applied in several ways in several projects, no specific definition reported.
Germany	In context of infrastructure or construction management the term safety is used and well-defined, rather than risk. No broadly accepted ProjectRM definition.
Japan	There is no official definition of ProjectRM. The Japanese Society of Civil Engineers advocates their own definitions as follows: "Risk is the phenomenon which obstructs achievement of the target which was being planned till then" and "ProjectRM is to achieve the aim of the project by utilizing limited resources effectively by restricting the influence of risk".
Netherlands	ProjectRM is defined as all activities and measures for dealing with risk for managing a project. This is the RISMAN definition by Van Well-Stam et al (2004).
Sweden	ProjectRM is defined following ISO 73:2009: coordinated activities within a project to direct and control the project organization with regard to risk.
Switzerland	No broadly accepted ProjectRM definition.
United Kingdom	ProjectRM is not universally defined by all members of the UK construction industry. Various definitions of ProjectRM have been identified and presented.

Main conclusions on ProjectRM definitions

From the table it can be concluded that in the majority of seven out of the ten countries (70 %) no specific, widely accepted, or official ProjectRM definitions are in use. In the remaining three countries ProjectRM definitions are slightly different, with a different origin. China reports an own ProjectRM definition, Netherlands refers to the RISMAN definition, and Sweden uses the definition of ISO 73:2009.

As remarked by the United Kingdom, there seems a very limited inclusion of the converse of risk management, which is opportunity capture. Despite the ISO 73:2009 definition of risk (which allows for positive possibilities as well as negative ones), the more general understanding of risk is the potential for loss. Risk management seems hence widely perceived as linked to mitigation or minimization of that loss.

1.2 Which ProjectRM standards, guidelines, and processes are used?

Country	Summaries of used ProjectRM standards, guidelines, and processes
Austria	Based on ISO/IEC 31000 (ISO 2009) the Austrian Standards Institute drew up the ON Rule 49000 "Risk Management for Organizations and Systems - Terms and basics - Implementation of ISO 31000".
China	Guidelines, regulations, and codes for safety and risk management for construction of subway and underground works (2007), railway tunnels (2007), highway bridge and tunnel construction (2011), underground works in urban rail transit (2012). These are all in Chinese.
Czech Republic	There are no guidelines/standards that would be generally accepted in the Czech construction industry. ISO/IEC 31000 (ISO 2009) on risk management is not well known in the construction community. Project RM is mentioned in the standards of Czech Chamber of Chartered Engineers and other publications.
Finland	Following Finnish laws and regulations, Finnish Transportation Agency has created the guidelines for railway works. For the road works the guidelines cover only the traffic safety at site. Ring Rail ISO/IEC 31000 and guidelines of Transportation Agency. An in-company certificated operation system.
Germany	There are no standardized procedures or guidelines for the application of ProjectRM in construction projects. Code of Practice for Risk Management in Tunnel works (ITIG, 2006) has been translated into German by Munich RE. ISO/IEC 31000 (ISO 2009) is not well known in the construction community
Japan	There are no official standards / guidelines for ProjectRM. The Japanese Society of Civil Engineers has own manual of ProjectRM for road projects. The Ministry of Land, Infrastructure, Transport and Tourism has a Guideline and a manual for a Construction Management (CM) system, which involves risk issues.
Netherlands	RISMAN method by Van Well-Stam et al (2004), ISO/IEC 15288 (2008) on systems engineering, ISO/IEC 31000 (ISO, 2009) on risk management. Furthermore many organizations developed their own processes, often supported by a strong and 'suite-for-purpose' ICT environment.
Sweden	ISO/IEC 31000 (SS-ISO 31000:2009) on risk management, "Manual for Risk Management in the Construction Document-, Procurement- and Production Stages of Civil Engineering Projects." (in Swedish), proprietary guidelines and processes within different companies & major clients of infrastructure projects.
Switzerland	Regarding safety during development and operation of constructions and infrastructure: Richtlinie SIA 465, Norm SIA 260, Norm SIA 197, Matousek (1982).
United Kingdom	In addition to ISO/IEC 31000 (2009), ISO/IEC Guide 73 (2009) and ISO 9001 (2008) the UK Highways Agency and HMSO has a significant library of published procedures. Furthermore ProjectRM guidelines, standards, and processes on a sector basis, risk registers, and software such as Active Risk Manager (ARM).

Main conclusions on used ProjectRM standards, guidelines, and processes

From the table it can be concluded that in seven out of the ten countries (70%) ISO-based standards, guidelines, and processes are mentioned. However, in three of these seven countries the ISO/IEC 31000 Guideline for risk management is not well known (Czech Republic, Germany), or mentioned in only one project (Finland). ISO seems rather well incorporated in Austria, Netherlands, Sweden, and United Kingdom. Of the remaining three countries, China reports their own ProjectRM codes, regulations, and guidelines, Japan does not present specific ProjectRM standards (except for road projects), and Switzerland presents a number of codes that are focusing on safety during development and operation of constructions and infrastructure.

1.3 In which kind of projects is ProjectRM applied?

Types of projects	Countries	Percentage
Underground construction: tunnels, subway (metro) stations, parking facilities.	Austria, China, Czech Republic (starting), Finland, Germany, Netherlands, Sweden, Switzerland, United Kingdom (9)	90 %
Major Highways	Austria, China, Finland, Germany, Japan, Netherlands, Sweden, Switzerland, United Kingdom (9)	90%
Large infrastructure projects: multidisciplinary projects with complex interactions between different actors & stakeholders, with different requirements/interests.	Austria, China, Germany, Netherlands, Sweden, Switzerland, United Kingdom (7)	70 %
Railways	China, Finland, Netherlands, Sweden (4)	40%
Harbours	China, Netherlands, Sweden (3)	30 %
Bridges	China, Netherlands, Sweden (3)	30 %
Large dams	China, Netherlands, Sweden (3)	30 %
Dikes	Netherlands (1)	10 %

Notes:

- Austria, Czech Republic, Germany, and Switzerland: No standardized systematic ProjectRM is applied in the construction projects. Public clients tend to transfer all the risks to their designers and contractors and do not implicitly require any systematic ProjectRM.
- Sweden: ProjectRM is applied in most projects, but not always exactly following e.g. ISO 31000 or other standards or guidelines. ProjectRM following standards is applied mainly in large projects.
- UK: Evidence in the UK indicates that the application of ProjectRM is only inconsistently applied to selected projects.

Main conclusions on the types of projects in which ProjectRM is applied

As presented in the notes above, five out of ten countries (50 %) report explicitly that standardized ProjectRM is not applied in *all* construction projects. Therefore, the table presents only in which types of projects the application of ProjectRM is common, even if sometimes just in a limited extent. The application of ProjectRM seems to be most common in underground constructions (e.g. tunnels, subway stations), major highways, and generally in large infrastructure projects. In the remaining types of projects ProjectRM seems to be applied in a minority of the participating countries.

1.4 In which project phases is ProjectRM applied?

Project phases	Countries	Percentage
Feasibility (mainly executed by clients)	China, Sweden, United Kingdom (3)	30 %
Pre- and Final Design (mainly executed by engineers)	Austria, China, Finland, Germany, Japan, Netherlands, Switzerland, Sweden, United Kingdom (9)	90 %
Tendering / Contracting	Austria, China, Finland, Germany, Netherlands, Switzerland, Sweden, United Kingdom (8)	80 %
Construction (mainly executed by contractors)	Austria, China, Czech Republic, Finland, Germany, Japan, Netherlands, Switzerland, Sweden, United Kingdom (10)	100 %
Maintenance	Japan, Netherlands, United Kingdom (Highways Agency) (3)	30 %
Decommissioning	United Kingdom (Highways Agency) (1)	10 %

Notes

- Netherlands: ProjectRM is applied in all phases of Design and Construct contracts and Design, Build, Finance and Maintenance contracts.
- UK: Evidence indicates that ProjectRM is applied inconsistently across project phases.

Main conclusions on the project phases in which ProjectRM is applied

As presented in the previous Section 1.3, five out of ten countries (50 %) report explicitly that standardized ProjectRM is not applied in *all* project phases. Furthermore, as presented in the notes above, the United Kingdom indicates that ProjectRM is applied inconsistently across the project phases. Therefore, the table above presents only in which project phases ProjectRM is common, even if sometimes just in a limited extent. The conventional order of subsequent project phases is presented, from feasibility to and including decommissioning.

From the table it can be concluded that ProjectRM application seems to be most common in the design phases, during tendering / contracting, and in the construction phase. Only the United Kingdom reports that ProjectRM is executed during decommissioning. China is now considering life-cycle ProjectRM that means ProjectRM executed from the feasibility phase to decommissioning.

Finally, it seems that ProjectRM is currently not always applied in all project phases, as ProjectRM theories do recommend.

1.5 What are the results of applying ProjectRM?

No.	Results of applying ProjectRM	Countries	Percentage
1	Reduction of probability of failure and minimizing *failure costs* against an acceptable risk profile	Austria, China, Czech Republic, Germany, Japan, Netherlands, United Kingdom (7)	70 %
2	Communication improves amongst participants during the construction and prevents potential *conflicts*.	Austria, Czech Republic, Germany, Switzerland, United Kingdom (5)	50 %
3	Increasing the *acceptability* of the project amongst the public.	Austria, Germany, Japan, Switzerland (4)	40 %
4	Structure and transparency results in *timely risk awareness* and management in the *entire organization*, instead of only amongst the specialists.	Finland, Netherlands, United Kingdom (3)	30 %
5	Better understanding of project value and *opportunities* for meeting strategic (client) goals	United Kingdom, Sweden (2)	20 %
6	Clients have *accountability* to politicians and other stakeholders, in order to minimize additional and unforeseen project costs	China, Netherlands (2)	20 %
7	The project and the parties get a better *image*	Finland (1)	10 %
8	Better *in control* in managing Design, Build, Finance and Maintenance type of projects.	Netherlands (1)	10 %
9	Brings *focus* on critical activities to *all parties* to towards a good project	Sweden (1)	10 %
10	Clarification of *risk ownership* in contract negotiations and claims, including *mitigation action owners* responsible for mitigating risks.	United Kingdom (1)	10 %
11	*Better understanding* of project, responsibilities, likely outturn costs, decisions on Go/No Go	United Kingdom (1)	10 %
12	Realizing successful projects with *sustainable and safe designs*, no surprises, on time and on budget	United Kingdom (1)	10 %

Main results of applying ProjectRM

From the ten country reports in total 12 different results of applying ProjectRM have been derived, by using data triangulation. This involved comparing and clustering largely similar ProjectRM results, as reported in the ten country reports. The numbering of the ProjectRM results is according to the highest number (also expressed in percentages) of countries that reported the results, and on alphabetical order of the country names.

The table shows that *reducing failure costs* (in 70% of the countries) and *avoiding potential conflicts* (in 50 % of the countries) are ProjectRM results that are most widely acknowledged. Increasing *project acceptability* amongst the public and *timely risk awareness and management* in the *entire* organization are reported by respectively 40 % and 30 % of the countries. Better understanding of *project value and opportunities* as well as *project accountability* to politicians is reported by 20 % of the participating countries. The remaining ProjectRM results of *image*, *focus* with all parties involved, *project control*, *risk ownership*, better *project understanding, and* project *sustainability and safety* are reported by one country each (10 % of the participating countries).

These results present a rather *wide scatter* of ProjectRM benefits. Moreover, from the country reports it was not always clear whether the reported ProjectRM results were *real* results derived from practice, or merely *anticipated or wishful* results. For this reason, ProjectRM success examples were also asked. These are presented in the table below by country in alphabetical order.

Country	**ProjectRM success examples**
Austria	PPP Ostregion – Build Operate Transfer (BOT) project for 51 km of motorways/expressways: sensible *allocation of risks* depending on the spheres of influence; different types of risk considered, e.g. geological risk, construction volume exceeding risk, traffic volume risk, licensing requirements risk, risk of changes in operation requirements, construction costs risk, availability risk, tender planning risk.
China	Shanghai Yangtze River Tunnel: ProjectRM was used in feasibility, design, and construction phases in 2005-2009, which helped the clients and builders to control the risks. *No serious risks or losses* happened during the project construction.
Finland	By systematic mapping and managing of the safety risks, Lemminkäinen has succeeded to *improve the safety* at work level remarkably. Due to ProjectRM, the reaction time is shorter for the realization of the risks, like in Ring Rail project where glycol was found as a possible contamination. Ring Rail has got three successive times the 'Safety at work' prize.
Sweden	Examples of ProjectRM success are quite difficult to find and *not readily available*. Exceptions are Citytunnel Malmoe, Citybanan Stockholm, Hvalfjördur Tunnel (Iceland).
Switzerland	Gotthard Basis Tunnel in Switzerland (Ehrbar, 2013): systematic RM in this megaproject helped to *prevent conflicts*, find *innovative solutions* for unexpected situations and *preserve the public acceptance* in spite of cost and time overruns and nine fatal accidents. A similar risk RM system was also used in the Lötschberg basis tunnel and Brenner tunnel.
United Kingdom	Application of ProjectRM *eased* the construction of a new viaduct on A82 in Scotland, A3 Hindhead tunnel of Highways Agency, ProjectRM on a dock wall stabilisation project in London *facilitated* the design process and the construction progress.

Main conclusions on the ProjectRM success examples

ProjectRM success examples were provided by 60 % of the participating countries. As Japan and Sweden notice, ProjectRM success are quite difficult to find and not readily available. Moreover, the ProjectRM benefits as presented in the examples are qualitatively, rather than quantitatively. The ProjectRM successes are not expressed in figures of the usual performance indicators for project success, such as cost, time, safety, and quality.

The reported benefits in the examples are *sensible risk allocation*, *no serious risks and losses* happening, *improved safety*, *prevention of conflicts*, finding *innovative solutions* in unexpected conditions, perseverance of *public project acceptance*, and *ease and facilitation* of design and construction. These benefits from practice align more or less with the ProjectRM results in the first part of this section.

1.6 What are hurdles for applying ProjectRM?

No.	Type	Hurdles for applying ProjectRM	Countries	In %
1	Os	It takes time, costs, additional paperwork, creates bureaucracy and apathy, while the benefits (RoI) is not always easy to proof.	China, Czech Republic, Finland, Netherlands, Sweden, UK, (6)	60 %
2	Oc	A tendency to hide risks and problems, instead of communicating them with other parties. Risks are not admitted, accepted, and communicated by (public) clients.	Austria, China, Czech Republic Germany, Switzerland, UK (6)	60 %
3	Oc	Risk-averse culture, which puts high value on safety and certainty; does not allow admitting potential risks.	Austria, Germany, Japan, Switzerland, United Kingdom (5)	50 %
4	Oc	Overconfidence in normalization and standardization and resulting belief that then nothing can go wrong.	Austria, Germany, Japan, Switzerland (4)	40 %
5	Oc	ProjectRM is perceived as risk distribution only, excluding communication and control of risks.	Austria, Germany, Switzerland (3)	30 %
6	Os	Feedback is generally non-existent, leading to no lessons learnt and underestimation of RM need.	Netherlands, United Kingdom, Sweden (3)	30 %
7	Os	Lack of knowledge and / or tools how to properly apply ProjectRM.	Netherlands, Japan, United Kingdom (3)	30 %
8	Os	Missing risk-based and long-term planning, prioritization, and insufficient preparation of projects. Focus on ad hoc problem solving instead of thinking ahead.	Czech Republic, United Kingdom (2)	20 %
9	Oc	Differences in risk culture between different project entities: management, engineers, design, execution.	Netherlands, United Kingdom (2)	20 %
10	Os	Lack of knowledgeable competent staff and trained risk managers, e.g. within engineering teams.	United Kingdom, Sweden (2)	20 %
11	Os	Due to separation of design and construction limited cooperation, as there is no clear leader / coordinator.	Germany, Japan (2)	20 %
12	Oc	Openness about risks can be considered a weakness (or not be valued to its value).	Netherlands (1)	10 %
13	Os	The position of the public client in management of the construction projects is generally weak.	Czech Republic (1)	10 %
14	Oc	High level of political influence on decisions in major project's planning obstructs objective ProjectRM.	Czech Republic (1)	10 %
15	Os	Project RM is new field/activity, it needs competent & qualified decision makers in relevant positions.	Czech Republic (1)	10 %
16	Oc	Unwillingness to dedicate resources to mitigation of risks especially of high impact, low probability.	United Kingdom (1)	10 %
17	Os	Lack of good lines of effective communication about several risks types with the team.	United Kingdom (1)	10 %
18	T	Problems with quantification of risks.	United Kingdom (1)	10 %
Type of ProjectRM hurdles: Os = Organization structure; Oc = Organization culture; T = Technical				

Main hurdles for applying ProjectRM

From the ten country reports in total 18 different hurdles for applying ProjectRM have been derived, by using data triangulation. This involved comparing and clustering largely similar ProjectRM hurdles, as reported in the ten country reports. The numbering of the ProjectRM hurdles is according to the highest number (also expressed in percentages) of countries that reported the results, and on alphabetical order of the country names.

All ProjectRM hurdles have been classified in three types: (1) hurdles primarily caused by the structure of (project) organizations (Os) involved in construction projects, (2) those primarily caused by the culture of these organizations (Oc), and (3) hurdles primarily caused by technical causes (T). Causes of organizational structure and culture seem often closely coupled. The tables shows that 17 out of the 18 hurdles (94 %) have an organizational cause, either structural (50 %) or cultural (44 %). Just one technical cause has been identified (6 %).

The table shows also that *additional efforts without explicit returns* and the *tendency to hide risks* (both in 60% of the countries) are the main ProjectRM hurdles. Other relevant obstructions are a *risk-averse culture* and *overconfidence* in *normalization and standardization* (reported by respectively 50 % and 40 % of the countries) and focusing on *risk distribution only*, lack of *feedback and learning* and *lack* of *knowledge* and / or *tools* how to properly apply ProjectRM (all three in 30 % of the countries). For the remaining ProjectRM hurdles that are reported by 20 % and 10 % of the countries reference is made to the table.

1.7 What are solutions for overcoming ProjectRM hurdles?

No.	Type	Solutions for overcoming ProjectRM hurdles	Countries	In %
1	Os	Parties participating in the construction projects should become educated in ProjectRM and its benefits.	Austria, Czech Republic, Germany, Japan, Switzer-land, United Kingdom, Sweden (7)	70 %
2	Oc	Public clients should accept and require ProjectRM explicitly, for instance as part of the Best Value Procurement.	Austria, Czech Republic, Netherlands, Germany, Japan, Switzerland (6)	60 %
3	Oc	Improvement of open risk communication, based on trust amongst the participants.	Austria, Czech Republic, Germany, Japan, Switzer-land, United Kingdom (6)	60 %
4	Os	Demonstrate that time and costs invested in ProjectRM pays off: identify & communicate success.	China, Netherlands, United Kingdom, Sweden (4)	40 %
5	Os	Apply ProjectRM as lean and simple as allowable, i.e. by linking project risks to project objectives (ISO31000).	China, Netherlands, United Kingdom, Sweden (4)	40 %
6	Oc	Participants should accept that risks exist and that risk identification & communication is needed for control.	Austria, Germany, Switzerland, Sweden (4)	40 %
7	Oc	In case of failure, identify system mistakes in instead of blaming individual participants.	Austria, Czech Republic, Germany, Switzerland (4)	40 %
8	Os	One should systematically analyse the finished projects in order to learn lessons from them.	Austria, Czech Republic, Germany, Switzerland (4)	40 %
9	Os	RM in general should be taught at universities for getting it standard in project planning & construction.	Czech Republic, Japan, Sweden, United Kingdom (4)	40 %
10	Oc	The perception of RM should be changed from a mere contractual allocation of risk to active ProjectRM	Austria, Germany, Switzerland (3)	30 %
11	Oc	Work on the 'mind-setting' of all the people involved and put attention to the relevant risks in meetings.	Netherlands, Sweden, Finland (3)	30 %
12	Os	More emphasis on good project planning and preparation, with willingness to invest into this phase.	Czech Republic, Japan, United Kingdom (3)	30 %
13	Os	Anchor and embed ProjectRM in the company's QHSE systems.	Netherlands, United Kingdom (2)	20 %
14	Os	Development and training of interdisciplinary risk management in technical professions	United Kingdom, Sweden (2)	20 %
15	Oc	Risks should be recognized, identified, described, allocated, discussed and managed, not ignored	Czech Republic, United Kingdom (2)	20 %
16	T	Use of standardized systems, generic pro-forma sheets, covering usual risk items and project specific risk register.	United Kingdom, Finland (2)	20 %
17	Os	Enforcement of legislation that requires a phased approach to ProjectRM throughout the entire project.	Japan, United Kingdom (2)	20 %

No.	Type	Solutions for overcoming ProjectRM hurdles (continued)	Countries	In %
18	Os	Arrange teams to help clients and builders to understand ProjectRM conclusions and methods for risk control.	China (1)	10 %
19	T	Use of Category I, II or III levels of review, dependent on the risk level of risk to project & society.	United Kingdom (1)	10%
20	Os	Presence of a full time resident engineer on identified medium and high risk elements of work	United Kingdom (1)	10 %
Type of ProjectRM hurdles: Os = Organization structure; Oc = Organization culture; T = Technical				

Main solutions for applying ProjectRM

From the ten country reports in total 20 different solutions for applying ProjectRM have been derived, again by using data triangulation. The numbering of the ProjectRM solutions is according to the highest number of countries that reported similar solutions, and on alphabetical order of country names.

The table shows that 18 out of the 20 solutions (90 %) have merely an organizational cause, either mainly structural (55 %) or rather more cultural (35 %). In total two mainly technical solutions have been identified (10 %).

The table shows also that ProjectRM *education*, including demonstration of its benefits, ProjectRM *acceptance and requirements* by clients, and *open risk communication* are the main ProjectRM solutions. These are raised by 70 % and 60 % of the ten participating countries.

Other relevant solutions, each identified by 40 % of the countries, are *demonstrating that time and costs invested in ProjectRM pays off*, applying ProjectRM as *lean and simple* as allowable, *acceptance* that risk exists, identifying mistakes in the system *without blaming* individual participants in case of risk occurrence, systematically analysing finished projects in order to *learn lessons* from them, and *risk management teaching* at universities for getting it standard in project planning and construction. For the remaining ProjectRM hurdles that are reported by 30 % to 10 % of the countries reference is made to the table.

The number one ProjectRM hurdle, lack of proves of ProjectRM benefits, did not emerge explicitly as the number one equivalent solution for providing proven ProjectRM benefits. According to the data retrieved, the solutions of GeoRM *education*, while including its benefits, *acceptance* with *requirements*, and *open risk communication* (solutions no. 1, 2, and 3) were raised by more countries than the solutions on providing Project RM benefits (solutions no. 4 and 8). However, providing benefits was raised in the education solution. Furthermore, effective education should be strongly connected to demonstrating the benefits of the ProjectRM, because education typically includes examples of successful applications. Nevertheless, while closely connected, providing ProjectRM benefits and providing ProjectRM education is not the exactly same and is likely to require different actions.

2 STATE OF THE ART OF GEOTECHNICAL RISK MANAGEMENT (GeoRM)

2.1 How is GeoRM defined?

Country	Summary GeoRM definitions
Austria	There is no unified definition of GeoRM.
China	GeoRM is defined as risk management of geotechnical engineering, which is identifying the main risks in projects' geology.
Czech Republic	There is no definition of GeoRM that would be broadly used in the Czech construction industry.
Finland	No specific GeoRM definition reported.
Germany	There is no unified definition of GeoRM. The term of "subsoil or foundation soil risk" (Baugrundrisiko) is defined in the norm DIN 4020 (DIN, 2010).
Japan	There is no official definition of GeoRM. However, several georisk definitions are used by different institutes. Public Works Research Institute (PWRI) defines geo risk as a combination of undesired geological phenomenon with a probability of occurrence. The Geological Risk Management Society / The Japan Geotechnical Consultants Association define georisk as a business risk concerning geology and including uncertainty and loss of a business cost.
Netherlands	GeoRM is considered that part of the RISMAN project risk management approach that specifically and explicitly considers the ground-bounded risks.
Sweden	In Sweden GeoRM is not defined as a separate Risk Management, it is part of the overall ProjectRM. It can be a main part and should include natural hazards.
Switzerland	There is no unified definition of GeoRM.
United Kingdom	There is no universal definition of GeoRM in the UK. Various GeoRM definitions have been identified, related to site conditions and engineering hazards .

Main conclusions on GeoRM definitions

From the table it can be concluded that in the majority of eight out of the ten countries (80 %) no specific and unified GeoRM definitions are in use. In Sweden GeoRM is not specifically defined, because it is considered an overall part of risk management.

The remaining two countries, China and Netherlands, do have their slightly different GeoRM definitions. China reports an own GeoRM definition, while in the Netherlands GeoRM is considered as a specific and explicit part of ProjectRM.

2.2 Which GeoRM standards, guidelines, and processes are used?

Country	Summaries of used GeoRM standards, guidelines, and processes
Austria	There are no guidelines on GeoRM that would be broadly used. Several standards on applying geotechnical design and investigations and Euro code.
China	A chapter is included in China standards for project risk management.
Czech Republic	There are no GeoRM guidelines/standards that would be generally accepted in the Czech construction industry. Recently, the Czech authorities have started to accept the GeoRM concept. Analysis of geotechnical risks is now required by several documents, e.g. Český Báňský Úřad (1996) after its amendment in 2012 or Rozsypal (2007). Publications that focus on the GeoRM are: Rozsypal (2001)
Finland	See ProjectRM guidelines, no specific GeoRM guidelines.
Germany	There are no guidelines on GeoRM that would be broadly used. Several standards on applying geotechnical design and investigations and Euro code.
Japan	There are no official standards/ guidelines for GeoRM.
Netherlands	The “Yellow guide”, a Dutch practice guide on GeoRM (Van Staveren, 2010) describes the geotechnical risk management steps in line with RISMAN (Van Well-Stam, 2004) and ISO/IEC 31000 (ISO, 2009). Several CUR guidelines, including risk-driven site investigations and risk-driven geotechnical monitoring.
Sweden	The Euro code EN1997 and the recommendations for ground investigation and controlling and review are followed. For the work environment the Work Environment Act applies, which can have a large influence on the execution of foundation works, as those are often considered as being connected with special risks.
Switzerland	There are no guidelines on GeoRM that would be broadly used. Several standards on applying geotechnical design and investigations, such as General conditions on underground constructions (SIA 2007).
United Kingdom	Several UK Highways Agency guidelines. Furthermore Clayton (2001) on managing geotechnical risk, Site Investigation Steering Group (1993) on site investigations, Natural Scotland (2006) on peat landslide hazard and risk assessment and Baseline Geotechnical Reports for contractual risk allocation.

Main conclusions on used GeoRM standards, guidelines, and processes

From the table it can be concluded that in seven out of the ten countries (70%) there are no GeoRM standards, guidelines, and processes that would be broadly used. Austria and Sweden refer to Euro code EN1997, which does however not specifically addresses GeoRM up to now. In the Czech Republic the authorities have started to accept the GeoRM concept and analysis of geotechnical risks is now required by several documents.

In the remaining three countries, China, Netherlands and United Kingdom, at least some specific GeoRM guidelines and processes are available and in use. In China, a GeoRM chapter is included in China’s standards for project risk management. In the Netherlands and in the United Kingdom, GeoRM practice guides are use, as are some risk-based geotechnical guidelines, for example for site-investigations, geotechnical monitoring, and landslide hazard assessments.

2.3 In which kind of projects is GeoRM applied?

Types of projects	Countries	Percentage
Underground construction: tunnels, subway (metro) stations, parking facilities.	China, Czech Republic, Finland, Germany, Japan, Netherlands, Switzerland, United Kingdom (8)	80 %
Major Highways	China, Finland, Netherlands, United Kingdom (4)	40 %
Large infrastructure projects: multidisciplinary projects characterized by complex interactions between different actors and stakeholders, with different requirements/interests.	China, Netherlands, United Kingdom (3)	30 %
Railways	China, Finland, Netherlands (3)	30 %
Harbours	China, Netherlands (2)	20 %
Bridges	China, Netherlands (2)	20 %
Dikes & Slopes	United Kingdom (1)	10 %
Large dams	China (1)	10 %
Wind farms	United Kingdom (1)	10 %
Building foundations	United Kingdom (1)	10 %

Notes:

- Germany: Theoretically, GeoRM should be applied in every construction project. Norm DIN 4020 (DIN, 2010) describes the requirements on sharing the geotechnical risk in construction projects. The risk of unexpected geotechnical aspects is born by the owner (Sondermann and Trunk, 2008). In practice, the GeoRM has not been applied to all projects but the share of projects where it is used is increasing. The application of GeoRM is mostly promoted by the construction companies.
- Czech Republic: GeoRM is in general a new thing. For example, the Czech State Mining Authority, has accepted the concept of risk just recently. Before that, admitting any risk/hazard would mean stopping of the works (which motivated all involved parties including construction companies to hiding potential problems).
- Japan: It becomes a common view that it is important to study geotechnical risk during the construction stage of projects in Japan, especially those risks that could lead to some serious troubles or accidents. Geo Risk has been treated as an "unforeseeable or unpredictable" geological condition, which results in actions for countermeasures after the risk is revealed.
- Netherlands: Applying specifically GeoRM in projects is relatively new.
- Sweden: Risk management is applied in most projects, but not always exactly following e.g. ISO 31000, or other standards. The Work Environment Act applies to all projects.
- United Kingdom: GeoRM is not applied to all projects. It is a generalization but the evidence suggests that the smaller the financial value of a project the less likely that GeoRM will be applied.

Main conclusions on the types of projects in which GeoRM is applied

As presented in the notes above, three countries report that GeoRM is applied in all projects, yet not always exactly following the standards (Sweden), or should be applied in all projects, which is in practice not the case (Germany), or is not applied in all projects (United Kingdom). Apparently, in these countries there is already a reasonable common GeoRM awareness, while not always put in practice. The Czech Republic, Japan, and the Netherlands report explicitly that GeoRM is relatively new, and becoming more important. The remaining countries, Austria, China, Finland, and Switzerland did not provide specific remarks.

In conclusion, it seems that GeoRM is not applied yet in all types of projects in the ten participating countries. Therefore, the table presents only in which types of projects the application of GeoRM is common, even if sometimes just in a limited extent. The application of GeoRM seems to be most common in underground constructions (e.g. tunnels, subway stations) and to a lesser extend in major highways, in large infrastructure projects, and in railway projects. In the remaining types of projects GeoRM seems to be applied in a minority of the participating countries.

As shown in the table below, if compared then GeoRM seems to be applied to a lesser extent than ProjectRM. The table below presents these figures for the distinguished project types. For example, application of ProjectRM in large infrastructure projects has been reported by 70 % of the countries. GeoRM application of in the same type of projects has been reported by 30 % of the countries.

Types of projects	**ProjectRM applied in percentage of countries**	**GeoRM applied in percentage of countries**
Underground construction: tunnels, subway (metro) stations, parking facilities.	90 %	80 %
Major Highways	90 %	40 %
Large infrastructure projects: multidisciplinary projects characterized by complex interactions between different actors and stakeholders, with different requirements/interests.	70 %	30 %
Railways	40 %	30 %
Harbours	30 %	20 %
Bridges	30 %	20 %
Large dams	30 %	10 %
Dikes & Slopes	10 %	10 %
Wind farms	00 %	10 %
Building foundations	00 %	10 %

2.4 In which project phases is GeoRM applied?

Project phases	Countries	Percentage
Feasibility (mainly executed by clients)	China, Finland, Netherlands, United Kingdom, Sweden (5)	50 %
Pre- and Final Design (mainly executed by engineers)	China, Finland, Japan, Netherlands, United Kingdom, Sweden (6)	60 %
Tendering / Contracting (mainly executed by clients)	China, Finland, Germany, Netherlands, United Kingdom, Sweden (6)	60 %
Construction (mainly executed by contractors)	Austria, China, Czech Republic, Finland, Germany, Japan, Netherlands, Switzerland, United Kingdom, Sweden (10)	100 %
Maintenance / Post-construction (after damage)	United Kingdom (1)	10 %
Decommissioning	-	0 %

Notes:

- Austria, Czech Republic, Germany, and Switzerland: In the planning phase, geotechnical risks are typically not well analysed, communicated, and managed.
- Germany: it is a given by law that the geotechnical risk must be treated in the contract.
- United Kingdom: GeoRM is incompletely applied across all project phases.

Main conclusions on the project phases in which GeoRM is applied

In the previous section it has been reported that standardized GeoRM is not yet applied in all types of construction projects. Furthermore, as presented in the notes above, in Austria, the Czech Republic, Germany, and Switzerland geotechnical risks are typically not well analysed, communicated, and managed during the project planning phase. The United Kingdom indicates that GeoRM is applied inconsistently across project phases.

Therefore, the table above presents only in which project phases the application of GeoRM is common, even if sometimes just in a limited extent. The conventional order of subsequent project phases is presented, from feasibility to and including decommissioning.

The application of GeoRM seems to be most common in the construction phase and to a lesser extend during the feasibility, design and tendering / contracting phases. Nevertheless, as indicated by the United Kingdom, it is likely that GeoRM is mainly applied in only one or two phases, rather than in all phases as all ProjectRM theories do recommend.

In comparison, GeoRM seems to be applied to a lesser extent during the design and tendering / contracting phases than ProjectRM. However, in the feasibility phase a few more countries reported GeoRM application than ProjectRM application. Execution of ProjectRM and GeoRM in projects during the construction phase has been reported by all ten countries. However, the presented data does not reveal whether ProjectRM and GeoRM are both performed in the same projects, or not. In other words, it is possible that in some projects only ProjectRM is executed, and in other projects only GeoRM. The table on the next page presents the comparison of the application of ProjectRM and GeoRM in the distinguished project phases.

Project phases	**ProjectRM applied in percentage of countries**	**GeoRM applied in percentage of countries**
Feasibility (mainly executed by clients)	30 %	50 %
Pre- and Final Design (mainly executed by engineers)	90 %	60 %
Tendering / Contracting (mainly executed by clients)	80 %	60 %
Construction (mainly executed by contractors)	100 %	100 %
Maintenance / Post-construction (after damage)	30 %	10 %
Decommissioning	10 %	0 %

2.5 What are the results of applying GeoRM?

No.	Results of applying GeoRM	Countries	Percentage
1	Avoiding *cost and time overrun* for clients and contractors, minimizing geotechnical risk to construction staff, maintenance staff and the public	Austria, China, Germany, Japan, Netherlands, United Kingdom, Switzerland (7)	70 %
2	Management of identified risks to ensure *sustainable and safe* design and construction.	Austria, Germany, Switzerland, United Kingdom (4)	40 %
3	Reduction of *conflicts*, contractual issues and claims	Austria, Germany, Switzer-land, United Kingdom (4)	40 %
4	Structure and transparency resulting in a *timely awareness and management* of the project risks.	Czech Republic, Japan, Netherlands, Finland (4)	40 %
5	Better *risk communication and risk ownership*, also to non-geotechnical experts	Czech Republic, Netherlands, United Kingdom (3)	30 %
6	Avoidance of *geo-hazards and unforeseen ground conditions*.	China, United Kingdom (2)	20 %
7	GeoRM will lead to *adequate supervision* in the construction phase (mitigation, alternative design).	Japan, Sweden (2)	20 %
8	Clients are *better* in *managing their Design, Build, Finance and Maintenance* (DBFM) type of projects.	China (1)	10 %
9	The project and the parties get a *better image*	Finland (1)	10 %
10	*Optimization* of construction by evolving the design to lower risk and lower costs of mitigation (i.e. by further site investigation).	United Kingdom (1)	10 %

Notes:

- Netherlands: Explicit results are yet scarce, as GeoRM has not been applied in many projects.
- Sweden: Explicit results are yet scarce, as GeoRM has not been evaluated separately in many projects. Moreover, while risks will be dealt with, it is seldom clear that it was successful GeoRM that eliminated project risks.
- United Kingdom: There appears to be a relative paucity of technical literature focusing on the value of GeoRM, as compared to focusing on geotechnical design approach and solutions. Whilst this may be a reflection of writing style, rather than a lack of evidence, it creates a difficulty in articulating fully what the results are of applying GeoRM.

Main conclusions on the results of applying GeoRM

The Netherlands, Sweden and the United Kingdom made explicit statements about the scarcity of GeoRM results. In addition, Sweden reports that project success is seldom attributed to successful GeoRM.

From the ten country reports in total 10 different results of applying GeoRM have been derived, by using data triangulation. This involved comparing and clustering largely similar GeoRM results, as reported in the ten country reports. The numbering of the GeoRM results is according to the highest number (also expressed in percentages) of countries that reported the results, and on alphabetical order of the country names.

The table with the results of GeoRM shows that *avoiding cost and time overruns* (in 70% of the countries), providing a *sustainable and safe design*, *reduction of conflicts*, and *timely awareness and management* of the project risks (all in 40 % of the countries) are GeoRM results that are most widely acknowledged. This is similar to the ProjectRM results in the previous chapter, except for sustainable and safe design, which was raised by only one country (10 %). Remarkably, sustainability and safety seems more a matter of GeoRM, than of ProjectRM.

Better *risk communication and risk ownership* is reported by 30 % of the countries. Two of the countries (20 %) reported the avoidance *of geo-hazards and unforeseen ground conditions* and adequate *site supervision*. The remaining GeoRM results of better *managing Design, Build, Finance and Maintenance (DBFM)* projects, better *image*, and *optimization of construction* are reported by one country each (10 % of the participating countries). Partly, these GeoRM benefits are similar to the reported ProjectRM benefits, partly these are more specific, because of the geotechnical character of GeoRM.

Nevertheless, the analysis of the ten country reports presents a rather wide scatter of GeoRM benefits. Moreover, from the country reports it was not always clear whether the reported GeoRM results were *real* results, derived from practice, or merely *anticipated* or *wishful thinking* results. For this reason, GeoRM success examples were also asked. These are presented in the table on the next page, by country in alphabetical order.

GeoRM success examples by country

Country	GeoRM success examples
China	Large tunnel projects: in Shanghai Yangtze River tunnel, Tsingtao undersea tunnel, Qianjiang tunnel. These have complicated and poor hydrology and geological conditions. GeoRM is used in all phases of Shanghai subway tunnels, which are buried in the city *populated* area.
Czech Republic	Dobrovsky (Kralovopolsky) tunnel in Brno: build in very difficult geotechnical conditions under built-up area. To *avoid damage* on the buildings above the tunnel, extensive compensation grouting was applied. Extension of Metro lane A in Prague Dejvicka-Motol: utilization of the TBM technology for the first time in the Czech Republic has been so far successful.
Finland	Ring Rail project: glycol was found as a possible *contamination* as a result of risk evaluation.
Germany	Offenbau tunnel (Linnemann and Jörger, 2008): GeoRM carried out cooperatively by all participants, which allowed to *efficiently reacting on unexpected geotechnical conditions*.
Netherlands	Tunnel project in Delft: *Preventing leakage and deformation* problems in a diaphragm wall close to a main station in a city, by applying an innovative way of risk-driven control of concrete quality in diaphragm walls Tunnel project in Maastricht: implementation of better communication protocols and tools in order to *communicate about risks in a transparent and open dialogue* with the public.
United Kingdom	The "D" shaped pile project at Tottenham Court Road station (part of Crossrail): constructing piles within the *sterilized zone of a live tube line* running tunnel.

Note:

- Czech Republic: The interest in GeoRM increased after severe problems in Blanka tunnel in Prague (three cave-in collapses during construction) and on the D47 highway (problems with subsoil during operation and differential settlement).

Main conclusions on the GeoRM success examples

GeoRM success examples were provided by 60 % of the participating countries. As the Czech Republic noticed, severe problems may be a trigger to start with GeoRM. Moreover, the GeoRM benefits, as presented in the examples, are evaluated qualitatively, rather than quantitatively. GeoRM successes are not expressed in figures of the usual performance indicators for project management, such as cost, time, safety, and quality.

The reported benefits in the examples are successful operation in city areas close to tunnels in use with avoidance of leakage and deformations resulting in damage, finding site contaminations, efficiently reacting on unexpected geotechnical conditions and transparent dialogues about geotechnical risk with the public. These benefits from practice correspond with many of the GeoRM results reported at the start of this section.

2.6 What are hurdles for applying GeoRM?

No.	Type	Hurdles for applying GeoRM	Countries	In %
1	Os	The probable additional time & cost to clients, contractors, and geotechnical specialists, without having a clear return on investment (RoI).	Austria, China, Czech Republic, Finland, Germany, Netherlands, United Kingdom, Switzerland (8)	80 %
2	Oc	Lack of recognition of georisks by clients, structural engineers, project managers, and architects. Not all parties are willing to talk and understand each other's points of view on risk and cost.	Austria, Czech Republic, Germany, Japan, Nether-lands, Switzerland, United Kingdom, Sweden (8)	80 %
3	Oc	The importance of planning and design works is often underestimated, resulting in underfinancing of preparation, planning and design works, incl. number and quality of site investigation.	Austria, China, Czech Republic, Germany, Japan, Switzerland, United Kingdom (7)	70 %
4	Os	Lack of geotechnical specialists with GeoRM competences, because GeoRM is not part of geotechnical and civil engineering courses.	China, Czech Republic, Netherlands, United Kingdom, Sweden (5)	50 %
5	Os	GeoRM focuses primarily on the contractual allocation of risks.	Austria, Germany, Switzerland (3)	30 %
6	Oc	Participants are used to apply standards and norms, rather than searching for project specific solutions	Austria, Germany, Switzerland (3)	30 %
7	T	Difficulties with reliability/probabilistic risk assessment due to limited data sets.	China, United Kingdom (2)	20 %
8	T	Lack of appropriate understanding / assessment of the ground conditions and material behaviour.	Netherlands, United Kingdom (2)	20 %
9	Os	Projects are influenced by different and contradicting requirements of different controlling authorities.	Czech Republic (1)	10 %
10	Os	Project structure, hierarchy, and communication protocols obstruct GeoRM application.	Netherlands (1)	10 %
11	Oc	Lack of geotechnical professionals able to communicate / operate in a project risk management setting.	Netherlands (1	10 %
12	Oc	GeoRM is seen as a slavish following of standards with a lot of paperwork and not tailored to the project.	Sweden (1)	10 %
13	Os	GeoRM successes are difficult to find.	Sweden (1)	10 %
14	Oc	GeoRM is often too detailed at first sight, often not used properly, creates bad feelings among parties.	Sweden (1)	10 %
15	T	Lack of access to relevant historic data and records and in a form which can be readily assimilated.	United Kingdom (1)	10 %
16	Oc	Limited focus on opportunities with savings, opposed to risk management. This is in part a mind-set issue.	United Kingdom (1)	10 %
17	Os	Lack of construction control on site and therefore not spotting deviations from design expectations.	United Kingdom (1)	10 %
Type of GeoRM hurdles: Os = Organization structure; Oc = Organization culture; T = Technical				

Main hurdles for applying GeoRM

From the ten country reports in total 17 different hurdles for of applying GeoRM have been derived, by using data triangulation. This involved comparing and clustering largely similar GeoRM hurdles, as reported in the ten country reports. The numbering of the GeoRM hurdles is according to the highest number (also expressed in percentages) of countries that reported the results, and on alphabetical order of the country names.

The table with hurdles for applying GeoRM on the previous page shows that the probable *additional efforts without explicit returns*, a *lack of geo-risk recognition*, *underestimation of project preparation*, and *lack of geotechnical specialists* with GeoRM competences are the four main hurdles (respectively reported in 80 %, 80 %, 70 %, and 50 % of the countries). The first GeoRM hurdle of *additional efforts without explicit returns* is also the main ProjectRM hurdle. The other main GeoRM hurdles were not recognized as main ProjectRM hurdles and are apparently specific for the geotechnical character of GeoRM.

Other relevant GeoRM hurdles are focusing on only *contractual risk allocation* and *overconfidence in normalization and standardization* (both reported in 30 % of the countries). These GeoRM hurdles were also noticed as ProjectRM hurdles, too a similar degree.

For the remaining GeoRM hurdles, which are reported by 20 % and 10 % of the ten countries, reference is made to the table.

Similar to the ProjectRM hurdles, all GeoRM hurdles have been classified in three types: (1) hurdles that are primarily caused by the structure of (project) organizations (Os) involved in construction projects, (2) those primarily caused by the culture of these organizations (Oc), and (3) hurdles primarily caused by technical causes (T). Causes of organizational structure and culture seem often closely coupled. The table indicates that 14 out of the 17 hurdles (82 %) have an organizational cause, either structural (41 %) or cultural (41 %). In total three technical causes have been identified (18 %). The table below presents the differences in the type of hurdles between ProjectRM and GeoRM.

Types of RM hurdles	Percentage of hurdles in ProjectRM	Percentage of hurdles in GeoRM
Os = Organizational structure	50 %	41 %
Oc = Organizational culture	44 %	41 %
T = Technical	6 %	18 %
Total	100 %	100 %

The table above demonstrates that the percentage of technical hurdles for GeoRM (18 %) is more than three times higher than those for ProjectRM (6 %). Nevertheless, the percentages of organizational hurdles for both ProjectRM and GeoRM, in total respectively 94 % and 82 %, are dominant. In other words, applying either ProjectRM or GeoRM is merely an *organizational* challenge than a *technical* one.

2.7 What are solutions for overcoming GeoRM hurdles?

No.	Type	Solutions for overcoming GeoRM hurdles	Countries	In %
1	Os	Education of clients in GeoRM benefits, non geoprofessionals, who have to manage geo components or schemes, and geoprofessionals.	Austria, China, Czech Republic, Germany, Japan, Switzerland, UK, Sweden (8)	80 %
2	Os	More emphasis on GeoRM in project planning & preparation, including alternatives & options, decision making by objective risk analysis.	Austria, Czech Republic, Germany, Japan, Switzer-land, United Kingdom (6)	60 %
3	Oc	Promotion of risk management supported by GeoRM cases, successes & lessons learned	China, Netherlands, United Kingdom, Sweden (5)	50 %
4	T	Developing GeoRM tools, e.g. checklists & breakdown structures, communication & allocation procedures.	China, Japan, Netherlands, Sweden (4)	40 %
5	Oc	Public clients should be willing to communicate geo-risk openly with the contractors.	Austria, Germany, Switzerland (3)	30 %
6	Oc	GeoRM perception should be changed / extended from merely contractual risk allocation to risk cooperation.	Austria, Germany, Switzerland (3)	30 %
7	T	Standardization of the procedures of GeoRM, with generic pro-forma risk sheets.	Czech Republic, Finland (2)	20 %
8	T	Applying new site investigating methods, such as GPS and GIS, for 3D spatial variability control.	China, Japan (2)	20 %
9	Oc Os T	Continuing with national joint industry development programs for minimizing geotechnical failures.	Japan, Netherlands (2)	20 %
10	T	Continuing with technical data analysis for minimizing geotechnical failures.	China (1)	10 %
11	T	Improving practices in geotechnical risk allocation, by developing both technical and legal competences.	Czech Republic (1)	10 %
12	Oc	Public clients should be willing to recognize and bear some of the risk.	Czech Republic (1)	10 %
13	Oc	Work on 'mind-setting' of everyone involved, attention to the relevant risks in meetings.	Finland (1)	10 %
14	Os	Anchoring GeoRM explicitly in the ProjectRM procedures and company's QHSE systems.	Netherlands (1)	10 %
15	T	Development of better techniques for risk quantification.	United Kingdom (1)	10 %
16	T	Clear scope definition for GeoRM.	United Kingdom (1)	10 %
17	Os	Registration of ground engineering professionals by using a peer review processes.	United Kingdom (1)	10 %
18	T	Provision of appropriate IT systems to support speedy data assimilation.	United Kingdom (1)	10 %
19	Oc, Os, T	Monitoring and site control by design team, for as built control and looking out for changes.	United Kingdom (1)	10 %
Type of GeoRM hurdles: Os = Organization structure; Oc = Organization culture; T = Technical				

Main solutions for overcoming GeoRM hurdles

From the ten country reports in total 19 different solutions for overcoming the GeoRM hurdles have been derived, by using data triangulation. This involved comparing and clustering largely similar GeoRM solutions, as reported in the ten country reports. The numbering of the GeoRM hurdles is according to the highest number (also expressed in percentages) of countries that reported similar solutions, and on alphabetical order of country names.

As done for the GeoRM hurdles, also the GeoRM solutions have been classified in three types: (1) solutions primarily caused by the *structure* of (project) organizations (Os) involved in construction projects, (2) those primarily caused by the *culture* of these organizations (Oc), and (3) solutions primarily caused by *technical* means (T).

Solution number 9 in the previous table, continuing with national joint industry development programs for minimizing geotechnical failures, has been classified as Os, Oc, and T as well, because these programs should include all three types of solution. Of the remaining 18 solutions, ten (56 %) have merely an organizational cause, of which five are mainly structural (28 %) and also five are more cultural (28 %). In total eight mainly technical solutions have been identified (44 %).

The table with solutions for overcoming GeoRM hurdles shows also that GeoRM *education*, including its benefits, more GeoRM application during *project planning and preparation*, and GeoRM promotion are the main GeoRM solutions. These are raised by respectively 80 %, 60 % and 50 % of the ten participating countries.

Other relevant solutions, identified by 40 % or 30 % of the countries, are *developing GeoRM tools*, (e.g. checklists & breakdown structures, communication & allocation procedures), public clients who should be willing to *communicate geotechnical risk openly* with the contractors, and a change of GeoRM perception from merely contractual risk allocation to *risk cooperation*.

For the remaining GeoRM hurdles that are reported by 20 % and 10 % of the countries reference is made to the table.

The table below presents the differences in the type of solutions between ProjectRM and GeoRM, as raised by the ten participating countries.

Types of RM solutions	Percentage of solutions in ProjectRM	Percentage of solutions in GeoRM
Os = Organizational structure	55 %	28 %
Oc = Organizational culture	35 %	28 %
T = Technical	10 %	44 %
Total	100 %	100 %

The table above demonstrates that the percentage of technical solutions for GeoRM (44 %) is more than four times higher than those for ProjectRM (10 %). Nevertheless, the percentage of organizational structure and culture hurdles for GeoRM, in total 56 % (28 % + 28 %), remains relevant. Nevertheless, based on only the derived solutions, overcoming GeoRM hurdles seems more a technical challenge than overcoming the ProjectRM hurdles.

In the table below, both the percentages of ProjectRM and GeoRM hurdles and solutions are presented, as raised by the ten participating countries. For instance, for ProjectRM the 50 % for organizational structure (Os) means that 50 % of the ProjectRM hurdles raised by the ten participating countries were classified as caused by the structure of (project) organizations (Os) involved in construction projects.

Types of RM hurdles and solutions	ProjectRM		GeoRM	
	Percentage of hurdles	Percentage of solutions	Percentage of hurdles	Percentage of solutions
Os = Organizational structure	50 %	55 %	41 %	28 %
Oc = Organizational culture	44 %	35 %	41 %	28 %
T = Technical	6 %	10 %	18 %	44 %
Total	100 %	100 %	100 %	100 %

The table above demonstrates that for ProjectRM, as well as for GeoRM, the percentages of technical solutions (10 % and 44 %) are at least twice as high as the percentage of technical hurdles (6 % and 18 %). In particular for GeoRM, 44 % of the solutions are technical, while only 18 % of the hurdles are classified as technical ones. This means that there is a risk that organizational hurdles are solved by technical means, which seems not the most optimum solution. In summary, merely *technical solutions* are raised for reducing merely *organizational causes*.

3 STATE OF THE ART OF INTEGRATION OF GEORM and PROJECTRM

3.1 What is the status of GeoRM - Project RM integration?

Country	Status of GeoRM – Project RM integration
Austria	No specific information provided, some similarities to Germany.
China	All GeoRM steps fit entirely in the ProjectRM steps, which may identify the potential risks. Nevertheless, geotechnical risk is often (too) generally mentioned in project risk registers. More integration of GeoRM in ProjectRM, by more cooperation between the respective managers and professionals, may overcome this hurdle
Czech Republic	During the construction phase, GeoRM is well integrated into Project RM, at least in the tunnel construction projects. In the planning phase, RM is almost completely missing. GeoRM is more advanced than Project RM. Application of GeoRM is mostly driven by the experts in geotechnics and was motivated by geotechnical failures.
Finland	GeoRM is an essential part of ProjectRM. No separate information of the part of the geotechnical risks from the other risks. The definitions used in practice of GeoRM and ProjectRM are more or less similar.
Germany	While large construction companies are obliged to have general RM standards on the company level, of which ProjectRM is an inevitable part and GeoRM is also required normatively, in the sense of sharing the geotechnical risk between the client and contractor, the integration of GeoRM and ProjectRM is not perfect. Both ProjectRM and GeoRM are mostly understood as contractual allocation of risks and responsibilities. The aspect of communication and cooperative management of risk is omitted.
Japan	Japan is on the way to establish risk management systems for construction project and has officially adopted the CM (Construction Management) System.
Netherlands	While all GeoRM steps fit entirely in the ProjectRM steps, geotechnical risk is often (too) generally mentioned in project risk registers. More integration of GeoRM in ProjectRM, by more cooperation between the risk managers and geotechnical engineers, may overcome this hurdle.
Sweden	GeoRM and the ProjectRM are already integrated, or rather not separated.
Switzerland	No specific information provided, some similarities to Germany.
United Kingdom	Varies within the spectrum full integration (Highways Agency) – partial integration (often poor and ad hoc) – no integration (British Geological Society) – no risk management. Full integration by published procedure does not ensure full integration by process implementation.

Main conclusions on the status of GeoRM – Project RM integration

GeoRM and ProjectRM seem only integrated in the Scandinavian countries Finland and Sweden. In the remaining countries, GeoRM seems generally partly integrated in ProjectRM, for instance depending on the construction phase and type of project (Czech Republic). In Germany ProjectRM is obliged in the large construction firms, and GeoRM is required normatively as well. Nevertheless, integration of GeoRM and ProjectRM is not perfect and both are yet too much focused on only contractual allocation of risk. The United Kingdom reports that integration varies on the full spectrum of even no risk management towards full integration (Highways Agency). In China and the Netherlands GeoRM fits well in ProjectRM, however more integration by more cooperation between ProjectRM and GeoRM professionals may help to reduce too general GeoRM approaches.

3.2 How contributes GeoRM to ProjectRM?

No.	Contribution of GeoRM to ProjectRM	Countries
1	GeoRM plays a *crucial role* in ProjectRM, as *geotechnical uncertainties* have major influence on construction projects. Compared to other construction materials, ground is extremely heterogeneous.	Austria, Czech Republic, Germany, Japan, Switzerland (5)
2	Managing geotechnical risks helps to *increase the safety* of the works and of the final constructions as it allows identifying potential hazards.	Austria, Czech Republic, Germany, Japan, Switzerland (5)
3	Systematic gathering of geotechnical information along with other information (e.g. construction performance and construction cost) would help to *improve the know-how and to learn* from past projects.	Austria, Czech Republic, Germany, Switzerland (4)
4	More *effective and efficient management of the geotechnical causes* of project risk, particularly in complicated large infrastructure projects.	China, Netherlands (2)
5	Remediating geotechnical risk in projects by involving QA/QC professionals for *aligning processes and achieving economies of scale and learning*	China, Netherlands (2)
6	GeoRM will provide some measures for ProjectRM to control risks	China (1)
7	GeoRM has worked very well and has proved very effective tool in identifying, assessing and mitigating risks as part of the overall risk assessment	United Kingdom (1)
8	GeoRM implementation in projects informs ProjectRM and appropriate steps are taken to manage geo-risk in the project life cycle.	United Kingdom (1)
9	GeoRM may influence the choice of which risk responses to adopt. Some responses may be able to deal not only with Geo risks, but also with other risks at the same time.	United Kingdom (1)
10	Specific approaches applied to GeoRM, such as the observational method, tolerable or robust forms of construction, may have potential applications as risk control strategies in some areas of Project RM.	United Kingdom (1)

While considering the contribution of GeoRM to ProjectRM, several countries provided remarks on geotechnical risk and failure costs:

- China: Failure costs of construction projects are generally assessed as about 3.5 % of the total project turnover, which is in total several billion RMB Yuan per year. Geotechnical problems have a considerable stake in these project cost overruns.
- Czech Republic: Geotechnical failures are severe problems in the Czech republic. Serious accidents occurred in recent years in the tunnel construction projects (CzTA Seminar 2010, Srb, 2013, Špačková, 2012), resulting in long delays and high financial losses. There is therefore an increasing interest to mitigate these risks. The geotechnical risks are thus perceived as the major ones in construction projects.

- Netherlands: Failure costs of construction projects are generally assessed as 10 % of the total project turnover, which is in total several billion euros per year. Geotechnical problems have a considerable stake in these project cost overruns.
- United Kingdom: The status of ground engineering risk is very low in the general UK construction market, despite published evidence that reports that poor understanding of the ground is probably the most significant contributor to cost and program over-run.

Main conclusions on the contribution of GeoRM to ProjectRM

The foregoing remarks indicate that geotechnical failure is of serious concern in a number of countries, resulting in considerable failure costs (China, Netherlands), triggering the interest in risk management (Czech Republic), but still keeping the status of ground engineering low (United Kingdom).

From the ten country reports in total 10 different contributions of GeoRM to ProjectRM have been derived, by using data triangulation. This involved comparing and clustering similar GeoRM contributions, as reported in the ten country reports. The numbering of the GeoRM contributions is according to the highest number of countries that reported similar solutions, and on alphabetical order of country names.

Acknowledging the fact that the country report of the Czech Republic and the combined country report of Austria, Germany, and Switzerland were provided by the same reporter reveals that there seems relatively little consensus on the GeoRM contributions to ProjectRM. The first three items in the table, (1) managing the *crucial role of geotechnical uncertainties* that have a major influence on construction projects, (2) *increasing the safety* of during the works and of the final constructions, and (3) combining systematic gathering of geotechnical information with construction performance and costs, for *improving know-how and fostering learning* from past performance were in fact raised by two and one reporter and their teams.

The remaining GeoRM contributions were also raised by only two countries or even one country. This implies that the views on the GeoRM contributions vary considerably amongst several countries, which allows learning from each other. One country may adopt one or more GeoRM contributions from other countries for strengthening ProjectRM in that particular country.

For instance, China and the Netherlands remediate geotechnical risk in projects by involving QA/QC professionals, for aligning processes and achieving economies of scale and learning. This approach could be valuable for the remaining eight countries that participated in this survey.

Another example, the United Kingdom suggests that GeoRM may influence the choice of which risk responses to adopt. Some responses may be able to deal not only with geo-risks, but also with other project risks at the same time, which also may result in economies of scale and learning. This benefit may be attractive for the other nine countries as well.

Finally, all of the ten types of contribution of GeoRM to ProjectRM are rather general and qualitative, rather than proven and quantitative contributions expressed in money, time, safety records, and so on.

3.3 How is GeoRM communicated to non-geotechnical persons?

No.	Type	Communication of GeoRM to non-geotechnical persons	Countries
1	Public	This is done on *civil type of infrastructure projects* by workshops, evening meetings, door knocking, promoting in local press, having a Q & A Kiosk or information centre outside the site boundary manned by trained staff or Open Doors Days for the project.	Czech Republic, Netherlands, United Kingdom (3)
2	Public	In a number of countries the *geotechnical hazard* is not limited to construction sites, e.g. in landslide prone areas. For parts of the country there are landslide hazard maps that give an overview of these areas.	Sweden, United Kingdom (2)
3	Team	During the construction phase, the geotechnical information are *discussed on the regularly meetings* of the project management team. However, sometimes the pressure on construction time and costs can cause that the geotechnical risks are not taken seriously enough.	Japan, Czech Republic (2)
4	Team	Project teams are supported by in-house geotechnical specialists for more detailed and site specific advice. It is the responsibility of specialists to present the consequences of identified risks *in terms that can be more widely understood* e.g. impact to meeting business objective and the 'balance' to be achieved.	Japan, United Kingdom (2)
5	Team	This dealt with *coordination and common practices* inside project.	Finland (1)
6	Public	Communication of GeoRM has serious attention in the *Geo-Impuls joint industry program* on reducing geotechnical failure, which developed a procedure to be used by communication managers and geotechnical engineers together in a project	Netherlands (1)
7	Public	For construction projects, geotechnical risks are sometimes communicated via *consultations with the public* as required in making the assessment of the effects of certain public and private projects on the environment.	Sweden (1)
8	Public	Applying the *ALARP (as low as reasonably possible) principle*, which is difficult, as risk acceptability varies greatly between sectors, countries and clients. For instance, compare risk communication protocols and acceptance criteria for slopes and landslides in Hong Kong with UK.	United Kingdom (1)
9	Team	For *project managers and contract managers*: communication generally through use of risk registers, presentation of ground models, results of risk analyses.	United Kingdom (1)
10	Team	In *risk meetings* ahead of tender on D&B schemes.	United Kingdom (1)

Notes on the *cultural and language issue* of risk communication:

- Austria, Germany, and Switzerland: Communication of risks in general is quite limited. This is mainly due to the cultural specifics that do not motivate open admission of potential problems. Especially in the technical field, the engineers highly rely on standards and norms and they are not used to analyse possible deviations from an ideal standardized state/progress. Therefore, risks are typically not communicated to the public in advance; it has been common to present the project as a safe and certain action. However, this paradigm seems to be changing. There has been a rising debate about the number of sever cost overruns in large construction projects and about the fact, that uncertainty of the cost estimates should not be neglected in the planning phase
- United Kingdom: Technical people often struggle to present information in a non-technical manner reverting to techno-speak and jargon that simply turns others off. There would therefore be value when considering the topic of communication to consider matters such as social styles, neuro-linguistic programming, geo-cognition (how people perceive and understand the Earth and earth processes) and Cognitive Sciences which consists of multiple research disciplines, including psychology, artificial intelligence, philosophy, neuroscience, linguistics, and anthropology.

Notes on the *fear factor* of risk communication:

- Czech Republic: The many serious accidents and cost overruns that occurred in the last years caused that the public is generally suspicious about the large construction projects. Open communication of geotechnical risks in future projects can thus cause exaggerated reactions of the affected inhabitants.
- Netherlands: For many clients and contractors it is quite a dilemma to either communicate about geotechnical risk before starting the project (which may make the public feeling uncomfortable about the project), or only once the geotechnical problems indeed occurs (for instance damage due to settlements) which would make the public not only feeling uncomfortable but quite angry as well.
- Switzerland: In Switzerland the direct democracy is well established. Also, the public is in general more involved in decisions about the large projects. For example, the Gotthard base tunnel showed that public involvement into the process (three referenda on realization of the project, on its financing etc.) ensured a general acceptance of the project amongst people in spite of large time and cost overruns and even fatalities during its construction.

Main conclusions on the ways of communication to non-geotechnical persons

The notes on the cultural elements, language issues and the fear factor of risk communication express that geotechnical risk communication particularly to non-geotechnical engineers, managers, as well as the public, is far from easy. It is therefore valuable that in total ten ways of GeoRM communication to non-geotechnical persons have been retrieved from the country reports, again by applying data triangulation as described before. Five ways of GeoRM communication have the public as target, the other five focus on project teams with non-geotechnical engineers and managers. Six of the ten communication suggestions are proposed by only one country, which allows considerable learning of the other nine countries from that particular country.

3.4 What are ProjectRM lessons from other sectors for GeoRM?

Country	ProjectRM lessons from other sectors for GeoRM
Czech Republic	Compare to, for example, large producers in *mechanical industry*, the innovations in the civil engineering construction are very slow (the *productivity* has been practically not increasing). One, often repeated, argument is that the civil engineering projects are unique and that they are not comparable to production of cars etc. However, in spite of this uniqueness, better planning of the civil engineering projects and systematic gathering of know-how from past projects (and learning from mistakes) might improve the productivity.
	For improvement of the RM, it is crucial to gather and share information. Organization of the construction companies and other participants in construction projects is typically *decentralized*; the *sharing of know-how* amongst the different project teams is very limited. This is one of the areas, where construction industry might learn from *other industries*.
Germany	There is an increasing interest in *simulation tools* in recent years, which allow *optimizing the organization of construction process*. Application of these tools is already sometimes applied in practice, for example for construction of *industrial premises* for clients from the field of *mechanical engineering* such as car producers that are used to optimize the production processes in their core activities and they thus demand similar approach also in the production (construction) of their factories. The simulation tools might also help in the process of analysing risks.
Netherlands	The *space industry*, for instance, shows that it is beneficial to integrate risk management in systems engineering and to focus on effective team communication regarding project risk assessments and remediation. For example, improving project risk management is part of the QA/QC department and managed by a continuous improvement manager, by setting and following clear key performance indicators.
Sweden	Construction projects are rather different from *other industries* with large uncertainties, few data and most often one-off projects. We should try to find out: how did they gain a foothold with management? What *tools and techniques* can we adopt?
United Kingdom	Good lessons can be learnt from the *insurance industry* that focuses on effective communication. Based on the principal issues that created insurance claims, we can conclude that in many cases we *have unqualified (incompetent?) people*. These are assigned to the management of ground risks by inexperienced project managers, who do not understand GeoRM. Also, these project managers do not understand the value that can be captured, if professionals are allowed to manage ground risks to the fullest extent, by focusing on the delivery of the most beneficial project outcomes.
	There is much to learn from the *chemical and nuclear industries* which set good *benchmarks*. In the geo-sciences we are beginning to catch-up but our experience is rather ad hoc and bespoke to specific projects and circumstances.
	In the *financial services industry* there is growing emphasis on *Enterprise Risk Management*, which emphasizes the need to consider all the risks of an enterprise holistically. This suggests that it is inefficient to consider geo risk separately from other risks.
	Techniques developed *for ProjectRM* of general applicability to GeoRM. These techniques need to be identified and applied to GeoRM rather than reinventing the wheel and considering GeoRM as a separate area.

Main conclusions on lessons from other sectors for ProjectRM and GeoRM

In total five out of the ten participating countries (50 %) suggested in total seven sectors outside the construction industry where valuable lessons for more effective and cost-efficient GeoRM can be found. These suggested industries are:

1. *Mechanical* industry, for learning how to increase productivity, despite the unique character of construction projects and the related risks and for using simulation tools for optimizing construction processes;
2. *Space industry*, for learning how to integrate risk management in systems engineering (which is increasingly used in the construction sector) and by developing risk management as part of a continuous organizational improvement program;
3. *Insurance* industry, for learning how to focus on effective communication and how insurance claims can be avoided or reduced, by using qualified and competent people;
4. C*hemical*, for setting clear risk benchmarks and combining risk and safety management,
5. *Nuclear industry*, also for setting clear risk benchmarks and combining risk and safety management;
6. F*inancial services industry*, for considering risk in a holistic and integral way,
7. C*onsulting industry*, for using project management techniques within the GeoRM processes.

These suggestions demonstrate that there is probably a wealth of proven methods, techniques, tools, and approaches out of the construction sector, which is waiting for adoption in well-integrated ProjectRM and GeoRM. This may save a lot of time, energy, and money, by avoiding reinventing the wheel by considering ProjectRM and GeoRM as separated and isolated disciplines.

4 CONCLUSIONS ON INTEGRATING GEORM AND PROJECTRM

Country	Conclusions on integrating GeoRM – Project RM
Austria	None.
China	GeoRM is necessary for risk management, and is elementary part for ProjectRM. The processes of GeoRM and ProjectRM are equal and fit well, definitions used in practice of GeoRM and ProjectRM are more or less similar. However, in practice it seems that the integration of GeoRM in ProjectRM can be improved, to be able to control project risks by better controlling geotechnical risk.
Czech Republic	ProjectRM and GeoRM are relatively new in the Czech construction industry. GeoRM seems to be more advanced than ProjectRM and probably most advanced in tunnel projects. The main issue of the Czech construction industry is thus not the INTEGRATION of GeoRM and ProjectRM but an INTRODUCTION of systematic RM into the practice. While several processes and techniques from international standards of GeoRM and ProjectRM are applied in the Czech practice, these are not standardized and formalized. RM education at universities is not of high quality.
Finland	ProjectRM is essential part of the follow up of total project progress. In all railway construction projects the guidelines of Transportation Agency are used. For road construction projects there is no special guidance. In general a big challenge in long-term and big projects where the responsible people are changing is the motivation and ensuring the continuity of the RM process during several years and project phases. Commitment of the management and people involved is essential.
Germany	In Germany, GeoRM is required by law, in the sense of contractual sharing of the risks rising from uncertain geotechnical conditions between owner and contractor. ProjectRM is required by law for the large construction companies, as a part of the management of companies' entrepreneurial risks. However, in the practice these two fields are not very well integrated. Some aspects of the ProjectRM and GeoRM are overlooked and RM is primarily understood as contractual allocation of risks. The communication of the risks and cooperation between the parties is rather low. An integral RM process that would cover the whole project life is missing.
Netherlands	The GeoRM and ProjectRM definitions used in practice are more or less similar. The processes of GeoRM and ProjectRM are equal and fit well. No major objections obstruct the integration of GeoRM and ProjectRM. Nevertheless, the application of GeoRM can still be improved, enabling a further reduction of project risks by a better management and controlling of geotechnical risks.
Japan	Geotechnical professionals should be entitled to be a Geo Manager for the construction manager of the project client. Moreover, actual proof of cost reduction by GeoRM for business execution and consensus building should be realized.
Sweden	In practice GeoRM is part of ProjectRM, although of course a project might be almost completely concerned with soil and rock works.
Switzerland	The management of technical risks is on very high level (processes for guaranteeing safety of the structure, safety of the operation, safety of works during the construction) but the processes are in many cases not sufficiently integrated with management of other types of risks such as economical risk, risks of delays etc.
United Kingdom	In the UK it is considered that we have not learnt and implemented good and best practice of GeoRM and ProjectRM from the past. This results in fuzzy risk terminology, lack of risk-focused evidence, standards not focused on value adding inputs and beneficial outcomes, lack of risk-competent resources, non-ideal training and education approaches, team attitudes that are not always right and can be negatively influenced by poor contracts, and inability to understand our audiences.

Main conclusions on integrating GeoRM and ProjectRM

A number of observations are made from the table with the conclusions of integrating ProjectRM and GeoRM of each of the ten countries:

1. From a methodological point of view, there seem to be no objections for (further) integrating GeoRM and ProjectRM, because definitions as well as processes are more or less similar and can strengthen each other, as reported by China and the Netherlands.
2. In some countries, for instance Germany, GeoRM is required by law as part of ProjectRM and part of enterprise risk management of large construction companies. Nevertheless, the focus it yet too much on only the risk allocation part of risk management and ProjectRM and GeoRM are not well integrated.
3. In Switzerland the focus of technical risk management is largely on safety issues. Therefore integral management with other types of risk, such as project delay or economic concerns, are not included.
4. The degree of implementation of ProjectRM, as well as GeoRM, seems to vary considerably between some of the participating countries. Both Scandinavian countries Finland and Sweden report that ProjectRM and GeoRM are well-integrated and an essential part of the total project process. In China and The Netherlands the integration of GeoRM and ProjectRM can still be improved by better cooperation. The Czech Republic and Japan are starting with ProjectRM as well as with GeoRM, while GeoRM seems even more advanced in tunnel projects than ProjectRM in the first country. The United Kingdom reports that learning and implementing best practices of GeoRM and ProjectRM has been missed to date.

Therefore, main conclusions could be that (1) in theory there are no objections for a full integration of GeoRM and ProjectRM, that (2) the awareness of the need for and potential benefits of such an integration is growing, but that (3) the complete application and integration of both types of risk management for full support of realizing project success in practice has still a lot of room for improvement.

For these reasons, the final chapter presents recommendations made by the ten countries for further and deeper integrating GeoRM and ProjectRM.

5 RECOMMENDATIONS ON INTEGRATING GEORM AND PROJECTRM

No.	Type	Recommendations on integrating GeoRM and ProjectRM	Countries	In %
1	Os	Provide education and training on GeoRM and ProjectRM and make it part of the curricula.	Austria, Czech Republic Germany, Japan, Nether-lands, Switzerland, UK (7)	70 %
2	Os	Identify and communicate success stories of integrating GeoRM and ProjectRM for achieving project objectives within time and budget.	Austria, China, Germany, Japan, Netherlands, Switzerland, UK (7)	70 %
3	Os	Provide short courses and tools for non-geotechnical risk managers about the need and benefits of integrating GeoRM in ProjectRM	Austria, Czech Republic, China, Germany, Nether-lands, Switzerland (6)	60 %
4	Os	Teach geotechnical professionals to communicate the effects of geotechnical risks in the language of non-geotechnical managers, such as project (risk) managers and contract managers.	Austria, China, Germany, Netherlands, Switzerland (5)	50 %
5	Os	Improve the know-how of GeoRM and ProjectRM by systematically learning from finished projects, by feedback and re-evaluation of the risk remediation actions.	Austria, Czech Republic, Finland, Germany, Switzerland (5)	50 %
6	T	Provide standards for RM processes in public investments projects that would be broadly accepted by the community. The standards should become living documents, in close communication with different parties (public clients, consulting companies, construction companies). Only in this way they can be accepted as a helpful tool, not as a formality.	Austria, Czech Republic, Germany, Switzerland, United Kingdom (5)	50 %
7	Oc	Increase the interest of public clients in RM, especially in effective risk communication and cooperation with the contractors. Increase their willingness to invest time and money into the ProjectRM and GeoRM.	Austria, Czech Republic, Germany, Switzerland (4)	40 %
8	Oc	Increase the awareness about existence of risks. Open communication of risks and uncertainties would increase their acceptance both in the society and amongst the practitioners.	Austria, Germany, Switzerland (3)	30 %
9	T	Adopt some new investigation methods or technologies, such as GPS and GIS in GeoRM to provide the enough geotechnical information to minimalize the uncertainty in ProjectRM.	China (1)	10 %
10	Os	Increase the pressure of insurance companies on application of Code of Practice.	Czech Republic (1)	10 %
11	T	Improve the quality of contractual risk-sharing.	Czech Republic (1)	10 %
12	T	Harmonize the requirements of the different public bodies that are supervising and controlling the safety of the construction works.	Czech Republic (1)	10 %
13	Os	The risk management should be part of the all construction projects and all of its phases.	Finland (1)	10 %

No.	Type	Recommendations on integrating GeoRM and ProjectRM (continued)	Countries	In %
14	Oc	Create an environment allowing for the integration of GeoRM and ProjectRM: ask for it, make it a project requirement, and provide training.	Netherlands (1)	10 %
15	Oc	Risk is not only about 'risk registers'. Therefore organizing activities like 'review sessions', 'checks between colleagues', 'risk sessions', 'second-opinions', will also help to properly address geotechnical risks.	Netherlands (1)	10 %
16	Os	Make an effort to get the people who handle risks today to adopt those parts of RM that they can benefit from. Most of those people are not called Risk Managers, they are those people that are responsible for reaching a certain objective, for instance a safe excavation.	Sweden (1)	10 %
17	T	Development of robust ground models and the associated management of identified ground hazards and geotechnical risks is crucial to effective delivery of construction and civil engineering projects.	United Kingdom (1)	10 %
18	T	Ground engineering standards should be innovated to add value but innovation must be managed by suitable competent ground engineers.	United Kingdom (1)	10 %
19	Os	Provide expertise and competence in teamwork, which is recognized by the insurance industry as a factor that can mitigate risks of failure and insurance claims.	United Kingdom (1)	10 %
Type of GeoRM hurdles: Os = Organization structure; Oc = Organization culture; T = Technical				

Main conclusions on the recommendations on integrating GeoRM and ProjectRM

From the ten country reports in total 19 different recommendations for integrating GeoRM and ProjectRM have been derived, by using data triangulation. This involved comparing and clustering largely similar recommendations, as reported in the ten country reports. The numbering of the recommendations is according to the highest number (also expressed in percentages) of countries that reported similar recommendations, and on alphabetical order of the country names.

Similar to the ProjectRM and GeoRM hurdles and solutions, all recommendations have been classified in three types: (1) recommendations that are primarily realized by changes in the organization structure of (project) organizations (Os) involved in construction projects, (2) those primarily realized by changing the culture within these organizations (Oc), and (3) recommendations primarily involving technical measures (T). Measures for changing organizational structure and culture seem often closely coupled. The table shows that in total 13 out of the 19 recommendations (68 %) are organizational of origin, of which 9 are structural (47 %) and 4 are cultural (21%). In total six technical recommendations (32 %) have been identified.

In summary, the *top six recommendations* for integrating GeoRM and ProjectRM, reported by 70 % to 50 % of the ten countries, are:

1. Provide education and training on GeoRM and ProjectRM and make it part of the curricula.
2. Identify and communicate success stories of integrating GeoRM and ProjectRM for achieving project objectives within time and budget.
3. Provide short courses and tools for non-geotechnical risk managers about the need and benefits of integrating GeoRM in ProjectRM.
4. Teach geotechnical professionals how to communicate the effects of geotechnical risks in the language of non-geotechnical engineers, managers, and the public.
5. Improve the know-how of GeoRM and ProjectRM by evidence-based learning from finished projects, in particular by systematic evaluation of the effectiveness and cost-efficiency of applied risk remediation actions.
6. Provide standards for RM processes in public investments projects that would be broadly accepted by the community.

Five of these six recommendations are classified as an Os (Organization structure) type. For instance, *GeoRM and ProjectRM education* should be formally organized and become part of the structure of the organizations participating in civil engineering and construction projects. In other words, the proposed several sorts of ProjectRM and GeoRM education should not stay voluntary for engineers and managers. It should become a formal part of their individual professional development, and a formal part of the professional development of organizations as well, either clients, engineering firms, contractors, or knowledge institutes, including universities.

Other recommendations, reported by 40 % and 30 % of the countries, involve increasing the *interest of public clients* in risk and increasing the *awareness about existence of risks*, as their open communication would increase their acceptance both in society and amongst practitioners.

For the remaining 11 recommendations, which are reported by 10 % or just one out of the ten countries, reference is made to the previous table with recommendations. Because these recommendations are suggested by just one country, these may be of particular interest for the other nine countries, where these recommendations appear to be unknown to date. Regarding recommendation nr. 16, the representatives from Sweden want to stress that risk management should be done by those who have the responsibility to see that a specific objective is reached.

In the table on the next page, the percentages of ProjectRM and GeoRM hurdles and solutions are presented, as raised by the ten participating countries. For instance, for ProjectRM the presented 50 % for Os (Organizational structure) means that 50 % of the ProjectRM hurdles that were reported by the ten participating countries were classified as caused by the structure of the (project) organizations involved in construction projects. In addition, the percentage of recommendations (mentioned as *advices*) for the integration of GeoRM and ProjectRM are presented in the last column of the table.

Types of RM hurdles and solutions	ProjectRM		GeoRM		Integration GeoRM ProjectRM
	Percentage of hurdles	Percentage of Solutions	Percentage of hurdles	Percentage of solutions	Percentage of advices
Os = Organizational structure	50 %	55 %	41 %	28 %	47 %
Oc = Organizational culture	44 %	35 %	41 %	28 %	21 %
T = Technical	6 %	10 %	18 %	44 %	32 %
Total	100 %	100 %	100 %	100 %	100 %

The table above demonstrates that for ProjectRM, as well as for GeoRM, the identified hurdles are mainly of an organizational type, either organization structure or culture. The percentage of technical hurdles varies from 6 % for ProjectRM to 18 % for GeoRM.

However, the technical solutions and advices for lowering the ProjectRM and GeoRM hurdles, as well as for integrating GeoRM and ProjectRM, are with respectively 10 % , 44 % and 32 % higher than their demand by technical hurdles of 6 % for ProjectRM and 18 % for GeoRM. Therefore, it seems that there is a tendency to solve organizational problems with technical solutions, rather than with organizational solutions. In other words, *technical solutions* are raised by the reporters for solving merely *organizational problems*. This seems to reflect what engineers have been trained to do and also highlights, perhaps, a gap in (post-graduate) engineering education. It should be a point of attention, when one is trying to reduce ProjectRM and GeoRM hurdles for (further and deeper) integrating both types of risk management.

Moreover, as remarked by the United Kingdom, throughout the report there seems a very limited inclusion of the converse of risk management, which is opportunity capture. Despite the ISO 73:2009 definition of risk (which allows for positive possibilities as well as negative ones), the more general understanding of risk is the potential for loss. Risk management is hence widely perceived as being linked to mitigation or minimization of that loss. Perhaps we should seek a paradigm change, whereby we are much more seeking out the opportunity for gain.

Finally, during all activities the main objective of integrating ProjectRM and GeoRM should be kept in mind: contributing to project success, by developing effective and cost-efficient risk management practices for civil engineering and construction projects, of any project type, in any project phase, at any project location in the world.

REFERENCES

For all references mentioned is this report reference is made to the chapters 6 in the country reports. Exceptions are a few references that have been used only in this state of the art report. These references are presented below.

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