Chapter 16
Natural Hazard Risk Assessment and Management Methodologies Review: Europe

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Abstract In the last decade, Europe-wide natural hazards have accounted for large numbers of the most serious causes of mortality; this death toll accompanies several billions of euros in damages. These facts support the need to reduce natural hazard impacts on the European territory in which, by in large, are going to augment in the future primarily due to climatic change and inappropriate land use management. In this context risk assessment and management through appropriate prevention and protection measures play fundamental roles in redefining natural hazard occurrences, risk areas prone to these events and reducing future phenomena at all levels. To better integrate the contextual role of risk assessment and management a descriptive state of the art based on scientific publications reviewed from 2000 to present is broken down into two domain types: hydro-meteorological and geophysical hazard events. A comparative examination draws potential viewpoints on choice of methodology which largely depends on the considered area and addressed target. Focus is put on analysing the prevention, protection and preparedness principle in which can define conclusive technical development; based on the results, some conclusions are drawn to support further developments at the knowledge-base level.

16.1 Introduction

In the last decade natural hazards have been one of the most serious causes of unintentional death Europe-wide, triggering billions of euros in damages. It has been estimated that floods alone produced over 700 fatalities and at least half a million persons have been evacuated since 1998; more than 25 billion euros of

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economic losses and invaluable socio-economic potential future losses have affected much of Central Europe, especially countries that interlink with the large rivers of the Danube, Elbe and Rhine [10]. Climatic alteration and inappropriate land use management continue to augment this impact which further underlines the need to reduce consequential effects [13]. It is evident the need to support the reduction of natural hazard impacts on the European territory interrelates with risk assessment and management as fundamental steps in defining risk prone areas and reducing potential impacts regardless of the authority in charge or stakeholder awareness. Through appropriate prevention and protection measures natural hazard impacts can reduce the threat to economic assets, society and environment.

A state of the art review of natural hazard risk assessment and management methodologies reveals that this knowledge-base is growing at an alarming rate; the specifics of this review will focus mainly on water-related hazard risk, since it undoubtedly is the most unsafe phenomena affecting Europe. The European Union (EU) published the Floods Directive [17], which aims to establish a common approach for flood risk management, and a set of reports and guidelines, in order to provide a common framework on disaster prevention and to delineate the current European environmental state.

16.2 Natural Hazards: Brief

Natural hazards can be divided into two main domain types: (1) hydro-meteorological hazards (i.e. floods, storms, water scarcity, extreme temperature events and forest fires) and (2) geophysical hazards (i.e. landslides, avalanches, earthquakes and volcanic eruptions). This European centric briefing extends as a case study for the continent at large; main natural impacts are divided according to the affected hazard zone (Table 16.1) [13] and are the basis for a geographical definition of natural hazard occurrences and risk areas prone to the event under consideration. In light of better understanding European dimensional components, it should be stated that the methods and concepts are not necessarily European centric specific; the scientific publications reviewed from 2000 to present outline the state of the art of the discipline and configure an evolving viewpoint which technically could be labelled as a developmental progression. To better set the tone for Europe as a whole, the topic brief will consider climatic change and issues of governance.

16.2.1 Climatic Change

An interlude to climatic change relates to the number, frequency and magnitude of events. A statistical viewpoint shows background and support for the development and necessity of developing assessment and management methodologies. The

Table 16.1 Continental Europe: main affected natural hazard zones [13]

Arctic	Decreasing in Arctic sea-ice coverage and higher risk of biodiversity loss
Northern (boreal region)	Less snow, lake and river ice cover, increasing river flows northward movement of species, higher risk of damages by winter storms
North western	Increasing in winter precipitation, increasing in river flow, higher risk of coastal flooding
Mountain areas	Increasing in temperature, decreasing in glacier and permafrost mass, higher risk of rock falls, higher soil erosion risk, higher risk of species extinction
Central and eastern	Higher extreme temperature, decreasing in summer precipitation, increasing in winter floods, higher water temperature, increasing in forest fires
Coastal and regional seas	Sea-level rising, higher sea surface temperatures, northward movement of species, higher risk for fish stocks
Mediterranean	Decreasing in annual precipitation, decreasing in annual river flow, increasing in forest fires, increasing in water demand for agriculture, higher risk for desertification, more deaths by heat waves, higher risk of biodiversity loss

consequences of climatic change will directly or indirectly affect all economic and social sectors, regions and citizens and is particularly prone to affect some European locations like the Mediterranean or arctic zone. Since the 1980s river and coastal floods, droughts, water scarcity and loss of biodiversity result as major natural impacts that support the climate change phenomena; the influence of these phenomena is affecting not only the ecological context, but also economic, political, social and medical sectors [13].

Natural hazards between 1998 and 2009 caused an increasing in the number of human fatalities per year mostly due to floods, heat waves and earthquakes which occurred mostly in Central and southern Europe. Differently, the economic losses from natural hazards tended to be higher in central-northern Europe, probably reflecting differences in the accumulation of infrastructure, wealth and living standard. The economic context of climatic change has especially influenced: (1) decreasing availability in arable land due to droughts, water scarcity and floods causing massive losses in crop output; (2) forest fires causing many infrastructural damages (besides a reduction in wood production); (3) decreasing thermal power and hydropower causing augmentation in energy demand; and (4) attractiveness of Mediterranean resources have been reduced causing losses in tourism and recreation-based activities [13]. In addition to these cause and effect impacts, it can be emphasised that climatic change can affect human health by way of changes in food and water quantity and quality, livelihood, temperature and mortality via disease rate and mismanagement of infrastructure and resources [13].

In order to limit the impact of climatic change, the EU has been moving toward an adaptation strategy that consists of an "adjustment of natural or human systems to actual or expected climate change [impacts] or its effects in order to moderate harm or exploit beneficial opportunities" [13]. This reflects three different adaptation responses or solutions: grey measures (technology oriented), green measures (eco-friendly based) and soft measures (political ratification). Climate change adaptation strategy is closely related to the concept of disaster risk reduction (DRR) which aims at reducing future impacts of natural and technical hazards. Adaptation options have a different implementation pending geography and, more specifically, locality: coastal zone management is primarily based on buildings and strengthening natural flood defences; metropolitan zone management is oriented on securing the functionally of essential infrastructure for energy provision, water supply, wastewater treatment, transport and health services.

16.2.2 European Governance

In order to reduce natural hazard impacts on the European territory, the EU Floods Directive now requires Member States (MS) to assess if all water courses and coast lines are at risk from flooding, to map the flood extent and asset the humans risk in these areas and undertake adequate and coordinated measures to reduce such risk [13]. The Floods Directive is complementary to the EU Water Framework Directive [16] in which policy must suitably reflect qualitative and quantitative status of all MS water bodies by 2015. The EU developed a set of guidelines to support these regulations by implementing risk assessment and mapping processes [15] and by developing a community framework on disaster prevention [13]. These guidelines aim at reducing the national gaps on risk assessment methodologies and to further develop a national risk management procedure by the close of 2011. It should be underlined that all MS must make available to the Commission relevant information on natural hazards risk in order to develop sound, future European governance [15]. In particular, guidelines focus on the reduction of three different types of natural hazards impacts: (1) human impacts referring to the number of affected people (i.e. permanently displaced, injured and deaths), (2) economic and environmental impacts referring to total costs (i.e. healthcare, emergency services, property damage, cultural heritage, environmental restoration and other associated costs between environment and economy), and (3) political and social impacts referring to public outrage or social psychological impact (i.e. public order and safety and political implications). The objective of the Council is to minimise these impacts by trying to reduce their potential negative consequences and improving local preparedness [14].

EU guidelines for national risk assessment and mapping enlist the development of gradually coherent and consistent risk assessment methodology and terminology via each MS. It provides risk management instruments for authorities, policy-makers, and public or private stakeholders. The development of a knowledge-base for disaster prevention policy can contribute to raising public awareness for better disaster prevention measures [15]. The three basic steps of the risk assessment process, defined for each MS, is (1) risk identification, (2) risk analysis and (3) risk evaluation; these steps generalise a primary outline for developing an EU-wide standard and principal background for national policies aligning with Commission

Table 16.2 EU set of relevant initiatives for natural hazards disaster prevention [15]

	Initiative
Step 1	Ensure that DRR is a national and local priority with a strong institutional basis for implementation
Step 2	Identify, assess, and monitor disaster risks (especially enhancing the early warning systems)
Step 3	Use knowledge, innovation, and education to build a culture of safety and resilience at all levels
Step 4	Reduce the risk factors by developing appropriate risk management measures
Step 5	Strengthen disaster preparedness for effective response at all levels

intentions. The Commission presented at the end of 2010 a set of relevant initiatives for natural hazards disaster prevention (Table 16.2) [15].

These initiatives must complement MS action and adopted and implemented plans; the Community framework on disaster prevention is focused on an understanding that the link between natural hazards and climatic change, in order to develop specific disaster management programs of prevention and on supporting MS' early warning systems, is raising public awareness and educating the populace at a cultural level [14, 33].

16.3 Risk Assessment and Management Methodologies: Review

Based on scientific publications, prevalent risk assessment and management methodologies are reviewed from 2000 to present and categorised into two hazard event groups: hydro-meteorological and geophysical. These two main groups address the impacts and risk and analyse criteria based on varying assumptions (Table 16.3).

Table 16.3 is designed with the conceptual framework expressed in each risk assessment or management method – specifically risk, hazard, vulnerability and exposure concepts and their application to the specific natural hazard under examination. The objective of the research describes the main steps of the application via the analytical approach adopted and the target group(s). The input data utilised are exposed and defined, distinguishing them based on the step of the method in which they operate. Conclusively, critical comparisons of the analysed risk assessment and management methodologies are presented in order to highlight main differences and common points and to identify gaps for future development and research.

16.3.1 Hydro-Meteorological Hazards

Hydro-meteorological hazards comprise primarily of floods, storms, water scarcity, extreme temperature events and forest fires. Within Europe water-related hazards

Table 16.3 Structure of the criteria used with definition: method review

Criteria	Definition
Objective	Purpose of the research
Analytical approach (A) and targets (T)	Specifies the kind of analysis employed in the method
Stakeholders and experts involvement	Indicates whether their role is utilised in the method and, if so, how
Geospatial scale	Classified as *local* if the pilot area covers a municipality (e.g. Paris); *regional* if the pilot area covers a wider territory (e.g. Île-de-France); *national* if the pilot area considers an entire state (e.g. France); or *supranational*, if the area involves two or more states (e.g. Europe) – specific case study is reported
Temporal scale	Specifies and quantifies the temporal forecast considered in the study; if considered, but the timeframe is not specified, the term used is not specified; if there are no specific forecast, the term used is not applicable
Model (M), input (I) and output (O)	Reports the applied tools and models and describes the input data used in the analytical approach and how the method's results are presented – extended detailing of the final output of every step of the method
Strengths (S) and weaknesses (W)	Highlights strong points and limitations of the method

encompass several natural phenomena and a large number of physical modifications such as dams, weirs, sluices, straightening, canalisation and disconnection of floodplains [12]. Furthermore, the water availability and the population density are unevenly distributed – except in some northern and sparsely populated countries that possess abundant resources. Where water scarcity occurs, particularly in southern Europe, it is confronted with a crucial combination of a severe lack of and high demand for water. Different water uses, such as storage of water for hydropower, navigation or flood protection, caused many hydro-morphological and ecological impacts, including: changes in hydrological regime, disruptions in the river continuum and soil erosions which change biological communities and cause biodiversity loss [12].

Flood events are undoubtedly the most relevant in Europe, causing intense flooding over the last few decades, especially between 2003 and 2008, in which much loss of life, displacement and heavy economic loss occurred. The most affected countries include the United Kingdom, Hungary, Romania, Turkey, Czech Republic and most Balkan states [11]; nonetheless it should be pointed out that regular annual floods provide water resources for domestic supply, irrigation and industrial use. An important benefit to such events is the linkage maintained via biological diversity in what is known as flood plain ecology. The increasing number of Europe-wide flood events in the previous last few decades suggests that the increase in population and development in exposed areas are the main factors [11]. Storm events, which are natural phenomena closely related to floods characterised by strong winds in combination with heavy precipitation have the second highest number of human fatalities from natural hazards after floods, heat waves and earthquakes –especially in Germany, UK, France, Spain, Italy and Sweden [11]. In the last decade, their frequency and magnitude have locally increased during recent decades due to atmospheric and climatic change [11].

Drought is also a key hydro-meteorological hazard that affects Europe primarily in the summer – principally the southern half of the continent; during this period each year an area that extends from Portugal and Spain to the Czech Republic and Bulgaria is most affected by varying levels of water scarcity. An example of this scarcity was in Barcelona, Spain in 2008 in which the city suffered its worst drought recorded in 60 years [11]. Moreover, major impacts from drought events affect human health and the economy at large – especially in south Eastern Europe where the duration of drought events continue to get longer. It has to be emphasised that this phenomenon is greatly amplified by human activities; this imbalance has been linked to abstraction and availability in which relayed effects are often related to agriculture, industrial use and tourism [11]. In addition, most drought-like natural hazards circumvent extreme high-temperature events, such as hot or warm spells, which are projected across Europe to become more frequent, more intense and much longer in years to come. The most affected countries to date are Romania, France and Germany, followed by the Mediterranean and Balkan areas [11]; however, low temperature extremes, such as cold spells, are a very dangerous natural hazard during winter periods, above all in northern countries.

Hydro-meteorological natural hazards also take into account forest fires which are an essential disturbance for the regeneration of certain tree species and ecosystem dynamics. Fire events are closely related to the extreme high-temperature events which mostly affect Europe in the summer months; about 70,000 fires per year occur throughout Europe, mostly in the Mediterranean area accounting for approximately 70 % in total. The most affected countries were Portugal in 2003 and Greece in 2007 [11]; however, it has to be emphasised that over the 95 % of fires are caused by humans, either deliberately, by negligence or accident. The major damages caused by forest fires are the loss of human life, but also the economic context is very relevant.

16.3.1.1 Hydro-Meteorological Hazards Methodologies

A methods review of the predominant hydro-meteorological hazards is presented in Table 16.4 and is broken down using the criteria described from Table 16.3. Within the reviewed papers, a varying definition of risk is provided; authors define risk using different parameters and assumptions. Some key variances include Forte et al. [18] which links the hazard factor to the vulnerability factor using a scalar quantity approach. In this case the hazard is considered as a combination of the intensity and frequency, while vulnerability is defined as a combination of rainfall intensity and regional distribution of socio-economic elements at risk. The final risk is represented by a risk index, which include the number of total people affected and the economic damage to the surrounding buildings. Likewise,

Table 16.4 Hydro-meteorological hazards method review

Author(s)	Objective	Analytical approach (A) and targets (T)	Stakeholders and experts involvement	Geospatial scale	Temporal scale	Model (M), input (I) and output (O)	Strengths (S) and weaknesses (W)
Vis et al. [38]	Develop a resilience strategy for flood risk management	**A**: flood damage assessment based of five steps **T**: urban areas (building and infrastructures), agricultural areas(crops)	Hydrologists, engineers, geographers, and economists, assign scores to criteria in a matrix	*National* – Netherlands	N/A	**M**: SOBEK-River model (Delft Hydraulics and RIZA, 1996), Delft-FLS model [37], Standard Damage Module [40], GIS **I**: criteria results from flood damage assessment steps **O**: GIS modeling results of assessment	**S**: involvement of stakeholders in assigning scores **W**: social criteria is specifically looked at
Forte et al. [18]	Assess flood risk	**A**: spatial, mathematical **T**: buildings and infrastructure (indirectly people)	Not involved	*Regional* – Salento (Italy)	N/A	**M**: GIS **I**: framework inputs **O**: assessment findings and potential policy implementation	**S**: new sustainable approach **W**: difficult to utilize if not replicated and used in a consistent manner; timeframe covered by the stakeholders' dialogue is too long, compared to the urgency of implementing the proposed strategies

Lavery et al. [26]	Manage the flood risk in the Thames Estuary	**A**: spatial, management based **T**: property, houses and people	Decision makers: define best management measure supported by a decision-testing tool	*Local* –River Thames Estuary (London, England)	Long-term prevision (100 years)	**M**: GIS **I**: framework inputs **O**: assessment findings and potential policy implementation	**S**: new sustainable approach **W**: difficult to utilize if not replicated and used in a consistent manner; timeframe covered by the stakeholders' dialogue is too long, compared to the urgency of implementing the proposed strategies
Schmidt-Thomé et al. [35]	Revise economic flood risk maps	**A**: spatial, mathematical **T**: potential economic damage, potential exposure of people	Not involved	*Supranational* – Europe	N/A	**M**: N/A **I**: number of floods, economic data, social data **O**: hazard map, vulnerability degree, risk map	**S**: the risk is assessed at European level **W**: used of only an economic perspective
Kenyon [22]	Manage flood risk in Scotland	**A**: multicriteria approach, composed by six steps **T**: Buildings, infrastructure and population	Citizens, which indentify the criteria, score the options and assign the weights	*Local* – Inverurie, Callender and Alloa (Scotland)	N/A	**M**: N/A **I**: scoring and weightings **O**: assessment results and potential policy implementation	**S**: method actively involves public **W**: citizens have to be briefly educated on all flood risk management options

(continued)

Table 16.4 (continued)

Author(s)	Objective	Analytical approach (A) and targets (T)	Stakeholders and experts involvement	Geospatial scale	Temporal scale	Model (M), input (I) and output (O)	Strengths (S) and weaknesses (W)
Forster et al. [19]	Assess flood risk for a rural detention area	**A**: spatial, mathematical **T**: agricultural production	Not involved	*Local* –Elbe river (Torgau, Wittemberg, Germany)	Annual prevision	**M**: N/A **I**: empirical data, number and frequency of floods, economic data **O**: expected damage expressed by graphs (histograms)	**S**: detailed economic damage estimation for every type of crop **W**: risk is assessed only as economic damage of agriculture
Meyer et al. [28]	Assess flood risk	**A**: multicriteria, disjunctive MAUT weighting **T**: expected damage expressed by graphs (histograms)	Decision makers: assigning threshold values and weights	*Regional* – Grimma (Germany)	Long-term prevision (200 years)	**M**: expected damage expressed by graphs (histograms) **I**: expected damage expressed by graphs (histograms) **O**: risk maps (for single criteria), multicriteria risk maps	**S**: risk is assessed in the economic, environmental and social dimension **W**: laborious method
Brundl et al. [6]	Apply the risk concept in risk management	**A**: mathematical, multicriteria **T**: buildings, infrastructure people and single individual	Not involved	*Regional* – Davos (Switzerland)	Long-term prevision (30 100, 300 years)	**M**: EconoMe (BAFU, 2009) **I**: topographic map, historic chronicles, field data **O**: individual and societal risk index	**S**: method allows to assess both the societal and the individual risk **W**: stakeholders are not involved

Kubal et al. [24]	Assess urban flood risk	**A**: multicritera, weighting **T**: buildings and infrastructure environment, population	Decision makers: assigning threshold values and weights	*Regional* – Leipzig (Germany)	Long-term prevision (100 years)	**M**: GIS, FloodCalc Urban [28] **I**: public social, economic and environmental data **O**: damage maps, risk maps (for single criteria), multicriteria risk maps	**S**: risk is assessed in economic, environmental and social dimension **W**: laborious and highly technical method
Merz et al. [27]	Manage flood risk in a changing world	**A**: five levels of response to change in flood risk management **T**: people, industries, buildings and natural environment	Organizations, institutions, societies and population involved in the open risk dialogue with decision-makers (fifth level)	N/A	N/A	**M**: N/A **I**: decision making **O**: assessment results and potential policy implementation, management based findings	**S**: considers the responses to future flood risk management changes **W**: method has not been tested through a case study application
Bosom et al. [5]	Assess coastal vulnerability	**A**: probabilistic approach **T**: coastal environment	Decision makers: involved in establishing the acceptable return time period of analysis	*Regional* – six Catalan beaches (Spain)	N/A	**M**: GIS **I**: physical data, geographic data **O**: hazard graphs (probability distribution curves), vulnerability maps	**S**: method is applicable to all beaches and involves active participation from stakeholders **W**: complicated mathematical functions

Schmidt-Thomé et al. [35] consider risk as the combination of hazard intensity and economic vulnerability; hazard intensity is explained as the effect of a natural hazard (i.e. flooding) and it is dependent on the average number of flood events that occurred in a specific area; the vulnerability concept is considered as an economic value expressed by the regional Gross Domestic Product (GDP) per capita (in euro) and by the population density – weighted equally. Brundl et al. [6] give an analogous and significantly different definition of risk, distinguishing between societal and individual risk; the first type of risk depends on the total expected loss of lives in a hazard area (i.e. expected damage) and on the frequency of a considered scenario. The total societal risk is indicated as the sum of the societal risk of each scenario. The second type of risk is individual, which is expressed by the probability for the single individual to die during a hazardous event, considering factors as exposure and mortality rate of persons. It should be noted that the total individual risk is calculated in the same way as the total societal risk and that in both cases, the risk is expressed by the probability of a group of persons or individual exposed to a natural hazard and by the mortality rate of that specific scenario.

Table 16.4 chronological describes some of the main analytical approaches adopted and shows a brief breakdown of each method; the methodologies that comprise hydro-meteorological hazards are somewhat variable in design and output but generally are oriented around a flood-based outline. A point of interest of the methods is reviewed. Among all methodologies, Vis et al.'s [38] approach is based on a previous risk assessment methodology; more precisely, it is a damage assessment methodology which involves five main steps that focus on selection of representative flood waves and a breach development scenario. This procedural method allows the determination of economic expected damage from flooding which is one of the criteria utilised to choose the best risk management measures. This method is based on a resilience strategy which implies "living with floods" instead of "fighting with floods".

Forte et al. [18] proposed a methodology that consists preliminarily in the identification of hazard areas using susceptibility maps which is followed by a detailed study of geo-environmental factors and flood causes. In a mathematical approach on flood hazard assessment the determination of frequency and rainfall intensity is examined and then combined into a matrix. Vulnerability assessment is based on a combination of hazard data with spatial distribution of elements at risk, which is calculated a damage degree (divided into nine vulnerability classes). The final flood risk is determined by defining mathematically a flood risk index by combining the hazard classes and the vulnerability classes.

Another flood risk management measure, defined as the Thames Gateway project, is proposed by Lavery et al. [26]; it is aimed at replacing future existing long-term tidal defences systems by testing their robustness and sustainability to which climate change scenarios are considered. The decision makers in this method decide the implementation of flood risk management measures based on the knowledge of socio-economic, environmental and physical and engineered factors. The idea is to constantly inform stakeholders of the process, namely, a "strategy envelope" in which an interim suggestion based on the current understanding of the estuary is put forth. This tool describes future trends at the economic, social and environmental level and attracts an approach of educating public opinion with an improved ideology of risk perception.

Schmidt-Thomé et al. [35] present a methodology based on a spatial approach for the calculation of a vulnerability degree, using GDP per capita and population density data. This method then converts the number of flood events in flood hazard intensity classes using input data as the average numbers of floods in the projected target area. The final risk is calculated by integrating the vulnerability degree with five flood hazard intensity classes via a matrix in order to define nine risk classes.

Another study based out of Scotland is by Kenyon [22] in which seven different types of flood management measures are proposed; these measures overlook flood walls and embankments that require buying and demolishing buildings in flood risk areas with the intention of regeneration of plants and trees; reduction of drainage on some agricultural lands (to create wetlands); and inspection, maintenance and monitoring of watercourses to provide flood warnings and sustainable urban drainage systems (SUDS). The SUDS approach is based on a scoring and weighting notion and formulates assessment results and potential policy implementations.

In the study conducted by Forster et al. [19] the approach uses a different spatial and mathematical approach to assess monthly and annual expected flood damage in a rural detention area. The probability of flooding is determined separately from the flood frequency analysis; a sensitivity analysis is used in order to evaluate the relative importance of different factors such as shared agricultural land use, market price of crops and flood return period(s). Forster et al. [19] empirical and field data illustrate the market value of agricultural production (in euro), the damage impact on targets (per month) and the relative damage cost (as a percentage); statistically, they define the risk by the monthly and annual expected flood damage.

Meyer et al. [28] work within a Geographic Information System (GIS) based multicriteria flood risk assessment methodology in which three risk dimensions are present: environmental, social and economic. This method expresses the expected damage of each dimension in an evaluation procedure calculated for different flood probability; that is, erosion potential, accumulation potential and inundation of oligotrophic biotopes (environmental dimension); annual average affected population and probability of hot spots to be affected (social dimension); and annual average damage (economic dimension). The annual average damage is derived from the sum of all expected damage from each dimension and utilised via two different approaches of multicriteria risk: (1) disjunctive approach, where the decision makers have to define a threshold level for each criterion (e.g. if a value is in excess, then the area considered is a risk area); and (2) the Multi Attribute Utility Theory (MAUT) weighting approach, where the criteria values (derived from the evaluation procedure) are normalised between 0 and 1. The weighted value for each criterion is calculated and the overall risk value is obtained by summing all the weighted value of each criterion. The results are analysed in a sensitivity analysis in order to eliminate uncertainty in the risk value.

In Switzerland, Brundl et al. [6] adopt a methodology based on three fundamental steps of risk, developed via the Swiss RIKO guidelines [29] and published within the *Interpraevent* research society, they overlook: (1) mathematical risk analysis, which in turn includes four analyses: hazard, exposure, consequence and risk calculation; (2) multicriteria evaluation of risk, which compares risk analysis results with predefined goals (i.e. the probability of death should not be higher of 1 % of the lowest risk); and (3) planning and evaluation of mitigation measures, based on a multicriteria approach which evaluates the cost-effectiveness of measures using a risk-cost diagram. Brundl et al. [6] consider topographic and geological maps, supported by aerial and satellite images and historical chronicles; three intensity maps are produced which forecast the flood hazard without the application of measures after 30, 100 and 300 years.

Kubal et al. [24] define risk using an evaluation procedure that standardises risk values between 0 and 1, then calculates them into a function of different preselect scenarios (i.e. EQUAL, ECON, SOCIAL, ECOL, SPOTS, COHORTS, ECON extreme and ECOL extreme) in the weighting approach. These scenarios are the sum of the different weights of each criterion, expressed in a percentage. For example, the EQUAL scenario represents an equal division of the weights (the sum is 100 %): economic 33.3 %, social 33.3 % and ecological 33.3 %. Another example is the SOCIAL scenario, where the social weight represents the 60 % and the economic and environmental weights the 20 % each. In this method the decision makers cover a central role and outputs calculate aggregated flood risk maps based on the standardised risk values from lowest to highest.

A shift from flood protection to flood management is the focus of Merz et al.'s [27] research in which three strategies are proposed: (1) managing of all floods and not only flood events of a given severity, (2) risk-informed decision making in which transparent and accessible estimation of flood risk is used to choose the correct risk response; and (3) integrated systems approach where risk reduction is replaced in order to reduce the effect of flooding (e.g. via warning systems, emergency measures or spatial planning regulation). Merz et al. [27] develop their risk management methodology to cope with current and near future environmental change – posed mostly by concerns with climate variation and change. It is underlined, sea level rise and increasing floods in both number and magnitude are key to better understanding long-term provisional strategies required to upgrade and modify recorded data and decision assessments.

The method proposed by Bosom et al. [5] assesses coastal vulnerability and not coastal risk; it begins with a hazard assessment, that is, hazard is defined as the potential coastal damages (caused by a storm), characterised by two main natural phenomena: erosion and inundation. Then, vulnerability is defined as the potential of a coastal system to be harmed by the impact of a storm and quantification compares the magnitude of the impact with the adaptation capacity of the system – defined by the physical characteristics of the beach to cope. This methodology is based on a probabilistic approach defined by the probabilities of occurrence of induced hazards along a coastline; the estimated and then compared spatial distribution of the expected magnitude of the impact (vulnerability) is examined in order to identify the potential most endangered areas.

16.3.2 Geophysical Hazards

Geophysical hazards include landslides, avalanches, earthquakes and volcanic eruptions; landslide events account for some of the most relevant hazards Europe-wide. They include two main characteristics: (1) material involved (rock, earth) and (2) type of movement (falls, topples, slides, spreads, flows). Landslides are closely connected with hydro-meteorological hazards, as storms can be often linked as a main cause. Landslides are a major threat to human life, property, buildings, infrastructure and natural environments – especially in mountainous and hilly regions. Countries located in the Scandinavian peninsula, in the Alpine region and in southern parts of Europe are most prone to these hazard events. One of the most affected regions in Italy was Friuli Venezia Giulia, in 2003, when more than 1,100 landslides caused over 364 million euros in damages [11]. Furthermore, climatic change is expected to increase the mean temperature and to alter precipitation patterns in Europe in the near future, causing an increase in overall landslide events.

Avalanches are another type of geophysical hazard that is related to varying hydro-meteorological hazards. Heavy precipitations, intense snowfalls and strong winds can be cause and effect events for avalanches to occur; the occurrence of large avalanches is not governed by general climatic trends but rather by shorten weather events. The last catastrophic winter in Europe with a large number of fatalities was in 1998–1999 where Austria, France, Switzerland, Italy and Germany fell victim to these event occurrences [11]. Generally avalanches are natural events that mostly occur without causing damage or even being noticed. Atmospherically, climate change is having a more pronounced effect; most of all at altitudes below 1,000 m, due to a reduction of snow coverage, has forced previously non-avalanche prone areas to consider this type of new threat.

Differently, earthquakes and volcanic eruptions are geophysical hazards that are not related to any other natural hazard and they are also totally independent from human activity. From 2003 to 2009, 15 great earthquakes occurred in the 30 European Economic Area Member States and one of the most damaging was in L’Aquila, Italy in 2009, causing 332 victims. Similarly, tsunami-based hazards are also earthquake-related and pose a serious threat to coast lines and communities. Major volcanic hazards are situated in Iceland and in southern Europe, specifically Italy and Greece (e.g. Vesuvio, Etna and Santorini) [11]. It should be cited that due to the massive movements of gas, dust and land volcanic eruptions often completely immobilise an affected area. About 20 countries closed their airspace (a condition known as ATC Zero) and affected hundreds of thousands of travellers throughout Europe when Mount Eyjafjallajökull, Iceland started volcanic eruptions during 2010 – ash covered large areas of northern Europe making atmospheric conditions hazy, dark.

16.3.2.1 Geophysical Hazards Methodologies

The basis of geophysical hazards is consistent with standardised risk assessment and management approaches and allows for consistency and comparative evaluation across the cited two domains. The reviewed geophysical hazards methods depict key prevailing papers and provide a chronological look at the direction and ideological change within the scientific field (Table 16.5). Within the reviewed papers, a differing level of risk is defined using various checks and hypotheses. The notion of risk plays an important role in decoding the analytical approach and reasoning behind the development of a method; a noteworthy example of this is Dai et al. [9] in which risk is a measure of the probability and severity of an adverse effect to health, property or the environment – expressing risk by the product of probability and vulnerability. In this case, hazard is described as the probability of occurrence of a given magnitude of the event, while vulnerability considers the level of potential damage, or degree of loss, of a given element.

Key reviewed geophysical hazards methodologies in Table 16.5 are illustrated chronologically; the review methods include key works within the sub-disciplines of landslide, avalanche, earthquake and volcanic eruption events. Identical to the structure of hydro-meteorological hazards methodologies, geophysical hazards methodologies are broken down at par with criteria explanation from Table 16.3. Geophysical hazards methods are to some extent variable in structure, nonetheless landslide events dominate the outlined literature and as a result have foreseen a miniature evolutionary development from alluvial science to long-term management course of action.

Among reviewed methods, Dai et al. [9] outlines a classic approach to assessing landslide risk of people and property using a mathematical approach; risk is calculated via probability of an annual landslide event, spatial and temporal impact (determined during the hazard assessment) and vulnerability. Respectively the general idea is a representation of a base-framework on hazard and vulnerability assessment in which hazard assessment is determined by combining the probability of landslide with the runout behaviour. The latter involves the delimitation of the endangered areas with three specific methods: empirical modelling, analytical modelling and numerical simulations. Dai et al. [9] expand by calculating the probability of a landslide event using three different approaches: heuristic (which involve experts to estimate the preparatory variables), deterministic (which is based on slope stability analysis) and statistical and probabilistic (which incorporate the application of the statistical determination of past variables that have led to landslides). The subsequent vulnerability assessment involves “the understanding of the interaction between a given landslide and the affected elements” [9]. In conclusion, the results are subsequently integrated with the hazard assessment outputs in order to produce landslide risk results.

Using a geomorphological approach, the methodology presented by Cardinali et al. [7] aims at assessing landslide risk for structures, infrastructures and population; it combines a data analysis of site-specific and historical information. Based on observed changes in the distribution and pattern of landslides they infer the possible

Table 16.5 Geophysical hazards method review

Author(s)	Objective	Analytical approach (A) and targets (T)	Stakeholders and experts involvement	Geospatial scale	Temporal scale	Model (M), input (I) and output (O)	Strengths (S) and weaknesses (W)
Dai et al. [9]	Assess and manage landslide risk	**A:** mathematical, spatial, heuristic, deterministic, statistic and probabilistic; cost-benefit analysis with a direct involvement of decisions makers in the selection of the best management measures **T**: property and people	Expert opinion in heuristic approach and in assigning vulnerability factor; decision-makers choose the best management measure	*Regional*- Hong Kong	N/A	**M**: GIS, frequency-number of fatalities curves, synthetic aperture radar interferometry (InSAR) [23, 31] **I**: historic data, physical data, field data, geographical data **O**: hazard data, vulnerability matrix, risk map	**S**: method involves many factors and approaches; allows to compare many different measures **W**: laborious due to the involvement of many different approaches; the definition of tolerability in the acceptance option does not involve directly the population
Cardinali et al. [7]	Assess landslide risk	**A**: multi-temporal, mathematical, spatial **T**: structures, infrastructures, population	Geomorphologic expert judgment on interpretation of aerial photographs	*Local* – Umbria (Rotecastello, Italy)	N/A	**M**: GIS **I**: historic data, topographic maps, field data, physical data **O**: hazard index, hazard maps, vulnerability table, risk map	**S**: applicable to all landslide events **W**: requires a lot of historical data

(continued)

Table 16.5 (continued)

Author(s)	Objective	Analytical approach (A) and targets (T)	Stakeholders and experts involvement	Geospatial scale	Temporal scale	Model (M), input (I) and output (O)	Strengths (S) and weaknesses (W)
Lateltin et al. [25]	Manage landslide risk in Switzerland	**A**: mathematical (using a matrix); based on protection goals and previous hazard assessment and definition of protection requirements, the prevention and protection measures are planned **T**: structures, infrastructures, population	Commission formed by political authorities, administrative officers, scientists and public to analyse each critical situation and each change in local risk management plan	*Local* – sorenberg; *national* - Switzerland	N/A	**M**: N/A **I**: landslide intensity, landslide frequency, probability data, geographic data **O**: hazard maps, damage table	**S**: approach allows for the hazard assessment of all kind of landslide; applicable to all the whole Swiss territory **W**: method does not involve social criteria; definition of safety goals does not involve stakeholders
Keiler et al. [21]	Assess avalanche risk	**A**: multi-temporal, mathematical **T**: buildings	N/A	*Regional* – Gaultur (Austria)	N/A	**M**: SAMOS [32], ELBA+[39] **I**: historic data, economic data **O**: risk graphs (line chart)	**S**: uses three different risk scenarios **W**: method does not make any future risk prevision

Garcin et al. [20]	Assess tsunami hazard and risk in coastal areas	**A**: spatial, mathematical **T**: population and buildings	N/A	*Local* – Beruwala to Weligama (Sri Lanka)	Long-term prevision (2100)	**M**: GIS, ARMAGEDOM (Sendan et al. 2003) **I**: physical data, GIS and geographic data damage function **O**: hazard maps, exposure maps, risk scenarios	**S**: method allows to assess the hazard and risk both for tsunami and sea level rise phenomena (monsoon); allows for long-term urban development **W**: stakeholders are not involved
Arattano et al. (2008)	Manage the risk of alluvian fan	**A**: 4 step assessment; improvement of civil protection intervention strategy **T**: buildings, infrastructures, population	Autorità di bacino del fiume Po (Po river basin authority) risk assessment; civil protection risk management	*Local* – Villar Pellice (Italy)	N/A	**M**: 4 step intervention strategy **I**: stakeholder involvement **O**: hazard maps, exposure maps, risk scenatios	**S**: method provides many practical solutions **W**: developed only for civil protection and not for other local authorities
Strunz et al. [36]	Assess tsunami risk	**A**: multi-scenario, spatial **T**: people	N/A	*Local* – pilot area; *national*- Indonesia	N/A	**M**: GIS, TsunAWI [3], DSS [30] **I**: geographical data, statistical data, physical data, social data **O**: hazard map, exposure map, evacuation map, risk map	**S**: tsunami risk is assessed at national and local scale **W**: method required a large number of data and relating datasets

(continued)

Table 16.5 (continued)

Author(s)	Objective	Analytical approach (A) and targets (T)	Stakeholders and experts involvement	Geospatial scale	Temporal scale	Model (M), input (I) and output (O)	Strengths (S) and weaknesses (W)
Alberico et al. [1]	Assess volcanic risk	**A**: spatial, mathematical **T**: buildings, infrastructure (indirectly people)	N/A	*Local* – Napoli (Italy)	N/A	**M**: GIS, HAZMAP [8] **I**: physical data, geographical data, topographic maps, economic data, social data **O**: hazard map, exposure map, risk map	**S**: method involves physical, economic and spatial dimension **W**: over-estimation of risk, due to the unavailability of vulnerability based assessment

change in slope, probable short-term types of failure and expected frequency of occurrence. The proposed method involves an inventory map and identification and mapping of elements at risk; using a spatial approach the inferred relationship between the intensity and type of expected landslide, and the likely damage that the landslide will cause, an evaluation of landslides risk is obtained via a hazard index.

Lateltin et al. [25] propose another ground breaking method based in both Switzerland and at the local municipality of Sorensen, Switzerland. The assessment of landslide hazards, respectively, expand Cardinali et al.'s [7] research by using a more complex approach based on the combination of landslide intensity with probability occurrence. Using a cross-reference matrix based on hazard levels, hazard maps are developed and factor the assessment of landslide hazard levels as a probability of occurrence which is defined using four different classes: high, medium, low and very low, according to return times of the landslide event of 1–30, 30–100, 100–300 and $>$ 300 years, respectively.

Avalanche risk assessment methodology presented by Keiler et al. [21] is another ground breaking approach; it utilises different risk scenarios to calculate avalanche tracks, using a multi-temporal approach quantified between the timeframe 1950–2000. It should be emphasised that this method aims at describing past risk scenarios without making any future risk forecast or any risk classification. Avalanche risk is expressed as the potential monetary loss of building values and vulnerability of buildings is understood as a degree of loss to a given element within the affected area. Four classes of vulnerability are defined: general damage level, specific damage level, destruction level and detach limit. Monetary values of buildings are estimated using the building volume and average prices per cubic meter. During the pilot studies, risk scenarios are calculated and describe mitigation measures and risk-influencing factors.

Garcin et al. [20] propose a methodology based on an integrated approach aimed at assessing the hazard and risk for coasts affected by tsunami and sea level rise; the latter has a relationship cause and effect with extreme storm events, for example monsoons. The methodology involves three main steps: (1) assessment of tsunami and sea level rise hazard using GIS; (2) analyse output data from a hazard assessment without using a specific numerical model in order to define a less generic spatial distribution of elements exposed; and (3) use the simulation tool ARMAGEDOM [34] in order to carry out the risk scenarios for tsunami events. The obtained results of combining the expected damage, related to natural hazards and exposure of each element at risk, emphasise explicitly the link between tsunamis and climatic change.

From the list of assayed methodologies, the most theoretical-based is Arattano et al.'s [2] approach; it does not have a final conclusive proposal that provides concrete measures to manage landslide risk via an alluvian fan. It does, however, offer a set of improvements at the civil protection intervention strategy level. That is, it puts forth practical, non-structural points which can be implemented either as part of: (1) territorial planning which is an imposed limitation in building construction or (2) civil protection intervention strategies and organisation before, during and after a catastrophic event. More precisely, with such an event an automatic early warning system and varying meteorological bulletins can forecast rainfalls to assist in preventing or minimising impending risks.

In 2011 Strunz et al. [34] proposed a tsunami risk assessment methodology based on the BBC framework by Birkmann [4]. The methodology's final target is people; it incorporates tsunami hazard assessment and vulnerability assessment. The hazard assessment is based on a multi scenario approach while the vulnerability assessment is divided via exposure estimation, which provides information about the distribution of people, and response capabilities and preparedness assessment, when considering: warning decision time, warning dissemination time, anticipated response time and evacuation time. The overall vulnerability assessment is based on the estimated time of arrival of a tsunami wave which can determine two groups of time components: (1) those depending on institutional behaviour (warning dissemination strategy) and (2) those depending on people's behaviour (evacuation strategy). The final risk is determined by spatial integration of three maps: hazard, population exposure and evacuation time. Strunz et al. [36] utilise the software entitled unstructured mesh finite element model for the computation of tsunami scenarios with inundation (TsunAWI) [3], to elaborate the tsunami inundation area, then integrate tsunami risk data into a decision support system (DSS) of early warning systems [30] – allowing assigned risk classes subsequently used to produce overall risk maps.

Another recent study conducted by Alberico et al. [1] examines volcanic risk in which four risk classes are established, from high risk to very low risk; based on the integration of hazard and exposure maps these risk classes are defined by superimposing themselves over each other and cross-referencing the combination. The outcome of the intermediate combinations is not explicitly reported; exposure input data is obtained from statistical land use data and maps, population density data and response capabilities.

16.4 Comparative Examination of Natural Hazards

A comparative examination of prevalent natural hazards risk assessment and management methodologies have been separated into two domains as a basis for breaking down natural hazards at large. Both hydro-meteorological and geophysical hazards, in a general sense, can somewhat be compared with each other as they both exist under a conceptual natural hazards umbrella; however, since each domain specifically draws upon specific methods it would be knowledgeable to focus a comparison at this level. That being said, a comparative examination draws potential viewpoints on choice of methodology which largely depends on considered area and on addressed target(s). In this sense, timeframe is very important and contrasts and similarities between methods is mostly case specific in which potential strengths and weaknesses can be identified. While method complexity may often imply a wide range of physical and social information that subsequently integrates the use of distinct tools, like TsunAWI or DSS, they regularly are based on historical developments that evolve via trial and error; tools are fostered and progressively improve via knowledge-base and scientific examination. Since natural hazards often cause varying levels of harm and destruction, readers should take into account the prevention, protection and preparedness principle in which defines conclusive technical development from a resilience viewpoint according to EU Floods Directive, Article 7. The development of these resilience-based views is where people participate, decide and plan their conurbation with the local government authorities, based on their capacities and resources under a EU backdrop; the extension of national policies within Commission guidelines plays an important part of this development.

16.4.1 Examination of Hydro-Meteorological Hazards Methods: Review

After analysing the hydro-meteorological hazards methodologies it is clear that there is more than one method that can be used to assess varying forms of flood and coastal risk. The choice of one methodology over another largely depends on the respected local and targeted subjects. In hydro-meteorological risk management the prevention, protection and preparedness principle can be examined. For instance, the prevention principle is expressed by correct land use planning, as avoiding the development of urban centres and inhabitations in flood-prone areas [27], the protection principle is highlighted by rising flood walls or river edge defences [26] and the preparedness principle is emphasised in developing a proper early warning system.

It must be emphasised that not all methods are aimed at conclusively putting forth a complete appraisal on risk; Forster et al. [19], in fact, estimate only economic expected damage and explicitly go no further, while Bosom et al. [5] stops at assessing only vulnerability. Differently, other methodologies perform a more complete risk appraisal through the integration of both hazard and vulnerability assessment [18, 35] or combine expected damage with the probability of flooding [6, 24, 28]. These methodologies present different levels of complexity and integration; for example, the method proposed by Schmidt-Thomé et al. [27] has quite a simple form of implementation since it involves three input data types (i.e. GDP, population density for vulnerability and average number of flooding for hazard) and combines the hazard and vulnerability outputs using a simple 5×5 risk matrix. On the contrary, the methodology presented by Forte et al. [18] is much more problematic in application, even though it utilises a similar conceptual framework, it requires several input data types before calculating final outputs via three different integration methods which include two different matrices. The methodology presented by Brundl et al. [6] allows for the calculation of two types of risk (social and individual) which are obtained separately using an elaborated mathematical approach involving several input data types – topographical maps and historical data. Additionally, the methods proposed by Meyer et al. [28] and Kubal et al. [24] are also quite complex; they integrate a large number of input data types into a software program made up of three risk dimensions (i.e. environmental, social and economic). The complexities depend on stakeholder involvement and decision makers; if the method is aimed at expert decision making, as in Meyer et al. [28] and Kubal et al. [24], risk is defined via threshold values and weights. The methodology proposed by Bosom et al. [5] is also rather complex as it uses a probabilistic approach which incorporates a large number of different functions in calculating overall vulnerability.

The methods presented by Kenyon [22], Lavery et al. [24], Merz et al. [27] and Vis et al. [38] also show a high level of complexity which may be limiting to laypersons as the terminology is not easy to understand. Kenyon [22] incorporates two different methods by assigning weights via two distinct mathematical functions (rank sum and rank order centroid) which combine these weights and scores from a third mathematical function (linear equation) into an integrated multicriteria evaluation. The methodology proposed by Lavery et al. [26] includes a complex framework of risk communication between stakeholders, public and decision makers while Merz et al. [27] provides a theoretical framework for risk-based adaptation. Differently, the methodology proposed by Vis et al. [38] aims solely at expert stakeholders; hence, a high level of complexity is exercised which includes three different types of mathematical models in order to assess flood damage before combining scores with strategies proposed in a Delphi method.

Inversely, if the methodology is aimed at the community level or public (or does not involve stakeholders) as in Schmidt-Thomé et al.'s [35] method, it typically is designed in a simplistic manner in order to be easily understood and explained to non-experts. As far as public participation is concerned, the methodologies developed by Meyer et al. [28] and Kubal et al. [24] obtain final risk through the involvement of stakeholders. More precisely, Meyer et al. [28] incorporates decision makers' threshold risk values into a developed multicriteria disjunctive approach and weights each criterion using a MAUT weight-based process; Kubal et al. [24] simple asks decision makers to define the weights for each scenario-based case. This is quite a significant characteristic as it relates to specific queries within European governance and current legislation relating to use of the EU Floods Directive and its implementation. Other methods obtain final risk by applying arbitrary chosen thresholds, derived from mathematical approaches – for example with the use of data normalisation.

Within the compared methods, the considered targets are very similar; Forster et al. [19] considers only agricultural production, while other authors consider buildings, infrastructure and population. This means that the presented methodologies, with the exception of Forster et al. [19], are very complete as they respectively allow for the assessment of different impacts on structures and population at large. Differently, Vis et al. [38] does not address population but only buildings and infrastructures due to its non-involvement of social criteria. It should be pointed out that methods that cover local or regional scales require much more detailed input data than national or supranational; similarly, large or regional scaled output are more detailed and accurate than national or supranational ones. For example, Schmidt-Thomé et al. [35] cover a supranational scale and consider flooding in a cross-border event and assess economic flood risk within a European study; in this scenario it would not be necessary to produce final risk maps that are extensively detailed since local risk is not taken into account. Among the applied tools GIS is the most present, Forster et al. [19] uses spatial integration of different information to perform and support a risk communication based approach by providing easy to understand outputs by way of risk maps; this communication is detailed via a cost-benefit and sensitivity analysis showing the probability of flooding.

16.4.2 Examination of Geophysical Hazard Hazards Methods: Review

The examination of geophysical hazard methodologies is very dependent on the type of natural hazard being looked at; a part from all the analysed geophysical hazard methods, Lateltin et al.'s [25] research did not comprise a complete risk assessment – it only focused on assessing hazard and damage. In most of the methods the concept of risk is similarly identified; however, Keiler et al. [21] bases its research on the interaction of hazard and vulnerability factors while Alberico et al. [1] consider only one constraint based on exposure outputs. In the landslides risk methodologies – generally – landslide risk is a combination of hazard-based factors which are expressed by physical characteristics (i.e. magnitude, velocity, intensity and frequency) and vulnerability-based dynamics are defined by way of distribution of elements at risk and their potential damage. In terms of landslide risk management measures – based on the prevention, protection and preparedness principle – the prevention principle is expressed by land use planning measures, as avoiding inhabitations or any other construction in landslide prone areas [25], the protection principle is highlighted by engineering options [9] and the preparedness principle is emphasised by developing proper early warning systems and emergency planning [2].

The complexity of the reviewed geophysical hazard methodologies indicates a varying level of intricacy; for example, Alberico et al. [1] join three different approaches in hazard assessment and a large number of physical input data. The methodology by Strunz et al. [36] entails a wide range of physical and social data types which subsequently is integrated using two distinct tools (i.e. TsunAWI and DSS). Similarly, the methodology proposed by Cardinali et al. [7] involves a wide range of input data within a large timeframe (1941–1999) to combine function-based processes within dual mathematical and spatial techniques. Likewise, in design, Arattano et al.'s [2] method is somewhat simplistic, in that it mainly addresses public and local authorities by proposing a set of improvements contra future events in the examined study area. In contrast, Dai et al.'s [9] risk assessment method is extremely complex – involving three distinct approaches in probability assessment, three different methods for predicting runout distance, a large number of physical datasets and active participation of stakeholders in its vulnerability assessment. Keiler et al.'s [21] research, less multivariate, aims at assessing past risk scenarios by way of input data as an economic value over exposed buildings and statistically combining them; furthermore, they do not provide any future risk forecast or any risk classification. Similarly, Dai et al. [9] involves stakeholders and public opinion in combination with a cost-effectiveness analysis in choosing the best management strategy. The complexity of each method is dependent above all on stakeholders and relevant decision makers; most of the presented approaches are elaborated for expert decision makers, hence a high level of complexity is used in order to accurately define risk [1, 9, 36]. Stakeholders are central to the functionality of the Dai et al. [9] and Cardinali et al. [7] methodologies, while the approach proposed by Garcin et al. [20] is stakeholder free. Garcin et al. [20] does, among all the review methods, explicitly report the link between tsunami and climatic change.

Generally, the considered targets are buildings, infrastructure and population; however, Keiler et al. [21] only considered buildings and Strunz et al. [36] population. This entails that most of the reviewed methods have a general grounding over all possible impacts from the considered natural hazard events – for example social aspects may deal with population efforts while economic may umbrella notions relating to buildings. This is especially important when dealing with landslide risk assessment as it is fundamental to understanding policy and structural relationships in direr needs before and after such events. Furthermore, all the analysed geophysical hazard risk methodologies, except for Keiler et al. [21], have final outputs as risk maps (i.e. landslide, tsunami, storms and volcano). It should be noted that among all the applied tools, GIS is the most present, exemplar of this use is Lateltin et al. [25] where performance via spatial integration of different information (e.g. environmental and social) to support an increased level of risk communication provides easy to comprehend risk maps.

16.5 Conclusion

Based on the review, the existing assessment and management methodologies for the two domains denote natural hazards under given reference to recent analysis and discussion of European reports, guidelines and scientific publications. The analysed reports and guidelines are focused above all on the link between the most relevant European natural hazards (i.e. floods, storms, landslides, seismic activity, volcanic eruptions and avalanches) and climate change; this issue is significant as it relates to the most affected geographical areas and proposes different risk assessment and management strategies and measures to reduce overall natural hazard risk [11] and mitigate climate change impacts [13]. The Commission's need for proper implementation of national scales, in reference to recently published regulations addressing natural hazards and specifically water-related hazards, concerning risk assessment and management implementation define the major impacts that MS have to address (i.e. human, environmental, social and economic). The three basic steps of risk assessment are: risk identification, risk analysis and risk evaluation – with its main initiative on community disaster prevention and resilience. One example of this initiative is the use of educational tools to help build a culture of safety and risk awareness [14]. The carried out review underlines that in recent years there has been a large production of scientific publications addressing risk assessment and management methodologies for natural hazards; this confirms a remarkable interest in the topic due to an increase in number, frequency and magnitude of natural hazards – above all in relationship to climatic change. In particular, the most threatening hazard events in Europe continue to cause a major number of fatalities and high economic loss.

In detail, risk methodologies that are characterised by hydro-meteorological hazard events address two different conceptual frameworks: integration of hazard and vulnerability and integration of the expected damage with the probability of the hazardous event. Accordingly, the considered methodologies are usually structured on three steps: hazard, vulnerability and risk, requiring the integration of different risk dimensions (i.e. social, economic and environmental) through different approaches – such as multicriteria analysis. Various levels of applicable comprehensiveness within varying spatial scales and target(s) comprise a state of the art. Likewise, the risk methodologies that overlooked geophysical hazards maintain a framework based on the integration of hazard and vulnerability, and in some cases also exposure; accordingly, the performed steps are hazard, vulnerability, exposure (when included) within a risk assessment and management method integrates various forms of information that is usually applied via matrices or a process of normalisation. Moreover, in most of the presented methodologies, a spatial approach is adopted with the implementation of GIS and supporting results for communication to end users via easy to comprehend hazard, vulnerability, exposure and risk maps.

It should be clear that risk jargon is method specific and that a glossary of definitions could pose as a solution to better integrating methodologies across schools of thought and advancement in assessment and management rationale. An analysis of the examined risk management methods, in a general sense, supports more suitable management measures (e.g. cost-effectiveness or cost-benefits analysis) and stakeholders' participation (e.g. public participation through workshops). According to the hazard of concern, they present a large number of different management solutions that reduce or prevent possible risks – both structural and non-structural. This takes into account sustainability and climate change concepts; stakeholders and experts are not always directly involved hence there are opportunities for further improvements. The need for a general and comprehensive (including environmental, social and economic) methodology, flexible to be tailored to different natural hazards and spatial scales is ideal. The analysed methodologies exemplify a sound starting point for future development in the field of risk assessment and management for natural hazards, offering room for improving both the natural science and socio-economic aspects; their integration through innovative spatial and mathematical approaches identify point of reference with adoption to structuring a genuine framework, approach and key components of what characterises successful advancement and what should be considered less important. Ideal support for further development is site specific and applicative target specific – development of better assessment and management techniques that circumvent this specificity is desirable.

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