Comparison of Risk Assessment Methods in the Field of Natural Disasters

Master Thesis

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Leoben, 03.12 2013

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Scope of work

Mr. **Dipl.-Ing. Karim Soliman** will research and write on the topic

"Comparison of Risk Assessment Methods in the Field of Natural Disasters"

in his Master Thesis.

The first part of this thesis will acquaint the reader with terms of risk management and risk assessment mainly linked to the field of natural hazards. Based on the definitions the requirements of the European Union Risk Assessment Guidelines for Disaster Management have to be worked out in detail. To support the process of risk assessment on national and European Union level the EU Commission suggested some risk identification methods based on the ISO 31000ff. These methodologies will be compared in terms of resources and capabilities, nature and degree of uncertainty, complexity and quantitative output.

The main part of this thesis is to oppose the Austrian methodology of risk assessment in the field of natural disaster with methods used in other EU member states. Comparison criteria have to be defined and differences as well as best practices should be worked out.

Finally an excursion into the risk assessment of the oil and gas industry has to be done. The risk management process as well as specific tools will be analysed and compared with the status of frameworks and methodologies in the field of natural disasters.

Leoben, June 2013 Dr. Werner Schröder

Kurzfassung

Die Anzahl der Katastrophen und Bedrohungen, die unsere Gesellschaft auf nationaler und internationaler Ebene gefährden, nehmen allmählich zu. Zusätzlich erhöht sich schrittweise die Intensität und Dauer solcher Katastrophen, wie in den vergangenen Jahren beobachtet werden konnte. Dies wird durch mehrere Statistiken, wissenschaftliche Arbeiten sowie durch die Wahrnehmung der heutigen Gesellschaft bestätigt. Um ein Sicherheitsgefühl in der Gesellschaft zu schaffen, wurden mehrere Ansätze und Methoden von den zuständigen Behörden zur Anwendung gebracht.

Im Mittelpunkt dieser Masterarbeit stehen die Identifizierung und der Vergleich bestehender Methoden in der Risikobewertung. Dies ist überwiegend im Zusammenhang mit Naturkatastrophen Risikomanagement zu sehen. Ein sekundäres Ziel ist die Identifizierung der vorhandenen monetären Analysen. Der Ausgangspunkt war die Feststellung, dass es keine monetäre Analyse im Naturkatastrophen Risikomanagement des Bundeslandes Steiermark gibt. Die Fragestellung war also: Sind monetäre Analysen in den vorhandenen Risikomanagement-Prozessen für Naturkatastrophen implementiert und wie sehen diese aus? Zu diesem Zweck müssen grundlegende Risikomanagement-Prozesse, vor allem Verfahren der Risikobewertung, klar verstanden werden.

Aufgrund der Wichtigkeit einer genauen, sowie angepassten Risikobewertung im Bereich von Naturkatastrophen Risikomanagement, empfiehlt die Europäische Kommission den EU-Mitgliedstaaten eigene nationale Verfahren zur Risikobewertung zu entwickeln. Ziel ist es, in Anlehnung an den einzelnen nationalen Verfahren, eine gemeinsame Risikobewertung auf EU-Ebene zu entwickeln. Genauere Ziele werden im Detail während der Masterarbeit besprochen. Richtlinien wurden von der EU-Kommission basierend auf internationalen Standards (ISO 31000ff) und verfügbaren nationalen Prozessen entwickelt. Die Einführung einer EU-weiten Risikobewertung soll im Jahr 2014 stattfinden. Bis zu diesem Zeitpunkt sollen die EU-Mitgliedstaaten mögliche Verbesserungsvorschläge einbringen.

Die EU-Kommission hat unterstützende Methoden für die verschiedenen Phasen der Risikobewertung (Risikoidentifikation, Risikoanalyse sowie Risikoevaluierung) erarbeitet. Diese Methoden wurden nach vorgegebenen Vergleichskriterien zueinander verglichen. Diese Kriterien sollten den zuständigen Behörden bei der Auswahl geeigneter Methoden bzw. bei der Entwicklung oder Verbesserung behilflich sein.

Die Risikobewertung ist eine der wichtigsten Elemente des Risikomanagements. Für ein besseres Verständnis wird der Prozess des Risikomanagements erläutert und es werden detaillierte Exkurse in die Risikobewertung durchgeführt. Zur Verbesserung der österreichischen Methodik muss ein klares Verständnis der aktuellen Situation gegeben sein. Zu diesem Zweck wird die österreichische Risikobewertungsmethode im Detail beschrieben. Darüber hinaus werden internationale Methoden zur Risikobewertung analysiert. Die vorliegende Arbeit soll dazu beitragen, die Weiterentwicklung und Zuverlässigkeit der österreichischen Risikobewertungsmethode zu garantieren. Dies wird anhand von Vergleichskriterien bewerkstelligt. Weiteres repräsentieren diese Kriterien die minimal erforderlichen Notwendigkeiten für eine sinnvolle monetäre Analyse.

Um die besten Praktiken im Bereich des Katastrophenmanagements zu identifizieren, wurde ein Exkurs in den führenden Branchen durchgeführt. In dieser Masterarbeit wurden Verfahren und Methoden der Öl-und Gasindustrie identifiziert.

Abstract

Number of disasters and threats affecting our society, on national and international territory, are increasing gradually. Additionally intensity and duration increased progressively over the past decades. This is proven by several statistics, scientific papers as well as through the sense of today´s society. To create a certain confidence to the society, several approaches and methodologies were applied by authorities.

Within this master thesis the attention will be focused on the identification and comparison of existing risk assessment methodologies, in relation to natural disaster risk management. A secondary objective is the identification of available monetary analysis in this specific context. The point of departure was the conclusion that no monetary analysis is actually implemented into the natural disaster risk management of the federal province of Styria. So the question was: Are there monetary analysis implemented within the actual risk management processes for natural disasters and how do they look like? For this purpose fundamental understanding of the risk management process, especially risk assessment process, have to be ensured.

Due to the importance of an accurate as well as adapted risk assessment in the field of natural disaster risk management, the European Commission recommend EU Member States to develop own national risk assessment procedures. The aim is to create a European Union wide risk assessment based on those national approaches. Objectives will be discussed into detail during the master thesis. Guidelines were developed by the EU Commission based on international standards (ISO 31000ff) and on available national producers. Implementation of a European Union wide risk assessment should start in 2014, till this date EU Member States should provide additional inputs and improvements to the existing guidelines. Additionally the EU Commission provided supporting methodologies for the various stages of risk assessment (risk identification, risk analysis as well as risk evaluation). Those methodologies will be explained as well as compared according to predefined comparison criteria. Those specific criteria should support responsible authorities in the selection of adequate methodologies for the development or improvement of own national risk assessment.

Risk assessment is the individual element of risk management. For better understand the risk management will be explained and a detailed excursion into risk assessment will be carried out. To improve the Austrian methodology a clear understanding of the actual situation has to be given. For this purpose the Austrian risk assessment is explained into detail. Furthermore international risk assessment methodologies of leading nations are analyzed. This measure should help to realize advancement and reliability of Austrian risk assessment. For this purpose comparison criteria are generated and will support this matter. Additionally those criteria indicate the minimum required inputs for a meaningful monetary analysis.

To identify the best practices in the field of disaster management, an excursion into leading industries is carried out. In this master thesis the procedures and methodologies of oil and gas industry will be identified. This specific industry is very advanced and could support the improvement of EU Commission guidelines and national risk assessment procedures.

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Abbreviations

AeDES	Post earthquake damage and emergency assessment plan
BIA	Business Impact Analysis
CBA	Cost Benefit Analysis
CCA	Cause and Consequence Analysis
CCS	Civil Contingencies Secretariat
D&C	Threats and Capabilities Programme
DSB	Directorate for Civil Protection and Emergency Planning
E&P	Exploration and Production
EM DAT	International Disaster Data Base
EQRA	Environmental Quantitative Risk Assessment
ETA	Event tree analysis
EU	European Union
FMEA	Failure Mode and Effect Analysis
FTA	Fault Tree Analysis
GDP	Net cost of economic output
GIS	Geographical Information System
GMES	Global Monitoring for Environment and Security
GNI	Gross National Income
HACCP	Hazard Analysis and Critical Control Points
HAZOP	Hazard and Operability Studies
HQ	Recurrence interval of a flood
HRA	Human Reliability Analysis
HSE	Health, Safety and Environment
IEC	International Electrotechnical Commission
INSPIRE	Infrastructure for Spatial Information in the European Community
IRGC	International Risk Governance Council
IWNV	Interdepartmental Working Group on National Safety and Security
LOPA	Layers of Protection Analysis
MOI	Ministry of the Interior
NGO	Non-governmental Organizations
NPV	Net Present Value
O&G	Oil and Gas
PHA	Preliminary Hazard Analysis

RAG	Risk Assessment Group
RASG	Risk Assessment Steering Group
RCA	Root Cause Analysis
RCM	Reliability Centred Maintenance
RCM	Root Cause Map
RWC	Reasonable Worst Case
SKKM	Federal Crisis and Catastrophy Protection Management
SNV	Steering Group on National Safety and Security
SPE	Society of Petroleum Engineers
TRA	Toxicological Risk Assessment
UNISDR.	UN-International Strategy for Disaster Risk Reduction
UN-OCHA	UN-Office for the Coordination of Humanitarian Affairs
WHO	World Health Organization
ZAMG	Zentralanstalt für Meteorologie und Geodynamik

1 Introduction

In our society the population is facing various types of risks. Some of those risks are recognized and others are invisible. Independent of specific type of risk, this fact creates a possible harm to the population of a society. So evaluating those risks is very important to ensure health and safety of population. Consequences of a certain event have to be understood to realize effective counter measures.

The European commission recommended EU Member States to develop own national risk assessments processes to identify possible risks and to have an idea about own capabilities to fight against disasters (natural or manmade). In this master thesis the risk assessment processes of various EU Member States will be presented and compared to each other according to predefined comparison criteria. This measure should help to reflect if monetary analyses are implemented into the actual national risk assessment processes.

The topic of risk assessment and risk management is worldwide topical, due to an increasing number of disasters occurred in the last few years. It is recognizable that interval between major disasters, occurring in national and international territorial areas, is decreasing gradually. At the same time the intensity of those disasters is greater than ever.

So developing a national risk management, including an accurate risk assessment is very important. This step should help to realize possible preventive measures, to reduce or eliminate the involved risks. To make a reliable decision about preventive measures, monetary analysis should be realized. Up to this moment there are no real monetary analysis dealing with the matter of natural disaster prevention.

In the first chapter definitions and terminologies used during this master thesis will be presented as well as explained. This specific measure should create a common basis, when going through the master thesis. The definitions and terminologies used are based on international standards to be comparative to other States beyond the territorial area of the European Union.

The second chapter will present standards, methodologies and guidelines recommended by European Union Commission for developing a national risk assessment process. Those guidelines will contain the main pillar to realize a national risk assessment for EU Member States. The aim is to create comparable national methods between EU Member States and in a more advanced stage (2014) a common EU wide risk assessment. This measure should help to combat risks and disasters in a more effective way. This decision is the upper most aim of the EU Commission (in the context of natural disasters) and should help to reduce risks over the whole territorial area of the European Union.

The third chapter will introduce methods for risk identification. The presented methods are subdivided into six major groups and are compared to each other according to specific comparison criteria. The comparison criteria listed below will be explained in more detail at a later stage:

- Resources and capabilities
- Nature and degree of uncertainty
- Complexity
- Quantitative output

In chapter number four the general situation and system complexity in Austria will be presented. Furthermore the procedure of risk assessment applied in Austria will be explained and the role of provinces (different authority levels) will be presented in more detail. Chapter number five gives attention to the situation of selected EU Member States. It will be recognizable that the advancement of national risk assessments is very diverse.

In chapter number six the former presented national and international (European Union level) risk assessment methods will be compared to each other. This will be realized according to predefined comparison criteria. Those comparison criteria will be explained in detail. The results of comparison will then be translated into an overall score to carry out a ranking of national risk assessments.

In chapter number seven an excursion into the oil and gas industry is accomplished. It has to be mentioned that the oil and gas industry is one of the most leading industries according to risk assessment and risk management. This fact is because of the nature of product processed as well as attention of community to operations of the oil and gas industry. In the last chapter the conclusion of this master thesis will be presented.

1.1 Definitions

For better and unambiguous understanding, definitions and used terminologies during this master thesis will be explained. This measure has the aim to terminate misunderstandings and should ensure a common understanding while going through the master thesis. All terminologies and definitions have to be understood in the context of natural disasters. Definitions are based on international standards, to be comparative to other scientific works.

1.1.1 Disaster

A disaster in legal terminology is defined as "*A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources*"[1]. In other words, this situation could lead to massive loss of human lives and important infrastructure. Disasters usually influence a large number of stakeholders and have a considerable effect on the economics of affected area. Disasters can be classified into several types. In this master thesis the author is mainly mentioning risk assessment of natural disasters. Generally two types can be classified. The first type is the naturally occurring once (natural disasters). The most common natural disasters influencing the European Union are listed alphabetically below[2]:

- Avalanches
- Dam failures
- Earth quakes
- Floods
- Forest fires
- Heat waves
- Landslides
- Solar storms
- Storms

[1] UNISDR (2009), P. 9.

[2] Cf. Swedish Civil Contingencies Agency (2011), P. 7.

- Vermin infestation
- Volcanic eruptions

Others disasters mentioned are man-made once, which could be cyber-attacks, disruption of food and drinking water supply, disruption of transport and major transport emergencies, disruptions in electronic communications, disruptions in energy supplies, disruptions in payment systems, disruptions in the supply of medicines, extensive fires in buildings and tunnels, oil spills, risk of societal instability and civil unrest, risks associated with chemicals, risks associated with nuclear and radiological materials as well as terrorism[3].

1.1.2 Hazard

A Hazard can be explained as "*A dangerous phenomenon, substance, human activity or condition*"[4]. The hazard could lead to[5]:

- Loss of life
- Injury
- Health impacts
- Property damage
- Loss of livelihoods
- Social and economic disruption
- Environmental damage

1.1.3 Natural Hazard

"*Natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage*"[6]. Natural hazard can be characterized by several factors, depending on type of hazard, Examples are[7]:

- Magnitude
- Intensity
- Speed of onset
- Area of extent

1.1.4 Technological Hazard

This specific type of hazardous event is resulting out of technological or industrial failures. Technological hazards are mainly outcomes of accidents, dangerous processes, infrastructure failure or human failures. All those events lead to loss of life or massive contamination of surrounding environment. Furthermore such technological hazards could lead to a massive impact on the economics of a certain area, ending up in possible social disruption[8]. Technological hazards could lead to contamination of a certain area for decades, leaving abandoned agricultural land behind.

[3] Cf. Swedish Civil Contingencies Agency (2011), P. 7.
[4] Council of the European Union (2011), P. 9.
[5] Cf. UNISDR (2009), P. 17.
[6] Council of the European Union (2011), P. 9.
[7] Cf. UNISDR (2009), P. 21.
[8] Cf. UNISDR (2009), P. 29.

1.1.5 Geological Hazard

"*Geological process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage*"[9]. Hazards belonging in this category could be:

- Earthquakes
- Volcanic activity
- Landslides
- Rockslides and others

1.1.6 Risk

Is defined by ISO 31010[10] as a combination of the consequences resulting out of a specific event (natural or manmade) and the relating likelihood of occurrence of the same event[11].

1.1.7 Risk Management

Risk management is an overall process covering all related evaluations and assessments in relation to risk. It is "*the systematic application of quality management policies, procedures, and practices to the tasks of assessing, controlling, communicating and reviewing risk*"[12]. Risk management is one of the main pillars in managing an origination of a risk. It is a very useful tool to reduce risks and to secure life of working staff. This is accomplished through implementation of risk reduction or elimination measures.

1.1.8 Risk Assessment

"*A methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend*"[13]. The process of risk assessment which is carried out by a responsible authority should include at least three elements:

- Risk identification
- Risk analysis
- Risk evaluation

1.1.9 Risk Identification

The process of risk identification is a systematic approach which is based on the application of information and data to identify possible hazards and thus corresponding risks. Those hazards are referring to a predefined risk question or a certain problem description. It is an important step in the process of measure identification as well as implementation (primer target of risk management).

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[9] UNISDR (2009), Page 16.
[10] Cf. IEC (2009), ISO 31010.
[11] Cf. Council of the European Union (2011), Page 10.
[12] EMA (2011), P. 10.
[13] UNISDR (2009), P. 26.

The mentioned information and data should be extracted out of reliable scores[14]:

- Historical data
- Theoretical analysis
- Informed expert´s opinions
- Concerns and experience of stakeholders

"*Risk identification addresses the "What might go wrong?" question, including identifying the possible consequences. This provides the basis for further steps in the risk management process*"[15]. Risk identification should be realized for a certain area of interest, to limit outcomes to a hand able level. This step creates the fundament of further steps in risk assessment and risk management process.

1.1.10 Risk Analysis

The process is defined as "*the estimation of the risk associated with the identified hazards. It is [...] linking the likelihood of occurrence and severity of harms. In some risk management tools, the ability to detect the harm (detectability) also factors in the estimation of risk*"[16]. The aim of risk analysis is to understand the possible risks by investigations of consequences as well as investigation of probabilities. This is carried out on former identified risks[17]. The identification is realized with risk identification methods (presented in chapter 3). Those methods could be qualitative, semi-quantitative or quantitative. During risk identification process already implemented measures have to be mentioned and effectiveness of them has to be clearly understood. This should avoid double acting measures.

1.1.11 Risk Evaluation

"*Risk evaluation involves comparing estimated levels of risk with risk criteria defined when the context was established, in order to determine the significance of the level and type of risk*"[18]. The level of risk is determined to evaluate if identified risk, with its consequences, is acceptable or if preventive measures should be implemented to minimize this risk. The risk criteria have to be selected carefully, because they have a significant influence on outcomes of the risk assessment and thus on the whole risk management process.

They are defined as the terms of reference to evaluate the significance of an investigated risk. Other important elements of risk evaluation are threshold values. According to those threshold values risks could be classified according to investigated risk criteria. The most common criteria utilized in the context of natural disasters, are[19]:

- Human
- Environment
- Economy
- Infrastructure
- Public Administration
- Social setting

[14] Cf. EMA (2011), P. 6.
[15] EMA (2011), P. 6.
[16] EMA (2011), P. 6.
[17] Cf. IEC (2009), ISO 31010, P. 13.
[18] IEC (2009), ISO 31010, P. 16.
[19] Cf. Australian Government et.al (2012), P. 4.

1.1.12 Single-risk Assessment

Is the assessment related to determination of likelihood and consequences of a singular risk, as a consequence of one type of hazard. This hazard occurs in certain area within a predefined period of time[20].

1.1.13 Multi-risk Assessment

Determination of likelihood and consequences for several hazards following each other or taking place at the same period of time. Each of the occurring hazards is depending on each other. This is also called follow on events or domino effect[21]. The assessment of such kind of risk is very complex and has to be realized in several smaller steps. This should ensure the overall complexity is captured.

1.1.14 Consequences

This terminology is related to negative or positive effects resulting out of disasters. Usually in the context of disasters and hazards it has a negative meaning. Consequences can be evaluated according to a wide range of criteria. During the process of national risk assessment, consequences are mainly investigated in relation to[22]:

- Human impacts
- Economic and environmental impacts
- Political and social impacts

1.1.15 Human Impacts

Are quantitative measurements relating to negative consequences and harms to humans living within a certain area of interest. This could be dispositived by measurements of[23]:

- Number of deaths
- Number of injured and ill people
- Number of people which are displaced

This type of impact is the most important once and has the highest priority. Humans are the engine of the society. Protection of territorial area has no sense if no humans are populating it.

1.1.16 Economic and Environmental Impacts

"*Are the sum of the costs of cure or healthcare, cost of immediate or longer-term emergency measures, costs of restoration of buildings, public transport systems and infrastructure, property, cultural heritage, etc., costs of environmental restoration and other environmental costs (or environmental damage), costs of disruption of economic activity, value of insurance pay-outs, indirect costs on the economy, indirect social costs, and other direct and indirect costs, as relevant*"[24].

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[20] Cf. Council of the European Union (2011), Page 11.
[21] Cf. Council of the European Union (2011), Page 11.
[22] Cf. Council of the European Union (2011), Page 10.
[23] Cf. Council of the European Union (2011), Page 10.
[24] Council of the European Union (2011), Page 11.

1.1.17 Political and Social Impacts

Semi-quantitative measure is the most common methodology used to quantify political and social impacts. Under those type of impacts the author understands "*Public outrage and anxiety, encroachment of the territory, infringement of the international position, violation of the democratic system, and social psychological impact, impact on public order and safety, political implications, psychological implications, and damage to cultural assets, and other factors considered important which cannot be measured in single units, such as certain environmental damage*"[25].

1.1.18 Risk Scenario

A scenario is an illustration of a certain risk situation. This could be a single-risk or multi-risk ending in negative consequences, within a certain area of interest. The risk scenario should help to assess risks in a more detail way. Furthermore additional consequences could be illustrated through the development of a scenario. Risk scenario under the advanced approach rules is a systematic process of involving expert opinions from various disciplines to derive reasoned assessments of likelihood and loss impact of plausible, high-severity operational losses.

[25] Council of the European Union (2011), Page 11.

2 European Union Risk Assessment Guidelines for Disaster Management

The risk assessment and mapping guidelines for disaster management, developed by the EU Commission, have the aim to support the development process for national risk assessment within European Union Member States, independent of current stage. In the case of EU Member States with no national risk assessment, the risk assessment guidelines for disaster management can be utilized as a guideline to create own national risk assessment. "*These guidelines build on experience in the practical implementations of national risk assessments and mapping, in particular existing good practice risk assessments of major natural and man-made disasters available in Member States. [ ]. The guidelines also gather results from most recent research in the area of risk assessment and mapping*"[26].

Risk assessment is one of the core elements (maybe the most important element) of risk management process. Risk management is a cyclic process involving several steps depending on each other. According to ISO 31000[27] the five core elements of risk management are[28]:

- Communication and consultation
- Establishing the context
- Risk assessment
- Risk treatment
- Monitoring and review

According to the guidelines risk assessment is defined as a comprehensive process for:

- Risk identification (definition according to chapter 1.1.9)
- Risk analysis (definition according to chapter 1.1.10)
- Risk evaluation (definition according to chapter 1.1.11)

To guarantee a successful national risk assessment as well as risk management process several risk identification methods and various core considerations are included in the recommended guidelines. The guidelines recommend by the European Union Commission will be updated on regular basis to fulfil and include the requirements for well adapted national risk assessment.

One of the major steps suggested for national risk assessment are the development of risk scenarios, accomplished during the identification phase. During the following stages, developed scenarios should be analyzed and evaluated into detail. Where possible EU Member States should try to develop own quantitative methods to analyze the developed risk scenarios. "*The long term goal should be 50 to 100 scenarios*"[29] for each Member State. "*The time horizon for assessments should gradually be developed from the initial 1-5 years to comprising risks in the coming 25-35 years*"[30]. Cross-border risk should also be analyzed and included in the national risk assessment of EU Member States.

[26] Council of the European Union (2011), P. 3.
[27] IEC (2009), ISO 31000.
[28] Cf. IEC (2009), ISO 31010, P. 8.
[29] Swedish Civil Contingencies Agency (2011), P. 11.
[30] Swedish Civil Contingencies Agency (2011), P. 11.

One of the main objectives of created guidelines is a common risk assessment process over the whole territorial area of the European Union. This specific step would end in a common risk management process, where further elements are realized with a similar methodology.

2.1 Main Objectives of the Guidelines

Improving coherence and consistency along the risk assessment realized by EU Member States is one of the main objectives of the guidelines, especially in the level of prevention, preparedness and planning. So to prevent or mitigate shared risks coherent methods of national risk assessment should be realized[31].

A comparable risk assessment methodology would allow EU Member States to share their risk assessment outcomes among regions with common shared risks. This measure also results in more cooperation and collective collaboration. The actual situation does not allow such kind of measures, due to country-specific assessment, assumptions and impact criteria. So a common sense is not given, but very useful.

A similar EU wide risk assessment has the benefit of consistency and comparability, ending up in more transparency and tractability. The guidelines created by the European Union Commission for national risk assessment and mapping have the following objectives[32]:

- Improvement for the use of good practices.
- Implementation of international standards across the EU, this measure should help to develop a common risk assessment methodology and terminology (Example terminology UNISDR[33]).
- The guidelines should help to develop a knowledge-based disaster prevention policies at various government levels.
- It should help to prioritize and allocate investments in risk management elements like prevention, preparedness, reconstruction measures and counter measures.
- The guidelines should support the development of EU wide risk assessment process. Furthermore it should support the creation of a common data base for emergency assistance.
- The guidelines should support the linking of risk management policy to threat and risk assessment decision making by 2014. This is communicated in the EU Internal Security Strategy In Action: five steps towards a more secure Europe.

With a common and comparable risk assessment process on EU level other benefits on various authority levels within attending EU Member States will be recognizable[34]:

- More effective and efficient collaboration between municipalities in assessing and treating common risks.
- More effective and efficient collaboration with state agencies and community organizations in assessing risk as well as evaluating and enhancing controls.

[31] Cf. Council of the European Union (2011), P. 6.
[32] Cf. Council of the European Union (2011), P. 7.
[33] UNISDR (2009).
[34] Cf. Australian Government et.al (2012), P. 5.

2.2 Basics of Risk Assessment

The guidelines created by the EU commission are mainly dialling with the subject of risk assessment. As mentioned before risk assessment is a core element of an overall process of risk management. Based on this core element further investigations and measures are carried out. "*Risk assessments deal with uncertainty and probabilities. These are the necessary subjects of a rational debate about the level of risk a Member State, or even the entire EU, may find acceptable when considering the costs of associated prevention and mitigation measures*"[35].

Generally the development of risk assessment is not a stand-alone process, many actors, facts, factors and parameters influence this process. For this purpose some of the most essential elements related to risk assessment will be introduced in the following few pages. The process of national risk assessment should have following characteristics[36]:

- Objective
- Comprehensive
- Based on the most robust available evidence

2.2.1 Purpose of Risk Assessment

The main purpose of creating a risk assessment is to understand possible risks based on authentic and reliable information. So treatment, selections of possible options and decision making could be realized in a more accurate way. Further benefits resulting out of this process are[37]:

- Risk and corresponding impact potential are clarified.
- Outcomes of this process are the fundament for decision making process.
- Possible treatment options are clarified and could be probably selected.
- Outcomes can be compared to treatment or elimination options.
- Monetary analysis can be performed according to outcomes (risk scenarios).

2.2.2 Stakeholder and Involved Parties

To develop a representative and reliable risk assessment, thus risk management, a wide range of stakeholders should be involved during the development process. As mentioned before it a complex matter and not a standalone process. So coordination of involved parties is a very important point to be considered. For the purpose of coordinating national risk assessment one authority must be specified at the beginning of the process. It could be the same authority coordinating the national risk management.

Due to variety of threats and disasters a number of working groups have to be created to cover different disciplines within the whole process. Furthermore different levels of authorities like federal, regional and national has to be involved. This clearly demonstrates that coordination is one of the key factors for successful national risk assessment procedure.

[35] Council of the European Union (2011), P. 6.
[36] Cf. Council of the European Union (2011), P. 12.
[37] Cf. IEC (2009), ISO 31000, P. 7 and 8.

Generally stakeholders can be classified into three major groups. It has to be mentioned that those groups are slightly overlapping and a clear separation is not always possible[38]:

1. Stakeholders affected by the threat or disaster
2. Stakeholders how contribute special knowledge in the field of risk assessment
3. Stakeholder relating to jurisdictional authority

The European Union Commission guidelines recommend a minimum number of stakeholders for the development of a national risk assessment. Those parties should be selected out of different fields as illustrated above. The aim is to create a common understanding of the risk and surrounding processes. The stakeholders who have to be at least involved are[39]:

- Public authorities
- Research experts
- Business experts
- Non-governmental organizations (NGO)
- Wider general public

The planning and developing of national risk assessment under pressure should be avoided. This can be achieved through characterises presented in the introduction of chapter 2.2 (objectivity, comparatively and readability) as well as adequate time planning. The involved stakeholders should build up several fundamental point[40]:

1. Agree and remain at scoring criteria defined at the beginning of the process.
2. Record implemented methodologies. Furthermore the level of uncertainty for each used methodology has to be evaluated and documented.
3. Note the justification for including or excluding specific risks.
4. The scores of allocated risks should be evaluated and recorded.
5. Work out a protocol recommending selected expert opinion.

2.2.3 Public Consultation and Communication

Stakeholders and authorities on all governmental levels (national, federal and regional) should be consulted with the drafting of the risk assessment. Through this specific measure policy makers could ensure, to a certain degree, the acceptance of risk assessment methodology and resulting outcomes. Even stakeholders who are not directly or partly involved in the process of development should be consulted. This measure has to be coordinated by the responsible authority, to generate reliable outcomes. The involvement of stakeholders in the risk assessment and risk management process has several positive effects[41]:

- Development of a communication plan.
- Definition of the context is carried out in an appropriate way.
- Interests of stakeholders could be better understood and considered. Ensuring more satisfied stakeholders.
- Through various levels of experience and various fields of experience of involved stakeholders different areas of risk identification and analysis are brought together, ending up in more reliable outcomes.
- More effective risk identification.

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[38] Cf. National Emergency Management Committee (2010), P. 17.
[39] Cf. Council of the European Union (2011), P. 12.
[40] Cf. Council of the European Union (2011), P. 12.
[41] Cf. IEC (2009), ISO 31010, P. 9.

- Insuring the support in implementing the treatment plan.

Several measures have to be realized along the development process of national risk assessment. The first is the publication of potential risk scenarios. This has the main purpose to inform population about possible measures and actions for emergencies. Furthermore this helps the population to protect themselves, because they have a clue what they could face and what emergency measures should carry out.

A second action is the permanent communication of risks with the stakeholders and general public. This measure could be easily realized through publication of hazards maps. The third measure is the cooperation with the private sector. This could lead to a significant input increase, as the private risk assessment could complement this of the public authorities, ending up in more reliable results as well as decreased uncertainty[42].

2.2.4 Reporting

The reporting to wider public range, stakeholders and involved parties is essential. This specific measure is realized after risk assessment process is completed and should secure that all parties have understood the procedure as well as possible outcomes. Reporting could create an additional value to national risk assessment process through possible feedback of informed parties. As mentioned before risk assessment and risk management process are cyclic once and are repeated in certain time lags. So implementation of feedback outcomes is realistic, possible as well as recommended. A risk assessment report should at least have the below mentioned elements[43]:

- Clear objective of the process
- Scope of risk assessment
- Stakeholders involved within the process
- Identified and used risk criteria
- Possible disasters and corresponding impacts
- Justification of accomplished work

2.2.5 Data

Various sources of data have to be utilized to create a representative national risk assessment. The challenges within this specific step are[44]:

- Data transparency
- Data reliability
- Data documentation
- Data Compatibility

A great number of data are still missing, because assessments of likelihood and impact for different types of disasters and threats are scarce. This simple fact ends up in more assumptions and estimations utilized during the development of national risk assessment. This type of uncertainty should be minimized and should have a large priority.

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[42] Cf. Council of the European Union (2011), P. 13.
[43] Cf. National Emergency Management Committee (2010), P. 19.
[44] Cf. Council of the European Union (2011), P. 13.

For this purpose EU Member States should try to be in line with the Infrastructure for Spatial Information in the European Community Directive (INSPIRE). This "*will help to ensure that spatial data infrastructures being developed in Member States will contribute to enhancing the usability of national data necessary for risk assessment*"[45].

A further important source of data is Global Monitoring for Environment and Security (GMES), which are encouraging the interoperability of data. Another aspect is the collecting of personal data, which should always be carried out under compliance with the Directive 95/46/EC[46]. Directive 95/46/EC regulates the "*protection of individuals with regard to the processing of personal data and on the free movement of such data*"[47].

Data and information about identification of new risks, development of scenarios, analyzing impacts, scouring impacts, likelihoods, assessing effects of prevention and mitigation measures are mainly provided by experts. So they create a very important pillar of the whole procedure. The selection, roles and mandates of experts should be carried out carefully, due to high influence on outcomes.

The procedure of data collection is also a cyclic once. The review of used data has to be performed on regular basis, to secure reliability. Whenever new data are implemented, this action has to be documented to ensure traceability and transparency of national assessment process.

2.2.6 Monitoring, Review and Reinforcement

Today measures, risks and methods could change within a short period of time, due to irresistible progress of science. So an important element of risk assessment and risk management are regular reviews. Measures, risks and methods should be always updated, to be fit for purpose.

Additionally "*The effectiveness of controls should also be monitored and documented in order to provide data for use in risk analysis. Accountabilities for creation and reviewing the evidence and documentation should be defined*"[48].

The aim of review is to verify[49]:

- Assumptions related to risks
- Assumptions used during the risk assessment process
- Conformation of outcomes
- Application of risk assessment techniques
- Effectiveness of risk treatment

Reinforcement of risk assessment should be carried out at least every 2 years. This is identified as the maximum period of reinforcement and is performed in that way by various EU Member States. Earlier reinforcements were performed every 5 years, but through the very fast development of society and due to massive changes in worldwide climate, 2 years is a reliable time lag. Several EU Member States are thinking about reinforcements within one year, but studies showed that this could be to a certain degree counterproductive and resource intensive.

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[45] Council of the European Union (2011), P. 14.
[46] European Parliament et.al (1995).
[47] Council of the European Union (2011), P. 15.
[48] IEC (2009), ISO 31010, P. 17.
[49] Cf. IEC (2009), ISO 31010, P. 11.

2.2.7 Documentation

The documentation of risk assessment process and corresponding outcomes is very important, for traceability as well as transparency reasons. Extend of documentation is strongly depending on objectives and scopes of realized assessment. In the case of national risk assessment the documentation should include[50]:

- Objective and scope of risk assessment
- Description of structure and relevant parts (including their function)
- Summary of context (internal and external)
- Implemented risk criteria, including explanation
- Used data and assumptions, additionally the source of them
- Risk analysis results and risk evaluations
- Description of used methodology for sensitivity and uncertainty analysis and their outcomes
- Used references
- Decisions made during the whole process

2.2.8 Uncertainty

Each realized risk assessment shows a certain degree of uncertainty. Those uncertainties have to be clarified and communicated to relevant parties and authorities. Determination of the inexactness in results is one of the main objectives of an uncertainty analysis. The inexactness results out of variations in utilized assumptions and parameters. They can also result from inaccurate results of intermediate steps. So it is necessary to identify the sources of uncertainty, especially those with increased sensitivity against the assessment.

Sensitivity Analysis

"*Sensitivity analysis is used to determine how sensitive a model is to changes in the value of the parameters of the model and to changes in the structure of the model*"[51]. In other words determination of size and significance of the degree of risks changes of individual input parameters is the main task of the conventional sensitivity analysis. The sensitivity analysis can make a contribution to establish whether the assumptions underlying a prediction are strong or not. If not further information needs to be collected[52].

Precautionary Principle

"*Where the scientific evidence is weak the precautionary principle can justify inclusion of relevant risks assessed on a qualitative basis especially when risks to the environment, human, animal and plant health are involved and where the consequences are likely to be substantial and irreversible and the likelihood of the occurrence of a negative consequence cannot be assessed*"[53]. Objectivity and transparency should create the basis of any precautionary actions realized.

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[50] Cf. IEC (2009), ISO 31010, P. 17 and 18.
[51] Breieroua et.al (2001), Page 46.
[52] Cf. Saltelli et.al (2004).
[53] Council of the European Union (2011), P. 32.

2.2.9 Risk Mapping

Information about hazards, vulnerabilities and risks in a certain area of interest can be attractively presented in Maps. Maps are an important tool to support the risk assessment process and strategy on national as well as European Union level. Through the visualization decision makers can set a certain priority for risk reduction measures and strategies. Through the used maps it is guaranteed that involved parties have common information for their assignment[54].

Risk Mapping is a very complex process. The mapping of natural hazards is very advanced through the GIS techniques, but a lot of accumulated needs for social, economic and environmental issues are recognizable. The weakness and challenges of risk mapping practices in Europe were reviewed and identified by Carpignano et al[55].

The European Union Commission recommends in the developed guidelines a step by step approach to carry out an accurate risk mapping[56]:

- Distribution of major hazards through maps, whereby different hazards and intensities should be presented in disconnect maps or in various colours.
- Spatial distribution of all relevant elements that need to be protected should be presented.
- A map with spatial distribution of vulnerability in terms of susceptibility to damage should also be prepared.

All the above mentioned maps should also be prepared to show the likelihood and impact of a certain event analyzed.

[54] Cf. Council of the European Union (2011), P. 34.
[55] Carpignano et.al (2007).
[56] Cf. Council of the European Union (2011), P. 35.

2.3 Risk Assessment Process

This chapter processes the most important methodologies for the development of a national risk assessment. The core elements which will be treated are establishment from framework, basic methodology, risk identification, risk analysis as well as risk evaluation. As mentioned before risk assessment is one of the core elements of risk management process. Based on the outcomes of risk assessment further steps are carried out on the risk management process (example: risk treatment).

In Figure 1 a typical workflow of a risk assessment is presented. It can be clearly recognized that the risk assessment, in its simplest form, is mainly consisting of three steps. Those steps are constitutive and depending on each other. Mistakes and incorrect outcomes of any step have a negative influence on the whole risk assessment and would end in an increase of uncertainty. The main components of risk assessment are risk identification, risk analysis and risk evaluation.

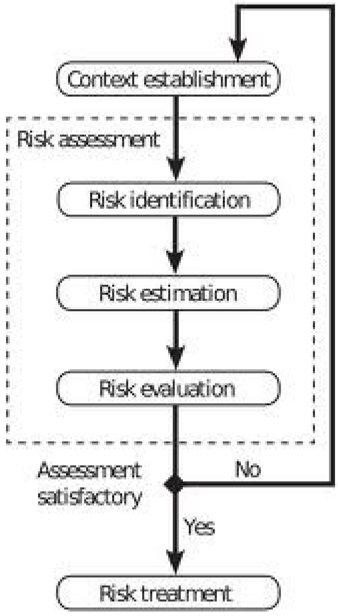

Figure 1: Typical risk assessment workflow[57].

2.3.1 Core Elements

Risks

Risks are defined as a combination of consequences of an event and associated likelihood of occurrence "*When the extent of the impacts is independent of the probability of occurrence of the hazard, which is often the case for purely natural hazards, such as earthquakes or storms, risk can be expressed algebraically as: Risk = hazard impact * probability of occurrence*"[58].

But having the case where the two terms are depending on each other (impact influences the likelihood), the formula to express risks changes as illustrated below to a functional relationship:

[57] Cf. BMC Services Research (2011), Access 23.09.2013.
[58] Council of the European Union (2011), P. 16.

"*Risk* $= f(p*E*V)$"[59].

Risk is a function of probability of occurrence of a specific hazard, the exposure (total value of all elements at risk, including people, property, systems, etc), and the vulnerability "*V is defined as the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard*"[60]. Increasing complexity of the model and number of involved factors is advisable, to improve certainty. The use of more assessments and expert opinion helps to improve resource efficiency and transparency.

Impact Categories

The guidelines recommended by the European Union Commission defined three major types of impact categories, which should be at least treated during national risk assessment. Those three types could be adapted or additional types could be included depending on requirements of specific national risk assessment.

1. **Human impacts**. This should reflect quantity of people affected by the disaster or threat. Human impacts can be further subdivided into death, injury or illness and displacement of people.
2. **Economic and environmental impact**. This impact criteria should reflect the total expenditures for healthcare, expenditure for emergency measures (immediate and long term), expenditure for reconditioning of buildings, public transport system and infrastructure. Furthermore expenditures related to the environment considering all aspects are taken into account. All direct and indirect expenditure which caused by the disaster or threat are considered under this impact category.
3. **Political and social impact**. Those types of impacts often cannot be captured with quantitative scales and even not in single units. In this case other methodologies, as semi quantitative, have to be utilized. Under those impacts the guidelines understand categories as "*encroachment of the territory, infringement of the international position, violation of the democratic system, and social psychological impact, impact on public order and safety, political implications, psychological implications, and damage to cultural assets and other factors considered important*"[61].

In advanced national risk assessments procedures six major impact categories are implemented[62]:

- People
- Environment
- Economy
- Social setting
- Public authority
- Infrastructure

Each of the impact categories recommended by the EU Commission can be measured in different ways. For example human impact is mainly measured with number of effected people, economical and environmental impacts can be evaluated with damage value in Euro. Semi-quantitative scales has to be utilized for political and social impacts, examples

[59] Council of the European Union (2011), P. 16.
[60] Council of the European Union (2011), P. 16.
[61] Council of the European Union (2011), P. 17.
[62] Cf. Australian Government et.al (2012), P. 10.

are presented below from small to large impact scale. Those classifications should be based on objective criteria[63]:

- Limited/ insignificant
- Minor/ substantial
- Moderate/serious
- Significant/ very serious
- Catastrophic/ disastrous

Each of before illustrated impact categories should be presented separately in a risk matrix. This measure results in a better comparability between the created scenarios on national and EU level. Double counting of impacts has to be avoided, because this fudges the results completely. So limitations and exact definition of area of interest would help to avoid this problem. In general empirical evidence and experience should be the fundament of impact analysis. Any assumption or estimates utilized during the process has to be clearly communicated.

The determination of each single impact category has its own challenge and experience made during the procedure should be documented to support future European Union wide risk assessment and other EU Member States. All impacts should be considered for two terms: The short term immediately after disaster or threat and midterm. All values calculated should be presented in today´s value, thus Net Present Value (NPV).

Risk Matrix

A risk matrix is a simple visualisation tool to present risks in a representative and comparative form. It consists mainly of two dimensions: Likelihood and impact. Each of the mentioned dimensions has to be evaluated according to best practice and methodologies available. The most important source of data to carry out the assessment of likelihood and impact are:

- Historical data
- Statistical data
- Expert opinions

Identified risks and risk scenarios are presented within the matrix according to their likelihood and impact. The scale of each dimension is depending on several factors and could be linear or logarithmic. It is important to keep the same scale during the whole process of actual and future risk assessments (for comparability reasons). Out of those two dimensions a certain position within the matrix is allocated.

The matrix is divided into several coloured zones. Those zones should help in the decision making process, because they help to accomplish a ranking of implemented risks or risk scenarios. The coloured zones indicate the level of risk. Most of the risk matrices consist of four zones:

- Green   low risk level
- Yellow   intermediate risk level
- Orange   high risk level
- Red   very high risk level

[63] Cf. Council of the European Union (2011), P. 17.

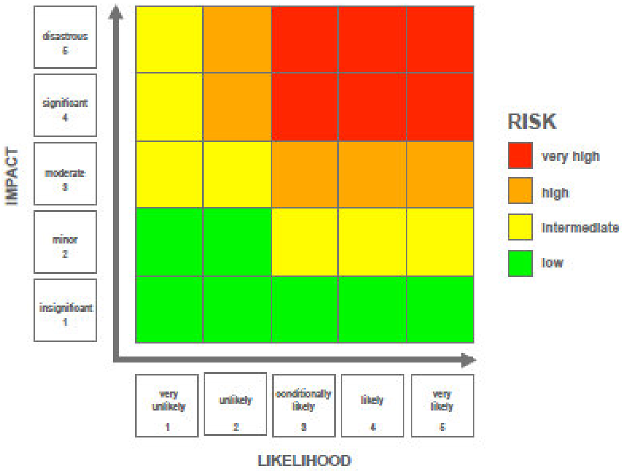

Figure 2: International risk matrix[64].

2.3.2 Establishment of Context

Establishing the context is one of the first processes realized during risk assessment. "*Establishing the context defines the basic parameters for managing risk and sets the scope and criteria for the rest of the process. Establishing the context includes considering internal and external parameters relevant to the organization as a whole, as well as the background to the particular risks being assessed*"[65]. During the process of establishment context, risk assessment objectives, risk criteria and risk assessment program are clarified as detailed as possible.

Figure 3: Process of context establishment[66].

As mentioned before the establishment of context should include[67] [68]:

- **Establishing external context**: Including cultural, political, legal, regulatory, financial, economic and competitive environment factors, not only in national but also in international context. Furthermore key factors influencing the objectives of the organization or system.

[64] Cf. Federal Office of Civil Protection and Disaster Assistance (2011), P. 22.
[65] IEC (2009), ISO 31010, P. 9.
[66] Cf. National Emergency Management Committee (2010), P. 16.
[67] Cf. IEC (2009), ISO 31010, P. 9 and 10.
[68] Cf. IEC (2009), ISO 31000, P. 5, 16 and 17.

- **Establishing internal context**: Including capacities of organization or system according to resources as well as knowledge. Definition of internal objectives, strategies, policies and processes. Furthermore the structure of the organization or system has to be clarified.
- **Establishing risk management context**: Definition of accountabilities, responsibilities, activities, methodologies, risk criteria as well as performance evaluation methodology.
- **Establishing risk criteria**: Involving measurement of nature and type of consequences, expected probabilities and level of risk, treatment and acceptance criteria.

2.3.3 Risk Identification

As mentioned before the specific part of national risk assessment process is composed of the following three steps:

1. Risk identification
2. Risk analysis
3. Risk evaluation

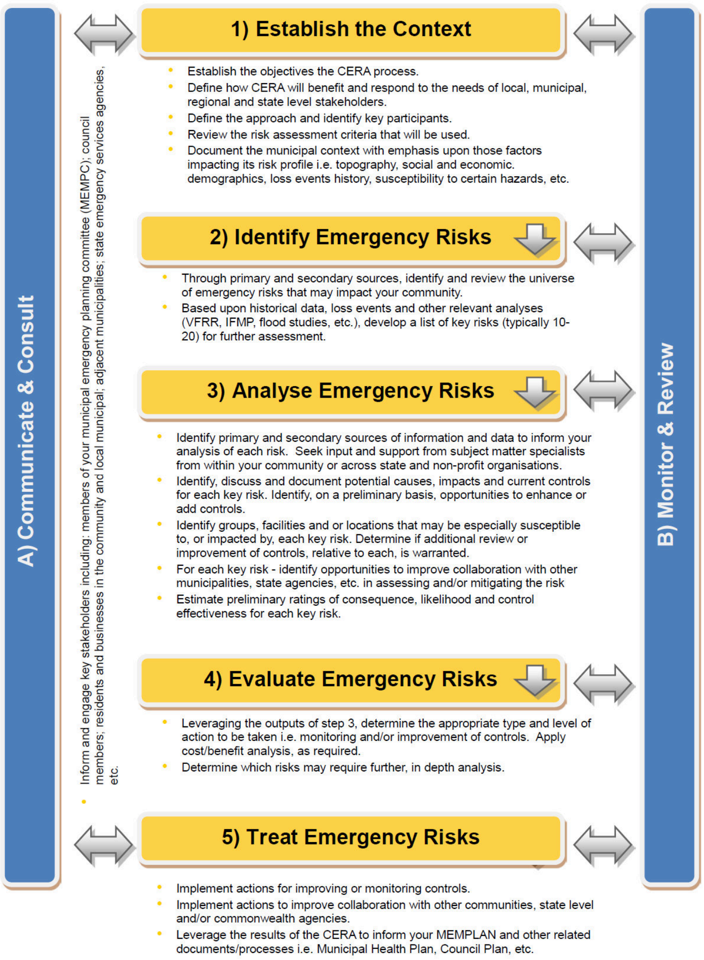

Figure 4: Stages of risk assessment presented in the context of risk management process[69].

[69] Cf. Australian Government et.al (2012), P. 4.

The first element to be processed is risk identification. Risk identification is defined by the guidelines as "*the process of finding, recognizing and describing risks. It is somehow a screening exercise and serves as a preliminary step for the subsequent risk analysis stage the process of finding, recognizing and describing risks*"[70]. Within this step European Union Member States should identify[71]:

- Sources of risk
- Areas of impacts
- Events and their causes
- Potential consequences

Generation of a comprehensive list of risks is the major aim of this step. This should be based on "*those events that might create, enhance, prevent, degrade, accelerate or delay the achievement of objectives. It is important to identify the risks associated with not pursuing an opportunity. Comprehensive identification is critical, because a risk that is not identified at this stage will not be included in further analysis*"[72]. Quantitative historical and statistical data should create the fundament of risk identification. Also qualitative methods can be used to fulfil the purpose of hazard identification. In following some examples of qualitative methods are shown[73]:

- Expert opinions
- Intelligence information
- Check-lists
- Systematic team approaches
- Inductive reasoning techniques
- Delphi methodology

Other techniques could be[74]:

- Brain storming
- Questionnaires
- Scenario analysis
- Risk assessment workshop
- Hazard investigation
- Auditing and inspection

So at the end of this stage a report with outcomes is prepared. In this report identified risks and risk scenarios are presented, described and prepared for the next stage to be analyzed into more detail. Especially risk scenarios have to be explained into detail, due to possible complex structures.

Risk Scenarios

Risk scenarios are core elements of risk identification and have significant influence on the whole risk management process. In the most preferable case risk identification should consider all eventual hazards and corresponding probabilities. Due to complexity of some situations with multi-hazard or multi-risk situation the preparation of scenarios should be accomplished. This helps to reduce possibilities to a certain number of identified situations.

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[70] Council of the European Union (2011), P. 20.
[71] Cf. National Emergency Management Committee (2010), P. 24.
[72] IEC (2009), ISO 31000, P. 17.
[73] Cf. Council of the European Union (2011), P. 20 and 21.
[74] Cf. Andrew L. Smith (2007), P. 8.

"*A risk scenario is a representation of one single-risk or multi-risk situation leading to significant impacts, selected for the purpose of assessing in more detail a particular type of risk for which it is representative, or constitutes an informative example or illustration*"[75]. Scenarios are created through experiences from the past and possible future events. A scenario creates a simplification of reality, so the use of assumption is volitional. Those assumptions have to be communicated and documented, so they can be reviewed and updated if required.

To obtain a minimum degree of coherence between the various national risk assessments the guidelines define specified levels of impacts and certain hazards probabilities. The risk scenarios provide fundamental information during the risk identification phase and also at risk analysis stage. Risk scenarios should at least try to describe[76]:

- The hazardous event into detail, with likelihood and impact
- Processes involved in scenario building
- Context of hazardous event
- Consequences of hazardous event
- Influence on predefined impact criteria

Single-risk and Multi-risk Assessments

A number of distinctions within the scenario development are introduced for the purpose of risk identification and risk analysis. Generally two types of scenarios could be described:

- **Single risk assessment**: This assessment is carried out for the case of one risk from a specific hazard. This is realized for a defined area during a certain period of time.
- **Multi risk assessments**: This type of assessment concludes from several hazards and their total risk. Two views could be used depending on circumstances. The first is that risks are caused by one triggering event and that risks are occurring at the same time (thus, depending on each other). The second view is that the risks are threatening the same element of impact criteria. Each of the single risk has a different source type[77].

Examples for risks related to the first view are a landslide triggered by a flood or triggered by a rain storm. This type also is referred to follow-on events or domino effect events. In this case the likelihood of the event must be correlated to the likelihood of occurrence of the following event. For this specific case the assessment has to consider the cumulative impact of all events. In most regions of the European Union this approach is suitable.

Risk Identification in the Context of National Risk Assessments

The national risk assessments create the fundament for an overview of probable future risks accruing within the European Union. Due to the conclusion that each Member State has a different level of advancement in their national risk assessment, the guidelines recommended a step-wise approach, to secure constancy[78]:

1. **Scenario building**. It is an essential and one of the most important steps. A minimum degree of common understanding is required to secure the comparability be-

[75] Council of the European Union (2011), P. 21.
[76] Cf. Ministry of the Interior and Kingdom Relations, (2009), P. 17.
[77] Cf. Council of the European Union (2011), P. 22.
[78] Cf. Council of the European Union (2011), P. 24.

tween EU Member States. One common point to be considered (threshold value) is that events with a probability of 1% or more have to be implemented into the national risk assessment process. Another one is relating to expenditure level, if the damage or impact exceeds more than 0.6% of gross national income (GNI) of an EU Member State it has to be considered.

2. **Extent of quantitative analysis**.
3. **Number of risks and risk scenarios considered**. For the first risk identification process a number of 50 to 100 scenarios is expected depending on the size of the Member State.
4. **Temporal horizon**. Immediate future has to be the main period of investigation. In this case the guidelines recommend investigation one to five years ahead. Also assessments for longer periods (25 to 35 years) are very useful but secondary for first cycle of national risk assessment. Long term investigations are used to evaluate possible trends and to create a global perspective and identify international interdependencies.

2.3.4 Risk Analysis

Risk analysis is utilized for "*[…] developing an understanding of the risk. It provides an input to risk assessment and to decisions about whether risks need to be treated and about the most appropriate treatment strategies and methods*"[79] or in other words it "*is the estimation of the risk associated with the identified hazards. It is the qualitative or quantitative process of linking the likelihood of occurrence and severity of harms*"[80].

A detailed estimation of probability of occurrence and degree of impact or damage is realized for each risk and risk scenario identified in the stage of risk identification. If possible that estimation should be on quantitative basis. The definition of geographic range for the analyzed risk scenario is a major step during the risk analysis. This specific measure should help to limit possible outcomes to a certain level for better handling. With advancing procedure more areas could be acquired and implemented into the assessment.

One of the major concerns during the process is the so called double-counting of impacts. So implementation of additional areas has to be accomplished very carefully to avoid this specific problem. Double-counting could lead, in extreme cases, to failure of risk assessment or into massively increased uncertainty of outcomes. It has to be mentioned that "*Risk analysis can be undertaken with varying degrees of detail, depending on the risk, the purpose of the analysis, and the information, data and resources available. Analysis can be qualitative, semi-quantitative or quantitative, or a combination of these, depending on the circumstances*"[81].

Two points have to be worked out carefully[82]:

- **Probability** of an event or hazard is the first. Historical occurrence of nearby events should be one of the main pillars for assessment of event or hazard probability. Relevant statistical data provide the second pillar. Those help to verify possible trends of probability for the main drivers of a certain event or hazards.
- **Impact** assessment is the second point to be worked out. This should be realized based on predefined impact criteria (chapter 2.2).

[79] IEC (2009), ISO 31010, P. 13.
[80] EMA (2011), P. 6.
[81] IEC (2009), ISO 31000, P. 18.
[82] Cf. Council of the European Union (2011), P. 25.

Both points have to be worked out based on most reliable quantitative data. In the case where the risk analysis is processed with qualitative data, "*there should be a clear explanation of all the terms employed and the basis for all criteria should be recorded*"[83]. Generally the risk assessment should be realistic and as objective as possible. Uncertainty of underlying evidence has to be document and recognized in any case or stage of the national risk assessment. Furthermore communication of uncertainty with involved parties has to be carried out on regular basis.

An essential element of risk analysis is the identification of controls and measures in place for specific risks. It is important to evaluate adequacy and effectiveness of those controls, so the most important questions to be asked[84]:

- Actually available controls for a specific risk
- Capacity and effectiveness of actual controls

Generally three major types of controls are identified[85]:

1. **Behavioural controls** are based on behaviour and experience of involved humans.
2. **Procedural controls** are an extension of behavioural controls with approved approaches from a risk management system.
3. **Physical controls** are not requiring human acting. They are carried out passively or automatically.

Two different types of analysis are realized during the risk analysis. They will be explained in detail within the next few pages. The performed types are essential for the differentiation during the national risk assessment process.

Single Risk Analysis

Within the single risk analysis natural and man-made hazards are analyzed, not dependant on other hazards or risk scenarios. There are various types of risk analysis procedures, depending on the type of risk processed, examples are: floods, industrial accidents, infrastructure and others. So it is important to have a specific procedure of single risk analysis. The main function is to guarantee a minimum level of coherence between the various EU Member States risk assessments.

At the end of single risk analysis process, all single analyzed risks come together in a risk maps. This measure should help to realize a fast and effective overview of single analyzed risks. In general the national risk assessments should at least address the following points when realizing risk analysis[86] (single or multiple risk analysis):

- For hazards analysis
    - Geographical investigation (location, extent)
    - Sequential analysis (frequency, duration, etc.)
    - Dimensional analysis (scale, intensity)
    - Likelihood of happening
- Vulnerability analysis
    - Recognition of elements and people potentially at risk (exposure)

[83] IEC (2009), ISO 31010, P. 13.
[84] Cf. IEC (2009), ISO 31010, P. 14.
[85] Cf. National Emergency Management Committee (2010), P. 26.
[86] Cf. Council of the European Union (2011), P. 27.

- Recognition of vulnerability factors/ impacts (physical, economic, environmental, social/political)
- Assessment of likely impacts
- Examination of self-protection capabilities

Depending on overall quality of risk identification, several risks can then be considered within the national risk assessment. Any additional risks and risk scenarios which are evaluated during the process should be immediately implemented into the ongoing work.

Multi Risk Analysis

Taking account of possible follow-on effects must be realized very adequately. This task is very difficult to ensure, but is essential to identify the most probable events out of a certain scenario. Not only natural hazards, but also follow-on effects on infrastructure (pipe lines, roads, etc) and effects on social life have to be considered. This should help to create adequate picture of the risks and corresponding consequences.

So it is essential to understand within the multi risk analysis the interdependency of hazards and risks. For this purpose several amplifications has to be realized, to get the most probable scenario and following effects. During the multi risk analysis the vulnerability of the below mentioned sensitive targets has to be analyzed in detail[87]:

- Population
- Transport systems
- Infrastructure
- Buildings
- Cultural heritage
- Economics

It is for sure possible to integrate single risk analysis into multi risk analyses, but this procedure will addict a massive challenge in realizing. Single risk analyses could have other point of departure (different time windows, different typologies of impacts, etc) than the currently performed multi-risk analysis.

Another challenge is the coordination and interfacing between involved authorities and agencies. Each of them is dealing with a specific hazard during the multi risk assessment, without working on a complete overview of the multi risk scenario. The EU guidelines are not providing a certain method to deal with the challenges of multi risk assessment, but they recommend several steps to be carried out for this purpose[88]. Those are also presented in the Principles of Multi-Risk Assessment edited by European Commission.

- The first is the detection of possible multi hazard scenarios. In the case of multi risk analysis the responsible authorities should start with a top event and evaluate the possible triggering of other hazards or events ending in additional hazards.
- Second recommendation is to carry out an exposure and vulnerability analysis for each individual hazard and risk. That analysis should be realized for different branches within investigated scenarios.
- For multi risk scenarios a risk estimate for each hazard and adverse event should be carried out.

[87] Cf. Council of the European Union (2011), P. 28.
[88] Cf. Council of the European Union (2011), P. 28.

Preliminary Analysis

During the procedure of risk analysis the most significant and minor risks are identified. A preliminary analysis of those risks should help in deciding if they should be further investigated. This specific analysis is carried out to ensure that the recourses utilized are concentrated on the most important risks. It has always to be considered that miner risks with high frequency could also have a massive influence on predefined impact criteria. So a detailed screening has to be realized to[89]:

- Take a judgment about immediate treatment of minor risks without additional assessment.
- Identify risks which don´t need any treatment.
- Identify risks which have to definitely further processed in the national risk assessment.

2.3.5 Risk Evaluation

"*Risk evaluation is the process of comparing the results of risk analysis with risk criteria to determine whether the risk and/or its magnitude are acceptable or tolerable*"[90]. The evaluation of the risk is realized against risk criteria, which represent the term of reference. The criteria could include:

- Associated costs and benefits
- Legal requirements
- Socioeconomic and environmental factors
- Concerns of stakeholders

"*The International Risk Governance Council (IRGC) describes the objectives of risk evaluation as a judgment on the reliability and acceptability based on balancing pros and cons, testing potential impacts on quality of life, discussing different development options for the economy and society and weighing the competing arguments and evidence claims in a balanced way*"[91].

The risk evaluation is the fundament for prioritization of risks identified in former stages of risk assessment[92]. "*How risk evaluation is conducted and used depends on the objectives of the risk assessment process and available resources, and on the nature of the hazard and its amenability to measurement and quantitative analysis*"[93].

For a successful risk evaluation frameworks have to be in place to define the risk criteria. One of the simplest frameworks provides only one criterion. Risks are allocated if they need treatment or not. This simple approach has a large disadvantage, because it does not indicate the uncertainty the user is dealing with.

For this purpose the European Union provides several frameworks and prevention standards, which could be used to support the creation of a successful risk evaluation. Some of those frameworks are presented be in Table 1. Other frameworks and prevention standards are actually under development or not available.

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[89] Cf. IEC (2009), ISO 31010, P. 15.
[90] Council of the European Union (2011), P. 30.
[91] Council of the European Union (2011), P. 30.
[92] Cf. Swedish Civil Contingencies Agency (2011), P. 17.
[93] OECD (2012), P. 37.

Type of hazard	Framework
Forest fires	Eurocode 1 (actions on structures) defines protective design measures against fire for buildings made of various materials (steel, concrete, wood, masonry)
Ground movements	Eurocode 7 defines calculation and design rules for stability of buildings according to Geotechnical conditions of construction site (XP ENV 1997, PR EN 1997-2, ENV 1997-3)
Earthquakes	Eurocode 8: EN 1998-1 (general rules, seismic actions), EN 1998-3 (assessment and strengthening of buildings), ENV 1998-4 (reservoir, pipes), EN 1998-5 (foundations, structures), EN 1998-6 (masts, towers…)
Storms, Hurricanes	Wind resistant design of buildings is covered by Eurocode 1 - EN 1991-1-4

Table 1: Eurocodes for relevant natural disasters[94].

2.3.6 Risk Treatment

Generally the action of risk treatment "*involves selecting one or more options for modifying risks, and implementing those options. Once implemented, treatments provide or modify the controls*"[95]. Risk treatment is a cyclic process involving several essential points to be considered[96]:

- Assessment of risk treatment
- Identification of tolerable remaining risks
- Developing new risk treatment measures and controls
- Monitoring effect of risk treatment

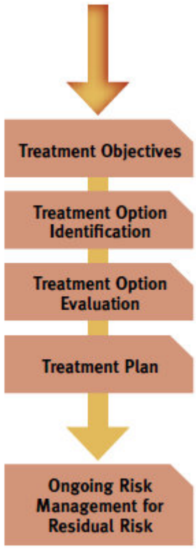

Figure 5: The process of risk treatment[97].

[94] Council of the European Union (2011), P. 30.
[95] IEC (2009), ISO 31000, P. 18.
[96] Cf. IEC (2009), ISO 31000, P. 19.

As illustrated in Figure 5 the process of risk treatment consists of several stages, which has to be carried out in the right order[98]:

1. Preparing of risk treatment objectives
2. Identifying, developing and designing of opportunities for risk treatment
3. Detailed evaluation of risk treatment opportunities
4. Development of reliable treatment plan
5. Implementation of risk treatment plan (risk management)
6. Monitoring of risk treatment controls and measures (risk management)

There are several options available for risk treatment. The most common treatments in general context are[99]:

- Elimination of the source of risk
- Modifying likelihood
- Changing of consequences
- Avoiding risk

The selection of risk treatment options has to be realized very carefully. Several essential points have to be considered throughout the whole process of risk treatment. One of the most important points to consider is the effectiveness of set controls and measures. This should be analyzed involving expenditures related to specific controls and measures. A good risk treatment option must show the highest value according to social responsibility and environmental protection.

Stakeholders should always be considered when implementing a counter measure to avoid or eliminate risk. Treatment plan communication to the stakeholders has a strong influence on acceptance of set measures. Monitoring of risk treatment performance has to be carried out on regular basis, due to risks coming from the risk treatment itself. Ineffective risk treatment could lead to an increase of risk and endangerment of population as well as environment.

[97] Cf. National Emergency Management Committee (2010), P. 47.

[98] Cf. National Emergency Management Committee (2010), P. 47.

[99] Cf. IEC (2009), ISO 31000, P. 19.

3 Risk Identification Methods

To support the process of risk assessment on national and European Union level the EU Commission suggested some risk identification methods based on the ISO 31000[100] and ISO 31010[101], which can be used to realize the national risk assessment and thus an adequate risk management. The presented methodologies are compared in terms of:

- Resources and capabilities
- Nature and degree of uncertainty
- Complexity
- Quantitative output

In the following the explanation of each single comparison criteria is presented:

- **Resources and capabilities**: Under this criteria required skills, experience, capacity and capability of the risk assessment team, to utilize the method, is indicated. Furthermore time, resources and budget constraints relating to selected method are considered.
- **Nature and degree of uncertainty**: An understanding of quality, quantity and integrity of information has to be given. This should go into detail and information about extent, sources as well as causes of the risk should be available. The uncertainty is resulting out of data quality and data collecting method used. The nature of uncertainty can be classified into two major types, external and internal uncertainty. Uncertainty has always to be communicated on regular basis to involved parties. This criterion indicates how large the uncertainty of applying methodology is.
- **Complexity**: With these criteria the complexity of risk should be indicated. The risks could be singular risks or risks which have strong connection to others (complex systems). "*Understanding the complexity of a single risk or of a portfolio of risks of an organization is crucial for the selection of the appropriate method or techniques for risk assessment*"[102].
- **Quantitative output**: This should indicate how quantitatively the outputs of selected risk identification method are. In general it is preferred, but not required, to apply quantitative methods for risk identification. In some cases it is not possible so application of semi-quantitative and qualitative methods is required.

Selecting adequate risk identification technique is very important, due to the influence on outcomes of national risk assessment. Selection of a wrong risk identification method could lead (in extreme cases) to a failure of the whole risk assessment process and thus failure of risk management, with undesired consequences to human and environment. Some basic characteristics have to be notified when selecting a risk identification method[103]:

- The method should be convenient to organization or system under investigation.
- Outcomes should clarify nature of risk. Additionally the methodology should indicate possible risk treatments (controls and measures).
- The selected method should be traceable, repeatable, verifiable and objective.

[100] Cf. IEC (2009), ISO 31000.
[101] Cf. IEC (2009), ISO 31010.
[102] IEC (2009), ISO 31010, P. 19.
[103] Cf. IEC (2009), ISO 31010, P. 18.

- Outcomes of the methodology are preferred to be quantitative.
- Selection should be based on quality and requirements of assessment.

Presented risk identification methods are subdivided into several categories, which are described shortly in the corresponding chapter.

1. Look-up methods
2. Supporting methods
3. Scenario analysis
4. Function analysis
5. Controls assessment
6. Statistical methods

3.1 Look-up Methods

Look-up methods				
Risk assessment technique	**Resources and capabilities**	**Nature and degree of uncertainty**	**Complexity**	**Quantitative output**
Check-lists	Low	Low	Low	No
Preliminary hazard analysis	Low	High	Medium	No

Table 2: Summary of look-up methods for risk identification.

3.1.1 Check Lists

Check lists are one of the simplest forms of risk identification. During this technique a listing of typical uncertainties to be considered is carried out. "*They may be used as part of other risk assessment techniques but are most useful when applied to check that everything has been covered after a more imaginative technique that identifies new problems has been applied*"[104]. Check lists could be created out of experience of involved parties or as a result of former realized assessments. The outcomes of this methodology are differing depending on application; examples could be a list of controls and measures which could be utilized to eliminate or reduce the impact of a specific risk.

3.1.2 Preliminary Hazard Analysis (PHA)

Preliminary hazard analysis (PHA) represents a simple inductive method. The main purpose of this methodology is to identify hazards, hazardous situations and contributing events. Through this method the harm to an activity, facility or system can be identified, based on the event. Furthermore ranking of hazards is possible and potential controls and measures could be reliably identified[105]. The procedure of a preliminary hazard analysis (PHA) consists mainly of four major steps[106]:

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[104] IEC (2009), ISO 31010, P. 30.
[105] Cf. Rausand (2005), P. 3.
[106] Cf. Rausand (2005), P. 7.

1. Preliminary hazard analysis (PHA) prerequisites
2. Hazard identification
3. Consequence and frequency estimation
4. Risk ranking and follow-up actions

Preliminary hazard analysis (PHA) has several advantages. One advantage is that this method could be utilized when limited data and information are available (to support another methodology). Furthermore it is possible to consider risks at a very early stage in a system or process lifecycle. Weakness of PHA method is that it only provides first round information, "*it is not comprehensive, neither does it provide detailed information on risks and how they can best be prevented*"[107]. The outcome of this methodology is a register of hazards and risks related to actual situation. Utilizing the preliminary hazard analysis (PHA) additionally results in recommendations for further investigations and assessments of unclear elements.

3.2 Supporting Methods

Supporting methods				
Risk assessment technique	**Resources and capabilities**	**Nature and degree of uncertainty**	**Complexity**	**Quantitative output**
Structured Interview and brainstorming	Low	Low	Low	No
Delphi technique	Medium	Medium	Medium	No
SWIFT Structured "what-if"	Medium	Medium	Any	No
Human reliability analysis (HRA)	Medium	Medium	Medium	Yes

Table 3: Summary of supporting methods for risk identification.

3.2.1 Brainstorming

Brainstorming is a creative problem solving method, which provides a makeshift to collect a number of ideas and evaluations. They are then ranked by a brainstorming team. This could be realized by one-on-one interview techniques or the most common one-on-many interview technique within a workshop. "*A good number of participants for a brainstorming session is between 6 and 12 people*"[108]. 12 Participants should not be exceeded, because then this methodology would be very time intensive. Under 6 participants the flow of ideas will be slow, but can still be very productive.

[107] IEC (2009), ISO 31010, P. 32.
[108] Balackova (2003), P. 39.

Each brainstorming season has to be carried out under predefined rules to guarantee constancy of this methodology. Brainstorming is usually utilized in combination with other risk assessment methodologies, due to its quick and easy establishment. Especially in the case when a risk identification team is in place for another methodology.

3.2.2 Structured and Semi-Structured Interviews

"*The purpose of conducting interviews is to collect information from a single person through a format that may range from structured, to semi-structured*"[109]. Generally there are two types of interviews in relation to risk identification methodology. The first are structured interviews, where the interviewed expert has to answer predefined questions. In this type of interview no variations are possible; additionally the degree of freedom in interacting is limited. The second type are semi-structured interviews, this type has a higher degree of freedom (related to utilized questions).

Interviews are utilized when brainstorming is impossible, due to geographical and time issues. This methodology can be applied at any stage of risk assessment and is processed based on predefined questions. Those questions should be related to a certain topic of interest and should be as simple as possible.

This methodology goes more into the depth, due to more time with the interviewing partner. Additionally a wider range of stakeholder could be involved, compared to brainstorming (maximum 12 participants). To guarantee the success of this methodology, several core elements have to be respected[110]:

- Creation of a friendly and opened interviewing environment
- Avoid asking leading questions (suggestion of particular answer)
- No debates or argumentations
- Interviewer should take good notes or record the interview

3.2.3 Delphi Technique

Delphi technique is a method based on the opinion of experts. "*A small monitor team designs a questionnaire which is sent to a larger respondent group*" [111]. Under support of those experts the source identification, influence identification, probability as well as consequence estimation of a risk could be realized. Delphi technique represents a collaborative technique, where the aim is to create a consensus among involved experts. So voting and opinions of involved experts is one of the core elements of the Delphi methodology.

If common expert's opinions are required Delphi methodology is applied. This method can be utilized at any stage of risk management process. The typical procedure of a Delphi technique is as follows[112]:

1. Creation of a team to perform and monitor the Delphi process
2. Selection of a group of experts associated to investigated topic
3. Formulation of questionnaires for the first round
4. Testing of formulated questionnaires

[109] Watkins et.al (2012), P. 106.
[110] Cf. Watkins et.al (2012), P. 109.
[111] Turoff et.al (2002), P. 5.
[112] Cf. IEC (2009), ISO 31010, P. 29 and 30.

5. Individually sending of questionnaire to involved experts
6. Results and outcomes from first round are analyzed and combined
7. Respond to involved experts
8. Repetition of the process until consensus between involved experts is reached

The output of this specific methodology is an opinion unification of involved experts about the investigated topic. Disadvantages of this method are that it is very time consuming and involved parties have to be very good at expressing their opinion by letter (only written communication). Advantages are that all opinions are treated equally (strong personalities are eliminated), unpopular opinions are phrased (no opposition as in a meetings or workshop) and involved experts do not have to come together[113].

3.2.4 SWIFT Structured "what-if"

SWIFT Structured "what-if" represents a method where a group is promoted to identify risks, usually accomplished during facilitated workshops. This method is normally linked to predefined risk analysis and evaluation technique[114]. "*The structured what-if checklist (SWIFT) technique is a method of identifying hazards based on the use of brainstorming. SWIFT is a more structured form of "What-if analysis" […], but may be seen as a less rigorous and quicker alternative to HAZOP*"[115].

Compared to hazard and operability studies (HAZOP) SWIFT has less sub elements and a compact set of asked prompts. The prompts are used by the chairman to initiate discussion within the group. Typical prompts utilized are[116]:

- "*What if ... ?*
- *Could someone ... ?*
- *Has anyone ever ... ?*"

The outputs of this specific methodology are a risk catalog and corresponding measures as well as controls. This catalog can be applied as a fundament for risk treatments. SWIFT is a very flexible, quick and can be adapted to any desired requirement. Operating personal should be involved due to their experience. Through that experience outputs are very reliable. A critical point within this methodology is the preparation of checklists. Additionally the outcomes are strongly related to skills and experience of methodology chairman.

3.2.5 Human Reliability Analysis (HRA)

In some critical situations only the human action could prevent a hazardous event. So humans play a major role in risk prevention and overall security. For this purpose human reliability analysis (HRA) transacts with the influence of humans on a specified system accomplishment. The main objective of this methodology is to identify human error influencing a specific system or process.

"*HRA can be used qualitatively or quantitatively. Qualitatively, it is used to identify the potential for human error and its causes so the probability of error can be reduced. Quantitative HRA is used to provide data on human failures into FTA or other techniques*"[117].

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[113] Cf. IEC (2009), ISO 31010, P. 30.
[114] Cf. IEC (2009), ISO 31010, P. 38.
[115] Veritas (2002), P. 33.
[116] Maragakis et al. (2009), P. 14.

The human reliability analysis (HRA) has a certain procedure to be followed to get the most reliable outcomes. A typical procedure is illustrated in Figure 6. The outcomes are presented in form of a catalogue of human errors that could happen and possible solutions for those errors. Errors are identified into detail so that information about error mode, error types and causes are available. More information about this risk identification method is available in Bell et.al (2009) [118].

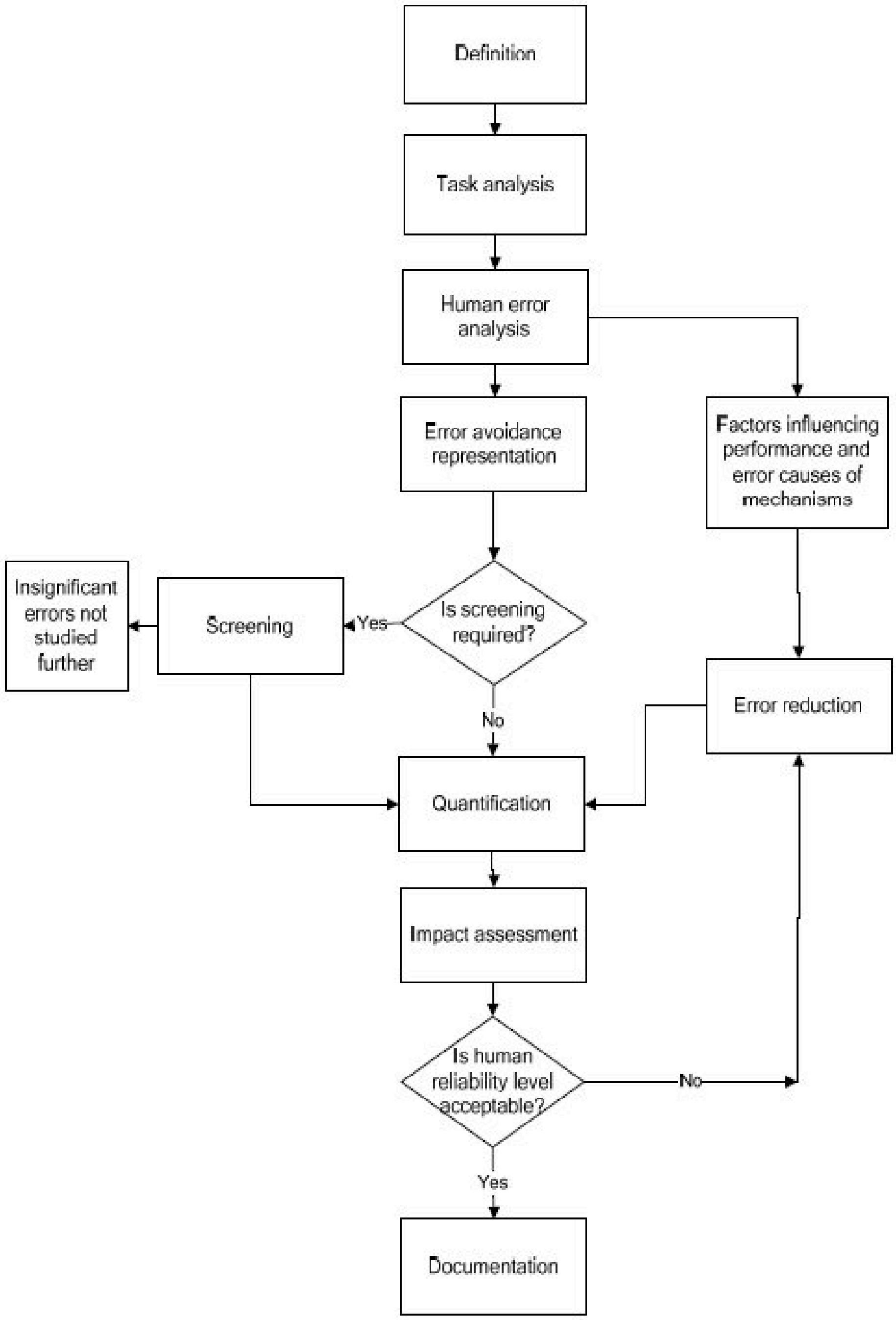

Figure 6: Typical example of human reliability assessment[119].

[117] IEC (2009), ISO 31010, P. 62.
[118] Cf. Bell et.al (2009).
[119] Cf. IEC (2009), ISO 31010, P. 64.

3.3 Scenario Analysis

Scenario analysis				
Risk assessment technique	**Resources and capabilities**	**Nature and degree of uncertainty**	**Complexity**	**Quantitative output**
Root cause analysis (single loss analysis)	Medium	Low	Medium	No
Scenario analysis	Medium	High	Medium	No
Toxicological risk assessment	High	High	Medium	Yes
Business impact analysis	Medium	Medium	Medium	No
Fault tree analysis	High	High	Medium	Yes
Event tree analysis	Medium	Medium	Medium	Yes
Cause/ consequence analysis	High	Medium	High	Yes
Cause-and effect analysis	Low	Low	Medium	No

Table 4: Summary of scenario analysis methods for risk identification.

3.3.1 Root Cause Analysis (RCA)

Root cause analysis (RCA) or single loss analysis is carried out to understand the contributory cause of a single loss. Additionally it identifies how the system could be improved to avoid losses in the future. For correctness of the method it should be considered which controls and measures were in place during the loss. Improvement related to actually installed controls and measures could also be evaluated. This method is mainly carried out during four major steps[120]:

1. **Data collection**: Complete understanding of event as well as data is required. Causal factors and root causes in relation to the event have to be accomplished. For the RCA collecting data is the most time consuming step of the whole process.
2. **Causal factor charting**: "*Causal factor charting provides a structure for investigators to organize and analyze the information gathered during the investigation and identify gaps and deficiencies in knowledge as the investigation progresses*"[121]. Causal chart should be one of the first elements of the RCA procedure. It should be carried out besides data collec-

[120] Cf. Rooney et.al (2004), P. 46.
[121] Rooney et.al (2004), P. 48.

tion, to indicate which data are missing. Data collection is not finished until involved parties and experts are pleased with the input data as well as all relevant causal factors are identified and implemented into the chart.

3. **Root cause identification**: Identification of root cause out of previous performed steps is the main objective of this step. It involves the utilization of a decision diagram, which is named Root Cause Map (RCM). The function of the RCM is to identify for each causal factor the underlying reasons.
4. **Recommendation generation and implementation**: Out of evaluated reasons and root causes, recommendations are generated to prevent the event or risk. Implementation of involved expert's recommendations has to be the overall aim of RCA process. In some cases it is very difficult to realize, so alternative recommendations have to be in place.

The root cause analysis is a very structured methodology, which provides an easy traceability of the process. Additionally it is very reliable due to "*considerations of all likely hypotheses*"[122]. Recommendations are a core element gathered as an outcome. As mentioned before implementation of elaborated recommendation could create a significant problem, resulting in a very time consuming process.

3.3.2 Scenario Analysis

Scenario analysis main objective is to identify possible future scenarios through imagination or extrapolation from the present. "*Scenarios are most useful in situations where the number of possible directions is large or where there is a large degree of uncertainty*"[123].This type of methodology plays a major role within the process of risk assessment (in all three assessment stages). It is a very useful decision tool and consists mainly of two important elements:

1. "*Evaluation of future possibilities (future states) with respect to a certain characteristic.*
2. *What we know now (current states) with regard to that characteristic for an entity*" [124].

A Scenario is described as "*a description of a possible future situation (conceptual future), including paths of development which may lead to that future situation*" [125]. Scenario analysis is very useful tool for assisting of future strategies. They are utilized to represent a wide range of scenarios:

- Best case
- Worst case
- Probable case

This methodology can be applied for the development of opportunities and threats, for all kinds of risks, independent from time extend and frame. Short frame scenario analysis ends up in a greater accuracy of outcomes, due to nearby extrapolation from the present state. Scenario analysis can be conducted in several ways formally or informally and qualitatively or quantitatively.

The scenario development process is processed within five stages[126]:

1. Scenario field identification
2. Key factor identification

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[122] IEC (2009), ISO 31010, P. 45.
[123] Watkins et.al (2012), P. 202.
[124] Dutta, et.al (2010), P. 1.
[125] Kosow et.al (2008), P. 10.
[126] Cf. Kosow et.al (2008), P. 25.

3. Key factor analysis
4. Scenario generation
5. Scenario transfer

The outcome of scenario analysis is a clear range of possible opportunities to react against identified risks with adequate controls and measures. Those are created through the most reliable scenario. The strength is that it gives an indication how the development of certain situations could end in the future. "*This strength however has an associated weakness which is that where there is high uncertainty some of the scenarios may be unrealistic*"[127]. Major problems of utilizing this methodology are availability as well as reliability of used data and parameters. So to use scenario analysis as a decision tool is a very dangerous matter. At least one further risk identification methodology should be applied to confirm outcomes and to guarantee confidence of decisions.

3.3.3 Toxicological Risk Assessment (TRA)

Toxicological risk assessment (TRA) "*involves analysing the hazard or source of harm and how it affects the target population, and the pathways by which the hazard can reach a susceptible target population. This information is then combined to give an estimate of the likely extent and nature of harm*"[128]. This specific methodology is utilized to identify possible risks to environment (plants and animals) and humans. Toxicological risk assessment mainly investigates risks pathways which could influence mentioned targets, as a consequence of threats from chemicals and micro-organisms. TRA is realized within five stages:

1. **Problem formulation**: Within this first stage definition of target population and hazard type is carried out.
2. **Hazard identification**: Hazards which affect the target population are recognized and documented during this stage. Hazards identification is based on expert knowledge, former performed assessments and review of literature. Other risk identification methods should be utilized to support this identification process.
3. **Hazard analysis**: In this stage mainly interactions and relations between target population and identified hazards are analyzed.
4. **Exposure analysis**: Possible pathways of hazardous material, with corresponding concentrations, are analyzed. In other words how could it reach the target population and which damage will this hazardous material create. This stage is very important, because possible measures could be realized and it is somehow a fundament of treatment plan.
5. **Risk characterization**: Within this stage outcomes of former performed hazard analysis and exposure analysis are brought together to get an overall picture of possible pathways and consequences. Detailed investigations would be essential if a great number of pathways and consequences are identified.

3.3.4 Business Impact Analysis (BIA)

Business impact analysis (BIA) is defined as "*the process of analysing business functions and the effect that a business disruption might have upon them*"[129]. This methodology should help to understand how risks could affect the operations of an organization. During business impact

[127] IEC (2009), ISO 31010, P. 42.
[128] IEC (2009), ISO 31010, P. 36.
[129] Charters (2011), P. 1.

analysis capabilities are identified as well as quantified, to evaluate if the event could be managed by the organization. At the same time required capabilities are identified to support the treatment of disruptions. In general there are three types of business BIA[130]:

- Strategic BIA
- Tactical BIA
- Operational BIA

One of the most important points to consider is a team which develops the BIA analysis. It is preferred to have mixture of team members knowing the organization well as well as externals. The purpose of externals is to identify problems and factors not visible for internal team members. Independent of desired type of BIA, several basic inputs are required to develop a reliable BIA[131]:

- Information related to organization (objectives, environment, operations and interdependences)
- Understanding of activities and operations, with corresponding financial influence on the organization
- Consequences resulting out of disruption of activities and operations
- Opinion and interview results from significant stakeholders

Business impact analysis can be realized through questionnaires, interviews and structured workshops investigating a certain aspect. The superlative methodology would be a combination of all three, ending up in low uncertainty of outcomes. Outcomes of a BIA are[132]:

- A list of organization critical processes with related interdependencies
- Financial and operational impacts resulting out of disruptions in essential operational processes
- Indication for the most supporting resources required to combat the disruption of essential operational processes

3.3.5 Fault Tree Analysis (FTA)

Fault tree analysis (FTA) can be explained as "an analytical technique, whereby an undesired state of the system is specified [...], and the system is then analyzed in the context of its environment and operation to find all credible ways which the undesired event can occur"[133] The methodology evaluates all possible pathways leading to a top event. The top event can be related to any type of risk or event desired to analyse (hardware failure, human errors, etc...). The fault tree analysis is presented in a graphical logical tree diagram.

Figure 7 shows an example of a simple fault tree analysis with corresponding symbols. A detailed explanation of symbols could be reviewed in Vesely et.al (1981). Required input data for a fault tree analysis are strongly depending on desired type of analysis[134]:

- **Qualitative analysis**: Understanding of structure, source of failures and technical understanding.
- **Quantitative analysis**: Data on failure rates, probability of failed state for all events in FTA.

[130] CF. Charters (2011), PP.61 - 102.
[131] Cf. IEC (2009), ISO 31010, P. 43.
[132] Cf. IEC (2009), ISO 31010, P. 43.
[133] Vesely et.al (1981), P. IV-1.
[134] Cf. IEC (2009), ISO 31010, P. 49.

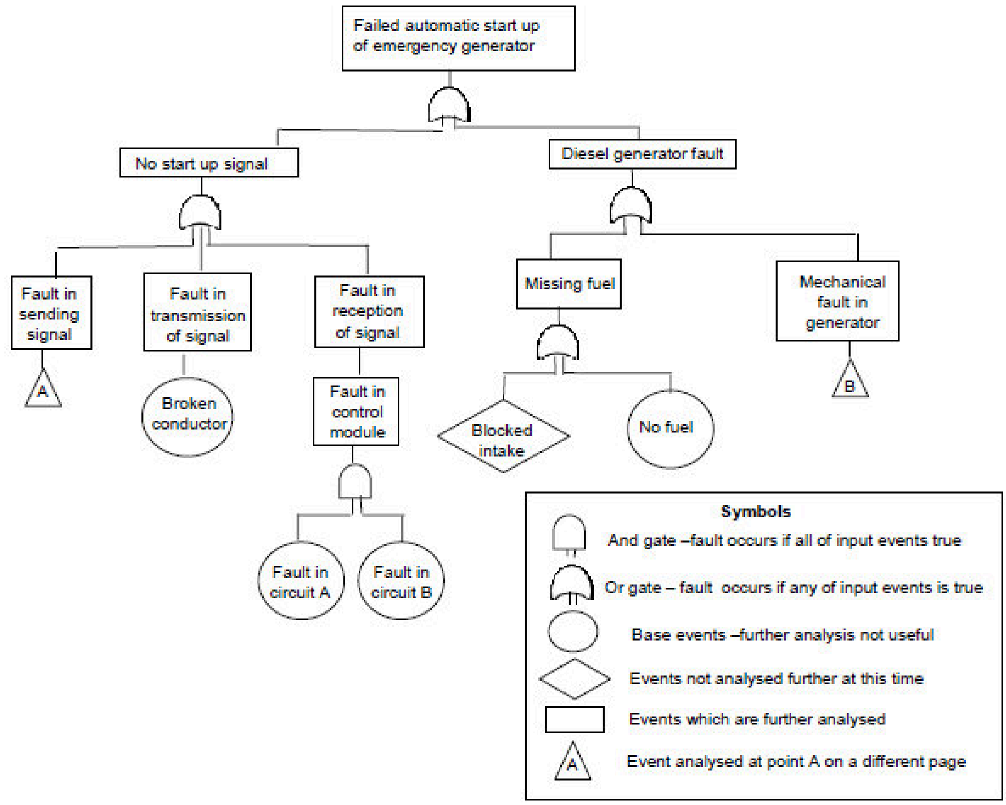

Figure 7: Example of fault decision tree analysis[135].

Complex fault trees require software packages to handle the complexity of accomplished calculations. Those software packages provide very effective graphical tools and ensure consistency, correctness and verifiability. Outputs of the fault tree analysis are:

- Pathways indicating how a top event could occur (graphical representation)
- Individual pathways of failure with corresponding probability
- Probability of the top event

3.3.6 Event Tree Analysis (ETA)

Event tree analysis (ETA) represents a translation of probabilities of different initiating events using inductive reasoning into possible outcomes of an event. It is "*a commonly applied technique used for identifying the consequences that can result following the occurrence of a potentially hazardous event. It was first applied in risk assessments for the nuclear industry but is now utilised by other industries such as chemical processing, offshore oil and gas production, and transportation*"[136].

This method can be applied in qualitative and quantitative way. "*By fanning out like a tree, ETA is able to represent the aggravating or mitigating events in response to the initiating event, taking into account additional systems, functions or barriers*"[137]. This methodology requires several inputs to generate a reliable outcome. The most important inputs are a list of suitable events with

[135] Cf. IEC (2009), ISO 31010, P. 49.
[136] Andrwes et.al (1999), P. 1.
[137] Cf. IEC (2009), ISO 31010, P. 52.

corresponding information about treatment possibilities, barriers and measures. The involved team has to have a clear understanding of the investigating processes. Event tree analysis (ETA) can be used at any desired stage of risk management process. It could be used as a supporting method to brainstorming methodology.

The outcomes of this methodology are explanation of problems as a consequence of a specific event (when developed qualitatively). In quantitative way it indicates probabilities of the events in consideration. Event tree analysis (ETA) helps to indicate measures or actions to avoid undesired outcomes.

3.3.7 Cause and Consequence Analysis (CCA)

Cause and consequence analysis represents a mixture of fault tree analysis (FTA) and event tree analysis (ETA). In this methodology causes and consequences are considered for the determination of outcomes of an initiating top event. Time delays can be implemented in this method, creating a real advantage compared to ETA.

"*The method is used to analyse the various paths a system could take following a critical event and depending on the behaviour of particular subsystems (such as emergency response systems). If quantified they will give an estimate of the probability of different possible consequences following a critical event*"[138]. The diagram created is consisting of several sub-fault tree diagrams. A typical example of the cause and consequences analysis is presented in Figure 8.

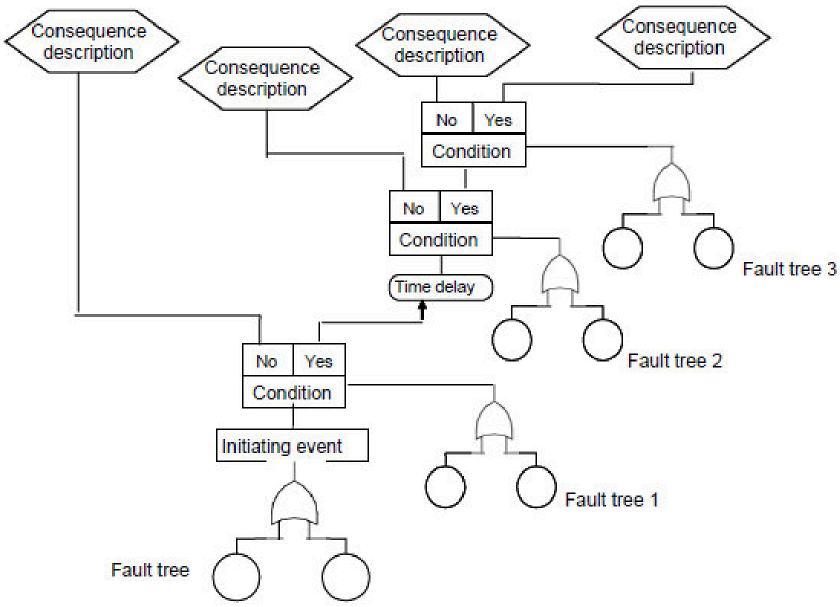

Figure 8: Graphical example of cause and consequences analysis[139].

The result of this methodology is a large graphical fault tree diagram with cause and consequence (including probability of the consequences) descriptions. Analyzing the events over time is one of the main advantages of this method. Further advantages are related to FTA and ETA advantages, as this methodology creates a combination (see chapter 3.3.5 and 3.3.6). Due to the complexity of this methodology some limitations are recognizable, but could be easily handled with some additional efforts.

[138] IEC (2009), ISO 31010, P. 54.

[139] Cf. IEC (2009), ISO 31010, P. 55.

3.3.8 Cause and Effect Analysis

Cause and effect analysis also called fishbone diagram. "*The fishbone diagram - so called because of its resemblance to a fish skeleton - is a cause- and -effect diagram that can be used to identify the potential (or actual) cause(s) for a performance problem. Fishbone diagrams provide a structure for a group´s discussion about the potential causes of a problem*" [140]. This methodology tries to indicate that several factors or causes could lead to a certain event. Those factors or causes could even be out of different categories and could result out of consideration from various scenarios. Tools used to support this type of method are brainstorming and structure tree. A cause and effect diagram is developed to identify[141]:

- Possible root causes and basic reasons for predefined problems or conditions
- Interactions and relationships among factors
- Identification of treatment controls and measures

This methodology has several advantages, which are[142]:

- Easy implementation and easy understanding through graphical visualisation
- Structured analysis
- All essential root causes identified through thoughtful analysis
- Fast and easy overview of the big picture
- Areas with little data are identified fast

The simplicity of this methodology creates also a disadvantage, due to inaccurate representation of the complexity of a situation. The cause and effect analysis has to be carried out in combination with other risk identification methodologies (root cause analysis, brainstorming, etc ...) to secure reliable outcomes.

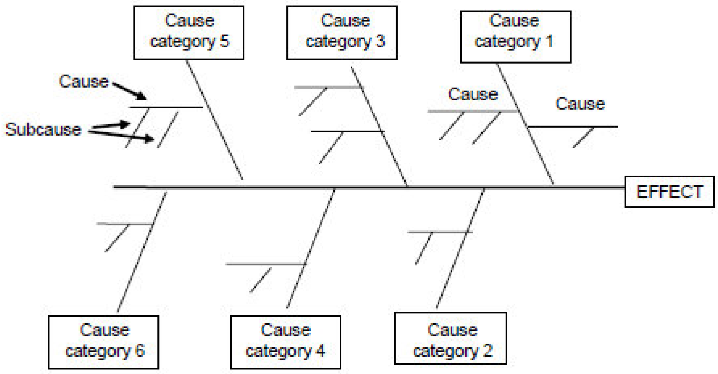

Figure 9: Process of cause and effect diagram[143].

The procedure of this methodology is very easy. At the beginning a certain effect has to be defined for analysis. Based on this effect main categories of causes are implemented into the diagram. Cause and sub causes are identified through repeated questions (example: what caused that?). After the identification and implementation of all causes and sub causes, a detailed review of all branches is carried out to confirm consistency and completeness. At the end of the process most reliable causes are highlighted based on the opinion of involved parties.

[140] Watkins et.al (2012), P. 197.
[141] Cf. IEC (2009), ISO 31010, P. 56.
[142] Cf. Watkins et.al (2012), P. 197.
[143] Cf. IEC (2009), ISO 31010, P. 57.

3.4 Function Analysis

Function analysis				
Risk assessment technique	**Resources and capabilities**	**Nature and degree of uncertainty**	**Complexity**	**Quantitative output**
FMEA and FMECA	Medium	Medium	Medium	Yes
Reliability centred maintenance	Medium	Medium	Medium	Yes
Snake analysis (Snake circuit analysis)	Medium	Medium	Medium	No
HAZOP Hazard and operability studies	Medium	High	High	Yes
HACCP Hazard analysis and critical control points	Medium	Medium	Medium	No

Table 5: Summary of function analysis for risk identification.

3.4.1 Failure Mode and Effect Analysis (FMEA)

Main objective of failure mode and effect analysis (FMEA) is the identification of failure modes as well as their corresponding causes and effects on investigated system. This methodology helps to identify measures to eliminate or decrease potential risk; additionally it indicates limitations of the investigated system. The significance of each failure mode (qualitatively, semi-qualitatively or quantitatively) is determined before the FMEA process by a criticality analysis. This could be based on the probability that the failure mode will result in system failure[144]. Failure mode and effect analysis (FMEA) can be classified into several types:

- Design FMEA used for components and products
- System FMEA used for systems
- Process FMEA used for manufacturing and assembly processes
- Service FMEA
- Software FMEA

"The primary output of FMEA is a list of failure modes, the failure mechanisms and effects for each component or step of a system or process. Information is also given on the causes of failure and the consequences to the system as a whole. The output from FMECA includes a rating of importance based on the likeli-

[144] Cf. IMCA (2002), P. 13.

hood that the system will fail, the level of risk resulting from the failure mode or a combination of the level of risk and the detect ability of the failure mode"[145]. Detailed information about the failure mode and effect analysis (FMEA) could be reviewed in IMCA (2002).

3.4.2 Reliability Centred Maintenance (RCM)

Reliability centred maintenance (RCM) is "*a process of systematically analyzing an engineered system to understand:*

- *Its functions*
- *The failure modes of its equipment that support these functions*
- *How then to choose an optimal course of maintenance to prevent the failure modes from occurring or to detect the failure mode before a failure occurs*
- *How to determine spare holding requirements*
- *How to periodically refine and modify existing maintenance over time*" [146]

This methodology is utilized to identify polices that should be implemented to a system to mange failures and to guarantee that an adapted as well as effective maintenance is carried out. To realize a successful application of this risk identification method, some core elements have to be proven, examples are: the understanding of equipment and structure of organization, operational environment, operational related system and subsystems, possible failures and their consequences to the organization[147].

RCM follows basically the steps of risk assessment (identification, analysis and evaluation), but in the context of the methodology. All steps and processes carried out during RCM are documented, because this assessment can be utilized as a reference for future assessments. Further detailed information can be viewed in IEC (2006), IEC 60812:2006(E)[148].

3.4.3 Snake Analysis

The snake analysis can also be called snake circuit analysis. Snake circuits are unwanted pathways within the organization leading to undesired consequences. The methodology is basically identifying those pathways (design errors). Those errors could result out of hardware, software, operator's actions or a combination of all three errors. Snake circuit analysis was developed by the NASA in the 1960 to "*verify the integrity and functionality of their designs*"[149]. It was utilized to identify inadvertent electric circuit paths and corresponding problem solutions. This methodology has a wide range of application. It can be used for trouble identification (software and hardware) for any kind of technology. Due to the possibility of integration of other methodologies (FTA, FMEA, HAZOO, etc ...) it is very reliable. There are four principal areas of investigation[150]:

- **Snake path**: Unintended path in the context of current, energy and flows
- **Snake timing**: Events arising in unexpected sequence
- **Snake indications**: Wrong representation of system conditions, leading to wrong measures or actions

[145] IEC (2009), ISO 31010, P. 48.
[146] American Bureau of Shipping (2004), P. 1.
[147] Cf. IEC (2009), ISO 31010, P. 67.
[148] IEC (2006), IEC 60812.
[149] IEC (2009), ISO 31010, P. 68.
[150] Cf. Miller (1989), P. 2.

- **Snake label**: Incorrect labeling of system functions

All of those principle areas have one common procedure consisting of four basic stages[151]:

1. Data preparation
2. Development of network tree
3. Network paths evaluation
4. Recommendations and final report

This methodology can be utilized at a very early stage of system development giving a good insight into the system and improving economics of it. This is realized through exhibition of other working solutions. Limitations are created when inaccurate network tree (creating the main input for this methodology) are used in the snake circuit analysis.

3.4.4 Hazard and Operability Studies (HAZOP)

A Hazard and Operability (HAZOP) study is "*a structured and systematic examination of a planned or existing process or operation in order to identify and evaluate problems that may represent risks to personnel or equipment, or prevent efficient operation*" [152]. With this methodology risks to the environment can be simply identified. HAZOP was elaborated to analyze chemical process systems and was then adapted to other processes as well as systems. Today this methodology has a wide range of application. A team is created to utilize this qualitative technique, if possible they should emphasize possible treatments to reduce or eliminate the risk. This methodology is comparable to FMEA, but starts with undesired outcomes and ends at the source and failure modes.

"*A HAZOP study is usually undertaken at the detail design stage, when a full diagram of the intended process is available, but while design changes are still practicable*"[153]. It can also be used during operational phase, but specific adoptions (to be fit for purpose) have to be realized. One of the most important references for the HAZOP is IEC (2001), IEC 61882:2001(E)[154]. There are various types of hazard and operability studies, examples are[155]:

- Process HAZOP
- HUMAN HAZOP
- Procedure HAZOP
- Software HAZOP

The output of this methodology is information about actual deviations, possible causes and measures to be implemented. In process related HAZOP also a responsible person is identified as an outcome. Implementing outcomes of created report results in improvement of the system, coming from reduced risk as well as more efficient operations.

HAZOP has several advantages; it is a systematic examination using operational experience within the organization or system. HAZOP covers human errors safety aspects and operational aspects, under the consideration of operational procedures. Expenditure and time aspects are one of the imitations of this method. Furthermore reliable analysis requires a high level of experience (experienced team), as well as very good documented data and information about the entire system.

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[151] Cf. IEC (2009), ISO 31010, P. 68.
[152] Rausand (2005), P. 3.
[153] IEC (2009), ISO 31010, P. 33.
[154] IEC (2001), IEC 61882.
[155] Cf. Rausand (2005), P. 8.

3.4.5 Hazard Analysis and Critical Control Points (HACCP)

Hazard analysis and critical control points (HACCP) is a method which measures and monitors specific characteristics within predefined limits to ensure quality and safety of a certain product. The main characteristics of this methodology are that it is proactive, systematic and a preventive system. The main objective is to reduce risk through implementation of controls and measures, rather through check up at the end of production process.

Originally the Hazard analysis and critical control points (HACCP) was developed to ensure the quality of food for the NASA space program. Today this type of analysis is utilized along the whole food chain. It is used for risk control of[156]:

- Physical hazards
- Chemical hazards
- Biological hazards

Inputs for this methodology are gathered from process diagrams representing the production flow for a certain product of interest. Additional information can be generated through supporting risk identification methods (chapter 3.2); examples are information affecting quality and safety of the product. HACCP process is established out of seven principles[157]:

- **Conduct hazard analysis**: Preparation and identification of processes, hazards as well as possible preventive measures.
- **Identification of critical control points**: Purpose is to control or eliminate the specific hazard at that critical control point.
- **Establishment of critical limits related to critical control point**: Controls realized at the critical points should operate within predefined limits to ensure the adequate control of hazard.
- **Establishment of monitoring procedures**: Monitoring of controls with predefined intervals to conform success and adapt deflections.
- **Establishment of corrective measures**: Those measures are utilized when controls in place are operating outside predefined limits.
- **Establishment of verification procedures**: Documentation of HACCP.
- **Establishment of recording procedures**: Continues documentation of the ongoing process.

The methodology of hazard analysis and critical control points (HACCP) is a very well structured procedure, identifying possible risk and giving possible reliable solutions. Limitations of HACCP would be input data, because a number of requirements have to be pre identified to guarantee a successful process. Uncertainty of input data has a significant influence of the process. This could be investigated with the support of sensitivity analysis. Further information on the methodology can be reviewed in the reference document IEC (2005), ISO 22000:2005(E)[158].

[156] Cf. USDA (1997), P. C-1.
[157] Cf. IEC (2009), ISO 31010, P. 35.
[158] IEC (2005), ISO 22000.

3.5 Controls Assessment

Controls assessment				
Risk assessment technique	**Resources and capabilities**	**Nature and degree of uncertainty**	**Complexity**	**Quantitative output**
LOPA Layers of protection analysis	Medium	Medium	Medium	Yes
Bow tie analysis	Medium	High	Medium	Yes

Table 6: Summary of control assessment for risk identification.

3.5.1 Layers of Protection Analysis (LOPA)

Layers of protective analysis (LOPA) represent a semi-quantitative method utilized to identify level of controls and measures to reduce the risk related to a specific process. "*A cause-consequence pair is selected and the layers of protection which prevent the cause leading to the undesired consequence are identified. An order of magnitude calculation is carried out to determine whether the protection is adequate to reduce risk to a tolerable level*"[159]. This risk identification methodology can be applied at any stage in the lifecycle of a project or process.

To gather a better cost to benefit ratio LOPA should be implemented when process flow diagrams are finished. In the case of ongoing processes this method should be utilized after the HAZOP review. Generally LOPA is used after a list of possible hazards and hazardous scenarios, with corresponding consequences, are identified by involved team. This listing is mainly realized with qualitative methodologies[160]. The procedure of layer of protection analysis is a very simple approach consisting of 6 main steps as illustrated in Figure 10. This methodology is carried out with a team of experts following the illustrated procedure.

A supporting methodology is the preliminary hazard analysis, which submits input information about hazards, causes and consequences to the LOPA team. Additional inputs required are information about controls (in place or proposed), probabilities as well as definitions of acceptable degree of risk. After utilizing the LOPA methodology recommendations for additional controls and measures are provided by the expert team. Effectiveness of each recommended control and measures are also presented. The layer of protection analysis methodology is mainly used in connection with safety related and instrumented systems for SIL assessments[161].

[159] IEC (2009), ISO 31010, P. 59.
[160] Cf. Summers et.al (2003), P. 3.
[161] Cf. IEC (2009), ISO 31010, P. 60.

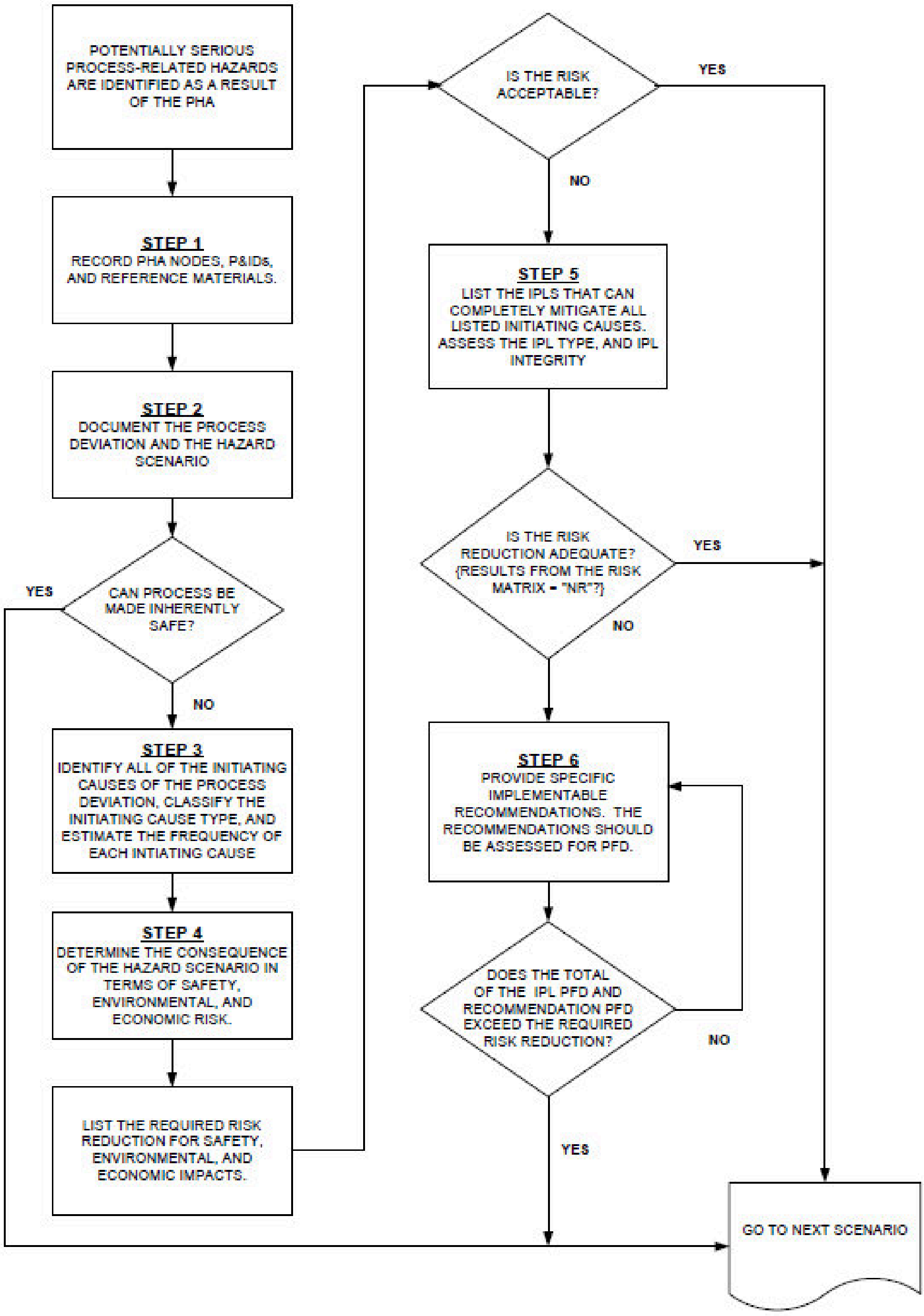

Figure 10: Typical procedure of layer of protection analysis (LAPO)[162].

3.5.2 Bow Tie Analysis

Bow tie analysis is a very similar to cause and consequences analysis (CCA). "*Typically Cause-Consequences Analysis (CCA) combines the various (inductive and deductive) of logic diagrams (e.g. event-tree analysis [ETA] or fault-tree analysis[FTA]) to assist in identifying the basic causes and consequences of potential accidents. Bow-Tie diagrams are less formal CCA than ETAs and FTAs*"[163].

[162] Cf. Summers et.al (2003), P. 5.
[163] Jones et.al (2012), P. 3.

This methodology is utilized in simple situations (clear pathway from hazard to failure) to represent risk with corresponding causes and consequences. As in other risk identification methods a clear understanding of causes and consequences of a certain risk is required. Additionally understandings of controls which prevent, mitigate or stimulate the risk are essential. The development of bow tie diagram requires identification of related hazards, aspects, threats, consequences, prevention barriers, migration barriers and control barriers[164]. A simple diagram is the output of this methodology, within this diagram the pathways and barriers of risks are presented (see Figure 11).

Advantage is the simple understanding and clear representation of investigated problem[165]. No high level of expertise is required to realize the bow tie analysis. Limitations of this risk identification method are complex systems, where several causes occur simultaneously.

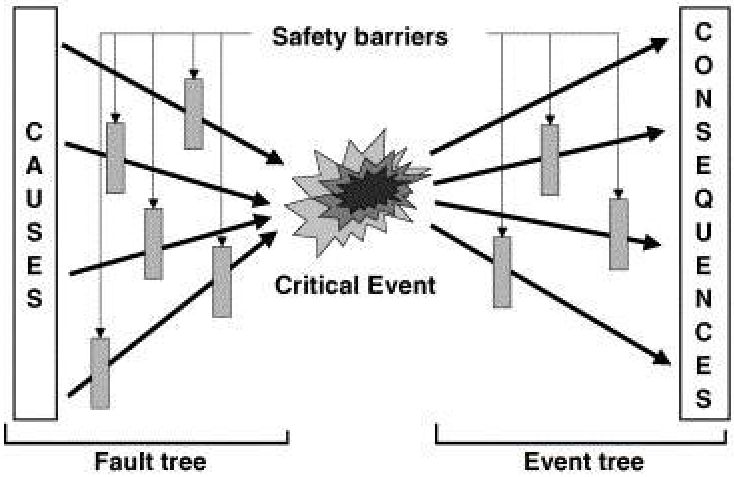

Figure 11: Example of bow tie analysis diagram[166].

3.6 Statistical Methods

Statistical methods				
Risk assessment technique	**Resources and capabilities**	**Nature and degree of uncertainty**	**Complexity**	**Quantitative output**
Markov analysis	High	Low	High	Yes
Monte-Carlo analysis	High	Low	High	Yes
Bayesian analysis	High	Low	High	Yes

Table 7: Summary of statistical methods for risk identification.

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[164] Cf. Jones et.al (2012), P. 3.
[165] Cf. IEC (2009), ISO 31010, P. 66.
[166] ScienceDirect (2013), Access 11.10.2013.

3.6.1 Markov Analysis

"*Markov analysis is used where the future state of a system depends only upon its present state. It is commonly used for the analysis of repairable systems that can exist in multiple states and the use of a reliability block analysis would be unsuitable to adequately analyse the system*"[167]. By implementing higher order of markov analysis the method could be set up in a more complex way. Further information about this methodology is presented in IEC (2006), IEC 61165:2006[168].

3.6.2 Monte Carlo Simulation

Due to complexity of some investigated systems, the utilization of analytical methods is resulting in unreliable outcomes, ending up in increased uncertainty. For this purpose some identification methods are applying system inputs randomly (within a certain range), while repeating the calculations N times. This methodology results in N possible outcomes of desired result. The Monte Carlo simulation got more and more popular with advancing technology in computer systems. In general the Monte Carlo simulation can be applied for two different purposes:

- "*Uncertainty propagation on conventional analytical models;*
- *probabilistic calculations when analytical techniques do not work*"[169].

To carry out Monte Carlo simulation input parameters are required. Those parameters show a certain degree of uncertainty and are then prepared for the methodology as random variables with a predefined distribution. This distribution is strongly depending on range of uncertainly. The most popular and common used distributions are:

- Uniform distribution
- Triangular distribution
- Normal distribution (Gaussian distribution)
- Log normal distribution

The typical performed Monte Carlo simulation consists of 4 major stages[170]:

1. **Statistic model generation**: Nearby reproduction of real scenario by deterministic model. This is realized while utilizing the most likely values for system input parameters.
2. **Input distribution identification**: Based on statistical procedures the identification of model input parameters is carried out. This specific step should be realized based on historical data for the input parameters.
3. **Random variable generation**: This represents the main simulation stage of Monte Carlo analysis (core element). It is based on distributions of input parameters and deterministic model. Randomly chosen input parameters are processed through the deterministic model as well as repeated.
4. **Analysis and decision making**: Statistical analysis is carried out based on repeated outcomes of the deterministic model. This should provide a certain degree of confidence for decision making process.

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167 IEC (2009), ISO 31010, P. 69.
168 IEC (2006), IEC 61165.
169 IEC (2009), ISO 31010, P. 73.
170 Cf. Raychaudhuri (2008), P. 92.

Several outputs types are generated through utilization of Monte Carlo simulation. Examples are[171]:

- Single value
- Frequency distribution
- Identification of function having the largest influence on simulation output

This methodology in applied to further identify probability of a defined outcome and expectations values (10%, 50%, 80%, etc …) of a certain problematic. To secure accurate outcomes the number of simulations should exceed a certain value (example 10000 repetitions). With today´s computer capacities the application of Monte Carlo simulation is not a problem anymore.

3.6.3 Bayesian Analysis

Bayesian analysis is a statistical method which makes use of earlier information and actual measures to generate an overall probability. Classical statistics assume that all distribution parameters are somehow fixed. This methodology does not assume fixed parameters; it assumes that all distribution parameters can be applied randomly. "*A Bayesian probability can be more easily understood if it is considered as a person's degree of belief in a certain event as opposed to the classical which is based upon physical evidence. As the Bayesian approach is based upon the subjective interpretation of probability, it provides a ready basis for decision thinking and the development of Bayesian nets* […]"[172].

This methodology is today very popular due to advanced computer capacities. It is used within a wide range of applications like: "*medical diagnosis, image modelling, genetics, speech recognition, economics, space exploration and in the powerful web search engines*"[173]. The inputs of the Bayesian analysis are nearby those of Monte Carlo simulation. The basic steps of this methodology are[174]:

- Definition of underlying system variables
- Definitions of causal links between defined variables
- Specification of the conditional and prior probabilities
- Addition of evidence to net
- Realization of belief updating
- Extraction of posterior beliefs

Further information about this methodology can be reviewed in Ferson (1996)[175].

[171] Cf. IEC (2009), ISO 31010, P. 75.
[172] IEC (2009), ISO 31010, P. 76.
[173] IEC (2009), ISO 31010, P. 76.
[174] Cf. IEC (2009), ISO 31010, P. 76.
[175] Ferson (1996).

4 Austrian Methodology of Risk Assessment in the Field of Natural Disaster

Austrian territorial area consists mainly of 9 federal provinces: Burgenland, Kärnten (Carinthia), Niederösterreich (Lower Austria), Oberösterreich (Upper Austria), Salzburg, Steiermark (Styria), Tirol (Tyrol), Vorarlberg and Wien (Vienna). Each of those mentioned federal provinces have far-reaching autonomy, where each of them has an own parliament and government. Within those provinces there are in total 2.304 cities and country municipalities implemented. The political system in Austria is divided into three major levels of responsibility[176]:

1. National/state
2. Land/federal province
3. Municipality

Districts (Bezirke) create an additional level between federal provinces and municipalities. Responsibility for the matter of civil protection, crisis and disaster protection management lies within the responsibility of Department II/4 – Civil Protection, Crisis and Disaster Protection Management of the Ministry of the Interior (MOI). Within this specific department there are two main units:

- International Civil Protection and Disaster Relief Affairs
- National Crisis and Disaster Protection Management

The Department II/4 – Civil Protection, Crisis and Disaster Protection Management of the Ministry of the Interior (MOI) is responsible for disasters affecting the whole territorial area of Austria, additionally they are responsible for the representation of Austria in the matter of crisis and disaster management[177]. This department also includes officers responsible for disaster protection on the federal level. The coordination of emergency measures is carried out by the Federal Alarm Centre of the Ministry of the Interior (MOI), which operates 24/7.

4.1 Risks within Austrian Territorial Area

In Austria probability and impact dimension of natural disasters is strongly varying and depending on the investigated area. However, extensive measures for the safety of public were realized since the year 1300. Due to topography of Austria, only 38% of territorial area is convenient for permanent settlement of Austrian population. In this case most popular areas are those lying in flat regions and valleys[178]. The density of population is in the range of 243 persons per square kilometre. In Austria there are 100.000 km of streaming water, which creates a large source of danger for the population. So flooding protection is one of the major tasks of authorities besides other probable hazards.

Approximately 60% of the territorial area (50.000 km^2) is acute threatened by torrent, snow slides and erosion. To be precise 12.000 torrents, 6.000 snow slide areas and 900 landslides

176 Leitgeb et.al (2004), P. IX/126.
177 Cf. MOI (2013), Access: 14.10.2013.
178 Cf. Hübl et.al (2011), P. 5.

are characterized as dangerous. 35 thousand buildings and 1.500 km infrastructure are affected by those specific hazards[179]. In Table 8 a list of natural disasters affecting Austrian territory are presented. They are compared to each other according to:

- **Human risk**: Indication for the intensity of affecting the life of humans or leading to massive injury and social disruption.
- **Strike risk**: Indicates the potential damage within the area of disaster occurrence.
- **Catastrophic potential**: Indicates dimension and influence of national interests like humans, economics, social, environment, infrastructure and politics.

Type	Human risk	Strike risk	Catastrophic potential
Flooding	Medium	Very high	Very high
Snow slide	Very high	Medium	High
Mudflow	High	Medium	Medium
Spontaneous landslide	High	Medium	Medium
Permanent landslide	Low	Medium	Medium
Rock slide	High	Medium	Medium
Stone chipping	Very high	Low	Low
Snow pressure	Medium	Low	Low

Table 8: Overview of natural disasters influencing Austrian territory[180].

4.2 Risk Management in Austria

As mentioned in the former chapter, the first measure carried out to protect Austrian population from natural disasters was accomplished in the 13th century. Disasters and risk management methodology and processes were massively realized and implemented starting in the year 1980.

Today a large number of risk and disaster management approaches are applied for the purpose of human and environmental protection. Additionally adequate treatment plans are in place, based on the outcomes of utilized approaches. Due to variations of responsibilities and accountability, the legal situation is very complex and has to be explained in the first order.

[179] Cf. Hübl et.al (2011), P. 6.
[180] Cf. Hübl et.al (2011), P. 5.

4.2.1 Principals of Natural Disaster Management

The Austrian legal order has explicit no interest in prevention of general natural disasters, but for specific natural hazards there are corresponding laws. Examples would be „***Wasserrechtsgesetz***“[181] including the protection from flooding and corresponding threats.“*[…] no uniform and consistent text of law with respect to the protection from the effects arising from natural hazards is given. In contrast, implications governed by public law are large in number and multifaceted, and include articles in the Austrian Forest Act, the Austrian Hydrography Act and the Disaster Fund Act at federal level as well as laws regulating spatial planning and land use planning on the Länder level, just to name the most prominent*”[182].

In Austria a so called “***normiertes Naturgefahrenmagement***” was established. In other words, independent from the possible extend of loss, there are protection targets defined through binding norms and guidelines. This should be also supported by an adequate personal (private) contribution, when public protection is not available or not possible. All measures, controls and actions realized are strongly related to a predefined protection target. The most important protection targets relating to natural disaster management are listed below. Out of those generally mentioned protections targets, specific once are redefined for a deeper investigation purpose.

- Protection of population’s life and health
- Protection of areas of settlement
- Protection of industrial areas
- Protection of infrastructure and public utilities
- Protection of environment
- Protection of economic ability

4.2.2 Institutions for Natural Disaster Management

Natural disaster management is carried out by a number of public and private institutions. A specified overview is connected to a massive effort and cannot be clearly prepared. So the main question is:

”WHO IS RESPOSIBLE?”

It is documented in the „***Bundesverfassungsgesetz***”[183] that prevention of natural disasters and corresponding measures and actions are laying within the responsibility of Austrian Government (national level), but the action of combating disasters is laying within the responsibility of federal provinces and their governments. The responsibilities and competencies are written in Austrian law and can be reviewed in RIS[184] and Jusline[185]. The most important competencies for the various levels are[186]:

National level

- Water protection “***Wasserreht***”
- Forest protection “***Forstrecht***”

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[181] Cf. Jusline.at (2013), WRG. Access 13.09.2013.
[182] Holub et.al (2009), P. 524.
[183] Cf. Jusline.at (2013), B-VG. Access 14.09.2013.
[184] Cf. RIS (2013).
[185] Cf. Jusline.at (2013).
[186] Cf. Holub et.al (2009), P. 524.

- Traffic "***Verkehrsrecht***"
- Health care "***Gesundheitswesen***"

Federal provinces

- Land use planning "***Raumordnung***"
- Civil engineering "***Bauwesen***"
- Catastrophic support "***Katastrophenhilfe***"
- Fire regulations "***Feuerwesen***"

Municipality

- Local infrastructure "***Örtliche Straßen***"
- Building regulations "***Baupolizei***"
- Local land use planning "***Örtliche Raumordnung***"

In Table 9 some more responsibilities of the three levels are illustrated:

Legislation	
National Level	• Water Act • Forest Act • Torrent Control Act • Water Construction Financing Act • Disaster Relief Fund Act • Ordinance on Hazard Mapping • Guidelines on Hazard Mapping • Technical Directive for Torrent and Avalanche Control • Directive for Cost- Benefit- Analysis on Torrent and Avalanche Control Measures
Regional Level (federal province)	• Civil Protection Acts • Areal Planning Regulations • Building trade Acts
Local Level (municipalities and communities)	• Hazard Maps on Torrent and Avalanche Control • Area planning scheme • Local development concepts • Development scheme • Planning and building permissions • Alarm and action plans for catastrophes

Table 9: Risk and disaster management on various levels[187].

Out of this table and former presented responsibilities it can be clearly recognized that developing a common national risk assessment process is a very complex affair, due to different responsibilities on various levels. So adaption of law has to be realized in the first order, to get an adequate fundament to rebuilt / adapt the actual risk assessment system.

"*Measures to avert, remove or alleviate the effects of imminent or past disasters (disaster relief, action planning) fall mainly within the responsibility of the Federal Provinces. The legal basis is provided by the catastrophy aid acts by the Federal Provinces, particularly the establishment of the disaster and the operational responsibility by the authority on a community, district and provincial level*"[188].

[187] Cf. Leitgeb et.al (2004), P. IX/127.
[188] MOI (2013), Access 03.09.2013.

4.3 Risk Assessment Methods

Due to the complex legal situations methodologies for risk assessment are strongly varying depending on the investigated federal province. Generally utilized methodologies are every advanced and reliable. This could be proven by the excellent measures and controls set in the last view years (flood protection, avalanche treatment measures, etc ...). Each of the federal provinces has an own risk assessment methodology with a certain degree of overlapping to other approaches. In the following three actual methodologies of Austrian federal provinces will be shortly introduced.

4.3.1 Tyrol

The federal province of Tirol is actually carrying out risk analysis on municipality level in cooperation with the project "alpS"[189] and Bavarian provincial government. Within the "alpS" project investigations on global climate change are carried out. To be precise the effect on regional and local human systems are investigated, especially in mountain areas. Through those investigations treatment plans as well as preventive plans can be generated, to reduce or eliminate possible risk (future developments in the territorial area of Tirol are simulated with this approach). The assessments and evaluations are based on climate and socio-economic scenarios. The project of "alpS" includes innovations for early warning and monitoring systems, developed for prevention of natural disasters. This provides an up to date tool for a modern risk management. Furthermore this acts as a supporting system for decision makers, based on scientific expertise. More information about "alpS" on the website: http://www.alp-s.at/cms/en/. Information and outcomes are implemented into a risk assessment and risk management plan of the Tyrolean provincial governmen

4.3.2 Carinthia

The risk assessment in Carinthia is a software supported process. Basically it consists of three main parts:

- Threat investigations
- Vulnerability analysis
- Risk identification

The threat investigations are carried out through collection of data, measurements, calculations as well as analysis of historical data and events. Through the chronology and areal appearance of historical threats, probabilities of occurrence for possible future events are calculated. The aim of vulnerability analysis is to identify potential damage within the area of interest. The Carinthian vulnerability analysis investigates mainly four categories which could be affected by hazardous event. All the outcomes are separately presented in a risk matrix, as recommended by the European Union Commission guidelines.

1. Human
2. Damage to property
3. Environmental damage
4. Influence on the economics of the region

The context of risk identification can be reviewed in former presented chapter 2.3.3.

[189] AlpS (2013), Access 29.08.2013.

4.3.3 Lower Austria

The lower Austrian risk assessment methodology is a simple paper based approach, developed by a number of risk assessment experts. For better understanding it is illustrated in Figure 12. This risk assessment is a part of an overall risk management process[190] including several steps as risk prevention and risk treatment.

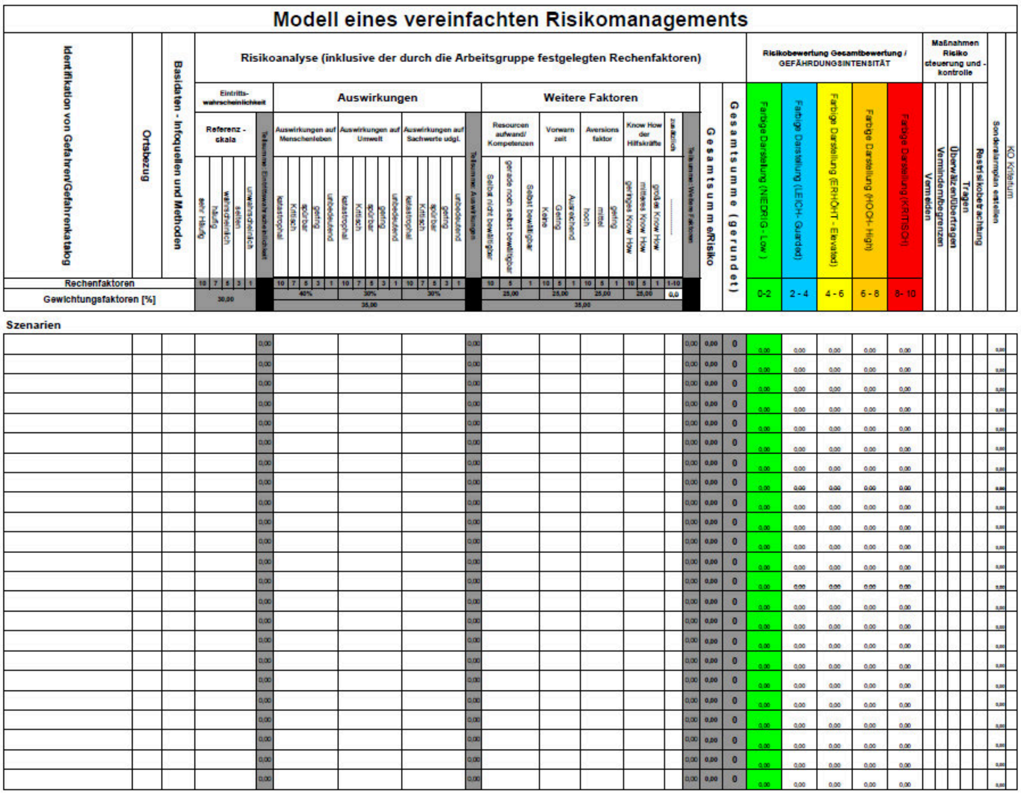

Figure 12: Lower Austrian risk assessment methodology[191].

The paper based approach is divided into several parts as in conventional risk assessment methodologies (risk identification, risk analysis and risk evaluation). Generally it has to be mentioned that this approach is a scenario based once, where individual overall impact scores are calculated. The first column includes identified disasters and threats. Those are written down in relationship to the most probable area of occurrence. Additionally source of information is documented for a better traceability and subsequent uncertainty analysis. The next column is mainly handling risk analysis, which creates the main part of this approach. To generate an overall impact score weighting factors are introduced at that point. Risk analysis is consisting of three subdivisions:

1. Probability of occurrence with corresponding weighting factor of 30%
2. Impact with corresponding weighting factor 35%
3. Further factors with corresponding weighting factor 35%

The probability of occurrence is subdivided into five qualitative described classifications (from unlikely to very likely). The investigated impact factors are human, environment and property. Additional factors investigated by the experts are capabilities, advance warning time, psychological influence on the population and knowhow of assisting stuff.

[190] NÖZSV (2013), Access 20.09.2013.
[191] Cf. NÖZSV (2013), Access 20.09.2013.

Each of the mentioned sub categories have an own weighting influencing the corresponding weighting factor of the column. So at the end the various scores of all single columns are summed up to an overall score and compared to other disaster scenarios. In the last major column possible measures are identified depending on investigated scenarios. It has to be mentioned that outcomes of this methodology are strongly depending on reliability of inputs. This procedure should give a first impression of impacts and disasters as well as acuteness of further investigations for specific scenarios. For more detailed investigations workshops are developed.

4.4 Coordination

"*Major disasters in Austria and abroad, such as the nuclear accident of Chernobyl in 1986 or the flood disaster in 2002, have repeatedly shown that a comprehensive coordination at large-scale events require overall coordination beyond the limits of administration and competence of local and regional bodies*"[192].

Since the year 2003 the Federal Ministry of the Interior is responsible for coordination of the National Crisis and Disaster Protection Management and the international disaster relief. In the year 2004 Federal Crisis and Catastrophy Protection Management (SKKM) was reorganized to be fit for purpose. The most important step within the reorganization was combination of various coordination bodies into one coordination committee chaired by the Director General for Public Safety and Security. It consists of[193 194]:

- Federal ministries
- Provinces
- Action organisations
- Media

Coordination in the case of emergency and disasters is one of the major functions of this committee. Additionally it coordinates planning of basic approaches and should act as centre point for national risk assessment process. One of the most important organizational tools of Federal Crisis and Catastrophy Protection Management (SKKM) is the Federal Alarm Centre.

This centre acts as an operational and information instrument not only within the borders of Austria. The aim of SKKM is to ensure a quick coordination among the involved parties for short or long term disasters. In Figure 13 the organizational structure of Federal Crisis and Catastrophy Protection Management (SKKM) is presented. It can be clearly recognized that there are various levels of communication, but all are coordinated by the Federal Alarm Centre.

[192] MOI (2013), Access 03.09.2013.
[193] Cf. MOI (2013), Access 03.09.2013.
[194] Cf. Jachs (2011),P. 20-23.

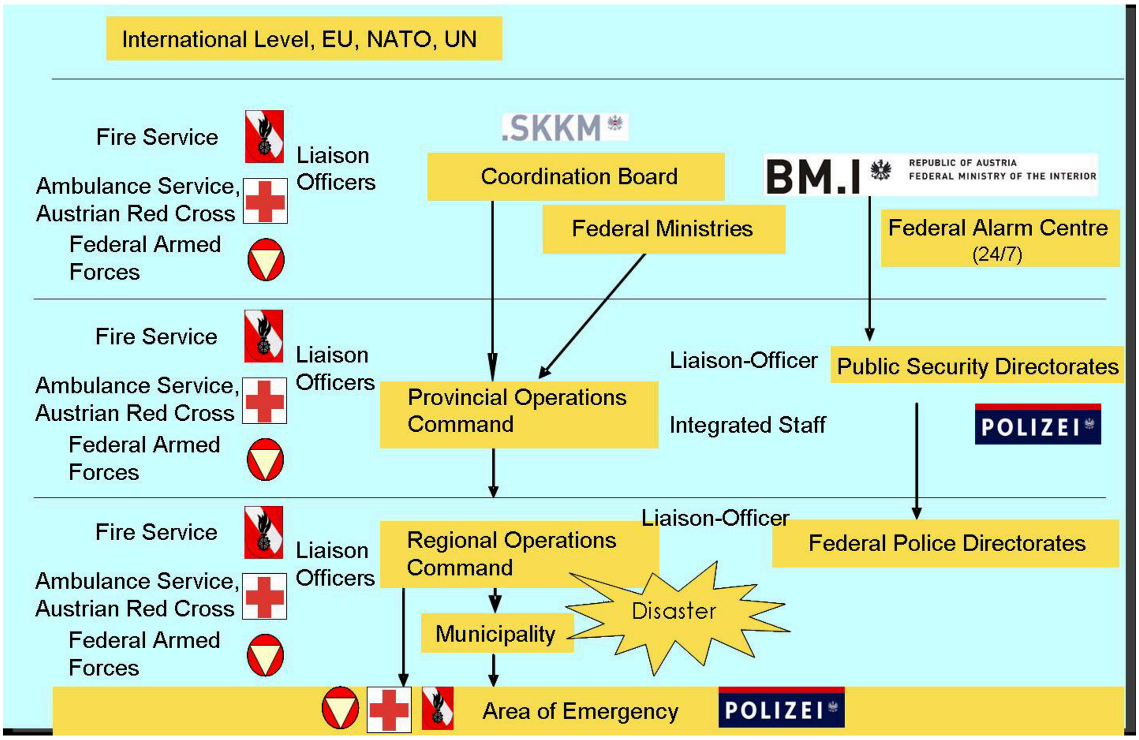

Figure 13: Organisational structure of Federal Crisis and Catastrophy Protection Management (SKKM).[195]

4.5 Recommendations for Austrian Risk Assessment

Actually there is no common Austrian risk assessment, due to complex legal situation and responsibility issues. The Austrian risk assessment is based on risk assessments developed by the nine federal provinces. Those nine provincial assessments are not comparable and somehow independent from each other. The aim is to create a common risk assessment procedure covering all the Austrian territory. For this specific aim a massive cooperation between federal provinces governments and national government has to be carried out.

A common national risk assessment and thus risk management would increase comparability and transparency of risks. Furthermore adapted decision making would be easier to realize and a common national methodology will be easier to update (less efforts). Additionally given capacities would be utilized in a more effective way. For a European Union wide risk management each of the Member States has to realize its own national risk assessment based on recommendations of EU Commission (see chapter 2).

For the creation of a common national risk assessment process an expert group has to be formed out of federal provinces and national government to guarantee a diversity of experts and involvement of all responsibility levels. The coordination of the whole process of national risk assessment and risk management is very important and could be performed by existing organisations like the Federal Crisis and Catastrophy Protection Management (SKKM). The development of a common national risk assessment process should be created according the EU Commission guidelines explained in chapter 2. Additional recommendations are that the national risk assessment process of Federal Republic of Germany (chapter 0) and Netherlands (chapter 5.3) should be taken into account, due to their ad-

[195] Jachs (2011), P. 22.

vancement and reliability. Furthermore positive and useful aspects of the nine provincial risk assessments should be implemented into the common national risk assessment. All those actions should result in a better understanding of possible risks and should help to investigate if the actual capabilities are enough, so that actions and measures could be realized more effectively in case of emergency.

4.5.1 Source of Information

As mentioned before the development of a national risk assessment should be based on former developed risk assessments created by the nine federal provinces, earlier performed risk analysis as well as existing risk management. Besides of those important sources of information, others inputs should be considered. This should guarantee a wide range of information and inputs, ending up in more accurate results and outcomes. A large number of information is already available on various platforms created by authorities or private organisations. To get a representative overview, some sources will be discussed and shortly explained in the following:

Naturgefahren.at

This platform is created with support of the "***Lebensmittel Ministerium***"[196]. The main objective is to provide a qualitative and historical overview of the potential risks within the territorial area of Austria. On this platform various risks are analyzed according to their cases and potential damage. The man investigated events are floods, snow slides and rock slides. The content is based on the visual acquisition of the GIS.

EM DAT – The International Disaster Data Base

The EM DAT main objective is to support decision making processes for disaster management related to humanitarian action at national and international levels. This is carried out through providing an objective base for vulnerability assessment and priority setting[197]. This platform contains essential core data on occurrence and impacts of over 18.000 large disasters occurred starting from the year 1900. The data available on EM DAT are provided through various organizations which are very reliable. Examples are:

- UN agencies
- NGO´s
- Insurance companies
- Research institutes
- Press agencies

Collected data can help to perform an accurate likelihood assessment and impact assessment for a number of probable hazardous events. That information is essential for a national risk assessment process and thus the national risk management. Evaluated data help, to make a right decisions and prioritization of preventive measures.

[196] Cf. Naturegefahren.at (2013), Access 15.07.2013.
[197] Cf. EM DAT (2013), Access 14.07.2013.

ZAMG - Zentralanstalt für Meteorologie und Geodynamik / Department of Geophysics

This specific platform provides data about earthquakes which affect the Austrian territory and neighbouring countries. Within this data base all earthquakes are recorded since the year 1900. Another important task of this platform is that it provides detailed maps about areas which could be affected by earthquakes. With the historical data a support to the assessments of likelihood and impact according to earthquakes could be realized[198].

Workshops

Another important source of information are expert workshops. During those workshops specific topics related to national risk assessment are discussed. Outcomes can then directly be implemented into the process. This is a very reliable and easy method, but has to be carried out carefully according to:

- Number of involved experts
- Selection of experts
- Heading and responsibility on the workshop

Those kinds of workshops should be carried out under a predefined method to guarantee the comparability and transparency of outcomes.

4.6 Summary

Due to the complex legal and responsibility situation in Austria no common risk assessment process was created. Each of the nine federal provinces has its own risk assessment process. Going into detail, an overlapping of the methodologies is recognizable. But still the methodologies are strongly varying from simple paper based approaches to software supported methods.

All requirements for a common national risk assessment process are actually given. There is a coordination organization (SKKM) which could act as a centre point for the national risk assessment process. Information, assessments and analysis are availed, due to the preliminary work and studies of the federal provinces (very reliable preliminary work). The methodology is provided by the EU Commission for a national risk assessment as well as from EU Member States which have very advanced processes.

Generally within the actual risk assessments conducted by the federal provinces there is no monetary analysis. So comparison of preventive measures to the do-nothing case is not possible. Monetary analysis should be included in a future Austrian wide risk assessment for better decision making and prioritization process.

[198] Cf. ZAMG (2013), Access 16.08.2013.

5 International Methods of Risk Assessment in the Field of Natural Disaster

National risk assessment process in the context of risk management is a very important issue, due to variety of risks which the international community are confronted with. Especially in the past decade likelihood as well as impact of disasters increased gradually, affecting the population and economics of some nations massively. Independent of cases, several essential measures and actions were realized to eliminate or reduce the impact of disasters (man-made or natural). This was mainly accomplished through implementing outcomes of adapted risk management. In Figure 14 some disasters, which the European Union and some neighbouring countries are confronted with, are illustrated.

Country	Flood	Land slides	Drought	Extreme temperature	Wind storm	Wild fire	Wave / surge
Albania	X	X	X	X	X	X	
Armenia	X	X	X		X		
Azerbaijan	X	X	X				
Belarus	X			X	X		
Bosnia and Herzegovina	X	X	X		X	X	
Bulgaria	X	X	X	X	X	X	
Croatia	X		X	X	X	X	
Czech Republic	X	X		X	X		
Estonia	X	X		X	X		
FY Republic of Macedonia	X	X	X	X	X	X	
Georgia	X	X	X		X		
Hungary	X		X	X	X		
Kazakhstan	X	X		X	X	X	
Kyrgyz Republic	X	X		X	X		
Latvia	X			X	X		
Lithuania	X		X	X	X		
Moldova	X	X	X	X	X		
Poland	X			X	X	X	
Romania	X	X	X	X	X		
Russian Federation	X	X	X	X	X	X	X
Serbia	X			X	X	X	
Slovak Republic	X			X	X	X	
Montenegro	X			X	X	X	
Slovenia	X	X		X			
Tajikistan	X	X	X		X		
Turkey	X	X		X	X	X	
Turkmenistan	X						
Ukraine	X	X		X	X		
Uzbekistan	X	X	X				

Figure 14: Risks in various European countries[199].

In this chapter national risk assessment processes of selected EU Member States will be presented and discussed. It has to be mentioned that the advancement level of single national procedures are strongly differing. Some of the leading countries are Federal Republic of Germany, Norway, Netherlands and United Kingdom. Most of the countries created their procedures according to the recommendations of European Union Commission, formerly presented in chapter 2. Some EU Member States adopted their methods according to specific national requirements. Those adoptions create a major pillar for EU wide risk assessment, which will be started in 2014. The adoptions create an additional benefit as well as input to EU wide assessment process.

[199] Cf. Pollner et.al (2008), P. 8.

5.1 Federal Republic of Germany

Civil protection and core elements of risk management in the Federal Republic of Germany are based on outcomes of realized risk assessment. Generally the risk assessment allows the determining of impact resulting out of various hazardous events. Based on the risk assessment efficient measures are carried out to protect the German population as well as to eliminate or reduce the source of risk.

The national risk assessment procedure is based on international standard of risk management and risk analysis, which are recommended by the EU Commission. Considerations of several federal authorities, international partner authorities and academia are also taken into consideration during the procedure. German authorities are realizing a national risk assessment to define the "*risk and its geographical distribution in the area, it helps to classify various technical sites and the obligation of their operators to support the civil service authorities. It is therefore the base for emergency planning in Civil Protection and Rescue Services*"[200].

5.1.1 Framework Conditions

The application of risk assessment method for civil protection is based on several frame work conditions, which are listed in the following. It is important to define such a framework at the starting point of the process. This action secures a common basis of understanding and eliminates ambiguities among involved parties[201].

1. Likelihood and impact are essential elements of risk assessment. Likelihood is referring to the occurrence probability of a hazardous event with certain intensity. In that specific context the impact refers to damages which are expected, if a hazardous event occurs.
2. "*During the risk analysis process, a well-balanced measure of scientific demand on the one hand and pragmatic approach on the other hand has to be found. Whenever there is a lack of statistical/scientific findings, it should be possible to compensate such deficits in knowledge (initially) by well-founded assumptions and estimations. Here, involvement of (local) experts ensures the highest possible degree of reliability*" [202].
3. Documentation of all procedures is a very important issue. The documentation should guarantee the traceability and trainability of process outcomes.
4. To simplify the process, limitation to realistic risks is advisable. Those risks should create a challenge to the administrative level and should indicate limits as well as measures which have to be taken to prevent a certain event.
5. Risk which occurs outside the reference area should also be considered. Those risks could have a significant impact on the area of interest. So information and data exchange between countries or regional authorities is an important matter throughout the whole risk assessment and risk management process.
6. "*Risk analysis for civil protection is an ongoing task. The applied method must allow for being optimized and adapted to new findings/framework conditions at any time*"[203].

[200] European Commission (2007), P. 9.
[201] Cf. Bundesregierung (2010), P. 15.
[202] Federal Office of Civil Protection and Disaster Assistance (2011), P. 17.
[203] Federal Office of Civil Protection and Disaster Assistance (2011), P. 17.

7. The risk assessment process should be understood as an instruction for the practical accomplishment. Special steps within the risk management process are required to implement the results in administrative and/or political acts.
8. The whole method is an ongoing process with several steps like analysis, evaluation, treatment as well as monitoring of risks, which has to be revised in regular time lags. This is usually carried out every two years.

Other general framework conditions can be reviewed in the ISO 31000: Risk management – Principles and Guidelines[204].

5.1.2 Procedure

As mentioned before the German procedure of risk assessment is carried out based on recommendations of European Union guidelines represented in chapter 2 as well as international standards like ISO 31000 and ISO 31010. Risk assessment is an essential part of risk management; this consists mainly of five steps, as illustrated in Figure 15.

Figure 15: German risk management process[205].

The core elements of risk assessment are risk identification, risk analysis as well as risk evaluation. The developed assessment is mainly influenced by outcomes of risk analysis. In the following the most important elements of the analysis will be explained. Generally it has to be mentioned that the German risk assessment is in a very advanced stage and shows a major differences compared to other national risk assessments of EU member states. The procedure is implemented by all federal states, but is adapted to a certain degree to fulfil requirements. This is strongly depending on the requirements of investigating team. Due to comparability of outcomes, collaboration between the federal states is very intensive, despite of slightly different legal basis.

[204] Cf. IEC (2009), ISO 31000.
[205] Federal Office of Civil Protection and Disaster Assistance (2011), P. 45.

5.1.3 Risk Matrix

The representation of risks in a comparative way is one of the major aims of risk assessment for civil protection, independent of type and source of risk. The representation of results is realized by a risk matrix, which is corresponding to recommended international standards. This matrix is presented below in Figure 16. On the X-axis the likelihood of an event and on the Y-axis the impact of that event are illustrated. The results of both values (likelihood and impact) for a specific risk scenario end up in a certain dimension of risk. Within the matrix the risk is divided into 4 categories: low, intermediate, high and very high, as indicated with different colours (from green to red).

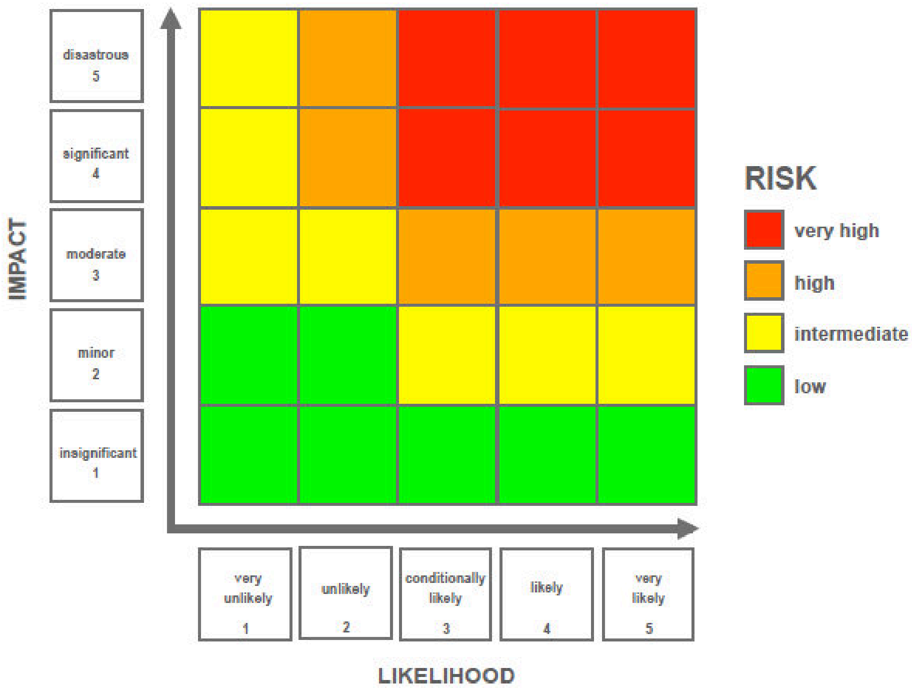

Figure 16: International risk matrix[206].

To develop a representative risk assessment, integration of modified information based on available data has to be realized. Quality and intensity of information have a direct impact on the risk assessment and thus on uncertainty of outcomes. For this purpose detailed investigations as well as specific procedures are carried out by the government and responsible authorities to guarantee a stable quality of input parameters, information as well as data. Additionally an accurate documentation is carried out to guarantee transparency and traceability.

5.1.4 Description of Reference Area

The risk analysis always refers to a territorial reference area. This investigated reference area has to be clearly identified. Examples of territorial areas are: Federal Republic of Germany, a federal state or an administrative district[207]. Independent of the extent of reference area, it has to be clearly defined and described. This could create a common point of departure for involved parties.

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[206] Cf. Federal Office of Civil Protection and Disaster Assistance (2011), P. 12.
[207] Cf. Federal Office of Civil Protection and Disaster Assistance (2011), P. 23.

Impact is always determined depending on the possible consequences of a certain hazardous events on a predefined area. Over the boundary events also has to be considered, because they could have a significant influence on events occurring within the reference area. It is generally better to have a smaller reference area for procedural and organizational reasons[208]. The accurate identification of reference area was defined as the first step of the risk analysis process. The identification and subdivision is realized into detail to cover all areas within the territorial area of Federal Republic of Germany. The responsibility for each area has to be clearly identified as well as documented. Target should be 100% coverage. For this purpose several types of information, according to reference area, are collected[209]:

- Geography of reference area (climate, land use, ...)
- Population (number of inhabitants, population density, ...)
- Environment (protected areas, ...)
- Economy (economic performance, business tax receipts, ...)
- Supply (infrastructures of electricity, drinking water supply, ...)

In Table 10 absolute minimum information required for the reference area are presented.

CATEGORY	INFORMATION	POSSIBLE SOURCES OF INFORMATION
MAN	Number of inhabitants	• Statistical offices • Federal Institute for Building, Urban and Rural Research • Registry offices
	Population density	
	Number of households	
ENVIRON-MENT	Protected areas[10]	• Federal Agency for Nature Conservation • Environment offices
	Agricultural land	• Statistical offices • Offices for agriculture
ECONOMY	Economic performance	• Statistical offices • Economic authorities
	Business tax receipts	
SUPPLY	Infrastructures of water supply	Economic authorities Infrastructure suppliers
	Infrastructures of electricity supply	Economic authorities Infrastructure suppliers
	Infrastructures of gas supply	Economic authorities Infrastructure suppliers
	Infrastructures of telecom-munication	Economic authorities Infrastructure suppliers
IMMATERIAL	Cutural assets	Authorities for preservation

Table 10:.Description of reference area with assigned categories[210].

Investigated information creates the fundament for the determination of impact on predefined reference area. They are subdivided into five main categories related to man, environment, economy, supply and immaterial. Additionally those categories mentioned are further differentiated for better accuracy of input data. Description of reference area should be compensated with corresponding maps for better understanding and to get a faster overview of area affected. Required adoptions as well as additional categories or information can be implemented, but has to be documented and scientifically justified.

[208] Cf. Bundesregierung (2010), P. 15.
[209] Cf. Bundesregierung (2010), P. 17.
[210] Cf. Federal Office of Civil Protection and Disaster Assistance (2011), P. 24.

5.1.5 Selection of Hazard and Description of Scenario

The identification of type of hazard is the second step of risk analysis. For this purpose a so called index number catalogue is introduced and can be utilized as a reference in further risk assessments and risk management stages. In this specific catalogue several types of hazards as well as the corresponding reference numbers are listed. They are divided into four main categories (including natural and man-made disasters)[211]:

- Hazards and requirements due to natural events and anthropogenic (3100)
- Hazards and requirements due to NBC situations, technology and transportation accidents and large-scale fires (3200)
- Hazards and requirements due to terrorism/attacks/assassinations/sabotage (3300)
- Acts of war on or above German territory or in border areas of neighbour states to Germany (3400)

In the following the most important hazards related to natural disasters and their corresponding subcategories are presented[212]:

3100	**Hazards and requirements due to natural events and anthropogenic environmental influences**
3110	**Extreme weather conditions**
3111	Storm/hurricane/tornado
3112	Intense rainfall, hail, freezing rain, black ice
3113	Long-lasting snowfall/snow banks
3114	Long-lasting strong frost
3115	Avalanches
3116	Strong thunderstorms with massive lightning strikes
3117	Heat and drought periods with bad harvests and/or shortage of drinking water
3118	SMOG
3120	**Earthquakes**
3130	**Earthmoving**
3131	Subsidence/land subsidence/landslides
3140	**Large-scale fires (forest fire, heath fire, moor fire)**
3150	**Floods/storm floods**
3151	Floods caused by dam bursts
3152	Local floods caused by heavy rainfall
3153	High water in brooks, rivers and river valleys
3154	Storm floods/floods on sea coasts and inland lakes
3160	**Impact of meteorites**

After the selection of a listed hazard, a scenario based on former defined reference area is developed. Scenario development is considered as the real starting point of risk analysis, earlier carried out steps had the purpose of preparation of information and data. If a serious risk is identified, additional hazards can be integrated into the catalogue. Those have to be based on scientific arguments. Generally developed scenarios have to describe investigated event clearly and into sufficient detail. This measure should provide a reliable fundament for assessment of likelihood and impact.

[211] Bundesregierung (2010), P. 34.
[212] Cf. Federal Office of Civil Protection and Disaster Assistance (2011), P. 60.

For this purpose it is necessary to define basic characteristics of the scenario; examples are:

- Type
- Spatial dimension
- Intensity
- Duration

For increased accuracy this should be based on historical data base, scientific findings and statistical findings; to compensate assumptions and assessments as well as to reduce the overall uncertainty. German authorities already have prepared for some of the listed hazards assumptions and prognoses concerning their expected intensity. Those have to be transferred to the investigating area. The scenario description has to be prepared accurately and should be based on parameters and questions presented in Table 11. It has to be mentioned that the impact should be evaluated based on usual units of measurement[213]:

- Floods in HQ 100
- Earthquakes in Richter scale Magnitude 6
- Release of hazardous substances in release of 100 kg of chlorine

"*If a qualitative description is necessary, the reference to real incidents is recommended in order to allow third parties to understand the assumptions and to make the further analysis more illustrative (example: Release of hazardous substances on 12 December 00 in the city of XY)*" [214].

PARAMETER	CENTRAL QUESTIONS
Hazard	• Which type of hazardous event is considered?
Scene of occurrence	• Where does the event take place?
Spatial dimension	• Which area is affected by the event?
Intensity	• How strong is the event?
Time	• When does the even take place? (time of year/time of day, if applicable)
Duration	• How long does the event and its direct impact last?
Development	• How does the event evolve?
Notice time for warning	• Is the event expected? • Is the population able to prepare for the event? • Are public authorities able to prepare for the event?
Who is affected?[12]	• Which subjects of protection are affected by the event? (persons, environment, objects etc.)
Reference incidents	• Have there been comparable events in the past?
Further information	• How well prepared are the responsible authorities/relief units/ helpers? • Findings concerning the damage susceptibility and/or robustness of the affected persons/elements. • What else is important for the scenario, but has not yet been gathered?

Table 11: Parameters and questions, prepared by German authorities, for a detailed description of a hazard scenario[215].

[213] Cf. Bundesregierung (2010), P. 18.

[214] Federal Office of Civil Protection and Disaster Assistance (2011), P. 25.

5.1.6 Assessment of Likelihood

The identification of likelihood for a specific scenario or event is determined and placed as the third step within the risk analysis process. Outcomes and classifications carried out within this core step have a high impact on outcomes of the risk analysis; thus on the overall procedure. Therefore it has to be performed very accurately and based on the best knowledge. The German authorities have defined a five step scale to be utilized as reference for likelihood. For each of mentioned steps a corresponding statistical likelihood is predefined.

VALUE	CLASSIFICATION	... per year	1x in ... years
5	very likely	≤ 0.1	10
4	likely	≤ 0.01	100
3	likely to a limited extent	≤ 0.001	1,000
2	unlikely	≤ 0.0001	10,000
1	very unlikely	≤ 0.00001	100,000

Table 12: Probability of occurrence of an event, subdivided into 5 steps.[216]

The values presented in Table 12 are not static and can be modified if necessary. As in other steps modification of values has to be clearly documented and communicated to all involved parties. It has to be clearly noticed and understood that modifications within the values lead to different outcomes. Available scientific and statistical findings should be taken into consideration to establish a more accurate and representative likelihood. So communication with professional authorities and research institutions is recommended.

Every possible database should be utilized to increase accuracy of information. The absence of scientific and statistical knowledge can be compensated by realistic assumptions and expert assessments. In this case also a reliable documentation has to be carried out. If no data are available for an accurate classification, the authorities recommended a qualitative correlation, which is realized with a simple classification:

- Very likely 5
- Likely 4
- Conditionally likely 3
- Unlikely 2
- Very unlikely 1

5.1.7 Assessment of Impact

Assessment of impact is ranked as the forth step within the risk analysis process. In this step the impact, which has to be expected from the predefined scenario (on the reference area) is assessed. The expectations of impact are analyzed for different so called impact categories or impact parameters. "*The determination of the expected impact requires the selection of appropriate impact parameters as well as the definition of appropriate threshold values for the classification of impact related to each impact parameter*"[217].

[215] Cf. Federal Office of Civil Protection and Disaster Assistance (2011), P. 26.
[216] Cf. Federal Office of Civil Protection and Disaster Assistance (2011), P. 27.
[217] Federal Office of Civil Protection and Disaster Assistance (2011), P. 29.

Selection of Damage Parameters

In Table 13 and Table 14 some examples of impact parameters are presented in relationship to five impact categories[218]:

- Man
- Environment
- Economy
- Supply
- Immaterial

The type of parameters presented are not depending on a certain type of hazard or event, they can be applied to any kind (natural or man-made). Those parameters should reflect the total impact caused by a predefined scenario or event on the reference area. For better identification of each parameter a capital letter and a subscript number are applied. In combination they indicate which impact category is under investigation. Each impact category can be complemented with further parameters to get a more realistic assessment. The represented impact parameters are a good and realistic selection for a national risk analysis.

Category	Abbre-viation	Damage parameter	Description/ Operationalisation	Unit
MAN	M1	Fatalities	Persons who die due to the incident in the reference area	Number
	M2	Injured	Persons who are injured due to the incident in the reference area or who become ill during/after the incident so that they need treatment by doctors or the health system (here long-term consequences/long-tail claims have to be included)	Number
	M3	Persons in need longer 14 days	Persons in need for public aid for physical survivla for more than 14 days	Number
	M4	Persons in need up to 14 days	Persons in need for public aid for physical survival up to 14 days	Number
ENVIRON-MENT	U1	Impairment of protected area	Protected areas which are damaged due to the incident (protected areas, national parks, biosphere reservations, land-scape protection areas, natural parks)	ha
	U2	Impairment of water bodies	Living space in surface waters or in the sea which are damaged due to the incident (rivers, canals, brooks, lakes, ponds)	km/ha
	U3	Impairment of ground water	Ground water which is contaminated due to the incident	ha
	U4	Impairment of agricultural land	Agricultural land which is damaged due to the incident	ha

Table 13: Example of impact parameters in the impact category man and environment[219].

[218] Cf. Bundesregierung (2010), P. 19.
[219] Cf. Federal Office of Civil Protection and Disaster Assistance (2011), P. 31.

Category	Abbre-viation	Damage parameter	Description/ Operationalisation	Unit
ECONOMY	W1	Physical damage	Sum of the replacement value of the direct material damage (destruction etc.)	Euro
	W2	Consequential damage	Sum of the indirect damage (loss of supply, delivery interruptions etc.)	Euro
	W3	Loss of econom-ic performance	Loss of economic performance, due to the incident	Euro
	W4	Loss of econom-ic profitability	Business tax losses due to the incident	Euro
SUPPLY	V1	Disruption of water supply	Duration and spatial extent of the disruption, number of persons affected	Number, hours/days
	V2	Disruption of energy supply	Duration and spatial extent of the disruption, number of persons affected	Number, hours/days
	V3	Disruption of gas supply	Duration and spatial extent of the disruption, number of persons affected	Number, hours/days
	V4	Disruption of telecommunica-tion	Duration and spatial extent of the disruption, number of persons affected	Number, hours/days
IMMATE-RIAL	I1	Impact on public order and safety	Extent of the consequences of the incident on public safety (e. g. public protests, violence against persons/objects)	Extent
	I2	Poitical implications	Extent of the consequences of the incident on the political-administrative sector (e. g. call for state actions, public calls for resignations)	Extent
	I3	Psychological implications	Extent of the loss of trust in public authorities (e. g. government, adminis-tration)	Extent
	I4	Damage to cultural assets	Cultural assets according to the Hague Convention which is damaged due to the incident	Number and degree of damage

Table 14: Examples of impact parameters in the impact category economy, supply and immaterial[220].

Definition of Threshold Values

Sufficient threshold values have to be defined to classify the impact intensity of each impact parameter. For description of the impact, a scale of five is utilized ranging from disastrous (with the impact value of 5) to insignificant (with the impact value of 1). In Table 15 to Table 19 several templates for impact classifications are presented.

They can be adapted depending on requirements of defined area and questions of the user. Having a more detailed look on the category man in Table 15, it can be clearly noticed that four impact parameters are presented. For each parameter a threshold value depending on the impact intensity has to be identified. For the development of the threshold values historical data, scientific results and results of earlier assessments have to be taken into consideration. By increasing database the explanatory power of results will also increase as well as the uncertainty will decrease.

[220] Cf. Federal Office of Civil Protection and Disaster Assistance (2011), P. 32.

Classification		MAN			
Value	in words	Fatalities	Injured	Persons in need longer than 14 days	Persons in need up to 14 days
5	disastrous	> ___	> ___	> ___	> ___ persons for > ___ hours/days
4	significant	___ - ___	___ - ___	___ - ___	___ - ___ persons for ___ - ___ hours/days
3	moderate	___ - ___	___ - ___	___ - ___	___ - ___ persons for ___ - ___ hours/days
2	minor	___ - ___	___ - ___	___ - ___	___ - ___ persons for ___ - ___ hours/days
1	insignificant	≤ ___	≤ ___	≤ ___	≤ ___ persons for ≤ ___ hours/days

Table 15: Model for classification of the category man[221].

Classification		ENVIRONMENT			
Value	in words	Impairment of protected area	Impairment of water bodies	Impairment of ground water	Impairment of agricultural land
5	disastrous	long term > ___ ha or temporarily > ___ ha	river > ___ km or lake > ___ ha or sea > ___ ha	> ___ ha	long term > ___ ha or temporarily > ___ ha
4	significant	long term > ___ - ___ ha or temporarily > ___ - ___ ha	river > ___ km or lake > ___ ha or sea > ___ ha	___ - ___ ha	long term > ___ - ___ ha or temporarily > ___ - ___ ha
3	moderate	long term > ___ - ___ ha or temporarily > ___ - ___ ha	river > ___ km or lake > ___ ha or sea > ___ ha	___ - ___ ha	long term > ___ - ___ ha or temporarily > ___ - ___ ha
2	minor	long term > ___ - ___ ha or temporarily > ___ - ___ ha	river > ___ km or lake > ___ ha or sea > ___ ha	___ - ___ ha	long term > ___ - ___ ha or temporarily > ___ - ___ ha
1	insignificant	long term ≤ ___ ha or temporarily ≤ ___ ha	river ≤ ___ km or lake ≤ ___ ha or sea ≤ ___ ha	≤ ___ ha	long term ≤ ___ ha or temporarily ≤ ___ ha

Table 16: Model for classification of the category environment[222].

Classification		ECONOMY			
Value	in words	Physical damage	Consequential damage	Loss of economic performance	Loss of economic profitability
5	disastrous	> ___	> ___	> ___	> ___
4	significant	___ - ___	___ - ___	___ - ___	___ - ___
3	moderate	___ - ___	___ - ___	___ - ___	___ - ___
2	minor	___ - ___	___ - ___	___ - ___	___ - ___
1	insignificant	≤ ___	≤ ___	≤ ___	≤ ___

Table 17: Model for classification of the category economy[223].

[221] Cf. Federal Office of Civil Protection and Disaster Assistance (2011), P. 33.
[222] Cf. Federal Office of Civil Protection and Disaster Assistance (2011), P. 33.

Classification		SUPPLY			
Value	in words	Disruption of water supply	Disruption of energy supply	Disruption of gas supply	Disruption of tele-communication
5	disastrous	> ___ persons for > ___ hours/days	> ___ persons for > ___ hours/days	> ___ persons for > ___ hours/days	> ___ persons for > ___ hours/days
4	significant	___ - ___ persons for ___ - ___ hours/days	___ - ___ persons for ___ - ___ hours/days	___ - ___ persons for ___ - ___ hours/days	___ - ___ persons for ___ - ___ hours/days
3	moderate	___ - ___ persons for ___ - ___ hours/days	___ - ___ persons for ___ - ___ hours/days	___ - ___ pers ons for ___ - ___ hours/days	___ - ___ persons for ___ - ___ hours/days
2	minor	___ - ___ persons for ___ - ___ hours/days	___ - ___ persons for ___ - ___ hours/days	___ - ___ persons for ___ - ___ hours/days	___ - ___ persons for ___ - ___ hours/days
1	insignificant	≤ ___ persons for ≤ ___ hours/days	≤ ___ persons for ≤ ___ hours/days	≤ ___ persons for ≤ ___ hours/days	≤ ___ persons for ≤ ___ hours/days

Table 18: Model for classification of the category supply[224].

Classification		IMMATERIAL			
Value	in words	Impact on public order and safety	Poitical implications	Psychological implications	Damage to cultural assets
5	disastrous	Extent: ________	Extent: ________	Extent: ________	Extent: ________
4	significant	Extent: ________	Extent: ________	Extent: ________	Extent: ________
3	moderate	Extent: ________	Extent: ________	Extent: ________	Extent: ________
2	minor	Extent: ________	Extent: ________	Extent: ________	Extent: ________
1	insignificant	Extent: ________	Extent: ________	Extent: ________	Extent: ________

Table 19: Model for classification of the category immaterial[225].

The impact parameters of the categories man, environment, economy and supply can be reliably classified by quantitative range of values. Categories like immaterial have to be classified by qualitative ranges, if quantitative classification is not fitting. The crucial step during the risk analysis process is the definition of impact values corresponding to individual impact parameter. So it highly recommended involving experts out of different branches, to end up in reliable statements.

[223] Cf. Federal Office of Civil Protection and Disaster Assistance (2011), P. 34.
[224] Cf. Federal Office of Civil Protection and Disaster Assistance (2011), P. 34.
[225] Cf. Federal Office of Civil Protection and Disaster Assistance (2011), P. 35.

In Table 20 and Table 21 an example with randomly chosen values for the impact parameters is presented. A simple arithmetic method is utilized to identify the total impact value of presented scenario, depending on the reference area in consideration. All impact values are summed up and divided by their total number, as illustrated in Table 21.

A weighting of impact values is also possible and should reflect the different priorities. This is carried out by counting the impact value several times. On the other hand also impact parameters which suffer no damage in the chosen scenario have to be considered. They would have the value of one or insignificant in qualitative methodology.

Category	Impact parameter	Unit	Expected impact (example)	Abbre-viation	Impact value (example)
MAN	Fatalities	Number	15	M1	2
	Injured	Number	120	M2	2
	Persons in need longer 14 days	Number	0	M3	1
	Persons in need up to 14 days	Number	120.000	M4	3
ENVIRON-MENT	Impairment of protected area	ha	500 (temporarily)	U1	2
	Impairment of water bodies	km/ha	none	U2	1
	Impairment of ground water	ha	none	U3	1
	Impairment of agricultural land	ha	none	U4	1
ECONOMY	Physical damage	Euro	4 billion	W1	5
	Consequential damage	Euro	currently not quantifiable	W2	1
	Loss of economic performance	Euro	currently not quantifiable	W3	1
	Loss of economic profitability	Euro	currently not quantifiable	W4	1
SUPPLY	Disruption of water supply	Hours/days, number	none	V1	1
	Disruption of energy supply	Hours/days, number	230.000, 3 days	V2	5
	Disruption of gas supply	Hours/days, number	none	V3	1
	Disruption of telecommunication	Hours/days, number	125.000, up to 1 day	V4	3

Table 20: Randomly chosen impact values for the categories man, environment, economy and supply[226].

Category	Impact parameter	Unit	Expected impact (example)	Abbre-viation	Impact value (example)
IMMATE-RIAL	Impact on public order and safety	Extent	none	I1	1
	Poitical implications	Extent	none	I2	1
	Psychological implica-tions	Extent	none	I3	1
	Damage to cultural assets	Number and degree of damage	3 significantly damaged	I4	3
				Sum:	37
				divided by number of impact parameters:	20
				Total impact value:	1,9

Table 21: Randomly chosen values for the category immaterial and total impact value of all categories[227].

226 Cf. Federal Office of Civil Protection and Disaster Assistance (2011), P. 37.

5.1.8 Classification and Visualization of Risk

Representing the results of performed process is the last step of risk analysis. This is realized by using a risk matrix (as shown in Figure 16). This matrix is consisting on likelihood of the event and the corresponding impact resulting out of the event. Furthermore it is strongly related to the risk matrix advised by the European Union Commission.

The comparative representation of different possible events is the aim of risk analysis. For this reason different risks related to a variety of scenarios should be analysed. In the ideal case a preventive measure will be carried out to avoid or minimize the damage resulting out of this scenario. With the information illustrated in the risk matrix, a prioritization of measures as well as treatment plans could be carried out. This process is an ongoing task and has to be updated in a certain lag of time, because situation is changing continuously. The documentation of ongoing processes and measures is very important and is one of the key factors. In Figure 17 different scenarios are compared to each other. Within the matrix there are different risk classes depending on likelihood and impact of examined scenario. The risk is subdivided into four classes:

- Very high
- High
- Intermediate
- Low

Action and measures within the risk class very high should be realized as soon as possible; due to the fact that likelihood and impact of this scenario in very high on the reference area. Afterwards actions and measures within other classes starting from high to low could be realized depending on given situation. In any case a detailed monetary analysis should be done to compare the value of damage to the value of preventive measures. This specific measure is not included into the actual risk analysis process.

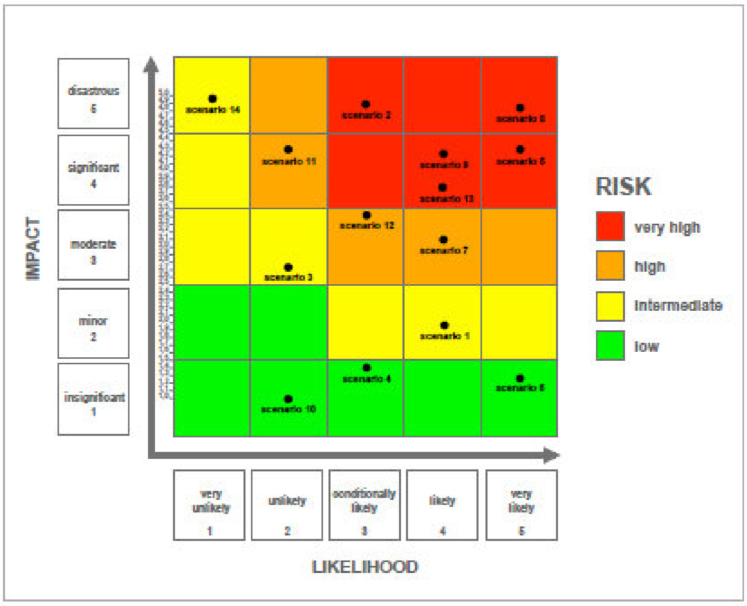

Figure 17: Representation of different scenarios within the risk matrix[228].

[227] Cf. Federal Office of Civil Protection and Disaster Assistance (2011), P. 38.
[228] Cf. Bundesregierung (2010), P. 26.

5.1.9 Summary

The whole risk assessment process created by the Federal Republic of Germany is at a very advanced level. The method is very helpful in identifying risks and possible hazards. Several categories of interest are developed (man, environment, economy, supply and immaterial) and analyzed into detail to help the responsible authorities to create realistic risk scenarios. In this case more categories of interest are classified than recommended in the European Commission Guidelines.

Through the implementation of threshold and impact values for each category as well as an overall impact value; the ranking of different scenarios is possible and measures can be realized depending on the acuteness. This specific step is more advanced than in other European Union Member State countries and should be integrated into the EU wide risk assessment process.

Monetary investigations of the created risk scenarios are not performed. So comparison of expenditures for preventive measures to expenditures for damages resulting of the hazardous event cannot be carried out. To integrate monetary analysis more specific input parameters has to be developed within the procedure and an adaption of some steps would be necessary. The integration of monetary analysis into the risk assessment process is advisable and would increase value of outcomes. This would create a better basis for decision making, ending up in a higher degree of population protection.

5.2 Norway

The main objective of a national risk assessment carried out by the Directorate for Civil Protection and Emergency Planning (DSB) is to identify possible risks within the territorial area of Norway. The authorities are trying to provide a common basis for planning within the civil protection and planning work. This specific measure should reduce the uncertainties und delete misunderstandings. Events with serious consequences had the primarily attention of Directorate for Civil Protection and Emergency Planning (DSB). To get a more comprehensive risk picture; dialogue and discussions were carried out across various sectors and disciplines, involving ministries, offices, scientists and stakeholder. As in European Member States the procedure of risk assessment is reviewed on an annual basis to integrate new data and information into the on going process. The process of risk assessment is realized in several steps and will be explained in more detail in the following.

5.2.1 Defining Societal Values

The first step within the process of creating a national risk picture is the definition of societal values. Incidents creating negative consequences, especially on fundamental social values are defined by the Norwegian government as undesirable incidents. They play a major role in the risk assessment process, furthermore they help to better define the national risk picture. The DSB has defined five fundamental societal values, which form the basis for further evaluations and assessments[229]:

1. Life and health
2. Nature and environment
3. Economy
4. Social stability
5. Ability to govern and territorial control

5.2.2 Identifying Threats and Risk

The second step within the Norwegian risk analysis process is the identification of threats and risks that could have a significant influence on the societal values defined in chapter 5.2.1. For this purpose different sources of information are considered, to cover a wide range of opinions, outcomes as well as findings. Possible sources are[230]:

- Ministries
- Authorities and players at a directorate level
- Risk, threat and vulnerability assessments on national as well as regional basis
- Other relevant information

To receive the input about incidents that could be challenging, DSB is holding meetings on regular basis with the national authorities. For simplification of the further risk assessment process, subdivision of those incidents is carried out into:

- Natural incidents
- System failure

229 Cf. DSB (2010), P. 7.
230 Cf. DSB (2010), P. 9.

- Intentional actions

The description of mentioned main categories should be realized accurately. Additionally the various types of incidents should be explained in the best possible and simplest way. Within the selection of individual risks one condition should be always fulfilled: The investigated event should have an effect on one or more of the defined societal values. This step creates a milestone within the risk assessment process. So definition of certain risks and threats corresponding to the mentioned categories has to be carried out. The risk analysis process is continued after getting feedback from the involved parties about the identified risks and threats. Those are presented below in Table 22:

<table>
<tr><th>Main category</th><th>Risk area</th><th>Scenario</th></tr>
<tr><td rowspan="4">Natural incidents</td><td rowspan="2">Extreme weather</td><td>Storm</td></tr>
<tr><td>Energy shortage</td></tr>
<tr><td>Rockslides</td><td>Rockslides</td></tr>
<tr><td>Pandemic</td><td>Influenza pandemic</td></tr>
<tr><td rowspan="3">Major accidents</td><td>Hazardous substances</td><td>Gas leak</td></tr>
<tr><td>Shipping accidents</td><td>Ship collision</td></tr>
<tr><td>Nuclear accident</td><td>Nuclear accident</td></tr>
<tr><td rowspan="3">Intentional incidents</td><td>Terrorism</td><td>Terrorist attack</td></tr>
<tr><td>Security policy crises</td><td>Security policy crisis</td></tr>
<tr><td>Cyber attack</td><td>Cyber attack on the financial infrastructure</td></tr>
</table>

Table 22: Norwegian national risk picture with the main categories, risk areas and scenarios.

As a result of the risk identification process nine major risks with corresponding scenarios were identified. Those scenarios are detailed and specific descriptions of the possible hazardous events. Additionally they include a description of possible future conditions and events or incidents leading to the scenario. The DSB has defined that the scenarios should be realistic worst case scenarios, to be possible to create an adequate emergency and treatment plan to fight against probable consequences.

5.2.3 Risk Analysis

Experts from different disciplines and sectors carry out the risk analysis during specified workshops. One workshop is standing for one risk analysis. Due to limited space for participants of such a workshop as well as for success reasons, a good selection should be carried out to create a representative result of examined incident. Some experts have to participate on several workshops to ensure a comprehensive and uniform risk analysis for the various incidents and scenarios.

The performed risk analysis workshop is based on a scenario which is defined by the authorities. This should represent a detailed and specific description of an undesirable incident, a description of a future condition and series of actions and incidents leading up to the incident. It should be avoided that the scenarios are unrealistic. They should be serious and also should appear to be likely. For this reason some conditions are defined to describe the scenarios[231]:

- Cause (underlying conditions/trends, trigger)
- Intensity of the incident (size, volumes, scope, duration)
- Contextual aspects (geography, demography, season, weather)
- Barriers and vulnerabilities (physical structures, warning, preparedness)
- Consequences (fatalities, social unrest, financial and material losses)

Based on societal values defined in the first step (chapter 5.2.1) of the process a set of consequence criteria are derived as presented in the following in Table 23:

Societal values	Consequence criteria
Life and health	Fatalities
	Injuries and illness
	Physical strain
Nature and the environment	Long-term damage to nature and the environment
Economy	Financial and material losses
Social stability	Social unrest
	Disruptions to daily life
Ability to govern and territorial control	Weakened national ability to govern
	Weakened control of territory

Table 23: Societal values defined by the Norwegian authorities and corresponding consequence criteria[232].

A further task of the workshop is creating probability estimates in relationship to the developed scenarios. The probability of such an event is related to a time lag of five years, where such an event could occur within the Norwegian territorial area. To get well suited results of the probability, various types of information and data are considered. The probability of unplanned incident is depending on several data basis:

- Historical data
- Assessment of intentional incidents
- Assessment of experts
- Statistical data

Besides of all realized processes within the risk analysis, an uncertainty has to be considered. This uncertainty has to be documented and communicated to all involved parties and has to be perceived by all of them. This uncertainty should be reduced whenever possible, so implementation of uncertainty analysis is required to detect the uncertainty and take adapted counter measures.

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[231] Cf. DSB (2010), P. 11.
[232] Cf. DSB (2010), P. 11.

5.2.4 Risk Matrix

The risk analysis creates the fundament of the later processed risk matrix. The risk matrix is summing up the context of realized risk analysis. Utilized matrix is according to International standards. This matrix is created out of two components, consequences and probability. Each of those components has a classification starting from A and ending at E. In Table 24 the classifications of consequences and probability are presented. The utilized matrix is strongly relating to the European Union guidelines recommended by the EU Commission for risk assessment and mapping presented in chapter 2.

Category	Consequence	Probability
A	Very low	Very low
B	Low	Low
C	Medium	Medium
D	High	High
E	Very high	Very high

Table 24: Classification of consequences and probability for the risk matrix[233].

Consequence

The description of consequences is based on before mentioned nine consequence criteria, which are discussed during risk analysis (Table 22). Each of those nine criteria is assigned to a score from A to E. This score is depending on the quantity of incidents within the performed risk analysis. Additionally it is depending on defined threshold values. To develop a total representative score for the consequences of a certain scenario, each score of involved consequence criteria is calculated. Afterwards all allocated scores are summed up and divided by number of consequence criteria.

Probability

The probability of a certain scenario is calculated based on assessments made in the risk analysis and experts workshops. In Table 25 various classifications related to probability of a scenario are presented. In this case non-intentional incidents are observed, for intentional once other estimates as well as classifications are taken into account.

Category	Qualitative description	Estimate (frequency)	Estimate (per cent)
A	Very low probability	>once per 100 000 years	0-0.05%
B	Low probability	>once per 10 000 years	0.05-0.5%
C	Medium probability	>once per 1 000 years	0.5-5%
D	High probability	>once per 100 years	5-50%
E	Very high probability	>once per 10 years	50-100%

Table 25: Definitions of various categories, qualitative descriptions and estimates[234].

[233] Cf. DSB (2010), P. 13.
[234] Cf. DSB (2010), P. 14.

Based on the two scores evaluated for consequences and probability, the results are then imbedded into a matrix. As mentioned before the matrix is relating to the EU Commission guidelines presented before as in Figure 16 as well as to international standards. There has to be a clear understanding that the matrix illustrates only some results of the total risk analysis and that relevant information to a certain scenario are not presented in the matrix. So for a deeper understanding a studying of the whole scenario, information as well as utilized processes has to be carried.

5.2.5 Summary

To create a representative national risk picture the procedure involved a number of experts from inside and outside of the Directorate for Civil Protection and Emergency Planning (DSB). Nine risk areas and ten associated scenarios have been identified and assessed during the national risk assessment. It has to be mentioned that not all challenges, which the society is confronted with during an event, are included in those scenarios. The Directorate for Civil Protection and Emergency Planning (DSB) is continually trying to expand with new risk areas and scenarios, to get a more precise national risk picture. All scenarios developed are representing realistic worst case scenarios, but they are not representative for all incidents possible within the national territorial area.

Within the actual process there is no consideration for the expenditures related to evaluated scenarios and incidents. So a comparing of preventive measures to reduce or to eliminate probable risks is not possible (no monetary analysis). Adaption has to be realized, which is carried out through the responsible authorities on an annual basis.

5.3 Netherlands

The government of Netherlands realized that the threats related to safety and security of Dutch people is changing annually, additionally they realized that those threats are interconnected to a certain degree. Relative simple threats could lead to failure of the whole system. For this reason an approach was developed to consider all possible threats affecting environment and society. In 2007 the Cabinet established National Safety and Security Strategy to implement this approach, to protect society and population on its own territory. This approach was even realized before the EU Commission recommend developing a national risk assessment for EU Member States. A further aim was to protect Dutch interests, which were defined as[235]:

- Territorial safety (threatened through a breach of our territorial integrity)
- Physical security (public health)
- Economic security (undisrupted working of the economy)
- Ecological security (living environment)
- Social and political stability (e.g. respect for core democratic values and the functioning of democratic institutions)

5.3.1 National Safety and Security Method

The developed method is supporting the Dutch Cabinet to carry out measures against threats that are influencing the national safety and security. Additionally it helps to predict possible threats as well as supporting the Cabinet to make correct decisions. The methodology for national safety and security is consisting mainly of three phases[236]:

1. National analysis of threats and assessment of risks. In other words, what could the Netherlands face within their territorial area? A differentiation between risk analysis and risk assessment is given. New and known threats are identified as well as scenarios are developed during the risk analysis. The main focus is lying on to medium and long term threats (going up to 5 years). Risk analysis also covers long term threats over 5 years and short term threats up to 6 month. All the results help to develop adequate scenarios representing possible threats. Deeper studies of developed scenarios within the context of risk analysis form the foundation of the national risk assessment (NRA).

2. The second step is a capability analysis. The main purpose is to determine if the Netherlands have necessary capabilities to fight, reduce or eliminate various types of possible threats. Furthermore additional capabilities which could lead a reduction of likelihood or impact are evaluated. So in other words "*what more the Netherlands (government, people, businesses and civil society) could do than it does already*"[237].

3. The third step is the monitoring. "*(how and where is national safety and security reinforced?) The Council of Ministers then decides whether national safety and security should be improved by*

[235] Cf. Ministry of the Interior and Kingdom Relations, (2009), P. 11.
[236] Cf. Ministry of the Interior and Kingdom Relations, (2009), P. 11.
[237] Ministry of the Interior and Kingdom Relations, (2009), P. 12.

reinforcement of capabilities and if so, where and how. Political/administrative choices are then converted into policy, legislation and concrete actions"[238].

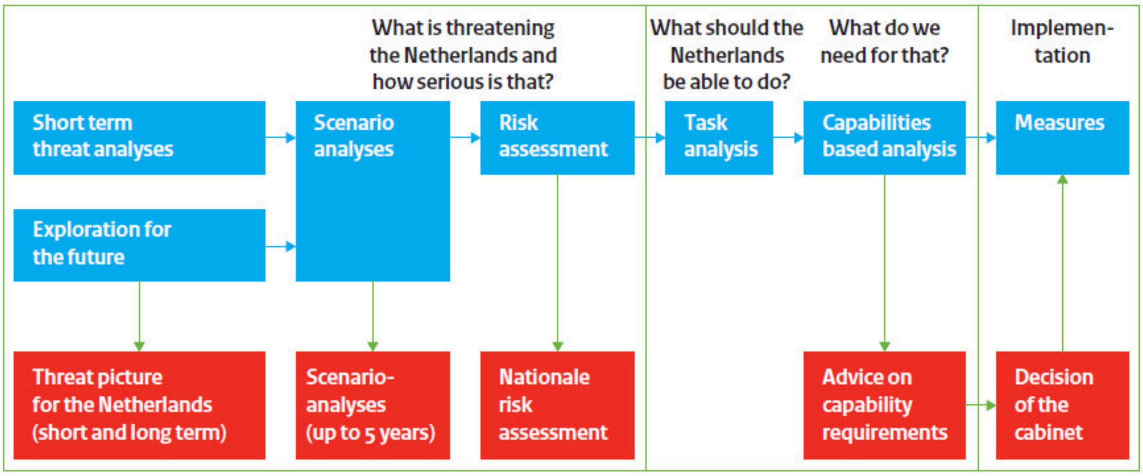

Figure 18: The national safety and security method of the Dutch government[239].

The developed methodology could be utilized across a wide spectrum of national safety and security matters. It should represent an additional framework to identify possible threats and to simplify the decision making process. In Figure 18 a graphical representation of the Dutch methodology is illustrated. It can be clearly recognized that the whole process is subdivided into the before explained three phases. Results and outcomes of each phase are represented within the red boxes; they create the basis for following assessment and decisions.

5.3.2 Stages and Roles in the Method

The Interdepartmental Working Group on National Safety and Security (IWNV) and a Steering Group on National Safety and Security (SNV) are involved in each single step of the methodology. The role of different involved parties within the method and during the various stages is described below:

National Risk Assessment Method

Developing and maintaining the method is underlying the responsibility of the Ministry of the Interior and Kingdom Relations / Threats and Capabilities (D&C) within the National Safety and Security Strategy. Advising the involved working groups as well as the reviewing teams could be supported by experts out of different branches. "*The method is presented to the Working Group on National Safety and Security (IWNV) and specified in a Steering Group on National Safety and Security (SNV)*"[240].

Scenarios

Scenarios are developed by specialist departments within their own policy fields. So an accurate distribution as well as responsibility clarification has to be carried out before investi-

[238] Ministry of the Interior and Kingdom Relations, (2009), P. 12.
[239] Cf. Ministry of the Interior and Kingdom Relations, (2009), P. 12.
[240] Ministry of the Interior and Kingdom Relations, (2009), P. 12.

gating the scenarios. If required additional support could be ordered from external parties. Examples of supporting organizations are[241]:

- Ministries
- Authorities
- Private individuals
- Knowledge centres
- Planning bureaus

The developed scenarios are then submitted to the Working Group on National Safety and Security (IWNV) and specified in a Steering Group on National Safety and Security (SNV).

Risk Assessment

A well chosen group of experts are carrying out the risk assessment based on before identified risk scenarios. The assessment is realized in connection to likelihood of occurrence and ten impact criteria; reflecting the five vital interests. Those vital interests are prepared by the national authorities and are presented on page 97. An arithmetic method is the base of Threats and Capabilities Programme (D&C), where scenario related scores are calculated and susceptibility analysis is carried out. Also in this step the results are presented to the Working Group on National Safety and Security (IWNV) and to the Steering Group on National Safety and Security (SNV).

Capability Analysis

To analyze the capability, a working group of relevant experts are brought together. This working group is created and headed by the responsible department. The result is a report containing studies, which go into the depth of thematic and also include recommendations for the Council of Ministers. The recommendations are mainly related to the capabilities which have to be improved to be fit for combating possible threats.

Findings Report

A group of representatives from the Working Group on National Safety and Security (IWNV) are lettering the findings report. This report is a detailed description of findings and outcomes from specific scenarios and realized risk assessment. As in other steps the results are presented in detail to the Working Group on National Safety and Security (IWNV) and to the Steering Group on National Safety and Security (SNV).

Advice to the Council of Ministers

The advice to the Council of Ministers in based on before created findings report as well as on the consultation with the Working Group on National Safety and Security (IWNV). The Steering Group on National Safety and Security (SNV) adapts the advice. Afterwards it is sent through the Council for Security and Legal Order of the National Security Council to the Council of Ministers. Subsequently the Lower House of Parliament receives the advice by the Minister of the Interior and Kingdom Relations.

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[241]. Cf. Ministry of the Interior and Kingdom Relations, (2009), P. 13.

Figure 19 illustrates the entire process with corresponding stages and responsibilities. It can be clearly identified that several parties are involved in the process. Each of them has a certain function to fulfil. The Cabinet has to carry out the final decision.

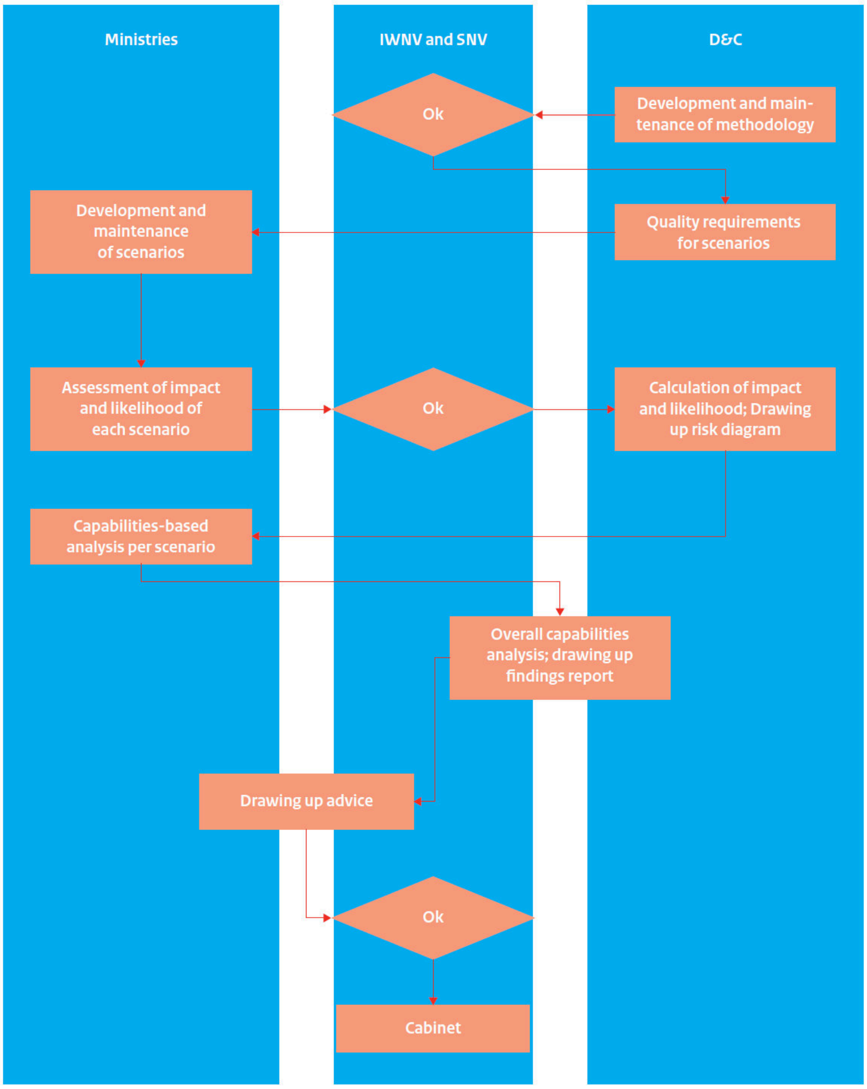

Figure 19: Various stages and corresponding responsibility within the Dutch methodology[242].

5.3.3 Scenarios

Determination of various scenarios which could create a threat to Dutch national safety and security is the first part of the national safety and security method. The mean period of consideration is the medium term up to five years. Fundament of the scenarios are "*out-comes of the strategic outlook (potential scenarios with a timescale longer than five years) or the outcomes of the short-term horizon scan (up to six months)*"[243]. The obtained scenarios should help to achieve right policy decisions, to improve the various phases of national safety chain, which are:

- Pro-action
- Preparation

[242] Cf. Ministry of the Interior and Kingdom Relations, (2009), P. 14.
[243] Ministry of the Interior and Kingdom Relations, (2009), P. 17.

- Repression
- Aftercare

The description of scenarios within the context of national safety and security method is defined by several core elements:

- "*The incident, i.e. (the nature and scale of) one or more inter-related events that have consequences for national safety and security and therefore have an impact at national level;*
- *the lead-up to the incident, consisting of the (underlying) cause and any underlying insidious process, and the trigger which actually creates the incident or brings the insidious process to the surface;*
- *the context of the events, indicating general circumstances and the degree of vulnerability and resistance of people, object and society, to the extent relevant to the incident described;*
- *the consequences of the incident, indicating nature and scale with an overall description of the response and the control measures;*
- *the effects of the incident on the continuity of vital infrastructure*" [244].

How a Scenario is Obtained

Various specialist fields provide inputs for scenario development; choice of those experts is depending on: Nature, context, progress as well as consequences of investigated scenario. Scenarios are often so complex that only a working group could handle the complexity. To handle the complexity of situation inputs from various fields and disciplines are required within the working group. But in any case officials out of involved governmental departments have a seat in those mentioned working groups. The most affected department has the responsibility over the working group; additionally this department has the presidency.

If the working group is not able to develop the scenario, an external party could be assigned to do this. In this case the terms of reference for the development of the scenario have to be predefined by the working group itself. Additionally it has to be secured that the developed scenario is in any case realistic and that the relevant impact criteria are considered. This should secure a representative risk assessment and the reliability of following steps.

Requirements of a Scenario

To secure that all before developed scenario are suitable to National Safety and Security Method, some essentials have to be clarified:

- Relativity to national safety and security
- Usability of scenario
- Considerations compared to other investigated scenarios
- Probability and possibility of scenario (could it happen?)
- Influence on one of the vital interests

Besides those specific requirements, some general once have to apply to the developed scenario:

- "*it must be a plausible story, with factual supporting information; or put another way: a report of events that could occur in the (near) future;*
- *it must be representative of one of the security themes chosen;*

[244] Ministry of the Interior and Kingdom Relations, (2009), P. 17.

- *the incident scenario must be described consistently (according to a schematic structure), and may vary in seriousness from fairly serious to the most serious imaginable;*
- *it must be structured consistently and logically;*
- *it must be psychologically expedient, so that it can be sold to and accepted by others;*
- *it must set the time horizon and the policy field or security topic to which it relates, including specific questions that are on the agenda;*
- *the incident scenario must be so specific that is possible to deduce from it which capabilities will have to be brought to bear in that scenario;*
- *it must take account of existing policy on measures for the various stages in the safety chain*" [245].

Time Horizon

Within incident scenarios two major groups are identified. The first are those incidents that are already realistic at the point of investigation (example are floods, dam failures, etc ...) and the second group are those incidents, where impact of them becomes in a longer term realistic (example are climate change, rise of the sea level, etc ...). Very important is the likelihood of occurrence, to evaluate the needed capabilities or to improve them depending on the time horizon.

For this purpose a separation into two periods is realized. The first is likelihood of occurrence within the next five years. For this case immediate actions has to be carried out to improve or to refresh capabilities to avoid possible threats. A period in longer term (20 to 25 years) is the second. For this scenario the development information should be based on best knowledge available at the moment as well as possible future trends. In Figure 20 the workflow of Dutch scenario development is illustrated into more detail.

[245] Ministry of the Interior and Kingdom Relations, (2009), P. 18.

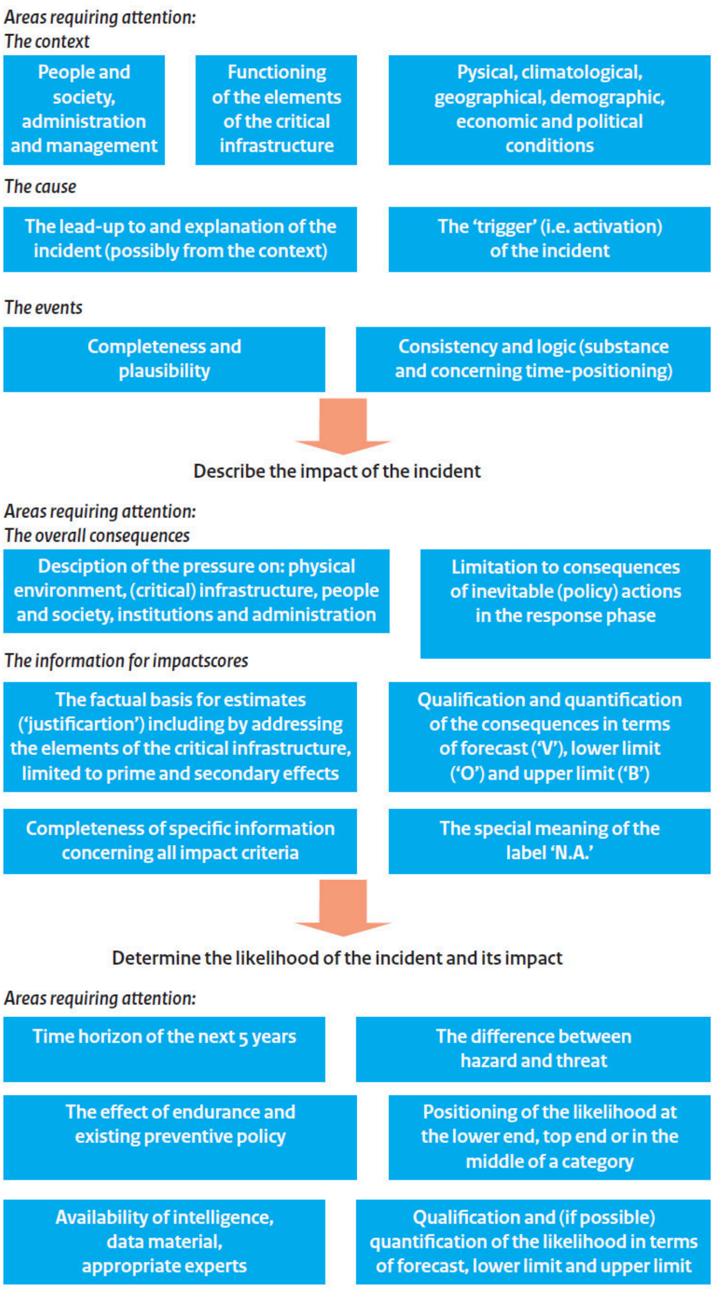

Figure 20: Work flow for creating scenarios for Dutch national security and safety[246].

5.3.4 National Risk Assessment

The Dutch national risk assessment process is suitable to all kinds of possible hazards (men made or natural disasters). This simple fact ensures that all provided risks to national safety and security are comparable and could be ranked independent of the developed scenario. During national risk assessment the attention is on likelihood of occurrence within the next five years as well as impact on the five vital interests. Outcomes are then integrated into the next step, which is the analysis of available capabilities to handle the threat. If reinforcement is necessary, Cabinet will be informed about this fact to take proper decisions, action as well as measures.

[246] Cf. Ministry of the Interior and Kingdom Relations, (2009), P. 20.

Method Characteristics

The most important characteristic of the method is that it is scenario based once, where risks are identifies and possible threats on national safety and security are investigated. Some further characteristics of such a methodology are presented in the following[247]:

- It is applicable for all kinds of threats, but differentiation has to be made between natural threats and those which were made by humans.
- The method consists of several sub methodologies were some of them are tried and others are tested. Additionally new elements are continuously implemented to be updated and fit for purpose.
- It is a very simple and transparent methodology. This should insecure a clear understanding when reviewing the method by externals.
- The sensitivity could be adopted with two factors: Seriousness and importance.
- The investigated scenarios could be easily ranked independent from disciplinary. Outcomes of assessment (likelihood and impact) are the only influencing factor for the ranking process.

The method was reviewed for several times for a better transparency and to eliminate possible mistakes. Developments into future are also possible and advisable. Reviews should be carried out with a time lag of two years. This period was identified as the maximum lag, due to the fast development of society as well as the ongoing climate change.

Concept of Risk

"*The method is oriented towards an assessment, and then ranking of risk*"[248]. Impact and likelihood are the two components which affect the concept of risk. In other words risk is likelihood times consequence. This formula results in a quantitative interpretation of possible risk. One of the major difficulties is estimation of likelihood, because of unavailable as well as incomparable data. Also quantifying possible consequences is not always possible. Not every threat can be expressed in money terms. So certain uncertainty is provided by this methodology and has to be clearly documented, communicated and handed out to every involved party in the assessment process.

Products

A report is the end product of the risk assessment process. To ensure comparability some essential elements have to be included into this report[249]:

- Detailed explanation of investigated scenarios
- Detailed explanation of risk assessment methods applied
- Explanation of the calculation of the scores of scenarios
- Risk diagrams comparing outcomes of scenarios to each other
- Sensitivity analysis, to understand degree of uncertainty

The supporting evidence of each mentioned point has also to be reported clearly.

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[247] Cf. Ministry of the Interior and Kingdom Relations, (2009), P. 23.
[248] Ministry of the Interior and Kingdom Relations, (2009), P. 24.
[249] Cf. Ministry of the Interior and Kingdom Relations, (2009), P. 25.

Steps within the Method

After scenario development several following steps are carried out. Those are listed below[250]:

1. Ensure the totality of the scenario description to enable the assessment of likelihood and impact.
2. Assessment of impact regarding to the ten impact criteria. Those impact criteria have a direct relation to the five vital safety and security interests.
3. Assessment of the likelihood. A separation has to be made between likelihood related to natural threats and manmade once.
4. Assessment of the risk scenario. Within this step all collected data and information about likelihood and impact of all scenarios are brought together in form of a two dimensional risk diagram.
5. Presentation of results is the last step. The focus should lay on the outcomes resulting out of the method as well as required additional assessments.

In the following chapters some of the mentioned steps will be explained in a more detailed way for the purpose of better understanding.

5.3.5 Impact Assessment

In this chapter before mentioned ten impact criteria are presented and explained in more detail for the first time. The criteria are related to the five vital interests. Each of those interests actually has one to maximal three criteria included. The ten criteria are an essential element of the National Safety and Security Strategy of the Nederland. With those criteria each developed scenario could be presented and ranked to others according to an overall impact score calculated. In Figure 21 the workflow of the calculation of overall impact score is presented. This overall impact score creates an important element for following steps. It plays a major role in evaluating results, to rank various scenarios.

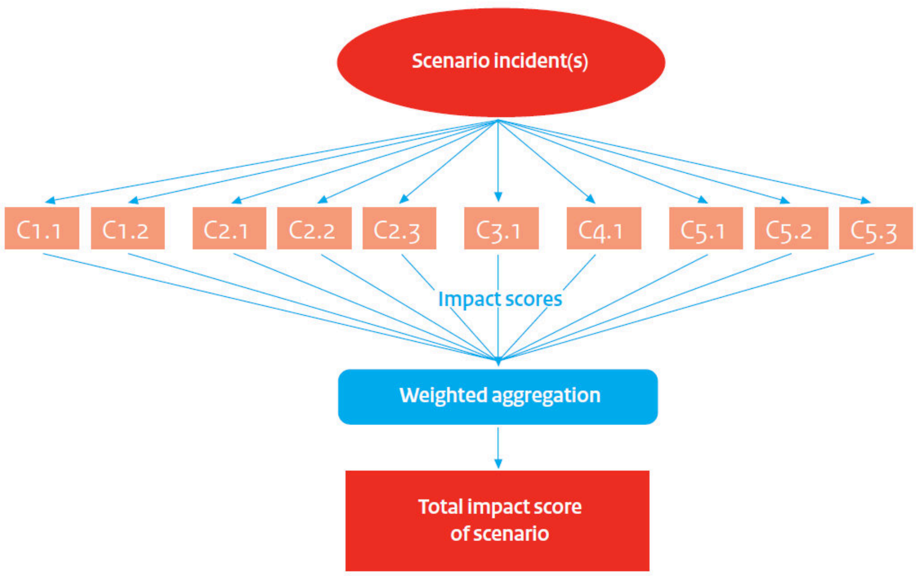

Figure 21: Workflow to generate the overall impact score[251].

[250] Cf. Ministry of the Interior and Kingdom Relations, (2009), P. 25 - 26.
[251] Ministry of the Interior and Kingdom Relations, (2009), P. 29.

In Table 26 a summary of vital interests and impact criteria are presented. Each criterion has a reference number for better traceability.

Vital interests	Criteria
Territorial safety	Encroachment on the territory of the Netherlands (1.1)
	Infringement of the international position of the Netherlands (1.2)
Physical security	Fatalities (2.1)
	Seriously injured and chronically ill (2.2)
	Physical suffering (lack of basic necessities of life) (2.3)
Economic security	Costs (3.1)
Ecological security	Long-term impact on the environment and on nature (flora and fauna) (4.1)
Social and political stability	Disruption to everyday life (5.1)
	Violation of the democratic system (5.2)
	Social psychological impact (5.3)

Table 26: Vital interests and corresponding impact criteria.

The total impact score of a certain scenario results out of the following steps:

- „*the events and the impact in the scenario are analysed against each of the ten impact criteria;*
- *this analysis leads to the determination of an impact score (label) per impact criterion;*
- *the ten individual impact scores are merged using an aggregation procedure into an overall impact score; this is done in a number of ways which differ from each other in the method of weighting the importance of the criteria and the labels*“[252].

To secure constancy of the method different impact criteria are measured in the same way. For each of the ten criteria, impact is rendered measurable by using five categories: A, B, C, D, E. The context of the five categories is shown in Table 27.

A	Limited consequences
B	Substantial consequences
C	Serious consequences
D	Very serious consequences
E	Catastrophic consequences

Table 27: Context of the five categories for score evaluation[253].

[252] Ministry of the Interior and Kingdom Relations, (2009), P. 30.
[253] Cf. Ministry of the Interior and Kingdom Relations, (2009), P. 30.

For the calculation of overall impact score, the method of weighted sum is utilized. It was decided to be the most reliable method after several experiments and examinations.

5.3.6 Likelihood Assessment

The likelihood of a scenario is determined under following assumptions[254]:

- Five category breakdown from A to E is utilized. Category A represents an incident scenario that is very unlikely, while Category E represents an incident scenario that is very likely. Where quantitative estimates are possible, the interval between each category should be a factor of 10. This should apply for both impact and likelihood.
- The categories A to D are broken down to three subcategories (low, medium and high).
- For the broken down subcategories determinations about forecast value, lower limit and upper limit has to be carried out.
- A differentiation between malicious threats and not malicious once has to be considered.
- The likelihood is determined depending on the impact of the scenario.
- Information sources which should be utilized to get accurate information are historic events, case histories, statistics, failure data, strategies analysis, actor analysis as well as expert opinions.
- Determination of uncertainty for likelihood has to be carried out. Furthermore the source of possible uncertainty has to evaluated and mentioned.
- Likelihood is expressed as the likelihood that the scenario will occur within five years.

Category	% per 5 years		Quantitative (%)	Qualitative description of the hazard
A	< 0.05	A-low A-medium A-high	< 0.005 0.005 – 0.02 0.02 – 0.05	very unlikely
B	0.05 – 0.5	B-low B-medium B-high	0.05 – 0.1 0.1 – 0.25 0.25 – 0.5	unlikely
C	0.5 – 5	C-low C-medium C-high	0.5 – 1 1 – 2.5 2.5 – 5	possible
D	5 – 50	D-low D-medium D-high	5 – 10 10 – 25 25 – 50	likely
E	50 - 100	E	50 - 100	very likely

Table 28: Breakdown of likelihood of hazards[255].

[254] Cf. Ministry of the Interior and Kingdom Relations, (2009), P. 53.
[255] Cf. Ministry of the Interior and Kingdom Relations, (2009), P. 54.

Category	Qualitative threat description
A	no concrete indication and the event is not deemed conceivable
B	no concrete indication, but event is deemed far-fetched but conceivable
C	no concrete indication, but the event is conceivable
D	the event is deemed very conceivable
E	concrete indication that the event will take place

Table 29: Breakdown of likelihood of threats[256].

5.3.7 Risk Diagram and Reporting

Outcomes of the national risk assessment are published in the risk assessment reporting. The main components of this report are a summary, explanations of inputs, risk diagram with an explanation, sensitivity analysis as well as a judgment about the results.

Risk Diagram

The scores resulting for each scenario investigated in the national risk assessment process are plotted into a risk diagram. As in other European Union Member States the risk matrix consists of two axes where results of impact and likelihood are plotted on a logarithmic scale. In Figure 22 a typical example of Dutch risk matrix is illustrated. It can be clearly recognized that all scenarios are compared to each other in terms of impact and likelihood. So comparison and prioritisation of developed scenarios is possible, but it has to be mentioned that diagram shows only graphical results. A more detailed investigation and comparison has to be carried out to get more accurate as well as realistic prioritisation. The graphical representation should only give a first indication of possible ranking.

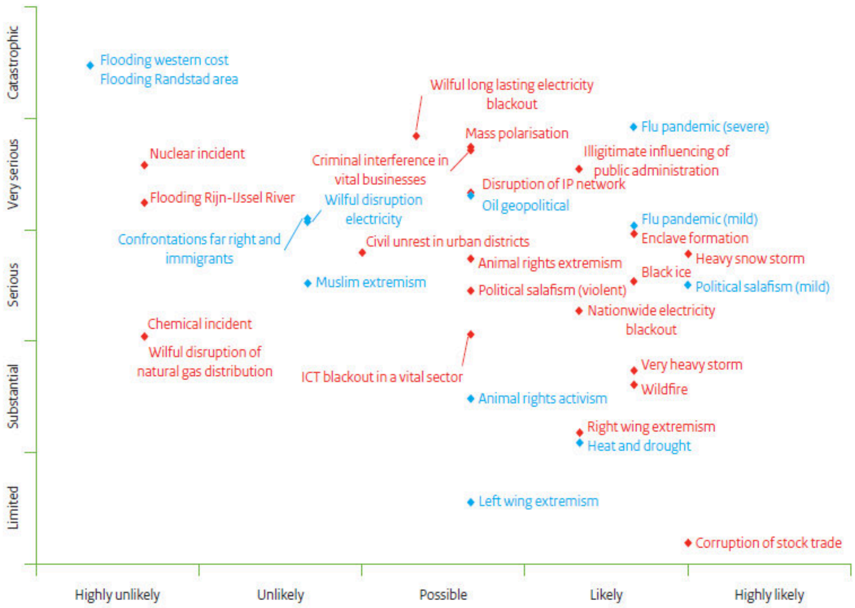

Figure 22: Risk diagram of the Dutch government with logarithmic aces of likelihood and impact of the derived scenarios[257].

[256] Cf. Ministry of the Interior and Kingdom Relations, (2009), P. 54.
[257] Cf. Ministry of the Interior and Kingdom Relations, (2009), P. 64.

Additionally a sensitivity analysis of each scenario is realized to understand the possible uncertainty resulting out of input parameters, calculations as well as assumptions utilized before. In Figure 23 the outcomes of realized sensitivity analysis are illustrated. There has to be a clear understanding of the results when changing the inputs for a certain scenario. The range of possible adaption has to be understood, to minimize the possible uncertainty of the outcomes.

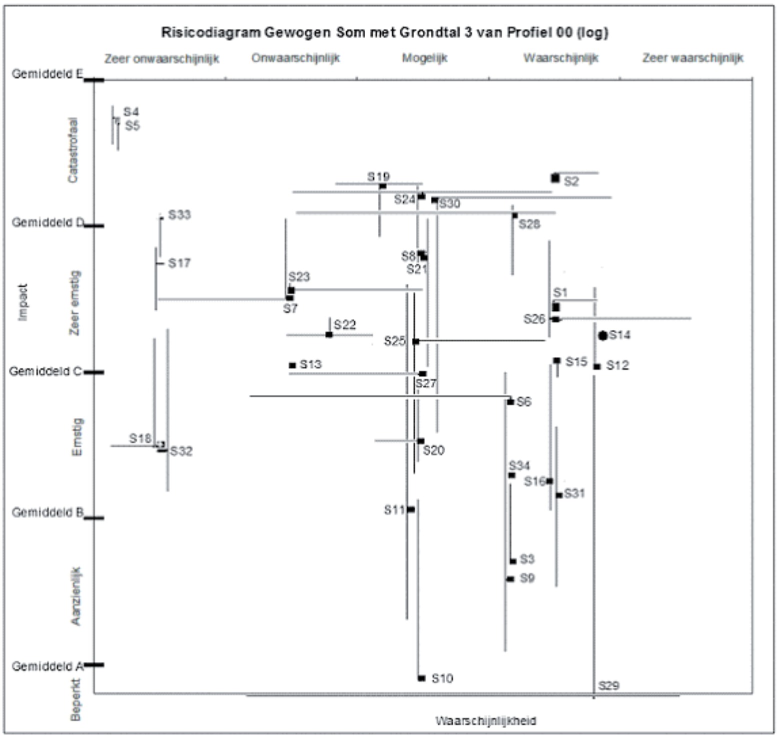

Figure 23: Graphical results of sensitivity analysis for the various scenarios[258].

The last step is to determine the capabilities to fight against possible hazards and threats. The whole national risk assessment process has the aim to develop the scenarios and to identify the national capabilities. The capabilities create also a significant part of possible monetary analysis. Future reinforcements of the whole process are realized through accurate monitoring. This should secure that Dutch risk assessment method in at any time updated and fit for the requirements.

5.3.8 Summary

The whole method of national risk assessment in Netherlands is in a very advanced stage, due to the fact that authorities started with this assessment and methodology even before the European Union Commission recommended creating a national risk assessment process. The advance, resulting out of earlier development, is clearly recognizable when comparing to other European Union Member States. The whole process of risk assessment is consisting of three parts:

1. Risk assessment and risk analysis
2. Capability analysis
3. Monitoring

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[258] Cf. Ministry of the Interior and Kingdom Relations, (2009), P. 65.

As recommend through the European Union Commission guidelines scenarios, likelihood and impact are investigated into detail. In comparison to other EU Member States the Dutch method includes capability, uncertainty analysis as well as sensitivity. A capability analysis could be a part of monetary analysis, which is not realized in the actual process.

6 Status of National and International Risk Assessment Methods in the Field of Natural Disasters

In this chapter national and international risk assessment methodologies, which were presented in chapter 4 and chapter 5, will be compared. Additionally investigated, but not presented risk assessment methods of European Union Member States will be included into this methodology comparison. This action will be realized according to predefined comparison criteria. Those criteria were generated out of presented national and international risk assessment methodologies in the field of natural disasters and guidelines recommended by European Union Commission (chapter 2). Further sources were international risk assessment methodologies.

This specific measure should illustrate actual status of investigated risk assessment methods of presented States Additionally it should indicate strength and weakness of compared methodologies. The target of European Union Commission is to develop an EU Wide risk assessment based on the developed national methodologies. For this specific purpose the national methods have to be on the same level and comparable to each other.

6.1 Criteria for Comparison of National and International Risk Assessment Methods in the Field of Natural Disaster

Before presenting the status of risk assessment methodologies for investigated States in the field of natural disaster, the criteria of comparison have to be introduced and defined. This master thesis has the aim to investigate if monetary analysis is implemented in national risk assessment methods of EU Member States. For this specific aim essential elements for a monetary analysis are selected as criteria of comparison. Chosen criteria have a major influence on outcomes of realized comparison. The selected criteria were identified as the minimum requirement for a representative monetary analysis. If desired other criteria could be chosen, ending up in different results. In the following the comparison criteria will be presented and explained into significant detail.

6.1.1 Risk Assessment

This criterion should indicate if there is a common national risk assessment method in the field of natural disaster. In several European Union Member States there are various levels of authorities (national, provinces and municipality). The mentioned levels often utilize different types of risk assessment methodologies and they are often responsible for different types of risks.

The goal should be a common national risk assessment methodology used by all national levels of authority, covering all types of risks in one assessment process. This should secure comparison, traceability and transparency of outcomes. Measures and decision making processes could be realized more efficiently, resulting in advanced as well as prompt help of the population. The long term goal of EU Commission is to develop a European Union wide risk assessment methodology implemented by all EU Member States. This measure should improve the collaboration between single Member States and increase data base utilized for the processes. Additionally it should help to reduce risks over the whole territorial area of the European Union, increasing overall security.

6.1.2 Impact Criteria

The EU Commission guidelines defined and grouped up impacts, which should be examined during the national risk assessment. Those are human impacts, economic and environmental impact as well as political and social impact[259]. Some EU Member States adapted those criteria for the purpose of a more detailed investigation. In the comparison carried out within this chapter mainly 6 impact criteria will be utilized. Those criteria cover a wide range of national interests. Outcomes of those impact criteria could be beneficially implemented into a subsequent monetary analysis.

- **Human:** This impact criterion should reflect the number of people affected by the disaster or threat. Not only fatalities, but also injured people as well as disrupted people are taken into consideration.
- **Economic:** This should reflect the impact of an event on the economics of investigated European Union Member State. Main points which have to be considered are activities of import and export as well as national production (supply security).
- **Environment:** Under this creation expenditures resulting out a certain event or hazard influencing the environment are investigated. Furthermore ecological damage and related expenditure to fix this damage are examined.
- **Politic:** This should reflect influence of an event or hazard on the political situation of the country, political implications as well as infringement of the international position.
- **Social:** Under this creation impact on public order and safety, psychological implications, and damage to cultural assets are investigated.
- **Infrastructure:** This impact creation should reflect the effect on public transport system, general transportation system and energy supply system (gas, fuel and electricity).

6.1.3 Threshold Values

Threshold values are utilized to classify the before introduced impact criteria. This action is strongly depending on the damage evaluated in relation to the impact criteria. The identification of threshold values should be based on historical data, scientific results and results of earlier assessments. For European Union wide risk assessment methodology the challenge is to create a common list of investigated impact criteria and corresponding threshold values. This should be as suitable as possible to all Member States.

6.1.4 Risk Scenarios

This creation should indicate if the process of risk scenario development is integrated in the national risk assessment process. "*A risk scenario is a representation of one single-risk or multi-risk situation leading to significant impacts, selected for the purpose of assessing in more detail a particular type of risk for which it is representative, or constitutes an informative example or illustration*"[260]. The creation of a scenario is based on past experiences and possible future events as well as impacts evaluated in earlier assessments. A scenario creates a simplification of reality, so the use of assumption is volitional. On the other hand those assumptions have to be communicated and documented so they can be reviewed and updated if required.

[259] Council of the European Union (2011), P. 17.
[260] Council of the European Union (2011), P. 21.

The EU Commission guidelines recommend that each national risk assessment process should at least have 50 to 100 risk scenarios[261]. They should be developed based on the guidelines to guarantee comparability between European Union Member State.

6.1.5 Risk Matrix

This creation should indicate if the European Union Member States are in use of a risk matrix as a visualisation tool for the outcomes of national risk assessment. Risk matrix represents the outcomes of developed scenarios in a graphical and comparative form. The recommended risk matrix consists mainly of two dimensions: Likelihood and impact. In addition coloured zones in the risk matrices support to define risks, which need more detailed analysis. This measure also helps to carry out a ranking of investigated scenarios.

Five or more shades can be utilized to scale / classify the two dimensions (logarithmic or linear). It is very important to utilize a single set of criteria for each impact category, independent of the scenario considered. For comparison reasons the European Union Commission guidelines recommend creating risk matrices for each single impact category.

6.1.6 Risk Mapping

Risk mapping creation should indicate if the outcomes are implemented into maps ending in a visualisation across the territorial area of involved European Union Member States. The risk maps should consist of information about hazards, vulnerabilities, extent and risks in the area of interest.

Maps are an important tool to support the risk assessment process and strategy on national and EU level. Through the visualization decision makers can set a certain priority for risk reduction measures as well as risk reduction strategies. Through the utilized maps it is guaranteed that the parties within the risk assessment process have common and well defined information as well as data for their assignment.

6.1.7 Uncertainty Analysis

Each realized risk analysis show a certain degree of uncertainty. This creation should indicate if the performing authority is analyzing the uncertainty of factors as well as parameters utilized during the national risk assessment. Those uncertainties have to be clearly understood, documented and communicated to relevant parties as well as authorities. Determination of the imprecision in the results is one of the main objectives of an uncertainty analysis.

The imprecision results out of the variation of used assumptions and parameters during the whole national risk assessment process. So it is necessary to identify the sources of uncertainty, especially those with increased sensitivity against the carried out assessment.

A further useful development would represent a sensitivity analysis. With this type of methodology the sensitivity of changing parameters in general as well as during the national risk assessment process is investigated. This measure should clearly indicate the influence of possible changes in parameters on the outcomes and consequently on the corresponding uncertainty.

[261] Cf. Swedish Civil Contingencies Agency (2011), P. 11.

6.1.8 Capability Analysis

Capability analysis is a very important matter, due to the fact that rare capabilities end up helplessness of responsible authority. The whole national risk assessment process has the aim to develop the scenarios and to identify the national capabilities for combating future events. A detailed knowledge about capabilities of European Union Member States would help to apply given sources and possibilities in the most effective as well as efficient way.

6.1.9 Monetary Analysis

The monetary analysis should indicate the expenditures required to combat outcomes of a certain developed scenario. Additionally those expenditures could be compared to the expenditures required to set preventive measures. So a certain cost to benefit ratio might be established. Monetary analysis could be utilized as a decision supporting tool. It has always to be considered that this type of analysis has to be carried out in combination with other decision methodologies, to conform outcomes.

6.2 Comparison of National and International Risk Assessment Methodologies in the Field of Natural Disaster

As mentioned before comparison of risk assessment methodologies in the field of natural disasters will be realized based on before presented comparison criteria. In the opinion of the author those nine criteria are the absolute minimum requirement for a meaningful risk assessment as well as monetary analysis. In Table 30 comparison results of seven EU Member States plus Norway are illustrated:

- Austria
- Federal Republic of Germany
- Italy
- Republic of Slovenia
- Poland
- United Kingdom
- Norway
- Netherlands

Those States are representative for the whole European Union, due to the fact that a wide range of risk assessment methodologies are presented. The most advanced States and States in the very early stage of national risk assessment are considered in this comparison. The outcomes of realized comparison are strongly relating to facts presented in chapter 4 and chapter 5 as well as information and data evaluated in the context of this master thesis (not presented).

Three abbreviations are utilized for the comparison purpose of presented methodologies:

- **(-)** stands for **no** and should indicate that the comparison criteria under investigation is not fulfilled at all.
- **(●)** stand for **yes** and should indicate that the comparison criteria under investigation are completely fulfilled.
- **(○)** stands for **partly** and should indicate that the comparison criteria under investigation are partly fulfilled. Essential elements have to be realized to fulfil the context of the comparison criteria and get a rating of (●).

Investigated States	Comparison Criteria													
		Impact Criteria												
	Risk Assessment	Human	Economic	Environment	Political	Social	Infrastructure	Threshold Values	Risk Scenarios	Risk Matrix	Risk Mapping	Uncertainty Analysis	Capability Analysis	Monetary Analysis
Austria	-	○	○	○	○	○	○	●	●	○	●	-	-	-
Germany	●	●	●	●	○	○	●	●	●	●	○	-	-	-
Italy	-	-	-	-	-	-	-	-	-	-	●	-	-	-
Slovenia	●	●	●	-	●	-	-	-	●	●	-	-	-	-
Poland	-	○	○	○	-	-	○	-	●	●	-	-	-	-
UK	●	●	●	○	-	●	●	○	●	●	-	-	-	-
Norway	●	●	●	●	●	●	○	○	●	●	○	-	-	-
Netherlands	●	●	●	●	●	●	○	●	●	●	●	●	●	-

Table 30: Results of the comparison of national risk assessment methods
in the field of natural disasters according to predefined comparison criteria.

For a more detailed comparison and to indicate the level of advancement of each single investigated European Union Member State (plus Norway), a scouring is carried out based on results of Table 30. This scouring is realized according to selected comparison criteria and should help to carry out a representative ranking of involved States. In Table 31 a transition from abbreviations utilized before (-, ● and ○) to score values is realized. It could be seen as a transition from qualitative comparison to quantitative once. This measure should give each considered risk assessment method a specific overall score. With those calculated scores ranking could be achieved in a more reliable way.

For each of the nine comparison criteria a maximum score of one is designated. This could only be achieved if the investigated criteria is completely fulfilled, thus has the abbreviation (●). For partly fulfilled criteria only 0,5 points are possible. Carrying out this scoring in a more detailed way would allow the partly fulfilled criteria to be scoured into more detail with wider variation (scoring from 0,1 to 0,9). In this stage of comparison it is not necessary to get into the far details.

If the comparison criteria are not fulfilled, thus abbreviation (-) is formally utilized, zero score would be the result. Due to six sub criteria within the impact criteria, the score one is divided by the number of sub criteria. In this case by six for each fully fulfilled criterion, thus a score of 0,16 is utilized. For partly fulfilled sub criteria a score of 0,08 is utilized, resulting out of the division of one by twelve (only half of possible points could be achieved).

Investigated States	Comparison Criteria Score														Sum
	Risk Assessment	Impact Criteria						Threshold Values	Risk Scenarios	Risk Matrix	Risk Mapping	Uncertainty Analysis	Capability Analysis	Monetary Analysis	
		Human	Economic	Environment	Political	Social	Infrastructure								
Austria	0	0,08	0,08	0,08	0,08	0,08	0,08	1	1	0,5	1	0	0	0	**4**
Germany	1	0,16	0,16	0,16	0,08	0,08	0,16	1	1	1	0,5	0	0	0	**5,33**
Italy	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**
Slovenia	1	0,16	0,16	0	0,16	0	0	0	1	1	0	0	0	0	**3,5**
Poland	0	0,08	0,08	0,08	0	0	0,08	0	1	1	0	0	0	0	**2,33**
UK	1	0,16	0,16	0,08	0	0,16	0,16	0,5	1	1	0	0	0	0	**4,25**
Norway	1	0,16	0,16	0,16	0,16	0,16	0,08	0,5	1	1	0,5	0	0	0	**4,91**
Netherlands	1	0,16	0,16	0,16	0,16	0,16	0,08	1	1	1	1	1	1	0	**7,91**

Table 31: Results of the score comparison of national risk assessment methods in the field of natural disasters.

In Figure 24 score results of Table 31 are translated into a graphical form. It can be clearly recognized that a wide difference in outcomes is observable.

Figure 24: Graphical comparison of risk assessment scores for national risk assessment of eight EU Member States.

It can be clearly observed that Italy has the lowest score of all investigated EU Member States. This is due to the fact that realized risk assessment of Italian Government is going into another direction. Hazards affecting Italian territory (volcanoes and earthquakes) cannot be easily forecasted and scenario building is somehow impossible. So the focus of authorities is on building adapted emergency plans, which can be realized fast to secure the population.

Poland has also a very weak risk assessment, according to selected comparison criteria, but they are working towards the development of a national risk assessment according to the guidelines of EU Commission. So some basic comparison criteria are fulfilled.

Member States like Slovenia, United Kingdom and Austria are ranked due to their score in the middle. They fulfil several essential elements for a representative monetary analysis and EU wide risk assessment process, but some important criteria are still missing. Authorities are actually adapting and reinforcing their national risk assessment processes. It is assumed that those States will be in a more advanced stage in a few years from now.

Norway and Germany are based on selection criteria in an advanced stage, but still criteria like uncertainty analysis and capability analysis are missing or only partly implemented in their national risk assessment methodology. It has to be mentioned that Germany is strictly working according to the European Union Commission guidelines and it is additionally adapting several essential elements for EU wide risk assessment.

The most advanced Nation is the Netherlands. This is resulting out of the simple fact that they started a reliable risk assessment process years before the EU Commission recommended the Member States to carry out a national risk assessment. Due to the geographical placement of the country and artificially created landscape (some areas are below the sea level); the Netherlands was always forced to carry out a national risk assessment. So they have collected a significant amount of experience as well as knowhow in this field. The only missing element is a monetary analysis. Netherlands have reached a score of 7,91 points out of 9 points, according to the selected comparison criteria.

6.3 Summary

Out of the before presented investigations, it could be clearly recognized that the level of advancement for national risk assessment process is strongly varying between the investigated EU Member States (plus Norway). None of those States have implemented a monetary analysis into their national risk assessment process.

The most advanced State is the Netherland, which started with national risk assessment several years ago. Germany and Norway show also a very advanced national risk assessment process, but still several essential elements for monetary analysis are missing.

European Union Member States which are still in a very early stage of development for a national risk assessment should lean on the risk assessment process realized by the Netherlands, Germany and Norway. Furthermore they should consider the guidelines developed by the EU Commission. The aim is to create a common EU wide risk assessment process to reduce risks and set accurate preventive measures.

7 Excursion into the Risk Assessment of Oil and Gas Industry

"*Risk management should be a continues and developing process which runs throughout the organisation´s strategy and implementation of that strategy. It should address all the risks surrounding the organisation's E&P activities past, present and in particular future*"[262]. The focus of the risk management is the identification as well as treatment of risk, especially those which have a significant influence on the company. A good implemented risk management is a key factor for overall success of a company in the E&P business. In today´s oil and gas industry risk management consists of a number of risk assessments processes in the wide range of oil industry fields. Those processes are essential for success of the overall risk management in an E&P company. Some selected examples of risk assessment processes are illustrated below:

- Environmental risk assessment
- Safety risk assessment
- Pipeline risk assessment
- Offshore risk assessment
- Plant risk assessment
- Health risk assessment and others

All those mentioned risk assessment processes are based on one common process, which has to be adapted depending on the investigated field. In this chapter the author will give a summary of methodologies and processes utilized in the oil and gas industry for risk management. This summary is based on SPE papers listed.[263] [264] [265] [266] [267] [268] [269] [270] [271] [272]. „*Having an effective risk management system incurs additional costs translated into money of the order of few percents. A good system generally cost much less than that: 1 to 2 percent of the total cost devoted to risk control and reduction is a very reasonable security against big surprises and cost organization faces when a major accident happens*"[273]. Implementation of well constructed risk management has several benefits. Additionally it reduces expenditure, due to savings in[274]:

1. Accident investigation and reports
2. Fines, legal costs and compensation for damage
3. Adverse publicity
4. Loss of sales
5. Long term environmental costs
6. Repair and replacement of plant and material

[262] Andrew L. Smith (2007), P. 1.
[263] Cf. Erik Wiig et.al (1996), SPE 35945.
[264] Cf. A.H. Walls et.al (1997), SPE 37853.
[265] Cf. Andrew L. Smith (2007), SPE 105503.
[266] Cf. Fredrick V. Jonet et.al (2012), SPE 156833.
[267] Cf. Robert S. Cram (2004), SPE 86707.
[268] Cf. Victor Watson (2012), SPE 127213.
[269] Cf. Graham Bower-White (2013), SPE 164969.
[270] Cf. F. Khalaf et.al (2008), SPE 111580.
[271] Cf. Hans Egil Eckhoff (2000), SPE 61213.
[272] Cf. S. McDermott (2012), SPE 108853.
[273] Cf. F. Khalaf et.al (2008), P. 3.
[274] Cf. F. Khalaf et.al (2008), P. 4.

7. Delayed medical treatment and aftercare
8. Hiring and training replacement people
9. Administration costs
10. Contractual delays and penalties
11. Loss of image and/or trust which may lead to loss of income and culminates finally in loss of business
12. Loss of quality of life of those who are directly or indirectly hurt

So a great economic potential is given through an adequate implementation of a risk management system. In most cases the risk management is a part of the HSE (Health, Safety and Environment) strategy of an E&P company. An adequate budget to handle treatment measurements is provided for HSE purpose. In the following core elements of risk management in oil and gas industry field will be listed as well as explained.

7.1 Risk Management Process

The risk management process has several basic functions to fulfil. Generally it helps to protect interests of the company. Furthermore it adds a significant economic as well as knowledge value to the company. Some of the most important functions of the risk management are listed below:

- Improve decision making, planning and prioritization by structured understanding of the activities within the investigated field
- Support an efficient use of capital and resources to combat evaluated risks
- Helps to optimize operational efficiency
- Protection of company's assets and working force
- Protection of company's image

The risk management process in the oil and gas industry consists mainly of seven steps that have to be considered. Several of those steps will be explained in more detail later this chapter. As in other risk management procedures risk assessment presents the core element of the whole process.

1. Organizational strategic objectives
2. Risk assessment
3. Risk reporting
4. Decision making
5. Risk treatment
6. Residual risk reporting
7. Monitoring

7.2 Risk Assessment

The process of risk assessment in the oil and gas is usually divided into risk analysis and risk evaluation. The risk analysis is carried out in 3 major steps:

1. Risk identification
2. Risk Description
3. Risk Estimation

The achievement of risk assessment process could take a long period of time. An average duration for a typical risk assessment is a team day. This is depending on a number of factors under investigation. Other factors influencing this process are:

- Scope of the analysis
- Internal company experience
- Availability of fundamental data
- External experience
- Availability of industry standards and codes
- Formality of analysis

7.2.1 Risk Identification

"*Risk identification addresses the "What might go wrong?" question, including identifying the possible consequences. This provides the basis for further steps in the risk management process*"[275]. This step requires detailed knowledge of the company and its social, political as well as cultural environment. Risk identification is carried out in a methodical way to cover a wide range of activities and to increase accuracy. The activities within such risk identification can be classified into[276]:

- Strategic
- Operational
- Financial
- Knowledge management
- Compliance (health, safety and environment (HSE))

The most common identification techniques in the E&P industry are listed below. Those techniques have been former explained in chapter 3[277]:

- What-if analysis
- Hazard and operability studies (HAZOP)
- Failure mode and effect analysis.
- Fault tree analysis (FTA)
- Event tree analysis (ETA)
- Cause and consequence analysis (CCA)
- Bow-tie analysis

Utilization of a certain methodology is strongly relating to the assessment requirements. Due to very high industry standards within the oil and gas business several adequate methodologies are utilized simultaneously. This specific measure should confirm outcomes from several methodologies, ending up in reduced uncertainty of applied inputs.

7.2.2 Risk Description

The main objective of risk description is to present identified risk into a structured form. This could be realized in a tabular way, as presented below. For comprehensive risk identification reasons as well as description reasons, the structure of utilized tables should be well

275 EMA (2011), P. 6.
276 Cf. Andrew L. Smith (2007), P. 4.
277 Cf. Fredrick V. Jonet et.al (2012), P. 3.

considered and designed. This measure should help to set a prioritisation of consequences and probability of each investigated risk. In Table 32 an example for a risk description table is illustrated[278].

Name of Risk	
Scope of Risk	Qualitative description of the event, their size, type, number and dependencies
Nature of Risk	Strategic, operational, financial, knowledge, compliance.
Quantification of Risk	Significance and probability.
Risk Tolerance	Loss potential and financial impact of risk, value at risk, probability and size of potential loss.
Risk Treatment and Control Mechanisms	Primary means by which the risk is currently managed, levels of confidence in existing control.
Potential Action for improvement	Recommendations to reduce risk.
Strategy and Policy Developments	Identification of function responsible for developing strategy and policy.

Table 32: Example of risk description.

7.2.3 Risk Estimation

The estimation of risk can be realized by quantitative, semi quantitative and qualitative methods. Probability of occurrence and degree of possible consequences play a major role in risk estimation. The utilized scales for both dimensions can vary from linear to logarithmic depending on type of estimated risk. Information and input data are provided by several assessments, workshops and predefined probabilities. Historical data, expert opinion and stakeholder opinion are also involved in the risk estimation. All information and data are reinforced on regular basis to be updated and fit for purpose. In general there are several platform provided by the industry to review frameworks, industry standards, scientific paper and regulations. An example would be the Society of Petroleum Engineers (SPE).

7.2.4 Risk Evaluation

Risk evaluation is followed by accomplished risk analysis process. Risk evaluation is "*the process of comparing the results of risk analysis with risk criteria to determine whether the risk and/or its magnitude is acceptable or tolerable*"[279]. The risk criteria must be predefined and could include:

- Associated cost and benefits
- Legal requirements
- Environmental factors

[278] Cf. Andrew L. Smith (2007), P. 4.
[279] Council of the European Union (2011), P. 10.

- Concerns of stakeholders

The significance of before identified and described risks is evaluated within this step. This is carried out according to company´s policy. Decisions are made if the specific risk is accepted or treated. Risk criteria can be established in either a qualitative or quantitative form. The criteria could be based on sources coming from[280]:

- Statutory requirements
- Scientific evidence
- Industry standard
- Corporate objectives and policies

Risk criteria should reflect the strategic and organizational objectives of the company. Furthermore they should be selected in such a way that they are fit for purpose. Each single step during selection has to be documented, due to sensitivity of risk criteria to the outcomes of risk management process.

7.3 Risk Reporting and Communication

Within a regular structured company there are various levels of responsibility. Each level should be provided with specific information from the risk management process. This should help to execute the function in best possible as well as reliable way. Generally a company could be divided into three main levels of responsibility:

- Board of directors
- Business units
- Individuals

The communication between the various levels is very important, because it is one of the key factors for a successful workflow to reduce or eliminate possible risks. Additionally it is often necessary to communicate to external parties like stakeholders. This is realized through external reporting. Generally the communication should consist of[281]:

- A list of all measures planned. This has to be specially communicated to the workers affected by the risk and their supervisors and line managers.
- Identification of any changes necessary and utilized communication tools
- The persons who are responsible for implementing risk reduction measures
- The date by which each measure is expected to be completed

The board of directors should be provided with information's about:

- Most significant risks affecting the organization in their operations
- Deviations in performance and possible effects on shareholder value
- Methods available to the organization to manage and handle crisis

The board of directors has the responsibility to publish a clear risk management policy. For this purpose the risk management philosophy and responsibilities have to be communicated within the company and beyond. The single business unit should be provided with information's about:

[280] Cf. A.H. Walls et.al (1997), P. 2.
[281] Cf. Hans Egil Eckhoff (2000), P. 3.

- Risks within their area of responsibility
- Overall strategy to combat risks
- Opportunities to manage risks
- Budget available to manage risks

Individuals are the most affected element within the company, due to the fact that they are directly exposed to possible risk. The individual should be provided with information's about:

- Risks within their area of responsibility
- Opportunities to manage risks
- Opportunities for self protection

The policies of risk management have to be communicated on regular basis to the stakeholder of a company. Furthermore successes of measures as well as actions set to reduce or eliminate risk have to be reported. In today´s oil and gas business more and more stakeholders and investment companies have a look on the success of implemented risk management. The major points analyzed by the stakeholders are:

- Protection of their interests
- General performance of the company and in specific the risk management performance
- Implementation of communicated management controls

For this purpose accurate reporting should be realized. Core elements to be addressed are:

- Risk management control methods
- Management responsibilities
- Risk identification methods
- Monitoring and review system in place

7.4 Risk Treatment

Risk treatment should be understood as the prices of selecting convenient methods to reduce or to eliminate risks. The main elements of risk treatment are risk control, risk avoidance, risk transfer and risk financing. Out of the before mentioned SPE paper it could be filtered out that any system of risk treatment should have at least:

- **Effective and efficient operation**: This is mainly provided through the assistance of risk analysis process, showing the risks which have to be treated by the management of the organization.
- **Effective internal control**: Is reflected through the degree of elimination or reduction of identified and treated risks. Controls have to be measured and compared. This is realized by comparing the economical outcomes of the do nothing case to costs of desired actions.
- **Going hand in hand with international laws and regulations**.

One commonly utilized simple approach is to evaluate expenditure and effort for a number of selected risk reduction measures. Followed by estimation of the degree of elimination or reduction for the investigated risk. At the end selected measures are compared to each other and the most effective once is implemented. Another approach is the cost benefit analysis (CBA). This type of method compares the do nothing case to several preventive measures to reduce or to eliminate the risk. The most reliable measure with largest benefit and lowest cost will be selected. This has to be carried out according to the organizational politics and international laws. Each measure placed for risk treatment has to be monitored against predefined performance criteria. This has to be carried out at periodic intervals or if risk changes.

7.5 Monitoring and Review of Risk Management Process

To realize an effective risk management a reporting and reviewing structure has to be in place. Due to dynamics of a company and the dynamic environment a company is dealing with, this measure has to be carried out on regular basis. Modifications have to be realized to secure constancy of organizational system. The monitoring process within the E&P industry has to determine:

- If the measures realized resulted in the predefined objective
- If information and procedures implemented are suitable
- Lessons learned for future assessments and managements
- Further adoptions which have to be realized to eliminate or reduce the risk

7.6 Sensitivity and Uncertainty

All performed risk management steps are "*subjected to a process of critical review to provide a level of validation of the results*"[282]. All the methods, processes and techniques utilized show a certain uncertainty coming from data, information and parameters used. So it is very important to evaluate the source and quality of input data. This should be judged by experts and other interested parties. For that purpose uncertainty analysis and sensitivity analysis should create a major pillar within the risk management process. Uncertainty could result in inaccurate outcomes, ending up in a failed risk assessment, thus failed risk management process. Two main types of uncertainty are identified:

1. **Fundamental uncertainty**: Resulting out of random variations in utilized variables, affecting directly the level of risk. This type of uncertainty has the largest influence on actual value of risk.
2. **Imperfect knowledge uncertainty**: Resulting out of statistical uncertainty and modelling uncertainty.

Sensitivity analysis main function is to vary parameters used for the assessment. This should be carried out within realistic boundaries. This variation in parameters should indicate how sensitive each parameter is on the outcome of the desired assessment.

7.7 E&P vs. EU Member State Assessment

Comparing risk management and risk assessment mythologies in the oil and gas industry to those of European Union Member States results basically into the same utilized approaches as well as same stages, but the degree of advancement is very differential. The overall situation of both parties is completely different. National risk assessment has high degree of uncertainty due to the wide range of fields, which have to be covered during such kind of

[282] A.H. Walls et.al (1997), P. 4.

process. Elements like human's impacts and environment impacts with all their aspects cannot be easily assigned.

One of the major advantages of the oil and gas business is that they are dealing with a production, which creates their major duty. It is something palpable. A national government has many other aspects with are un-palpable as well as un-understandable. Additionally a government cannot be strictly managed as an organization.

The matter of overall risk assessment was very early developed by the oil and gas industry (including natural disasters). This was mainly resulting out of two facts:

- Environment and product they are dealing with
- Disasters occurred over the last century (example: Oil spills)

The first frameworks and standards were developed in the early 50´s, creating a nearly 50 years advance compared to other industries or even to governments. Today's standards and frameworks, which are implemented by responsible companies, are at a very high level, due to reasons formally presented. New assessments, treatments and measures represent only a minor advance into to overall risk management. Major steps where set and implemented decades ago.

To turn over to the context of this master thesis, there is no specific step for monetary analysis in the oil and gas business. Moreover the monetary analysis is implemented into several smaller steps of the whole process of risk management. Examples would be risk financing which is implemented into the risk treatment process or cost estimations which are even earlier applied during the risk evaluation process. Combining all available calculations and assessments would result in an adequate monetary analysis.

But is has to be clearly addressed that risk assessment and corresponding degree of complexity is much lower than for a national risk approach (due to wide range of factors to be considered). Calculations and inputs are more reliable in the oil and gas business. Humans represent a good example to illustrate this fact: How could authorities decide what the monetary value of 1000 dead, injured or disrupted human´s is? But it is possible to calculate the loss of one day of hydrocarbon production, when a certain measure is not implemented. So comparing the do nothing case to preventive measure is much easier to perform as well as to benchmark.

For the purpose of national risk assessment and European Union wide risk assessment, the oil and gas industry can provide several helpful elements to be implemented. In the specific case of monetary analysis it is also possible, but adoptions has to be realized, due to different points of departures. Additionally the complexity of national situations has to be clarified and binding standards as well as frameworks have to be developed.

8 Conclusion

In the last two decades number of natural disasters increased gradually affecting a large number of humans and their surrounding environment. To combat those events an adapted and efficient crisis management was established. Crisis management counts as a reaction measure, thus an attempted to reduce or eliminate the risk leading to such events is desirable. This should be realized with proactive measures. For this specific purpose risk management was introduced.

Generally this methodology consists of five main stages: Establishing of context, risk identification, risk analysis, risk evaluation as well as risk treatment. Risk identification, risk analysis and risk evaluation constitute the risk assessment. Risk assessment is the individual element of overall risk management process. Outcomes of risk assessment play a major role in further steps of risk management as well as in the decision making process of authorities or responsible parties.

Due to this simple fact, the European Union Commission decided to create for European Union Member States a risk assessment and mapping guideline for disaster management. Those guidelines can be applied for any type of disaster (intentional or unintentional, manmade or natural), because the fundamental producers are basically the same. The European Union Commission recommended EU Member States to create own national risk assessments based on the provided guidelines.

The aim is to develop, starting from 2014, a European Union wide risk assessment, based on national risk assessments of Union Member States. This specific measure should help to ensure adequate decision making process for risk reduction or elimination measures as well as help to identify:

- Risks affecting the European Union territorial area
- European Union capabilities for natural disaster management
- Risk reduction, treatment controls and measures

The target of this master thesis was to identify if there are monetary analysis implemented into risk assessment as well as risk management process of EU Member States. A monetary analysis should provide the possibility to compare outcomes of a certain event to the outcomes of the same event with implemented preventive measures. The outcomes should be investigated according to predefined national impact criteria. Examples are: Population, economics, supply, infrastructure, environment and politics. The monetary analysis should be seen as a decision tool for responsible authorities, due to represented economical outcomes of the preventive case as well as the do nothing case.

To fulfil the target of this work the risk assessment processes on national and European Union level where investigated. Austria, Federal Republic of Germany, Norway as well as Netherlands have been investigated into significant detail. Several observations were identified as the outcomes of this master thesis:

- Advancement level of national risk assessment on European Union level is very diverse. Leading EU Member States are Netherland, Norway, United Kingdom and Federal Republic of Germany.

- There is actually no common risk assessment methodology applied by all European Union Member States.

- Several elements of advanced national risk assessments are overlapping and comparable, whereby single Member States developed adaptations to handle own requirements. The adaptations are requested by the EU Commission to create an EU wide risk assessment fulfilling all the recommendations of the Members.
- The Commission's target to develop a European Union wide risk assessment by 2014 is not realistic and cannot be fulfilled. This is due to the slowly deployment of several EU Member States.
- The legal situation and responsibilities within some Member States were identified as complex. So the development of an own national risk assessment is a time consuming and resource intense approach. To implement outcomes of a monetary analysis the legal situation and financial responsibilities have to be clarified.
- There are only rudimental elements for monetary analysis in advanced national risk assessments. Generally there is no monetary analysis implemented into the actual risk assessment process of EU Member States. Additionally suggested methodologies have to be adapted, to be able to embody monetary analysis.
- Risk identification methodologies are available and could be utilized according to investigated risk type. Outcomes of risk identification create a significant part of future monetary analysis.
- To realize monetary analysis, reliable standards and frameworks have to be defined and worked out by experts.
- Monetary analysis has to be considered form the beginning of the risk management process.

9 References

9.1 Books, Reports, Scientific Paper

- A.H. Walls, S. Ried, J. Urbanus, G. Bishop, C. Rogers, A. Whitehead, L. Backwell, I. Buchanan, D. Hainsworth, A.A. Duff (1997), *Environmental Risk Assessment in E&P Activity*, SPE/AKOOA European Environmental Conference, Aberdeen, Scotland, Society of Petroleum Engineers Inc, SPE 37853.
- Adam M. Johanson and Ludger Evers (2007), *Monte Carlo Methods*, Lecture Notes, Department of Mathematics, University of Bristol, Bristol, United Kingdom, Source: http://www.maths.bris.ac.uk/~manpw/teaching/notes.pdf.
- Aine Gornely, Simon Pollard, Sophie Rocks (2011), *Guidelines for Environmental Risk Assessment and Management- Green Leaves III*, Department for Environment, Food and Rural Affairs, Collaborative Centre of Excellence in Understanding and Managing Natural and Environmental Risks, Cranfield University, United Kingdom, Source: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file /69450/pb13670-green-leaves-iii-1111071.pdf.
- American Bureau of Shipping (2004), *Guidance Notes on – Reliability Centered Analysis*, American Bureau of Shipping, Houston, U.S.A, Source: http://www.eagle .org/eagleExternalPortalWEB/ShowProperty/BEA%20Repository/Rules&Guides /Current/132_ReliabilityCenteredMaintenance/Pub132_RCM_GN.
- Andrea Saltelli et.al (2004), *Sensitivity Analysis in Practice – A Guide to Assessing Sceintific Models*, Joint Research Centre of the European Commission, Ispra, Italy, ISBN 0-470-87093-1, Source: ftp://usys-ftp.ethz.ch/ITES/FE/Alvaro/4Dev/ SALTELLI2004.pdf.
- Andrew L. Smith (2007), *New Risk-Management Standard for Delivering Superior Environmental and Safety Performance*, Society of Petroleum Engineers Inc, Environmental and Safety Conference, Galueston, Texas, U.S.A., Reference number: SPE 105503.
- Angela E. Summers, Scott Sandler (2003), *INTRODUCTION TO LAYER OF PROTECTIVE ANALYSES*, The Instrumentation Systems and Automation Society (ISA), ISA EXPO, Huston, Texas, U.S.A., Source: http://www.isa.org /Content/Microsites838/Safety_Division/Home818/ISA_Safety_2003_Papers/In troduction_to_LOPA.pdf.
- Australian Government, State Government Victoria (2012), *Community Emergency Risk Assessment (CERA)*, Making a difference across Victoria´s communities, Version 2.0, Source: http://www.ses.vic.gov.au/prepare/em-planning/em-partners-resources/community-emergency-risk-assessment-manual.
- Bundesregierung (2010), *Bericht über die Methode zur Risikoanalyse im Bevölkerungsschutz 2010*, Deutscher Bundestag 17. Wahlperiode, Drucksache 17/4178, Source: http:// dip21.bundestag.de/dip21/btd/17/041/1704178.pdf.
- Cabinet Office (2013), *National Risk Register of Civil Emergencies*, London, United Kingdom, Source: https://www.gov.uk/government/uploads/system/uploads /attachment_data/file/211867/NationalRiskRegister2013_amended.pdf.

- Carpignano, A. et.al (2007), *A methodological approach for the definition of multi-risk maps at regional level: first application*, Dipartimento di Energetica, Politecnico di Torino, 10129, Torino, Italy, European Commission DG JRC, Institute for the Protection and Security of the Citizen, FP 6 NARAS project.
- CEA, Insurers of Europe (2007), *Reducing the Social and Economic Impact of Climate Change and Natural Catastrophes* , Brussels, Belgium, Source: http://www.eaee.gr/web/uploads/Cea%20Report%20On%20Climate%20Change%20And%20Natural%20Catastrophes.pdf.
- Council of the European Union (2011), *Risk Assessment and Mapping Guidelines for Disaster Management*, Commission Staff Working Paper, Brussels, Belgium, Document number: 17833/10, Source: http://register.consilium.europa.eu/pdf/en/10/st17/st17833.en10.pdf.
- Det Norske Veritas (2002), *Marine Risk Assessment*, Offshore technology report 2001/063, London, United Kingdom, ISBN: 0 7176 2231 2, Source: http://www.hse.gov.uk/research/otopdf/2001/oto01063.pdf.
- DSB, Directorate for Civil Protection and Planning (2010). *Special Issue, National risk picture, Process and Method.* Grøset, Norway, ISBN: 978-82-7768-231-0, Source: http://www.dsb.no/Global/Publikasjoner/2010/Tema/Metodedokument%20NRB.pdf.
- EMA, European Medicines Agency (2011), *Quality Risk Management (ICH 09*), EMA / INS / GMP / 79766/2011, London, United Kingdom, Source: http://www.ema.europa.eu/docs/en_GB/document_library/Scientific_guideline/2009/09/WC500002873.pdf.
- Environmental Agency (2009), *Ecological risk assessment: A public consultation of framework and methods for assessing harm to ecosystems from contaminations*, London, United Kingdom, Source: http://www.basqueecodesigncenter.net/Documentos/Noticias/12225507-D45D-42D6-A4CD-9A35B747EDEB/UK-EPAeraconsultation_608719.pdf.
- Environmental Agency (2009), *Flooding in England: A National Risk Assessment on Flood Risk*, London, United Kingdom, Source: http://a0768b4a8a31e106d8b0-50dc802554eb38a24458b98ff72d550b.r19.cf3.rackcdn.com/geho0609bqds-e-e.pdf.
- Erik Wiig, Ellinor Nesse, Anita Norke (1996), *Environmental Quantitative Risk Assessment*, International Conference on Health , Safety and Environment,New Orleans, Louisiana, U.S.A., Society of Petroleum Engineers Inc, SPE 35945.
- European Commission (2007), *Report on Risk Assessment Procedures in the Field of Civil Protection and Rescue Services in Different European Union Counties and in Norway*, Brussels, Belgium, Source: http://ec.europa.eu/echo/civil_protection/civil/pdfdocs/riskassfinrep.pdf.
- European Parliament and Council of European Union (1995), Protection of individuals with regards to processing of personal data and on the free movement of such data, Brussels, Belgium, Source: http://www.icm2006.org/imgs/congresos/Directive%2095%2046%20EC.pdf.

- F. Khalaf, M. Abu El Ela (2008), *The Risk Management Process – An Overview*, SPE International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, Nice, France, Society of Petroleum Engineers Inc, SPE 111580.
- Federal Office of Civil Protection and Disaster Assistance (2011). *Method of Risk Analysis for Civil Protection.* Section II.1 – General Policy Issues of Civil Protection, Risk Management and Emergancy Preparedness, Bonn, Germany. ISBN: 978-3-939347-41-5, Source: http://www.bbk.bund.de/SharedDocs/Downloads/BBK/EN/booklets_leaflets/Method_of_%20Risk_Analysis.pdf?__blob=publicationFile.
- Florentin Ranft (2008), *Fehlerbaumanalyse – Fault Tree Analysis (FTA)*, Institut für Systemwissenschaften-, Innovations- und Nachhaltigkeitsforschung, Graz, Austria, Source: http://www.uni-graz.at/en/innoxwww_ranft_fehlerbaumanalyse.pdf.
- Fredrick V. Jones, Kumar (Chris) Israni (2012), *Environmental Risk Assessment Utilizing Bow-Tie Methodology*, SPE/APPEA International Cnference of Health, Safety and Environment in Oil and Gas Exploration and Production, Perth, Australia, Society of Petroleum Engineers Inc, SPE 156833.
- Freeman, Paul K., Landis Mechler, Leslie Martin, Reinhard Mechler, and Koko Warner.(2000), *Integrating Natural Catastrophe Exposure into Development Planning: Case Study of Natural Catastrophe Risk in Honduras*, Laxenburg, Austria: International Institute for Applied System Analysis.
- G. Fiebiger, F. Rudolf-Miklau (2002), *Measures and programs considering to mountains – management of natural disasters*, Mountain Watershed Management, Swiss Agency for Environment, Forests and Landscape, Berne, Switzerland.
- G. Fiebiger, M. Leitgeb (2002), *National Reports on the Management of Mountain Watersheds 2000-2002* - National Report Austria, Mountain Watershed Management, Swiss Agency for Environment, Forests and Landscape, Berne, Switzerland.
- Graham Bower-White (2013), *Demonstrating Adequate Management of Risk: The Move from Quantitative to Qualitative Risk Assessment*, SPE European HSE Conference and Exhibition, London, United Kingdom, Society of Petroleum Engineers Inc, SPE 164969.
- Gurenko E. et al. (2008), *Mitigating the Adverse Financial Effects of Natural Hazards on the Economies of South Eastern Europe: A Study of Disaster Risk Financing Options.* UN/ISDR-World Bank, Geneva, Switzerland.
- Halka Balackova (2003), *Brainstorming: a creative problem solving method*, Masaryk Institute of Advanced Studies, Czech Technical University, Prague, Czech Republic, Source : http://www.unido.org/fileadmin/import/16953_Brainstorming.pdf.
- Hannah Kosow, Robert Gaßer (2008), *Methods of Future and Scenario Analysis – Overview, Assessment, and Selection Criteria*, German Development Institute, Bonn, Germany, ISBN 978-3-88985-375-2, Source: http://dspace.cigilibrary.org/jspui/bitstream/123456789/26008/1/Methods%20of%20future%20and%20scenario%20analysis%20-%20overview,%20assessment,%20and%20selection%20criteria.pdf?1.

- Hans Egil Eckhoff (2000), *Health Risk Assessment*, SPE International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, Stavanger, Norway, Society of Petroleum Engineers Inc, SPE 61213.
- Hübl J., Hochschwarzer M., Sereinig N., Wöhrer-Alge M. (2011), *Alpine Naturgefahren. Ein Handbuch für Praktiker*, Forsttechnischer Dienst für Wildbach- und Lawinenverbauung Vorarlberg, Voralberg, Austria, Source: http://www.google.at/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&ved=0CC8QFjAA&url=http%3A%2F%2Fwww.adaptalp.org%2Findex.php%3Foption%3Dcom_docman%26task%3Ddoc_download%26gid%3D542%26Itemid%3D79&ei=fdBbUoqkOovMswabr4GwAw&usg=AFQjCNFbaEhRdbVp_TiJB9eRaJsewcN7ig&bvm=bv.53899372,d.Yms.
- Hübl J., Kienholz H., Loipersberger A. (2006): DOMODIS: *Dokumentation alpiner Naturereignisse [Documentation of Mountain Disasters]*, Schriftenreihe 1, Handbuch 1, , Klagenfurt, Austria.
- Ian Charters (2011), *A Practical Approach to Business Impact Analysis – Understanding the Organization through Business Continuity Management*, British Standard Institution, London, United Kingdom, ISBN 978-0-580-73101-3, Source: http://shop.bsigroup.com/upload/Shop/Download/Books/BIP2214-samplechapter.pdf.
- IEC, International Electrotechnical Commission (2001), *Hazard and operability studies (HAZOP studies) - Application guide IEC 61882,* Geneva, Switzerland, Reference number IEC 61882:2001(E).
- IEC, International Electrotechnical Commission (2005), *Application of Markov techniques ICE 61165*, Geneva, Switzerland, Reference number IEC 61165:2006.
- IEC, International Electrotechnical Commission (2005), *Food safety management systems - Requirements for any organization in the food chain ISO 22000*, Geneva, Switzerland, Reference number ISO 22000:2005(E).
- IEC, International Electrotechnical Commission (2006), *Analysis techniques for system reliability - Procedure for failure mode and effects analysis* (FMEA) IEC 60812, Geneva, Switzerland, Reference number IEC 60812:2006(E).
- IEC, International Electrotechnical Commission (2009), *Risk management – Principles and Guidelines ISO 31000,* Geneva, Switzerland, Reference number ISO 31000:2009(E).
- IEC, International Electrotechnical Commission (2009), *Risk management - Risk assessment techniques ISO 31010,* Geneva, Switzerland, Reference number IEC/FDIS 31010:2009(E).
- IEC, International Electrotechnical Commission (2002), *Risk Management – Vocabulary-Guidelines for use in standards*, Geneva, Switzerland, Reference number: ISO/IEC Guide 73:2002.
- Ilias Maragakis et al. (2009), *Guidance on Hazards Identification,* Safety Management System and Safety Culture Working Group (SMSWG), European Strategic System Safety Initiative, Source: http://easa.europa.eu/essi/ecast/wp-content/uploads/2011/08/ECASTSMSWG-GuidanceonHazardIdentification1.pdf.

- IMCA, The International Marine Contractors Association (2002), *Guidance on Failure Modes & Effects Analyses (FMEAs)*, London United Kingdom, Report number: IMCA M 166, Source: http://www.imca-int.com/media/73361/imcam166.pdf.
- Institute for Environment and Health, Environmental Agency (2000), *Guidelines for Environmental Risk Assessment and Management – Revised Departmental Guidance*, London, United Kingdom, ISBN 0-11-753551-6, Source: http://www.leadammunitiongroup.co.uk/pdf/Environmental%20Risk.pdf.
- Islam H. Afefy (2010), *Reliability_Centered Maintenance Methodology and Application: A Case Study*, Industrial Engineering Department, Faculty of Engineering, Faoum University, Faoum, Egypt, Source: http://www.google.at/url?sa=t&rct=j&q=&esrc=s&source=web&cd=9&cad=rja&ved=0CHQQFjAI&url=http%3A%2F%2Fwww.scirp.org%2Fjournal%2FPaperDownload.aspx%3FpaperID%3D3165&ei=TBRIUtj9EqaC4gTE4YDgAg&usg=AFQjCNGQ7zPKwMRd-hdLS79yzrSk-snx_Q&bvm=bv.53217764,d.Yms.
- J. D. Andrwes, S. J. Dunnett (1999), *Event Tree Anaylsis Using Binary Decision Diagrams*, Department of Mathematical Sciences, Loughborough University, Loughborough, United Kingdom, Source: http://www.lboro.ac.uk/microsites/maths/research/preprints/papers99/99-25.pdf.
- James J. Rooney, Lee N. Vanden Heuuel (2004), *Root Cause Analysis For Beginners,* Quality Basics, Source: https://servicelink.pinnacol.com/pinnacol_docs/lp/cdrom_web/safety/management/accident_investigation/Root_Cause.pdf.
- Jeff Miller (1989), *SNAKE CIRCUIT ANALYSIS FOR THE COMMON MAN*, Rome Air Development Center (RADC), Air Force System Command, New York, U.S.A., RADC-TR-89-223, Source: http://www.reliability-safety-software.com/download/SCA4TheCommonMan.pdf.
- John Andrews (1998), *Fault Tree Analysis*, Proceedings of the 16th International System Safety Conference, Department of Mathematical Sciences, Loughborough University, Loughborough, United Kingdom, Source: http://www.fault-tree.net/papers/andrews-fta-tutor.pdf.
- John Pollner, Jolanta Kryspin-Watson, Sonja Nieuwejaaar (2008), *Disaster Risk Management and Climate Change Adaption in Europe and Central Asia*, Global Facility for Disaster Reduction and Recovery (GFDRR), , Washington DC, U.S.A., Source: http://www.gfdrr.org/sites/gfdrr.org/files/publication/GFDRR_DRM_and_CCA_ECA.pdf.
- Julie Bell, Justin Halroyd (2009), *Review on human reliability assessment methods*, Health and Safety Laboratory, Buxton, United Kingdom, Research Report RR670, Source http://www.hse.gov.uk/research/rrpdf/rr679.pdf.
- Kabir K. Dutta, David F. Babbel (2010), *Scenario analysis in the Measurement of Operatinal Risk Capital: A Change of Measure Approach*, Charles River Associates, Boston, U.S.A., Source: http://fic.wharton.upenn.edu/fic/papers/10/10-10.pdf.
- Kirsti Russell Vastveit (2011), *The use of national risk assessment in the Netherlands and the UK*, Faculty of social sciences, University of Stavanger, Stavanger, Norway, Source: http://brage.bibsys.no/uis/bitstream/URN:NBN:no-bibsys_brage_25846/1/Russell%20Vastveit%20Kirsti.pdf.

- Leitgeb M. (2001), *Analyse von Schutzkonzepten in Wildbacheinzugsgebieten anhand zweier ausgewählter Beispiele*, Diplomarbeit am Institut für Alpine Naturgefahren und Forstliches Ingenieurwesen an der Universität für Bodenkultur, Wien.
- Leitgeb M., Rudolf-Miklau F (2003), *Risk management in torrent, avalanche and erosion control in Austria*; "Forests in sustainable mountain development", International IUFRO-Workshop, 9 – 13 June 2003, Galtür, Austria.
- Leitgeb M., Rudolf-Miklau F. (2004), *Risk and Disaster Management in Natural Hazards as Floods, Debris Flow, Landslides, Rockfall and Avalanches in Austria*, International Symposium Interpraevent 2004, Riva, Trient, Italy, Source: http://www.interpraevent.at/palm-cms/upload_files/Publikationen/Tagungsbeitraege/2004_4_IX-125.pdf.
- Lucia Breieroua, Mark Choudhari (2001), *An Introduction to Sensitivity Analysis*, MIT System Dynamics in Education Project, Massachusetts Institute of Technology, Massachusetts, U.S.A, Source: http://clexchange.org/ftp/documents/Roadmaps/RM8/D-4526-2.pdf.
- M. Holub, S. Fucks (2009), *Mitigating mountain hazards in Austria – legislation, risk transfer and awareness building*, Natural Hazards and Earth System Sciences, Reference number: Nat. Hazards Earth Syst. Sci., 9, 523–537, 2009, Source: http://www.nat-hazards-earth-syst-sci.net/9/523/2009/nhess-9-523-2009.pdf.
- M.G. Mennen (2013), *National Risk Assessment 2011*, National Institue for Public Health and the Environment, Ministry of Health, Welfare and Sport, Bilthoven, Netherlands, Project Number: E/609042/01, Source: https://www.google.at/url?sa=t&rct=j&q=&esrc=s&source=web&cd=14&cad=rja&ved=0CEsQFjADOAo&url=https%3A%2F%2Fwww.nctv.nl%2FImages%2Fnational-risk-assessment-2011-def_tcm126-506977.pdf&ei=VmxSUunLDcfKtAaMt4CQDw&usg=AFQjCNHmlYucQ9ZPpouco99ufOEu23pkCg&bvm=bv.53537100,d.Yms.
- Marco Martuzzi, Joel A. Tickner (2004), *The precautionary principle: protecting public health, the environment and the future of our children*, World Health Organization (WHO) Europe, Geneva, Switzerland, ISBN 92 890 1098 3, Source: http://www.euro.who.int/__data/assets/pdf_file/0003/91173/E83079.pdf.
- Marvin Rausand (2005), *HAZOP – Hazard and Operability Study*, Department of Production and Quality Engineering, Norwegian University of Science and Technology, Trondheim, Norway, Source: http://frigg.ivt.ntnu.no/ross/slides/hazop.pdf.
- Marvin Rausand (2005), *Preliminary Hazard Analysis*, Department of Production and Quality Engineering, Norwegian University of Science and Technology, Trondheim, Norway, Source: http://ab-div-bdi-bl-blm.web.cern.ch/ab-div-bdi-bl-blm/Literature/fmcea/pha.pdf.
- Ministry of the Interior and Kingdom Relations, (2009), *Working with scenarios, risk assessment and capabilities in the National Safety and Security Strategy of the Netherlands*, Den Haag, Netherlands, Source: http://www.hetlocc.nl/aspx/download.aspx?file=/contents/pages/106264/292793leidraadengels.pdf.
- Murray Turoff and Harold A. Linstone (2002), *The Delphi Method – Techniques and Applications*, Reading, Massachusetts, U.S.A, ISBN 0-201-04294-0, Source: http://is.njit.edu/pubs/delphibook/delphibook.pdf.

- Murlidharan, T.; Shah, H. (2003), Economic Consequences of Catastrophes Triggered By Natural Hazards. Vulnerability, Economic Impact, Empirical Evidence, and Theoretical Models, Dissertation, Department of Civil and Environmental Engineering, Stanford University. Stanford, U.S.A., Source: https://blume.stanford.edu /sites/default/files/TR143_Murlidharan.pdf.

- National Aeronautics and Space Administration (NASA)(2000), *Reliability Centered Maintenance Guide for Facilities and Collateral Equipment*, Washington, D.C., U.S.A., Source: http://www.hq.nasa.gov/office/codej/codejx/Assets/Docs/ RCMGuideMar2000.pdf.

- National Emergency Management Committee (2010), *National Emergency Risk Assessment Guidelines*, Tasmanian State Emergency Service, Hobart, ISBN 978-0-9805965-1-9 (PDF), Source: http://disaster.qld.gov.au/Disaster%20Resources/ Documents/NERAG-National_Emergency_Risk_Assessment_Guidelines_ 2010.pdf.

- OECD, Organisation for Economic Co-operation and Development (2012), *Disaster Risk Assessment and Risk Financing*, A G20 / OECD methodology framework, Source: http://www.oecd.org/gov/risk/G20disasterriskmanagement.pdf.

- OECD, Organisation for Economic Co-operation and Development (2003) *Emerging risks in the 21st century*, Source: http://www.oecd.org/dataoecd/23/56/ 19134071.pdf.

- Robert S. Cram (2004), *3D Model for Qualitative Risk Assessment*, Seventh SPE International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, Calgary, Canada, Society of Petroleum Engineers Inc, SPE 86707.

- Rudolf Faber (2006), FLOOD RISK ANALYSIS: RESIDUAL RISKS AND UNCERTAINTIES IN AUSTRIAN CONTEXT, Department of Water, Atmosphere and Environment, Institute of Water Management, Hydrology and Hydraulic Engineering, BOKU, Vienna, Austria, Source: http://iwhw.boku.ac.at/dissertationen/ faber.pdf.

- Ryan Watkins, Maurya Weat Meiers, Yusra Laila Visser (2012), *A Guide to Assessing Needs – Essential Tools for Collecting Information, Making Decisisons, and achieving Development Results*, The World Bank, Washington, D.C., U.S.A., ISBN (paper): 978-0-8213-8868-6.

- S. McDermott (2012), *Risk Assessment (Hazard Management) Process Is a Continual Process, Not a One Off*, SPE Asia Pacific Health, Safety and Environment Conference and Exhibition, Bangkok, Thailand, Society of Petroleum Engineers Inc, SPE 108853.

- Samik Raychaudhuri (2008), *INTRODUCTION TO MONTE CARLO SIMULATION*, Oracle Crystal Ball Global Business Unit, Broomfield, Colorado, U.S.A, Source: http://www.informs-sim.org/wsc08papers/012.pdf.

- Scott Ferson (1996), *Bayesian Methods in Risk Assessment*, Applied Biomathematics, New York, U.S.A, Source: http://www.ramas.com/bayes.pdf.

- Siegfried Jachs (2011), *STAATLICHES KRIESEN- UND KATASTROPHEN-SCHUTZ- MANAGEMENT (SKKM)*, Fachgespräch mit Innenminsterin Maria Feckter (24.03.2011), Bundesministerium für Inneres, Vienna, Austria, Source: http://www.bmi.gv.at/cms/BMI_Service/Aus_dem_Inneren/Staatliches_Krisen_und_Katastrophenschutzmanagement.pdf.
- Swedish Civil Contingencies Agency (2011), A first step towards a national risk assessment, Karlstad, Sweden, Publication number MSB 336-2011, ISBN 978-91-7383-180-2, Source: https://www.msb.se/Upload/Forebyggande/Krisberedskap/A_first_step_towards_a_nat_riskassessment_en_final_.pdf.
- The Economist Intelligence Unit (2007), *Best practice in risk management - A function comes of age*, Source: http://www.kpmg.com.au/Portals/0/eiu_Risk_Management.pdf.
- The World Bank (2006), *Hazards of Nature, Risks to Development - An IEG Evaluation of World Bank Assistance for Natural Disasters*, Independent Evaluation Group (IEG), World Bank, Washington, D.C., U.S.A, ISBN-10 0-8213-6650-5, Source: http://lnweb90.worldbank.org/oed/oeddoclib.nsf/DocUNIDViewForJavaSearch/F0FCEB17632CB93485257155005081BE/$file/natural_disasters_evaluation.pdf.
- UK Cabinet Office (2008), *National Risk Register*, Source: http://www.cabinetoffice.gov.uk/media/cabinetoffice/corp/assets/publications/reports/national_risk_register/national_risk_register.pdf.
- UNISDR, United Nations International Strategy for Disaster Reduction (2009), *UNISDR Terminology on Disaster Risk Reduction*, Geneva, Switzerland, Source: http://www.unisdr.org/files/7817_UNISDRTerminologyEnglish.pdf.
- USDA, United States Department of Agriculture (1997), *Guidebook For The Preparation Of HACCP Plans*, Food Safety and Inspection Service, Washington, D.C., U.S.A., Source: http://www.haccpalliance.org/sub/haccpmodels/guidebook.pdf.
- Victor Watson (2012), *A Quantitative Risk Assessment Approach*, SPE International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, Rio de Janerio, Brazil, Society of Petroleum Engineers Inc, SPE 127213.
- W. E. Vesely, F. F. Goldberg, N. H. Roberts, D. F. Haasl (1981), *Fault Tree Handbook*, System and Reliability Research Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, D.C., U.S.A., Source: http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0492/sr0492.pdf.

9.2 Web

- AlpS (2013), http://www.alp-s.at/cms/en/about-alps/. Access 29.08.2013
- BMC Services Research (2011), http://www.biomedcentral.com/1472-6963/11/244/figure/F1?highres=y, Access 23.09.2013.
- EM DAT – The International Disaster Data Base(2013), Center of Research on the Epidemiology of Disasters (CRED), http://www.emdat.be/, Access 14.07.2013.
- European Commission (2013), http://ec.europa.eu/echo/civil_protection/civil/vademecum/images/at/structure2.jpg, Access 04.09.2013
- FEMA: Risk mapping, assessment and planning (2013), http://www.fema.gov/plan/prevent/fhm/rm_main.shtm, Access 25.09.2013.
- HORA, Natural Hazard Overview & Risk Assessment Austria (2013), http://www.hora.gv.at/, Access 17.08.2013.
- Jusline.at (2013), B-VG, Bundesverfassungsgesetz, Source: http://www.jusline.at/Bundes-Verfassungsgesetz_%28B-VG%29.html, Access: 14.09.2013.
- Jusline.at (2013), WRG, Wasserrechtsgestz, Source: http://www.jusline.at/Wasserrechtsgesetz_%28WRG%29.html, Access: 13.09.2013.
- Lower Austrian Government (2013), http://www.noe.gv.at/, Access 20.09.2013.
- MOI, Ministry of the Interior (2013), http://www.bmi.gv.at/cms/BMI_Zivilschutz/more_on_topic/National_Crisis_and_.aspx. Access 03.09.2013.
- MOI, Ministry of the Interior (2013), Source: http://www.bmi.gv.at/cms/BMI_Zivilschutz/more_on_topic/Department_II4.aspx, Access: 14.10.2013.
- Naturegefahren.at (2013), Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, http://www.naturgefahren.at/, Access 15.07.2013.
- NÖZSV, Niederösterreichischer Zivilschutzverband (2013), http://www.noezsv.at/noe/media/0_Dokumente/KKM_Risikoanalyse%20Bild.pdf, Access 20.09.2013.
- NÖZSV, Niederösterreichischer Zivilschutzverband (2013), http://www.noezsv.at/noe/pages/startseite/katastrophenschutz-noe/risikomanagement.php, Access 20.09.2013.
- Oxford dictionary (2013), http://oxforddictionaries.com/definition/english/threat, Access 20.09.2013.
- RIS, Rechtsinformationssystem (2013), Bundeskanzleramt Österreich, http://www.ris.bka.gv.at/, Access: 13.09.2013.
- Salzburger Land (2013), http://www.salzburg.gv.at/themen/se/sicherheit/kat-katastrophenschutz/kat_katastrophenschutz_oesterreich.htm, Access 15.08.2013.
- ScienceDirect (2013), http://www.sciencedirect.com/science/article/pii/S0304389405003808, Access 11.10.2013.
- ZAMG - Zentralanstalt für Meteorologie und Geodynamik (2013), http://www.zamg.ac.at/cms/de/aktuell, Access 16.08.2013.