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GUIDANCE ON IMPLEMENTATION OF BINGO WP4 – ASSESSMENT OF IMPACTS OF EXTREME WEATHER EVENTS

Developing risk identification

Bingo project – Bringing INnovation to onGOing water management – a better future under climate change

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Title

GUIDANCE ON IMPLEMENTATION OF BINGO WP4 – ASSESSMENT OF IMPACTS OF EXTREME WEATHER EVENTS
Developing risk identification

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GUIDANCE ON IMPLEMENTATION OF BINGO WP4 - ASSESSMENT OF IMPACTS OF EXTREME WEATHER EVENTS

Developing risk identification

Abstract

The *main objectives of BINGO* are to provide adaptation strategies for climate change-related challenges, by coproduced tools and methodologies for water and land resources management strategies that are based on an *improved understanding* of future climate and its impact on the hydrological cycle and in human activities, in order to sustain key economic sectors and the environment.

Decision under uncertainty (climate changes evolution) is a risk management process, of weighing policy alternatives, in consultation with all interested parties, considering risk assessment and other relevant factors and, if needed, selecting appropriate prevention and control options. The main job of BINGO is to put in practice, in a realistic but scientific way, a comprehensive risk management framework approach, aiming to support efficiently decision-making for sustainable development and improved governance, resulting in the adaptation strategies and policies to be achieved in work package 5 (WP5 - risk treatment).

BINGO work package 4 (WP4) will perform the assessment of impacts of climate change extreme scenarios on human activities, at each research site, based on the risk assessment procedure of ISO 31000:2009, in such a way that its results assist to develop risk validated adaption strategies to cope with climate changes in WP5.

This document aims at providing some guidance to BINGO partners to perform **risk identification** at each research site. This first step of risk assessment is the outcome of Task 4.2 of WP4 (Deliverable 4.2). This guidance explains how ISO 31000:2009 needs to be adapted into BINGO project, clarifying the concepts involved as provides tips for implementation of sequential steps as well as exemplificative cases. It also demonstrated the articulation of risk identification with the remaining project activities.

Keywords: BINGO / ISO 31000:2009 / Risk identification/ Risk assessment / Risk analysis

ORIENTAÇÕES PARA IMPLEMENTAÇÃO DA ATIVIDIDADE 4 DO PROJETO BINGO - WP4: AVALIAÇÃO DOS IMPACTOS DE EVENTOS CLIMÁTICOS EXTREMOS

Desenvolvimento da identificação de riscos

Resumo

O *projeto BINGO* visa desenvolver estratégias de adaptação aos desafios colocados pelas alterações climáticas, através de ferramentas e metodologias de gestão dos recursos hídricos e do solo, baseando-se em um conhecimento mais aprofundado da evolução climática e dos seus impactos sobre o ciclo hidrológico e sobre as atividades humanas, a fim de sustentar sectores chave da economia e o meio ambiente. Decisão sob incerteza (evolução das alterações climáticas) é um processo de gestão de risco, que consiste em ponderar alternativas de estratégias e políticas, consultando todas as partes interessadas, tendo em consideração a avaliação dos riscos e outros fatores relevantes e, se necessário, a seleção de opções de prevenção e de controlo adequadas. O BINGO visa desenvolver, de forma realista, mas científica, uma abordagem holística de gestão dos riscos associados a fenómenos meteorológicos extremos, apoiando de forma eficiente o processo de tomada de decisão, orientado para o desenvolvimento sustentável e para uma melhor governança, resultando em estratégias e políticas de adaptação (BINGO WP5 - Tratamento de risco).

BINGO WP4 irá realizar a avaliação dos impactos dos cenários de fenómenos extremos associados às alterações climáticas sobre as atividades humanas, em cada caso de estudo do projeto, com base no processo de avaliação de riscos da ISO 31000: 2009, para que os seus resultados validem as estratégias de adaptação a desenvolver na atividade WP5.

O objetivo deste documento é providenciar algumas orientações para desenvolvimento da identificação de riscos em cada caso de estudo do BINGO. É a primeira fase do processo de avaliação de risco, a ser concretizada na Atividade 4.2 da WP4. Este documento explica como a ISO 31000: 2009 deve ser adaptada ao projeto, clarifica alguns conceitos e definições, providencia dicas para desenvolvimento da atividade, ilustrando com alguns casos exemplificativos. Evidencia ainda os pontos de articulação com as restantes atividades do projeto

Palavras-chave: BINGO / ISO 31000:2009 / Identificação de risco / Análise de risco / Avaliação de risco

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Acronyms

ABLGVFX	Associação de Beneficiários da Lezíria Grande de Vila Franca de Xira (Association of Beneficiaries of Lezíria Grande de Vila Franca de Xira)
BINGO	Bringing INnovation to onGOing water management
CC	Climate change
CSO	Combined Sewer Overflows
CY	Cyprus
DE	Germany
EDP	Eletricidade de Portugal (Electricity of Portugal)
EPAL	Empresa Portuguesa das Águas Livres – Grupo Águas de Portugal (EPAL – Public Water Supply Company to Lisbon and all the right margin of lower Tagus river)
ISO	International Organization for Standardization
IWRM	Integrated Water Resources Management
LGVFX	Lezíria Grande de Vila Franca de Xira
NL	Netherlands
NO	Norway
PIP	Public Irrigation Perimeter
PT	Portugal
PWS	Public Water Supply
RMP	Risk Management Process
RS	Research Sites
SP	Spain
WP	Work package
WR	Water Resources
WRM	Water Resources Management

1 | Introduction

The ultimate objective of BINGO project is to provide risk adaptation strategies for climate change-related challenges, validated by a risk management framework. The risk approach followed in BINGO is *based* on ISO 31000:2009 (ISO, 2009b). BINGO work packages were structured according to this risk framework (Figure 1.1).

Figure 1.1 – Risk management phases in relation to BINGO Work packages (Figure 5 of BINGO, 2014)

ISO 31000:2009 risk management framework needs to be duly adapted to the project and to each research site (RS). In Rocha, 2016, the phases of the risk management process are identified, as well as some suggestions for project adaptation.

This document aims at providing some guidance to BINGO partners to perform risk identification, the first step of the risk assessment process that is the purpose of Task 4.2 of BINGO. The outcome of Task 4.2 will be **deliverable D4.2**.

Risk identification is a two steps process. According to the characteristics and objectives of each research site within BINGO, this document will help partners to decide upon the need to perform: *i)* both steps, resulting in the identification of risks that may have an effect over the risk management objectives defined for each research site in Task 4.1, in such a way that risk assessment can be achieved (Figure 1.2), or *ii)* simply the first step, allowing however to identify the main factors of risk that need to be subjected to adaptation measures, later identified in work package 5.

As this stage, context for the risk owners of each research site were already developed under Task 4.1 (WP4) and the risk management objectives (RMP) established and presented in deliverable D4.1 (Rocha *et al.*, 2017). Chapter 2 provides a very brief highlight of some key points useful to perform risk identification.

In chapter 3 the concepts involved in risk identification are clarified being explained, at the same time,

how they can be easily adapted to BINGO. The relevance of step 1 and step 2 for each research site according to their characteristics and objectives will also be addressed, allowing partners to decide on the extent of risk identification they are willing to develop for their respective research sites. BINGO related examples are also provided along the steps.

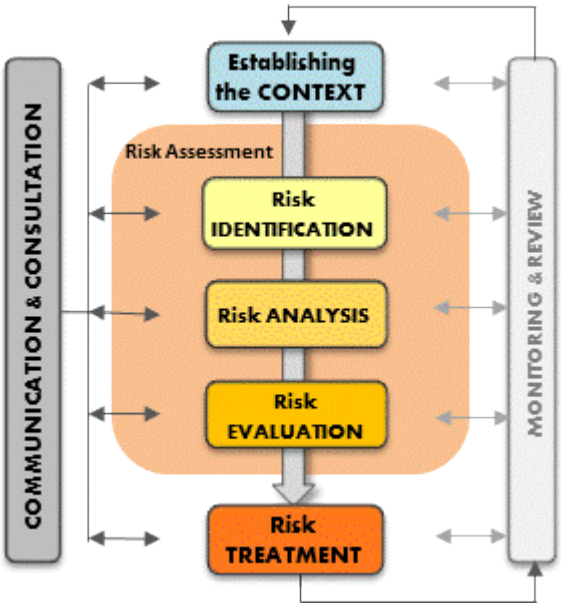


Figure 1.2 – Risk Management Process (ISO 31000:2009)

2 | Overview of BINGO research sites for risk identification

Natural hydro-meteorological hazards addressed in BINGO

In BINGO project the sources of hazards (triggers) that may give rise to risks are mainly extreme meteorological conditions, related with precipitation or wind and atmospheric pressure conditions.

These meteorological conditions have different hydrological manifestations of river flow, storage capacity (superficial or groundwater) and marine behaviour, giving rise to inundations (riverine, urban, estuarine) or droughts.

The sources of hazard (extreme meteorological conditions) are addressed in work package 2. Their repercussions in the natural water cycle or in the urban areas (hydrological manifestations) are addressed in work package 3. According to the way the research sites were set in BINGO, the hydrologic repercussion of the meteorological conditions is, in fact, where the hazard (potential for harm) relies to humans (Figure 2.1).

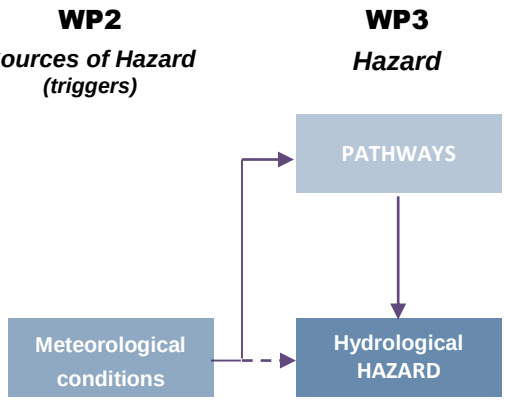


Figure 2.1 – From hazard sources (meteorological conditions) to hazards (hydrologic repercussion)

In some BINGO case studies, the hydro-meteorological hazard is associated with other sources of hazard, as for example, oceanographic sources (sea level rise, spring tides) or domestic sewerage, resulting in combined sewerage overflow (CSO). The complexity of the pathways linking the meteorological conditions to the existing hazards differs for each BINGO research site.

The **hydro-meteorological hazards** covered by the six BINGO research sites are:

- **Droughts**, associated with extreme dry periods;
- **Inundations** with inland origin, due to intensive precipitation episodes:
  - River floods;
  - Urban floods (due to insufficient pluvial sewerage capacity);
  - Combined sewerage overflow (CSO); and
- **Inundations** with marine origin (storm surges), due strong winds and low atmospheric pressure conditions.

Socio economic activities addressed

Work package 4 (WP4) is responsible within the project for assessing the potential impacts of the extreme hydro-meteorological conditions on people or on socio-economic water related activities (elements at risk) and for assessing the potential consequences on the objectives established for the risk management processes in Task 4.1, for each research site (Figure 2.2).

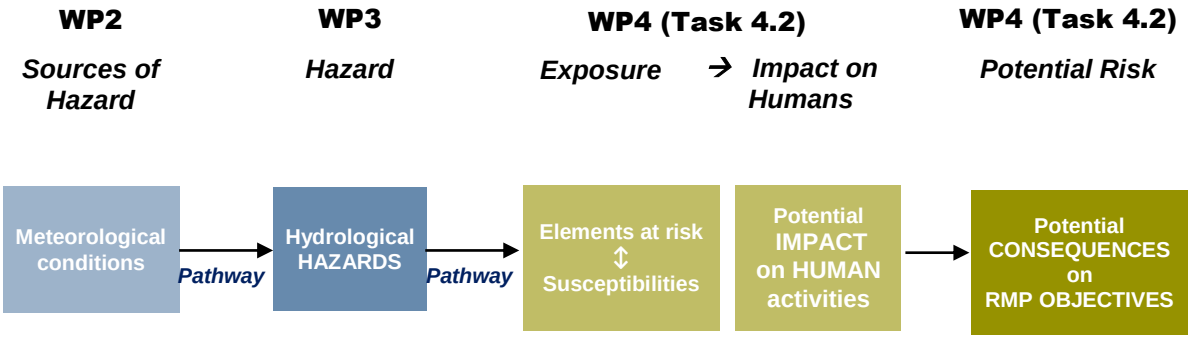


Figure 2.2 – BINGO work packages aligned with risk identification steps

Table 2.1 summarises the public or economic water related sectoral activities addressed per type of natural hazardous event considered. They are the following:

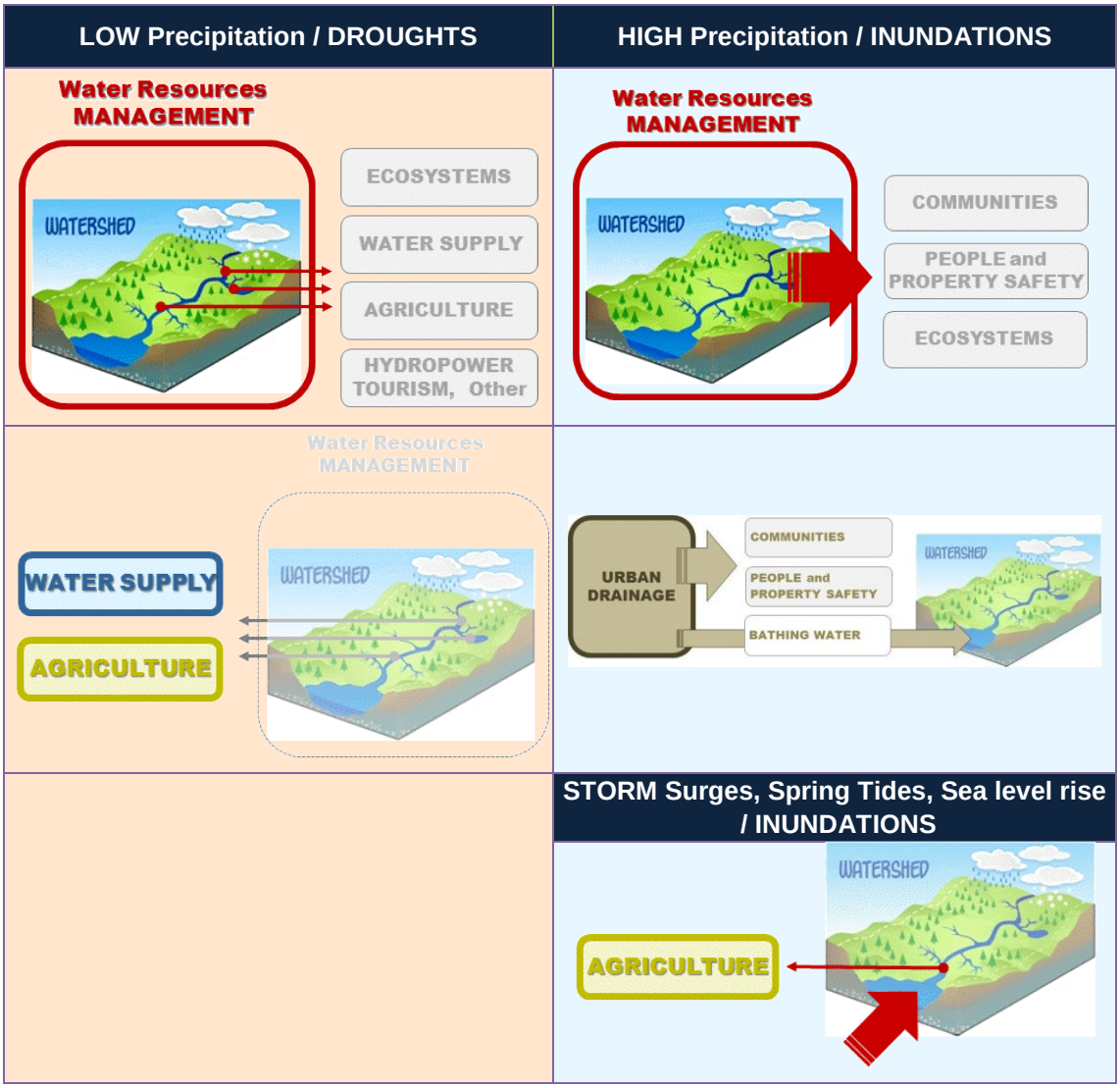
- Water resources management (DE and NL);
- Urban drainage management (NO and SP);
- Public water supply (PT, CY, NL and NO);
- Agriculture water supply (PT and CY).

Objectives of the RMP at the six research sites

At this point of BINGO development, the categories of risks to be addressed were already selected in Task 4.1, and expressed into scopes and specific objectives.

Figure 2.3 and Figure 2.4 summarize the main broad objectives (scopes) of the risk management processes at each research site per type of hydrologic hazard, drought or inundations, developed in Task 4.1 and presented in Deliverable 4.1 (Rocha *et al.*, 2017). They include mainly: continuity of the service; environmental protection; financial; image and reputation; people safeguard and property protection. To fulfil those scopes, specific objectives were also defined. The aim of Task 4.2 is to identify, for the selected hydro-meteorological hazards, what endanger the achievement of those specific objectives.

Table 2.1 – Socio-economic activities addressed in each research site for the hydro-meteorological hazard selected



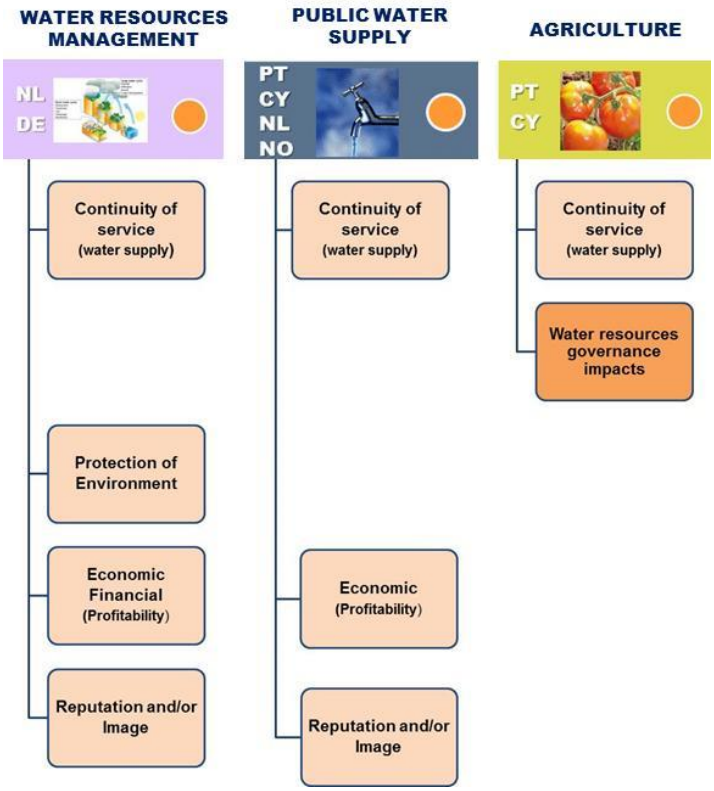


Figure 2.3 – Droughts: Scopes of the RMP at each research site

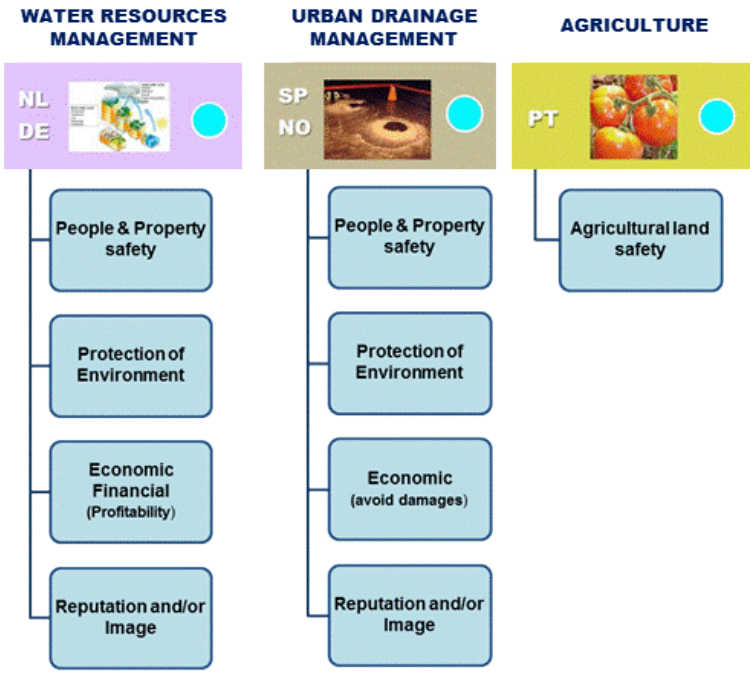


Figure 2.4 – Inundations: Scopes of the RMP at each research site

3 | Risk Identification

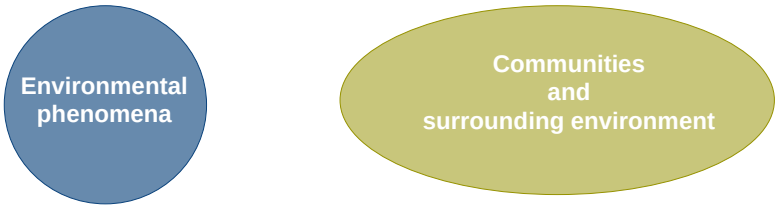
3.1 RISK relevant definitions and concepts

Risk concept

Risk (effect of uncertainty on the achievement of the objectives of an organization) is associated with the interaction between environmental phenomena, communities and the surrounding environment. Under ISO 31 000:2009 the emphasis is on "**the effect**" rather than on "the event" (something happening). Risk is expressed in terms of a combination of the consequences of an event, or a change in circumstances, and the associated probability of occurrence.

A social based approach is inherent to this framework. If there is no interaction between environmental phenomena and the human community or surrounding environment there is any risk associated. If some of the elements of the community and its environment are exposed, the environmental phenomena then become a hazard (Figure 3.1).

a) Without exposure there is no risk



b) Risk requires human assets exposure

Figure 3.1 – Risk requires interaction between environmental phenomena, communities and the surrounding environment

Thus, to identify risks, it is necessary to take into account the ***nature of the hazard*** and the ***factors*** that affect the consequences or impacts over the human elements and its surrounding environment.

RISK (*r*) = Probability (*p*) x Consequences (*c*)

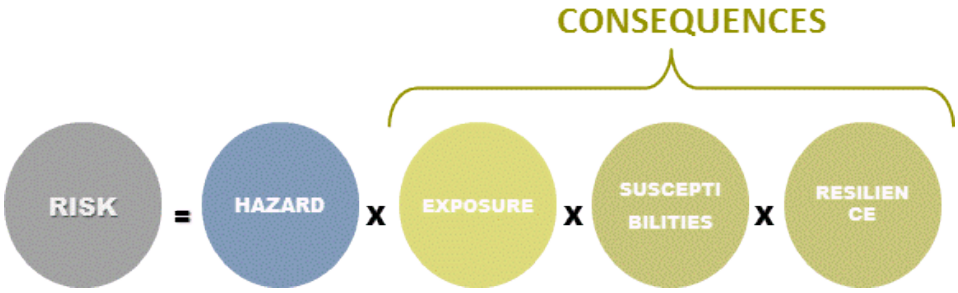


Figure 3.2 – Risk concept (ISO 31000:2009) where risk is expressed in terms of a combination of the consequences of an event and the associated probability of occurrence

Consequences = f (exposure, susceptibility, resilience)

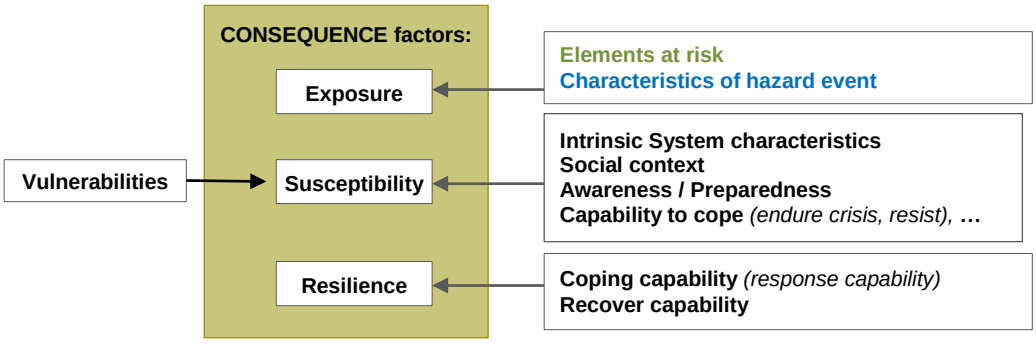


Figure 3.3 – Factors affecting consequences of an event

As said, the factors affecting consequences are a complex function of the exposure, the susceptibilities of the elements exposed and the resilience of a system (Figure 3.3):

i) the degree of exposure (measured by the number of the elements at risk or by their value);
ii) the susceptibility of the system referring to the propensity of exposed elements to suffer adverse effects (damages) as a consequence of certain level or characteristic of the hazardous event (measured by the sensitivity of those elements to risk, originated by their vulnerability);
iii) the system preparedness and resilience (coping and recovery capacity).

In colloquial terms is possible to say (UNESCO-IHE):

Exposure: considered as the predisposition of a system to be disrupted by a hazardous event (flood, drought, or other) due to its location in the same area of influence.

Exposure can be also understood as the values that are present at the location where a hazardous event (floods, drought, etc.) can occur. These values can be tangible, as goods, infrastructure or mostly people, or intangible- as cultural heritage or image.

The indicators for this component can be separated in two categories: 1) the first one covers the exposure of different elements at risk and the second ii) the second one gives details on the general characteristics of the hazardous event.

Susceptibility: considered as the elements exposed within the system, which influence the probabilities of being harmed at times of hazardous event (due to their vulnerabilities).

Susceptibility relates to system characteristics, including the social context of hazardous event damage formation. For floods, for instance, the physical vulnerabilities (infants, elderly, disabled), especially the awareness and preparedness of affected people regarding the risk they live with (before the flood), the institutions that are involved in mitigating and reducing the effects of the hazards and the existence of possible measures, like evacuation routes to be used during the floods.

Resilience: considered as the capacity of a system to endure any perturbation, like floods, droughts or other hazardous phenomena, maintaining significant levels of efficiency in its social, economic, environmental and physical components.

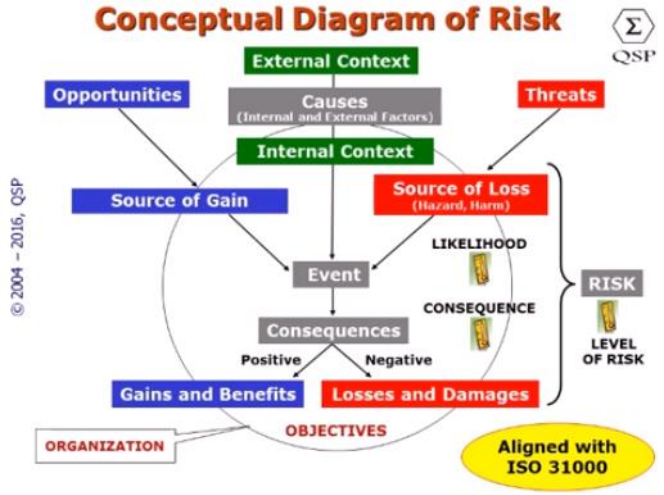
Resilience to a hazardous event damages can be considered only in places with past events, since the main focus is on the experiences encountered during and after the events.

Impact or consequence: considered as the extent of harm, which can be expected under certain conditions of exposure, susceptibilities and resilience.

Whenever possible, the risk definitions from ISO Guide 73:2009 were used, aiming to achieve a BINGO project risk common language. Complementary terms were defined among partners when considered necessary. This information is included in the BINGO GLOSSARY presented in Annex I of Deliverable 4.1. In Annex I of this document a selection of the terms relevant to risk identification are presented, to be handy.

Related risk definitions

The conceptual diagram of risk aligned with ISO 31000:2009 (Source: QSP, 2004) helps to understand how all components contribute to all phase of the of risk assessment process (Figure 3.4). Next sub-chapter details the steps involved in risk identification.



Some terms used in the Conceptual Diagram of Risk:

⇒ **Risk: effect of uncertainty on objectives**

| Note: An **effect is a deviation from the expected – positive and/or negative** (ISO 31000:2009)

⇒ **Objective: result to be achieved (ISO/IEC Directives, Annex SL, 2012)**

⇒ **Opportunity: source of potential benefit to individuals, a system or organization, the environment or the community**

| Note: Opportunity is a source of risk leading to consequences (IEC/ISO CD1 31010:2016)

⇒ **Threat: source of potential non conformity, unwanted incident, or other undesirable situation, which can result in loss, damage, harm to individuals, a system or an organization, the environment or the community**

| Note 1: The term threat includes but has broader meaning than words such as peril, hazard, jeopardy or danger.

| Note 2: ***Threat is a source of risk*** leading to potential ***negative*** consequences (IEC/ISO CD1 31010:2016)

⇒ **Event:** occurrence or change of a particular set of circumstances (ISO 31000:2009)

⇒ **Consequence:** outcome of an event affecting objectives (ISO 31000:2009)

⇒ **Likelihood:** chance of something happening (ISO 31000:2009)

⇒ **Level of risk:** magnitude of a risk, expressed in terms of the combination of consequences and their likelihood (ISO 31000:2009)

Figure 3.4 – Conceptual diagram of risk (Source: QSP, 2004)

3.2 RISK IDENTIFICATION process overview

Risk identification (ISO 73:2009) is a process that involves **finding, recognizing, and describing the risks** that could affect the achievement of an organization's **objectives**. It is the process of identifying possible sources of risk, areas of impact, events, their causes (or sets of circumstances) and their potential consequences. An event can be a change in circumstances with potential to affect the achievement of objectives. The aim of risk identification is to generate a comprehensive list of risks based on those events that might create, enhance, prevent, degrade, accelerate or delay the achievement of objectives.

A **step zero** of risk identification is the systematization of knowledge about past events, the hazard profile, which is a written description of the set of risks under analysis. This process describes the causes and characteristics of each hazard; how it has affected in the past; and, what elements were impacted: geographical area with impacted population, infrastructure, and environment that have historically been vulnerable to each specific hazard. Profiling hazard events includes the documentation of the history, causes and characteristics of the hazard in the impacted geographical areas.

Risk identification is usually a two steps process. It involves:

Step 1: Identify relevant hazards, risk sources and risk factors:

- **Risk sources (threats; opportunities)**: Sources refer to element which alone or in combination has the intrinsic potential to give rise to risk. It is where the hazardous event is potentially originated. A risk source can be tangible or intangible.
- Relevant **hazards** identification (causes or sets of circumstances of the events). Examples of water related potentially hazardous natural phenomena are:
    - Atmospheric or meteorological: tropical storms; atmospheric pressure changes; etc.
    - Hydro-meteorological: river flooding; storm surges; drought; salinization; erosion and sedimentation, etc.
- **Risk factor** is something that can have an effect on the risk level, meaning that can affect consequences or likelihood of the event. It is related with exposure and system vulnerabilities. Examples: infrastructures conditions; human physical vulnerabilities; social and economic vulnerabilities, preparedness, etc. (Figure 3.3).

Step 2: explore scenarios and potential events

When a hazardous threat actually happens and harms humans, it is an event. In this step one must explore scenarios and potential **events** (occurrence or change of a particular set of circumstances), their causes and consequences (Figure 3.5):

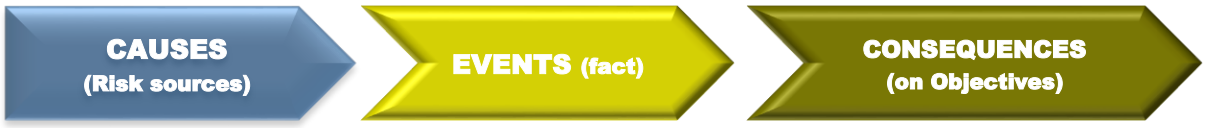


Figure 3.5 – Step 2 of risk identification: events design

- **Causes** are opportunities, threats and sometimes the hazards. Causes are the sources of risk (ISO, 2009b). They can be internal or external to the system. A cause is the potential triggers that may result in the risk event occurring. A single risk event may have a specific cause or multiple possible causes. A single cause may be applicable to multiple risks. Each cause corresponds to a risk source identified in step 1 or a combination of risk sources;
- An **Event** (occurrence or change of a particular set of circumstances) can be one or more occurrences, and can have several causes (ISO, 2009a). Exploring events is a mean to find possible causes of risk and adverse consequences. Consequences were not yet considered in the first step (hazard and sources and factors of risk identification).
- **Consequence (or impact)** is the outcome of an event affecting objectives (ISO, 2009a).

Notice that ***step 1*** focus on a general, but very useful, identification approach, the identification of *risk sources* (sources of hazard, associated with the environmental hazardous phenomena and sources of exposure, associated with human elements exposed) and on *risk factors* (factors that can affect final outcome of consequences). On the other hand, ***step 2*** designs possible events (facts happening), from their causes (set of risk sources), impact on socioeconomic activities, till their final consequences on the risk management objectives of an entity. Step 2 is the basis for risk analysis.

The conceptual diagram of risk presented in Figure 3.4 may help to understand these concepts. If that is the case see Annex II, were Table II.1 - 1a refers to hazard sources identification, while Table II.1 – 1b refers to hazard identification (the source may not cause harm by itself but its effects may have potential to cause harm - the hazard). Table II.1 - 2a refers to step 2 of risk identification, the setting of scenarios events, their causes and consequences. In Table II.1 – 2b the potential losses and damages resulting from the impact of the events are identified.

Table II.2 shows that to proceed from step 2 of risk identification to risk analysis only requires assessing (quantitatively or qualitatively) the likelihood of the event and of the vulnerabilities, in order to assess the risk.

In point 3.3 the concepts involved in risk identification are explained in more detail, indicating, at the same time, how they can be easily adapted to BINGO, along with some examples. The relevance of step 1 and step 2 for each research site according to their characteristics and objectives is also be addressed, allowing partners to decide on the extent of risk identification that is necessary to be developed for their respective research sites.

3.3 Tips to perform risk identification in BINGO

3.3.1 Decision on risk identification extent in BINGO and on methodological approach

As stated in chapter 3.2 the outcomes of the different risk identification steps have different purposes and different possible follow ups.

Step zero, based on the hazard profile (knowledge about past events) has as main added value to BINGO the systematization of information about the causes and characteristics of each hazard and their consequences in past events. It provides no new information. Relevant past risk events were identified in Task 3.1 and in deliverable D3.1 (Beek T, *et. al.* 2017).

Due to BINGO chronogram, hazard profile can be quite helpful to support Task 5.3 development, till final climate change scenarios predictions from WP2 and respective hydrological pathways from WP3 are achieved. Each research site team should decide if hazard profile presented is enough to perform the following tasks or if some further detailing should be developed.

Step 1 focusing, for each hazard, on the *identification of risk factors* (factors that can affect the final extent of consequences, either by affecting the probability or magnitude of the hazard, or by affecting the vulnerabilities of the system), identifies the aspects upon which it is possible to perform risk treatment (climate change adaptation in BINGO).

It is a general, but very useful approach, allowing jumping directly to risk treatment, if necessary, in spite of existing relevant limitations, summarised in Table 3.1. Recourse to WP2 and WP3 may or may not be necessary in this step.

Step 2 designs possible events (facts happening), from their causes (set of risk sources), impact on socioeconomic activities, till their final consequences on the risk management objectives. The events designed in this step will be the events subjected to risk analysis (assessment of the probability of the event occurrence and magnitude of their consequences).

In WP2 different meteorological events can be selected. WP3 predicts their possible pathways in the water cycle, identifying the hazard(s) generated. WP3 allows designing plausible events.

Risk identification needs to be adapted to each BINGO research site according to its goals within the project and to the risk management process established in Task 4.1. Risk framework implementation is a process of continuous adaptation within the project. As new information or deeper knowledge is being obtained, re-evaluation of some previous decisions may be justified.

This is the moment to decide upon risk identification extent for each case study of each research site, because it has influence: i) in the approach to pursue for risk treatment; ii) on the steps and techniques to perform risk identification and ii) on risk assessment achievement.

Highlights on links between risk identification in BINGO (WP4.2) and risk treatment (WP5) are presented in Table 3.1 to help on decision.

Please bear also in mind that in some case studies, prioritization of risks or of risk factors can be a very delicate and sensitive process, with strong social and political links, that can lie beyond BINGO scope.

Table 3.1 – Links in BINGO between risk identification (WP 4.2) and risk treatment (WP5)

WP4 - Task 4.2 ***Risk Identification***	**WP2 and WP3** ***(Risk sources and Hazard Results)***	**WP4 - Task 4.3** ***Risk Analysis Risk Evaluation***	**WP5** ***Risk Treatment (CC Adaptation)***
Step 0 ***Hazard profile***	Not necessary	Not possible	**➔ POSSIBLE with limitations** No further knowledge then before BINGO about existing risks (hazard and impact on human activities). Quite useful to support Task 5.3 before obtaining WP2 & WP3 final simulations
Step 1 ***Identification of relevant hazards, risk sources and risk factors***	Necessary only to a certain extent, as means to identify the hazard sources pathway and, in some cases, the elements at risk	Not possible	**➔ POSSIBLE with limitations** Identification of the risk factors is equivalent to identification of the aspects upon which it is possible to perform risk treatment, for each hazard. Associated level of risk is not known nor is a prioritization of factors possible.
Step 2 ***Explore scenarios and potential events***	Indispensable for event probability assessment, and, in some cases, for identification of elements at risk	Possible Can be a very delicate or sensitive procedure, with strong social and political impact	**➔ POSSIBLE in all extent** Allows full risk treatment and setting of a strategy supported by a risk assessment frame work, as risks and risk factors can be prioritized (depending on set of events designed).

The selection of a **technique or methodological approach** to perform effective risk identification must consider:

- The type of risk and the nature of the socioeconomic activity addressed;
- If risk analysis and risk evaluation are going to be performed. If that is the case, methodologies need to be compatible in order to assure that risk assessment can be achieved.

Qualitative, semi-quantitative and quantitative methods, as well as or a combination of these, can be used for risk analysis and risk evaluation, depending on the circumstances, as referred in ISO 31010:2009 (IEC/FDIS, 2009). Examples of common risk identification methods are the following (others do exist, as seen in Annex III):

- Objectives-based risk identification - Any event that may endanger achieving an objective partly or completely is identified as risk;
- Primary hazard analysis - risk identification is a breakdown of possible risk sources;
- Check-lists – Each risk in the list can be checked for application to a particular situation related with the risk management objectives. If checklists of possible risk events are developed,

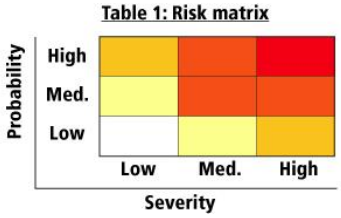
organizing them by the source of the problem may a good suggestion. This greatly facilitates allocation of responsibility (either before or after the event);

- Risk charting – This method combines lists of assets at risk, of threats to those assets and of modifying factors which may increase or decrease the risk and consequences it is wished to avoid. Creating a matrix under these headings enables a variety of approaches. One can begin with assets and consider the threats they are exposed to and the consequences of each. Alternatively, one can start with the threats and examine which assets they would affect, or one can begin with the consequences and determine which combination of threats and assets would be involved to bring them about;
- Consequence/ probability matrix – They are widely used. They combine the *frequency or magnitude* of the hazardous events with the *severity of their consequences*, in a quantitative or qualitative way (Figure 3.6). **They can aggregate different types of risks or address them in an isolate way**. They can be used for several purposes:
    - Determine how significant each risk is;
    - Prioritize or rank risks relative to one another;
    - Highlight areas for further more detailed risk assessment (e.g. fully quantitative rather than qualitative for higher level risks);
    - Support decision related to acceptability of a risk.

Main disadvantages of consequence/ probability matrix are:

- The method doesn't provide quantitative values that can be used in cost-benefit analysis of risk reduction measures;
- The assessment of impacts and frequencies is often difficult, and one area might have different combinations of impacts and frequencies, what might be difficult of representing in the matrix.

a)



b)

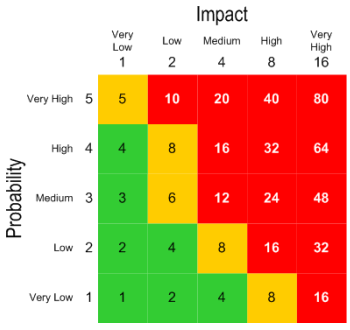


Figure 3.6 – Examples of risk matrixes: a) qualitative; b) semi-quantitative

3.3.2 Step 1: Identify relevant hazards, risk sources and risk factors

Step 1 is about identifying relevant hazards, risk sources and risk factors. Figure 3.7 illustrates the relation between risk sources and factors leading to a hazard and a risk, if exposure occurs.

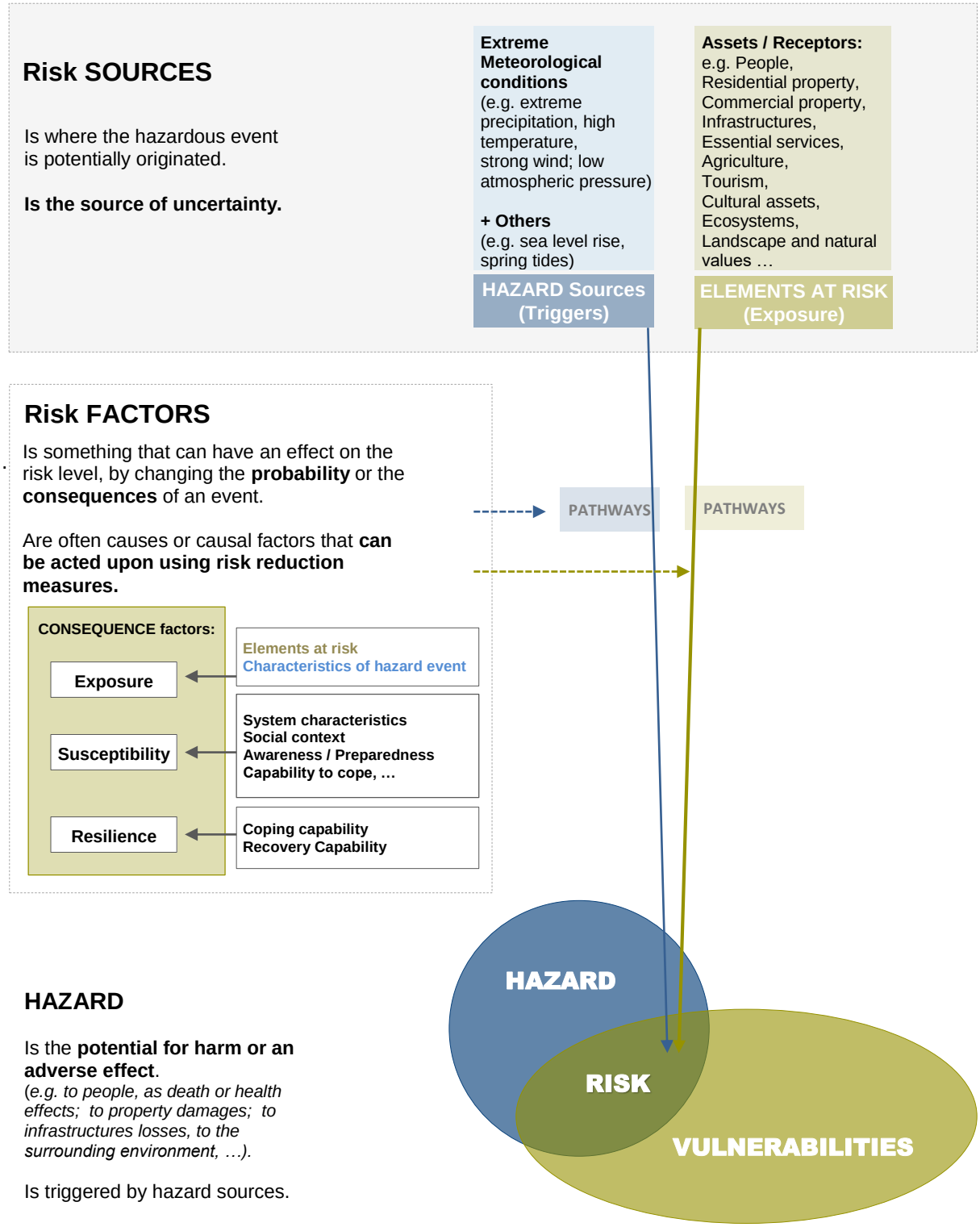


Figure 3.7 – Step 1: Identification of relevant hazards, risk sources and risk factors

As referred in 3.3.1 the methodologies to perform risk identification can vary. To accomplish step 1 it is suggested to simply start with a list, to be filled in for each case study, of each research site. The template can have different sequential items; for example, can be organized by risk sources and risk factors or by hazard and consequences, as illustrated in Table 3.2 and Table 3.3.

Table 3.2 – Example 1 of a template to perform step 1 of risk identification

	STEP 1				
Risk Management Objectives	**HAZARD**	**Risk SOURCES**		**Risk FACTORS**	
		HAZARD Source(s)	**ELEMENTS Exposed**	**Affecting Hazard likelihood**	**Affecting Consequences (on elements exposed)**

Table 3.3 – Example 2 of a template to perform step 1 of risk identification

	STEP 1				
Risk Management Objectives	**HAZARD**	**HAZARD**		**CONSEQUENCES**	
		Hazard SOURCE(S)	**Risk FACTORS Affecting likelihood**	**ELEMENTS Exposed**	**Risk FACTORS Affecting elements exposed**

Some concepts explanations and tips to identify step 1 are provided now.

Risk sources

Risk sources (threats; opportunities) are where the hazardous event potentially begins or is originated. Sources refer to element which alone or in combination has the intrinsic potential to give rise to risk. A risk source can be tangible (e.g. extreme precipitation episode) or intangible (e.g. legislation alteration, political changes). They are the sources of uncertainty.

Risk addresses the effect of uncertainty on the achievement of the objectives of an organization (risk owner), being *effect* a deviation from the expected, either positive and/or negative. Therefore, risk sources are threats and opportunities, or sources of losses or gains. BINGO is more focused on negative effects, hence, from now on, risk identification tips will only address negative impacts, corresponding to the right side of the conceptual diagram (Figure 3.4). However, in some cases, positive impacts may be considered.

The interpretation of the definition of risk source can vary. Some consider that risk sources can be external or internal to the system that is the target of risk management or a conjugation of both. Other considers that threats are (external) risk sources in the same way as weaknesses are (internal) risk sources (the same applies for opportunities and strengths), meaning that internal risk sources are more associated with risk factors. Some agree with this latter opinion stating that external risk sources are beyond the control of the organization (a real source of uncertainty), while internal risk sources are under the control of the organization. It is a mere question of terminology. What really matters is to recognise that **risk sources can include the threats** (sometimes also the hazards) **and the**

elements exposed. Also, that identification should include risks whether or not their source is under the control of the organization, even though the risk source or cause may not be evident (ISO, 2009b).

Table 3.4 provides some tips for risk sources identification in BINGO research sites.

Table 3.4 – Tips for risk sources identification in BINGO research sites

RISK SOURCES	**In BINGO**
HAZARD sources	The meteorological phenomena can be considered as the trigger, the main hazard source or threat agent. It is the main source of uncertainty. In BINGO, the extreme meteorological conditions considered are: intensive or reduced precipitation episodes; temperature increase; strong winds and low atmospheric pressure conditions. (In fact, we could recede and consider the source of the meteorological phenomena - frontal systems, blockage of Azores high, etc.- but that is not the issue in WP4). Extreme meteorological episodes are addressed in BINGO WP2. The meteorological phenomena can be the single hazard source or can be combined with other sources, as for example, oceanographic sources (sea level rise or spring tides) in coastal areas. Other possible combined hazard source is domestic sewerage, as source of water contamination (CSO addressed in SP and NO). This is an example where is necessary to decide if it should be considered as a hazard source or not (alternative being considered as a risk factor). It is a source of contamination, but it is not a source of uncertainty. It is internal rather than external to the system; therefore, the inherent risk can be reduced by separating sewerage network from pluvial network (under control of some entity). Teams need to decide what they consider being more adequate, and keep consistent with the decision along the following BINGO tasks. Note: Attending to the setup of the BINGO case studies, the meteorological phenomena causes no harm (to humans) by themselves. It could cause harm if any of the case studies addressed rain-fed agriculture, or livestock, for example, directly dependent on precipitation, but that is not the case.
Elements EXPOSED	Process of identifying or inventorying the elements (assets or receptors) that can be harmed if exposed to the hazard. They differ for each research site according to the hazard addressed (drought or inundation) but also to case set up, meaning the adaptation goals within the project and the objectives set for the risk management process formulated in Task 4.1. For inundations they cover assets like people, infrastructures, residential or commercial property, essential services (public water supply, transportation), tourism, agricultural lands, etc. For droughts in cases like NL and DE they include essential services (public water supply), tourism, cultural assets, ecosystems, landscape and natural values, image and reputation of services providers, etc. In cases like PT and CY the point of view is from agricultural and public water supply systems.

Hazard

Hazard is the potential for harm or an adverse effect (for example, to people as health effects; to organizations as property or equipment losses; or to the environment). In BINGO, the harm comes from the hydrological manifestations of the meteorological phenomena, rather than from the meteorological phenomena itself. These hydrological manifestations refer to river flows, to storage capacities (superficial or groundwater) and to storm surges, giving rise to inundations (riverine, urban, estuarine) or to droughts.

The main sources of hazard (extreme meteorological conditions) are addressed in WP2. Their hydrological manifestations in the natural water cycle (river urban areas and in the estuaries) are addressed in WP3, as already referred in chapter 2 and illustrated in (Figure 2.1).

Hydrological hazard is part of the hazard pathway. Which level of the hazard pathway should be considered as the real hazard, with potential to cause the harm for humans, depends on the risk management objectives. As an example, it is referred that in flooding cases addressed in BINGO, the potential for harm do not rely on the river flow itself but in the overland flow, being the hazard harmful characteristics the water height, runoff velocity, water density (destruction capacity), water contamination, etc. The pathway from the source till the potential for harm needs to be understood. WP3 may identify the pathways between the meteorological sources of hazard and their hydrologic manifestation, but in some cases do not identify the potential for harm itself (water height in flooded areas, runoff velocity, etc.).

For some BINGO case studies it is also important to bear in mind that hazard can be natural but also man induced. This is the case, for example, of the supply systems addressed in BINGO, due to the supply demand and the water resources induced imbalance (either for public or agricultural supply or other purposes) (PT, CY, NL, DE). Risk in supply systems is directly related to water shortage, which differs from hydrological drought because it is related to a water deficit to satisfy demands. The shortage results from an unbalance between the water resources available for supply and the demand. It is originated by a meteorological phenomenon, but is also conditioned by other time-varying factors, such as demand development, supply infrastructures and management strategies.

According to different component of the natural hydrologic cycle or human activities affected by a drought event, it is possible to distinguish among: meteorological, agricultural, hydrological drought or operational drought (supply systems drought) (Iglesias A. *et al*., 2007):

- *Meteorological drought*: A meteorological drought indicates a condition of reduction of precipitation with respect to normal values, consequent to precipitation variability probably. As a direct consequence of meteorological drought, a soil moisture deficit occurs (*agricultural drought*), affecting especially agriculture and livestock systems in rain-fed conditions;
- *Hydrological drought*: subsequently, when the previous deficit affects surface water and groundwater bodies, a *hydrological drought* occurs*,* with a surface and/or groundwater flow decreasing with respect to the normal values;
- *Water resources shortage (operational drought):* finally, drought can have effects on water supply systems leading to *water shortages.* The latter is sometimes defined as *operational drought,* and in relation with the environmental, economic and social system features it can have economic and intangible impacts. Both the water availability reduction and its impacts depend, besides the importance of the drought event, on the efficiency of the mitigation measures adopted in water supply and social-economic systems.

In some BINGO case studies, the hydro-meteorological hazard may be associated with other sources of hazard, as for example, oceanographic sources (sea level rise, spring tides); domestic sewerage, resulting in combined sewerage overflow (CSO) or water demand for water resources droughts. The

complexity of the pathways linking the meteorological conditions to the existing hazards differs for each BINGO research site.

Table 3.5 provides some examples of hazards addressed in BINGO and their risk sources.

Table 3.5 – Examples of hazards and risk sources addressed in BINGO

HAZARD		RISK SOURCES		
Hydro-meteorological event	**Hazard (Potential for harm)**	**Hazard sources**	**Pathways ***	**Elements at risk (Assets / Receptors)**
River induced Inundation	• **Water height** • **Runoff velocity**	• Rainfall • River flow	• Overland flow / Direct inundation of low-lying river margins • Overtopping of dykes, barriers or defences • Breaching of dykes, barriers or defences • Via river access points and boat ramps; …	• People • Residential and commercial property • Infrastructures • Essential services • Cultural assets • Ecosystems • Landscape and natural values
CSO Inundation	• **Water height** • **Runoff velocity** • **Microbiological contamination**	• Rainfall • Network flow • Domestic Sewerage	• CSO Overland flow • Marine water contamination	• People • Residential and commercial property • Infrastructures • Essential services • Tourism
Storm surge Inundation	• **Water height** • **Runoff velocity** • **Salinity of water**	• Wind • Atmospheric pressure	• Overtopping of dykes, barriers or defences • Breaching of dykes, barriers or defences;	• Agricultural land • Livestock • Equipment
Drought	***Hydrological drought:*** • **Low river flow** • **Low groundwater recharge**	• Lack of rainfall • Evaporation	• Low flows, • Low inflow to reservoirs, • Low reservoir storage, • Low groundwater recharge, • Water quality degradation, • Reduced dilution capacity, • Contamination; …	• Ecosystems • Landscape and natural values; …
	Water resources shortage (operational drought): • **Water shortage for human needs**	• Lack of rainfall, • Evaporation increase • **Increase in water demand**	• Low flows, • Low inflow to reservoirs, • Low reservoir storage, • Low groundwater recharge, • Water quality degradation, • Reduced dilution capacity, • Contamination, • **Water resources shortage for water supply, …**	• Essential services (public or irrigation water supply) • People • Ecosystems • Cultural assets • Landscape and natural values; • Tourism …

* *Provided for example purposes*

This is the embryo of a check-list. As previously referred, each risk in the list can be checked for application to a particular situation related with the risk management objectives. If checklists of possible risk events are developed, organizing them by the source of the problem may a good suggestion. This greatly facilitates allocation of responsibility (either before or after the event).

Risk factors

The hazard only becomes a risk if it can cause potential damage, harm or adverse effects to individuals, goods or to organizations (the receptors, or assets). Without human presence the hazard give rise to no risk. The severity of a disaster depends on both the physical nature of the extreme event and the social nature of the human populations and communities affected by the event.

Risk sources are associated with the hazard origin while ***risk factors*** are related with the **susceptibilities of the system**, or elements exposed to the hazard**.** They are both contributing to the risk. Vulnerability is the socio-economic dimension of disasters.

Risk factor is something that can have an effect on the risk level, by changing the **probability or the consequences** of an event. **Risk factors** are often causes or causal factors that **can be acted upon using risk reduction measures**.

Vulnerability can be a challenging concept that tends to mean different things to different people. Due to different interpretations, risk identification is often described as being as being about to identify a variety of terms including ‘predisposition’, ‘fragility’, ‘weakness’, ‘deficiency’ or ‘lack of capacity’.

In vulnerability definition of ISO 31000:2009 (intrinsic properties of something resulting in susceptibility to a risk source that can lead to an event with a consequence), **exposure of an element is separated from vulnerability of the element** (Figure 3.3), since it is possible to be exposed and, at the same time, not susceptible to the hazard. Vulnerability also refers to the characteristics of an individual, a group or an organization in terms of its capacity to anticipate, cope with, resist and recover (resilience) from the impact of a hazardous event.

Risk factors typically cover three main categories of elements exposed, namely: **human** factors; **environmenta**l factors; and **physical** factors. Vulnerability of human elements result of the range of economic, social, cultural, institutional, political and psychological factors that shape people’s lives and the environment that they live in (Twigg, 2004).

Some examples of risk factors include (not exhaustively):

- **Human** factors (a core point here is that *different people, even within the same region, have different vulnerability and therefore susceptibility to natural hazards*):
    - *Social factors*: wealth/poverty and inequality, education, disability and age, gender, psychological factors, amongst other factors);
    - *Economic factors*: vulnerable rural livelihoods, dependence on single industries, uninsured sector, globalisation of business and supply chains, etc.;
    - *Governance*: presence/ absence of policies to reduce vulnerability and improve preparedness;
    - Technology: available technologies and capabilities (e.g. knowledge or information) to forecast extreme events, withstand the impacts of the events, and recover afterwards;
- **Environmental** factors:

- Example for *natural resources*: overconsumption of natural resources; poor environmental management; decline of risk regulating ecosystem services; climate change; etc.
- Example for *a business or service* (being environmental risk factors those factors that influence the frequency and/or business impact of risk scenarios):
  - *Internal environmental factors* are, to a large extent, under the control of the enterprise, although they may not always be easy to change;
  - *External environmental factors* are, to a large extent, outside the control of the enterprise.

- **Physical** factors: equipment/infrastructures conditions, poor design and construction of buildings, unregulated land use planning, etc.;

Risk factors are assigned to the elements exposed (assets or receptors) or to components of the asset. Table 3.6 provides some examples of relevant risk factors related with hazards addressed in BINGO, although not directly assigned to the elements exposed nor research site oriented.

The external and internal contexts developed in Task 4.1 (deliverable D4.1) should help to identify some of the existing vulnerabilities associated with the exposed elements.

It is reminded that **risk factors identify the vulnerabilities that can be acted upon using risk reduction measures.** Distinction among categories of risk factors is relevant to identify if it is really possible to act upon them (it is not often possible to act on some environmental factors) and to identify the responsible(s) for action. Risk factors identification is an important step to perform Task 5.3 (WP5).

Step 1 of risk identification ends after the identification of the elements (assets or receptors) exposed to the hazard and their vulnerabilities (Figure 3.8). The assessment of the inherent susceptibilities to the hazard and the potential extent of consequences is part of risk analysis (Task 4.3).

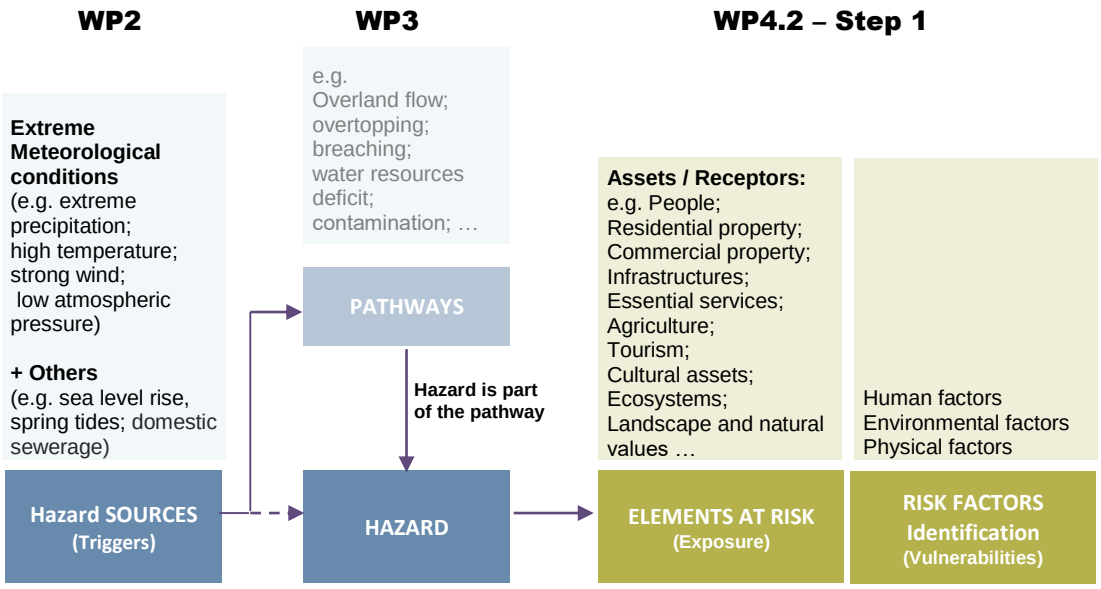


Figure 3.8 – Step 1: Examples of relevant hazards, risk sources and risk factors for BINGO research sites

Table 3.6 – Examples (not exhaustive) of risk factors related with hazards addressed in BINGO

HAZARD	RISK FACTORS	
Hydro-meteorological hazard	**Category**	**Risk factors** (examples)
Inundations	**Human** factors	• Exposure time • Social factors: human reliability; behavioural factors; people physical vulnerability, capacity to cope, etc.) • Economic factors: uninsured sector; dimension of business; etc.) • Governance: policies in place to reduce risk; preparedness, crises management structure; • Technological: forecast capability; warning systems; miscommunication; equipment for recovery, etc.)
	Environmental factors	• Temperature • Wind intensity • Contaminant concentration • Receiving water level • Etc.
	Physical factors	• Infrastructures conditions (e.g. protection dykes) • Existing barriers • Component location • Lack of detection systems • Etc.
Water resources Droughts	**Human** factors	• Exposure time (duration) • Social factors: *Affecting water demand*: community characteristic (rural, industrialized); demand development, people awareness; *Affecting capacity to cope and adapt*: wealth/poverty; people academic education and age; technical staffs' academic education;, etc. • Economic factors: uninsured sector; dimension of business; etc.) • Governance: WRM policies in place; sectorial preparedness, management strategies; • Technological: technical preparedness to cope and adapt
	Environmental factors	• Temperature • Wind intensity • Contaminant concentration • Nutrient concentration • Receiving water level • Soil type • Suspended solids in source or supply water
	Physical factors	Water supply Infrastructures: • Water storage, transport and distribution Infrastructures conditions • Equipment malfunction (measurement and control) • Equipment design (irrigation optimization or for public water supply) • Irrigation operational schedule Public water supply treatment: • Equipment design • Etc.

3.3.3 Step 2: Events

The aim of this step is to generate a comprehensive list of risks based on events that might create, enhance, prevent, degrade, accelerate or delay the achievement of objectives set in Task 4.1. Besides identifying what might happen, it is necessary to consider possible causes and scenarios that show what consequences can occur (why and how). All significant causes and consequences should be considered (ISO, 2009b).

This step is especially relevant to support risk analysis, as it can be performed based on *events* (or *scenarios*) set up in step 2 of risk identification. It enables to assess the extent of consequences and the likelihood of the events and, hence, the level of risk. Step 1 was an identification process, where impacts on elements exposed to the hazard were not explicitly addressed. No concrete situations were set in place. Step 2 moves forward, setting scenes that, by allowing later assessment (risk analysis and evaluation), enable prioritization of risks or assets at risk.

This step intends to identify why and how can it happen. This is accomplished by:

- Setting events (facts), and
- Identifying their causes (combination of hazard sources) and potential consequences (impacts on elements exposed and then consequences over the objectives of the risk management process).

Figure 3.9 summarises the steps involved in step 2 of risk identification based on events. An event can have a combination of sources and have multiple consequences.

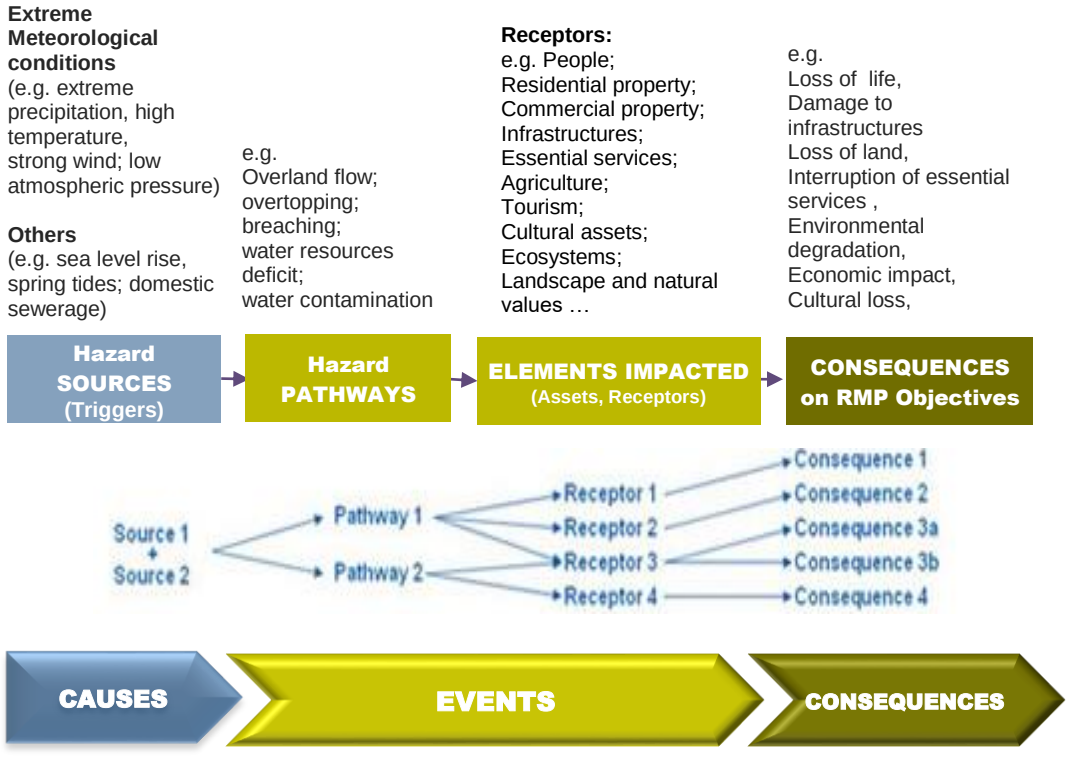


Figure 3.9 – Step 2 of risk identification: setting of events

At this point, teams should have already decided if they intend to pursue this second step or not, as discussed in chapter 3.1.

If performing this step was decided, then teams should consider the objectives set for each risk owner and consider the possible causes and scenarios of each risk identified threatening those objectives (failure of continuity of service, financial, reputational, etc.). Any event that may endanger achieving an objective partly or completely is identified as risk (objectives-based risk identification).

Once again, several methodologies can be used. A simple list based on any of the following templates can be used.

Table 3.7 – Example 1 of a template to perform step 2 of risk identification

	STEP 2			
Risk Management Objectives	**EVENT description**		**CAUSES** (set of Hazard Sources)	**CONSEQUENCES (on RMP objectives)**
	HAZARD pathways	**ELEMENTS Impacted**		

Table 3.8 – Example 2 of a template to perform step 2 of risk identification

	STEP 2			
Risk Management Objectives	**CAUSES** (set of Hazard Sources)	**EVENT description**		**CONSEQUENCES (on RMP objectives)**
		HAZARD pathways	**ELEMENTS Impacted**	

Causes

Identifying causes is the process of identifying the potential triggers that may result in the risk event occurring. A single risk event designed may have one specific cause or multiple possible causes. A single cause may be applicable to multiple risks. The causes can be external or internal to the system.

The hazard sources considered so far in BINGO are meteorological conditions, oceanographic conditions and domestic sewerage. If a risk source considered relevant was not considered in step 1, it should be included now.

Cause(s) is one of the risk sources identified in step 1 or a specific combination of several of those risk sources. Examples: i) extreme meteorological conditions of strong wind and low pressure (source 1) combined with a spring tide (source 2); ii) extreme intensive precipitation combined with domestic sewerage occurring during summer time; iii) extreme low precipitation during two consecutive years combined with increase in water demand.

Extreme meteorological conditions are forecasted in work package 2, and a probability of occurrence can be associated to each meteorological episode selected.

Events

When selecting events take into consideration the following:

- An event is only a risk if there is a degree of uncertainty associated with it;
- A natural hazard is a threat (or source) of a naturally occurring event only if it will have a negative effect on humans (usually called a natural disaster);
- An event comprehends the natural hazard pathway and the human "pathway" or elements impacted (assets, receptors or resources exposed). The hazardous event is part of the event pathway. Its effects on assets are also part of the pathway, or event description (Figure 3.9). When describing an event refer both.

The hazardous event is part of the event pathway. However, it may be easy to associate a probability of occurrence to a set of meteorological conditions triggering the event but it may not be equally easy to associate a probability to its hydrological manifestation, due to a set of circumstances. In step 2 of risk identification, assess the likelihood it is not an issue, but as this step serves as the basis for risk analysis, attention should be paid to this matter (Figure 3.10).

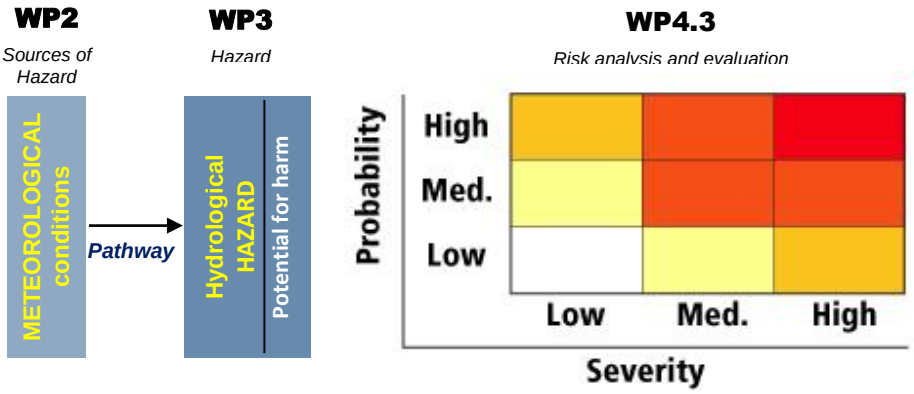


Figure 3.10 – Linking events to Task 4.3

Consequences

Some notes:

- An event can lead to a range of consequences. A consequence can be certain or uncertain and can have positive or negative effects on objectives. Consequences can be expressed qualitatively or quantitatively;
- As BINGO is focused on negative impacts, opportunities and positive effects are not extensively pursued, but can be if appropriate for the case study;
- A single risk event may have a specific consequence or multiple possible consequences. A consequence may be common across multiple risks;
- A hazard source can trigger a serious of the knock-on effects of particular consequences, including cascade and cumulative effects (pathway). Hydrological manifestation is an example of a primary effect of the meteorological precipitation phenomena. Hazardous process of all

types can have primary, secondary and tertiary effects. Risk identification should/ could include examination of the knock-on effects:

- *Primary* effects occur as a result of the process itself. For example overland flow during a flood, or water deterioration during a drought;
- *Secondary* effects occur only because a primary effect has caused them. For example, disruption of water service as a result of a flood or as a result of insufficient water resources for supply during a drought; contamination resulting from forest fires triggered by dry weather and temperature rise;
- *Tertiary effects* are long-term effects that are set off as a result of a primary event. These include things like loss of habitat caused by a flood, desertification caused by a long drought, etc.

As previously referred, in risk identification process consequences are identified but not assessed in severity. Later, in risk analysis consequences can be expressed qualitatively or quantitatively, and in terms of direct or indirect economic, social, environmental or other impacts. Therefore in step 2 is still useful to notice the following:

- A wide range of consequences should be considered even if the risk source or cause may not be evident. Consider possible causes and scenarios that show what consequences can occur. All significant causes and consequences should be considered;
- Set a sufficient number of events in order to allow risk analysis and risk evaluation (prioritizing risks, etc.) (Figure 3.11).

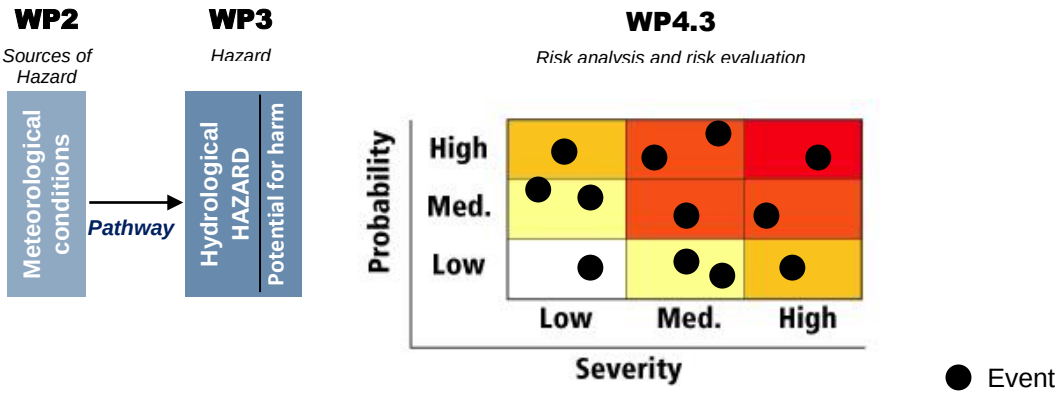


Figure 3.11 – Linking events to Task 4.3

Some synthetic and non-exhaustive examples of events, according to step 2 of risk identification, are presented in Table 3.9.

Table 3.9 – Example of a template for risk identification based on events

RISK IDENTIFICATION – Step 2				
Risk ID	**Risk category**	**Events**	**Causes**	**Consequences**
1	People safety	Strong velocity runoff and depth water level in downtown Odivelas, affecting schools, train station, shops and access to services, due to river Trancão overland flooding	Abnormal intensive precipitation	People injury Economic losses for several sectors of society…
2	Service continuity	Failure to supply water for an extended period due deficit of water resources to supply demand	Abnormal low precipitation during an extended period; Increase in water demand.	Revenue losses; Reputational damages
3	Regulatory	Failure to meet environmental compliance obligations under Water Framework Directive due to water resources degradation	Abnormal low precipitation during an extended period; High temperature	Increased costs due to fines, Damages to water related activities (tourism, etc.)
4	Regulatory	Failure to meet contractual obligations with customers due deficit of water resources to supply demand	Abnormal low precipitation during an extended period; Low reservoir and groundwater storage; Increase in water demand.	Legal processes, Reputational damages,…
5	Financial	Failure to produce hydroelectric energy due deficit of water resources to supply demand	Abnormal low precipitation during an extended period; Low reservoir storage	Revenue losses, …

This is the embryo of a check-list. As previously refereed, each risk in the list can be checked for application to a particular situation related with the risk management objectives. If checklists of possible risk events are developed, organizing them by the source of the problem may a good suggestion. This greatly facilitates allocation of responsibility (either before or after the event).

4 | Next steps

Before proceeding from risk identification to other BINGO tasks, it is useful to remind that alternative liaisons exist between risk identification steps and risk treatment, to be performed in Task 5.3 (WP5), although with different in-depth levels (Table 4.1). Step 0 and step 1 allow to procced directly to WP5, jumping Task 4.3. Teams need to decide the approach to pursue in their case studies.

Table 4.1 – Liaison between risk identification steps and risk treatment

WP4 - Task 4.2 ***Risk Identification***	**WP4 - Task 4.3** ***Risk Analysis Risk Evaluation***	**WP5** ***Risk Treatment (CC Adaptation)***
Step 0 ***Hazard profile***	Not possible	**➔ POSSIBLE with limitations** No further knowledge then before BINGO about existing risks (hazard and impact on human activities). Quite useful to support Task 5.3 before obtaining WP2 & WP3 final simulations
Step 1 ***Identification of relevant hazards, risk sources and risk factors***	Not possible	**➔ POSSIBLE with limitations** Identification of the risk factors are equivalent of identification of the aspects upon which are possible to perform risk treatment, for each hazard. Associated level of risk is not known nor is a prioritization of factors possible.
Step 2 ***Explore scenarios and potential events***	Possible Risks, risk factors and sectors impacted can be prioritized (depending on set of events designed) Can be a very delicate or sensitive procedure, with strong social and political impact	**➔ POSSIBLE in all extent** Allows full risk treatment and set up of a strategy supported by a risk assessment frame work.

After events design in step 2 risk identification, it is possible to proceed easily to risk analysis based on these events (Figure 4.1). Task 4.3 is an assessment phase, developing a systematic analysis of several contributing and leading factors (e.g. extent of the exposure, multiple exposures, and vulnerability characteristics of the population or systems being assessed) resulting in: 1) assessments of the likelihood of adverse events, and 2) assessments of consequences (i.e. their impact).

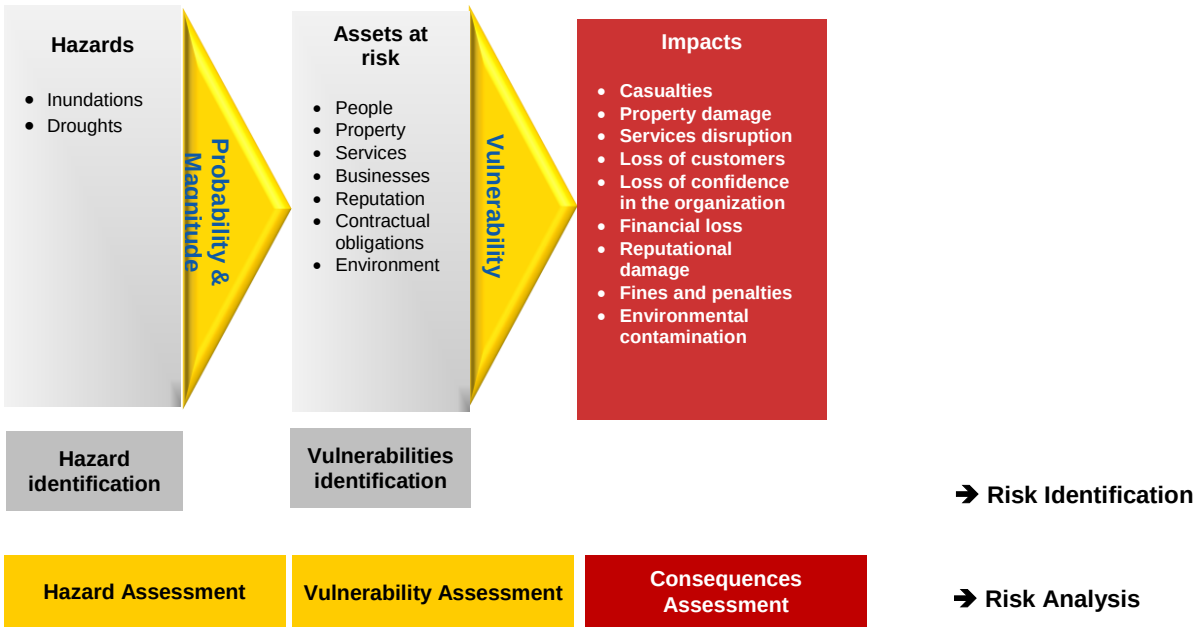


Figure 4.1 – From risk identification to risk assessment (Adapted from https://www.ready.gov/risk-assessment)

Risk analysis requires a point of view. This point of view was identified in Task 4.1 (risk owner). The evaluation of the magnitude of consequences, to assess the risk, is based on the indicators established in Task 4.1 for the risk criteria. Then, for grading the level of risk in risk evaluation (e.g. high, moderate, low) it is necessary to have established the acceptance levels of risk criteria. This task should have been accomplished in the context (Task 4.1) but it was not possible in some research sites. It needs to be established prior to Task 4.3 dead line.

This is the right moment for teams to review the context (Task 4.1) and decide if the point of view identified really corresponds to the approach desired for their case studies. It is also advisable to review the indicators selected in risk criteria to assess the extent of consequences. They can require too much information or information not available. If this is the case, it is opportune to reformulate the indicators at this stage. The objective is to achieve a satisfactory risk assessment.

Figure 4.2 – Steps of the Risk Management Process (ISO 31000:2009)

As summary, Figure 4.3 illustrates the significance of all steps involved in risk assessment aligned with risk concept, as defined in Figure 3.2.

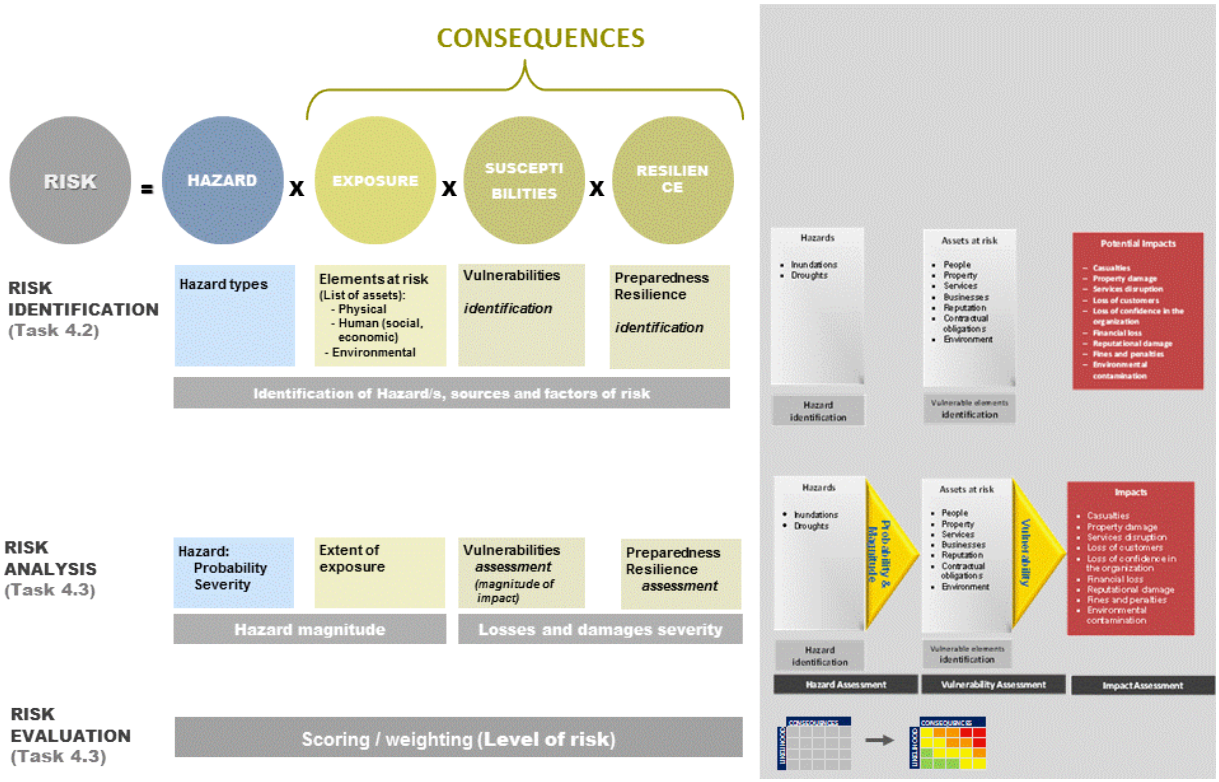


Figure 4.3 – Significance of steps involved in risk assessment aligned with risk definition

Lisbon, LNEC, November of 2017

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Annexes

ANNEX I
Relevant definitions for risk identification based on ISO Guide 73:2009

Most relevant definitions within BINGO based on ISO Guide 73:2009

Expression	Definition	Clarification and other Sources
RISK	(ISO Guide 73:2009, definition nº 1.1): Effect of uncertainty on objectives. An effect is a deviation from the expected — positive and/or negative. Objectives can have different aspects (such as financial, health and safety, and environmental goals) and can apply at different levels (such as strategic, organization-wide, project, product and process). Risk is often characterized by reference to potential events and consequences, or a combination of these. Risk is often expressed in terms of a combination of the consequences of an event (including changes in circumstances) and the associated likelihood of occurrence. Uncertainty is the state, even partial, of deficiency of information related to, understanding or knowledge of an event, its consequence, or likelihood.	Risk is expressed in terms of combination of the consequences (damage) of a hazardous event (including changes in circumstances), and the associated likelihood of occurrence (probability). The level and magnitude of the consequences will depend on the characteristics of the hazardous event as well on the vulnerability of the system. Risk is also often defined as the product of the physical hazard (and its characteristics), the elements at risk and their vulnerability (Blaikie et al., 1994; Nott, 2006).
Risk Identification	(ISO Guide 73:2009, definition nº 3.5.1): Process of finding, recognizing and describing **risks.** Risk identification involves the identification of risk **sources, events**, their causes and their potential consequences. Risk identification can involve historical data, theoretical analysis, informed and expert opinions, and stakeholder's needs.	
Risk source	(ISO Guide 73:2009, definition nº 3.5.1.2): Element which alone or in combination has the intrinsic potential to give rise to risk. A risk source can be tangible or intangible.	Risk source is where the hazardous event potentially begins.
Event	(ISO Guide 73:2009, definition nº 3.5.1.3): Occurrence or change of a particular set of circumstances. An event can be one or more occurrences, can have several causes. An event can consist of something not happening. An event can be referred to as an "accident" or "incident". An event without consequences can also be referred to as a "near miss", "incident", "near hit" or "close call".	
Hazard	(ISO Guide 73:2009, definition nº 3.5.1.4): Source of potential harm. A hazard can be a risk source.	A dangerous phenomenon (substance, human activity or condition) 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 (MRC-CCAI, 2013).
Hazardous event		An event which can cause harm, e.g. a situation that leads to the presence or release of a hazard (Beuken, 2008). The hazardous event is part of the event pathway.
Likelihood	(ISO Guide 73:2009, definition nº 3.6.1.1): Chance of something happening. NOTE 1 In risk management terminology, the word "likelihood" is used to refer to the chance of something happening, whether defined, measured or determined objectively or subjectively, qualitatively or quantitatively, and described using general terms or mathematically (such as a probability or a frequency over a given time period). NOTE 2 The English term "likelihood" does not have a direct equivalent in some languages; instead, the equivalent of the term "probability" is often used. However, in English, "probability" is often narrowly interpreted as a mathematical term. Therefore, in risk management terminology, "likelihood" is used with the intent that it should have the same broad interpretation as the term "probability" has in many languages other than English.	Chance of something happening, whether defined, measured or determined objectively or subjectively, qualitatively or quantitatively, and described using general terms or mathematically such as a **probability** or a **frequency** over a given time period.

Expression	Definition	Clarification and other Sources
Probability	(ISO Guide 73:2009, definition nº 3.6.1.4): Measure of the chance of occurrence expressed as a number between 0 and 1, where 0 is impossibility and 1 is absolute certainty. NOTE See definition 3.6.1.1, Note 2.	
Frequency	(ISO Guide 73:2009, definition nº 3.6.1.5): Number of **events** or outcomes per defined unit of time. NOTE Frequency can be applied to past events or to potential future events, where it can be used as a measure of likelihood / probability.	
Risk factor		Something that can have an effect on the risk level, by changing the probability or the consequences of an event. Risk factors are often causes or causal factors that can be acted upon using risk reduction measures. Typically three main categories are considered namely human factors, environmental factors and equipment/infrastructure factors.
Exposure	(ISO Guide 73:2009, definition nº 3.6.1.2): Extent to which a system is subject to an event.	Refers to the inventory (and values) of elements that are present in areas in which hazardous events (floods or other) may occur and can be adversely affected (potentially damaged or disrupted) by those events. These values depend on the presence of people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, cultural assets in places that could be adversely affected (IPCC, 2013).
Consequence	(ISO Guide 73:2009, definition nº 3.6.1.3): Outcome of an **event** affecting objectives. An event can lead to a range of consequences. A consequence can be certain or uncertain and can have positive or negative effects on objectives. Consequences can be expressed qualitatively or quantitatively. Initial consequences can escalate through knock-on effects.	Considered as the extent of harm, which can be expected under certain conditions of exposure, susceptibilities and resilience. The indicators for this component can be separated in two categories; the first one gives details on the general characteristics of the hazardous event and the second one covers the vulnerability of the different elements at risk.
Vulnerability	(ISO Guide 73:2009, definition nº 3.6.1.6): Intrinsic properties of something resulting in susceptibility to a risk source that can lead to an event with a consequence.	Vulnerability refers to the propensity of exposed elements (such as human beings, their livelihoods and assets) to suffer adverse effects when impacted by hazard events. Vulnerability is related to predisposition or capacities that favour, either adversely or beneficially, the adverse effects on the exposed elements. Vulnerability refers to exposure, susceptibility and resilience.
Susceptibility		Susceptibility is the degree to which the system is affected, depending on the own intrinsic characteristics of its exposed elements within the area in which hazardous events may occur. These intrinsic properties include, for instance, the physical characteristics of exposed elements (infrastructures, buildings, etc.), the economic and social context of the community, etc. For floods, for instance, important capacities are the awareness and preparedness of affected people and the existence of mitigation measures to reduce the effects of the hazards, like warning systems and emergency plans.
Resilience	(ISO Guide 73:2009, definition nº 3.8.1.7): Adaptive capacity of an organization in a complex and changing environment.	Considered as the adaptive capacity of a system to endure any perturbation, like floods, droughts or other hazardous event, maintaining significant levels of efficiency in its social, economic, environmental and physical components; Resilience to a hazardous event damages can be considered only in places with past events, since the main focus is on the experiences encountered during and after the events.

ANNEX II
Conceptual diagram of risk – steps involved in risk identification (Adapted: QSP, 2004)

Table II.1 - Conceptual diagram of risk – steps involved in risk identification (Adapted: QSP, 2004)

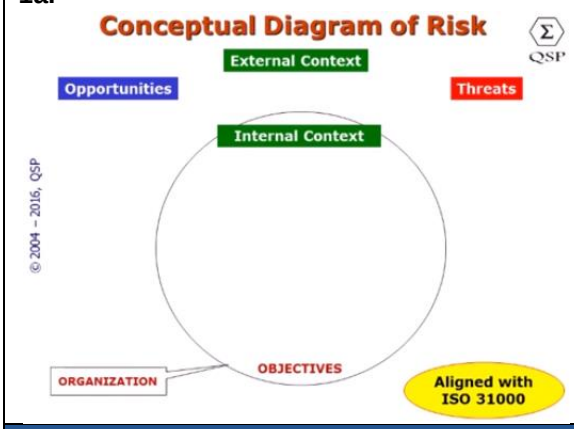
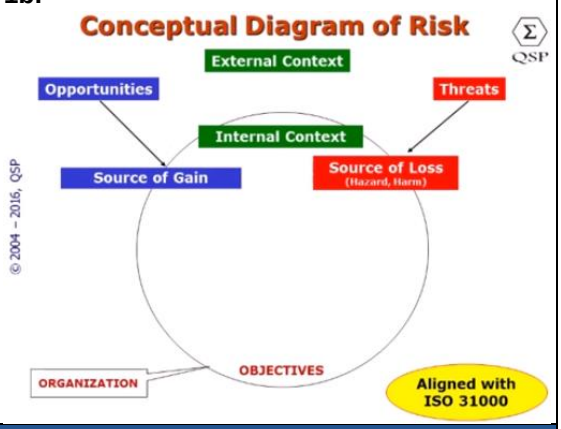
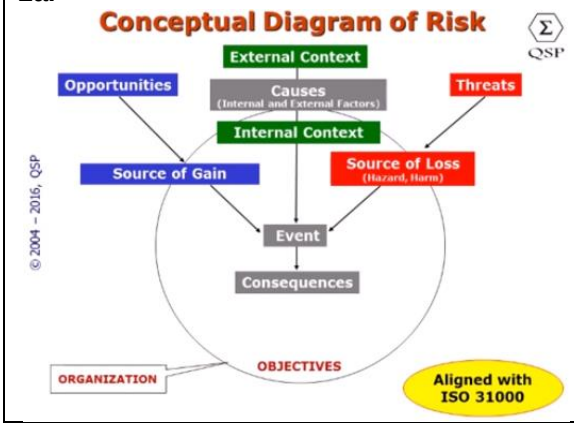
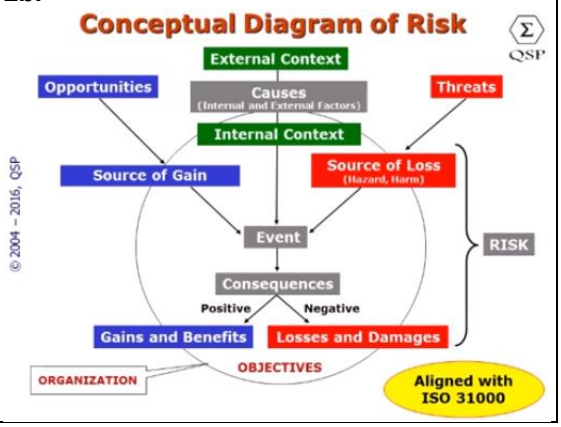
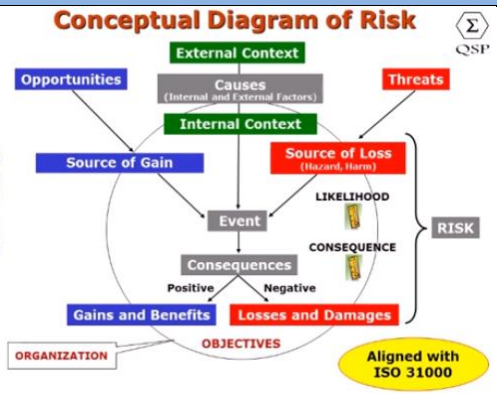
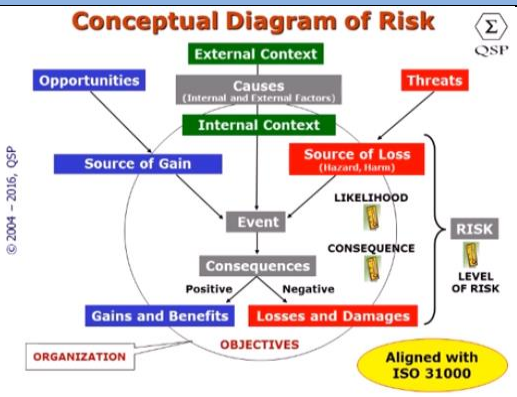
RISK IDENTIFICATION	
1. Identify hazards, risk sources and risk factors	
1a.	**1b.**
	
RISK IDENTIFICATION	
Step 2. Identify events, their causes and potential consequences	
2a.	**2b.**
	

Table II.2 - Conceptual diagram of risk – steps involved in risk analysis and risk evaluation (Adapted: QSP, 2004)

RISK ANALYSIS	RISK EVALUATION
Estimate likelihood (probability) and extent of the consequences	**Estimate the level of risk**
	

ANNEX III
Risk assessment tools and techniques

Risk assessment tools and techniques (Adapted from ISO, 2009c)

Tools and techniques	Risk Assessment process					See Annex
	Risk Identification	Risk Analysis			Risk evaluation	
		Consequence	Probability	Level of risk		
Brainstorming	**SA**	NA	NA	NA	NA	B 1
Structured or semi-structured interviews	**SA**	NA	NA	NA	NA	B 2
Delphi	**SA**	NA	NA	NA	NA	B 3
Check-lists	**SA**	NA	NA	NA	NA	B 4
Primary hazard analysis	**SA**	NA	NA	NA	NA	B 5
Hazard and operability studies (HAZOP)	**SA**	SA	A	A	A	B 6
Hazard Analysis and Critical Control Points (HACCP)	**SA**	SA	NA	NA	SA	B 7
Environmental risk assessment	**SA**	SA	SA	SA	SA	B 8
Structure « What if? » (SWIFT)	**SA**	SA	SA	SA	SA	B 9
Scenario analysis	**SA**	SA	A	A	A	B 10
Business impact analysis	**A**	SA	A	A	A	B 11
Root cause analysis	**NA**	SA	SA	SA	SA	B 12
Failure mode effect analysis	**SA**	SA	SA	SA	SA	B 13
Fault tree analysis	**A**	NA	SA	A	A	B 14
Event tree analysis	**A**	SA	A	A	NA	B 15
Cause and consequence analysis	**A**	SA	SA	A	A	B 16
Cause-and-effect analysis	**SA**	SA	NA	NA	NA	B 17
Layer protection analysis (LOPA)	**A**	SA	A	A	NA	B 18
Decision tree	**NA**	SA	SA	A	A	B 19
Human reliability analysis	**SA**	SA	SA	SA	A	B 20
Bow tie analysis	**NA**	A	SA	SA	A	B 21
Reliability centred maintenance	**SA**	SA	SA	SA	SA	B 22
Sneak circuit analysis	**A**	NA	NA	NA	NA	B 23
Markov analysis	**A**	SA	NA	NA	NA	B 24
Monte Carlo simulation	**NA**	NA	NA	NA	SA	B 25
Bayesian statistics and Bayes Nets	**NA**	SA	NA	NA	SA	B 26
FN curves	**A**	SA	SA	A	SA	B 27
Risk indices	**A**	SA	SA	A	SA	B 28
Consequence/probability matrix	**SA**	SA	SA	SA	A	B 29
Cost/benefit analysis	**A**	SA	A	A	A	B 30
Multi-criteria decision analysis (MCDA)	**A**	SA	A	SA	A	B 31

SA - Strongly applicable
NA - Not applicable
A - Applicable.