BORIS2

Cross **BO**rder **RIS**k assessment for increased prevention and preparedness in Europe: way forward

D2.1
Comparison of existing schemes and methods for emergency management

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disaster risk management, urban scale, civil protection, emergency planning, earthquakes, floods, seismic risk, floods risk, multi-risk, seismic hazard, flood hazards, vulnerability models, exposure models, damage and impact indicators, emergency limit conditions, national DRM legal frameworks, tools, platforms, prevention, preparedness, response plans

1. SUMMARY

Building on the foundations laid by the BORIS project, Project Cross BOrder RISk assessment for increased prevention and preparedness in Europe: way forward (BORIS2) aims to extend and enhance multi-risk assessment methodologies for emergency conditions at urban scales across transnational borders in Europe. The project seeks to establish a replicable model of cross-border cooperation in the prevention phase of natural disasters, thereby enhancing the capacity of EU countries to manage and mitigate risks associated with seismic and flood events. The deliverable D2.1 Comparison of existing schemes and methods for emergency management, originates from Work Package 2 of the BORIS2 project which focuses on 'Context Analysis and Needs Assessment'. The core objective of Deliverable D2.1 is to provide a comprehensive analysis of existing seismic and flood risk assessment methodologies from an effective disaster risk management (DRM) perspective at the urban level. It also aims to review and evaluate the diverse DRM frameworks, decision-making processes, and legal and institutional arrangements adopted by different countries, highlighting areas for potential alignment.

The approach undertaken in this deliverable involved a detailed analysis of methodologies used for seismic and flood risk assessments at the urban level, focusing on their effectiveness in DRM. This analysis covered the hazard, vulnerability, and exposure models used for structures and infrastructures deemed critical during emergencies. Additionally, this deliverable scrutinized the DRM frameworks of the participating countries by examining the coordinated responsibilities, prevention, preparedness, and response plans. It also focuses on the roles of real-time monitoring, warning, and alerting activities along with tools and maps used specifically for emergency management. Each BORIS2 project partner contributed with the overview of their national assessments, later used for a comparative review, ensuring a comprehensive understanding and highlighting points for further alignment.

The chapters 2 through 6 of Deliverable D2.1 provide an extensive analysis of DRM practices across Italy, Slovenia, Austria, Turkey, and Montenegro. Each country exhibits unique methodologies tailored to their specific environmental and urban challenges, reflecting diverse approaches to seismic and flood risk management at an urban scale. Each section is divided into sub-sections that cover the hazards, vulnerabilities, exposure levels, damage and impact indicators and tools (platform) for risk assessment related the respective risks. Special attention is given to the role of seismic and flood risk analysis in effective DRM as well as multi-risk assessment methods at urban scale.

The Chapter 2 delves into overview of DRM at urban scale for Italy. It is shown that current practices exemplifies a highly structured approach to DRM, with significant emphasis on both seismic and flood risk assessments at the urban level. As it is shown, in Italy advanced tools, such as the I.OPà.CLE (Indices for evaluation of the Operational efficiency of Limit Condition Emergency) method, are developed. This tool provides the evaluation of critical components in the system in order to ensure their operability during the emergency phase. Up to now, I.OPà.CLE has been tested by the Italian's National Department of Civil Protection and is not still adopted as tool for municipalities.

As discussed in the Chapter 3, Slovenia, similar to Italy, conducts comprehensive seismic and flood risk assessments at the urban level. The Slovenian approach is detailed in its use of exposure models to understand and mitigate risks within urban environments. However, Slovenia does not prominently feature a specific tool or platform to specifically assess the flood risk at an urban scale and the existing tools and applications for the seismic risk assessment are mainly intended for the CP (civil protection) response after an earthquake. Moreover, Slovenia discusses multi-risk scenarios, within its emergency management framework; however,

these are qualitatively rather than quantitatively assessed, which limits the integration of these factors into a fully cohesive urban-level DRM strategy.

As it is elaborated in Chapter 4, Austria shows a more detailed approach towards flood risk management compared to seismic risks. While there is a good overview of seismic hazards facilitated by real-time monitoring and hazard maps, the detailed risk assessments for seismic events are not as developed as those for floods. Austria lacks a national tool or platform for urban-level risk assessment. Multi-risk assessment across all levels is not conducted but it is possible to assess different hazards for a specific point/ any location to some extent. The emphasis, however, is more on public awareness and preparedness rather than on detailed modeling of risk exposures within urban settings.

In chapter 5 overview of DRM framework at urban scale for Turkey is presented. DRM in Turkey extensively covers both seismic and flood risks at the urban level. Sophisticated tools and platforms are developed to provide access to accurate and valid disaster and emergency data, various reports, statistics, follow-up information, inquiries, analyses, etc. at any time, before or after a disaster. Still, multi-risk assessment at national, regional and local level has not yet been conducted.

The overview of DRM at the urban scale in Montenegro is detailed in Chapter 6. Montenegro is developing its DRM capabilities, but on a smaller scale compared to other countries discussed. The primary source of data for risk assessments at the urban level, encompassing both seismic and flood risks, are the protection and rescue plans for municipalities. However, these plans vary among each other in terms of the depth of the assessment and the sophistication. The decision-making processes and responsibilities in case of an emergency are well established, although multi-risk assessments at the urban level are not conducted.

Chapter 7 provides a thorough and clear comparative analysis of seismic and flood risk assessment procedures at the urban scale across various countries. The focus is on the distinct methodologies used to evaluate seismic hazards, vulnerabilities, exposure models and damage and impact indicators tailored to urban environments.

Chapter 8 offers a comprehensive review of the national institutional and legal frameworks for CP systems within the participating countries. This examination delves into how the legal and institutional structures in different countries either facilitate or impede effective DRM practices. The chapter specifically focuses on coordination and responsibility equations, prevention, preparedness, and response plans, as well as the role of real-time monitoring and warning systems, along with emergency management tools. Ultimately, the chapter concludes with recommendations for harmonizing national civil protection systems.

The findings from this deliverable will contribute significantly to the BORIS2 project's subsequent phases, particularly in developing Harmonized framework for urban multi-risk assessment in scope of work package 4.

2. OVERVIEW OF DRM AT THE URBAN SCALE FOR ITALY IN 2024

2.1. Procedural frameworks for DRM

Disaster risk management (DRM) is one of the core activities carried out by the National Civil Protection Service. This means that it is an integral part of the national, regional and local Civil Protection policies. The management of civil protection risks involves a series of diverse activities, systematically divided into four interrelated phases that form a continuous cycle. The progress in each phase continuously influences the actions of the next. These phases are forecasting, prevention, emergency management, and recovery. In the following the first three are detailed, since they are more relevant to the objectives and research activities of the project.

As illustrated in Dolce et al. 2020, in the risk management cycle, **the forecasting phase** encompasses all activities focused on identifying and studying potential risk models and impact scenarios. These scenarios form the knowledge base for the National Civil Protection Service's warning alert activities related to foreseeable risks (as flood) and guide the preparation of civil protection planning at various territorial levels for all risks (including flood and seismic risks). Forecasting a catastrophic phenomenon means defining, in probabilistic terms, where, when and with what intensity it could occur, and therefore identifying possible event scenarios and their impact. This activity, understood as the assessment of a specific risk, is conducted using historical and geological data, results from empirical and/or mathematical models, and direct knowledge of the area's criticalities. However, forecasting activities are also conducted "in real time," either during or just before the event, possibly with the support of precursors and their monitoring. In such cases, the anticipated event and its potential impacts on the area can be predicted, and during the event, its accuracy and severity can be verified through ongoing monitoring and surveillance. Pre-announcement allows the National Civil Protection Service to be activated in advance, making it possible to implement the mitigation actions of the effects determined by the event, by implementing the contrast measures provided for in the civil protection plans. When citizens are reached with this pre-announcement activity, so that they can implement self-protection behaviors, the result is also an increase in the capacity and therefore higher resilience of the communities.

Prevention activities are manifold and are implemented by the Components and Operational Structures of the National Service at various territorial levels. The components of the National Service are identified in Article 4 of the Civil Protection Code (DL 1/2018 – Civil Protection): State administrations, Provincial councils, Municipalities, Mountain communities. Article 13 of Legislative Decree n. 1/2018, identifies as Operational Structures of the National Service different organizations, as: the National Fire and Rescue Service, the Competence Centers, the structures of the National Health Service, the structures in charge of the management of meteorological services at national level. Prevention is addressed to risk reduction through the implementation of both structural and non-structural actions, also carried out in an integrated form. Structural prevention measures are real works and ordinary and extraordinary maintenance actions on the territory, implemented by the competent Administrations. In the context of "passive" non-structural prevention measures we have the application and updating of technical regulations, about urban planning regulations, building codes and the activation of insurance coverage. Then there are also "active" non-structural measures, such as the preparation of civil protection plans at different territorial levels by the Authorities and the Operational Structures of civil protection, the training of civil protection operators, the dissemination of knowledge and of the culture of civil protection and the information to the population on risk scenarios, related rules of conduct and civil protection planning. In the context of BORIS2 project, the civil protection plan is an essential tool where integrate risk assessment at urban scale with the emergency management.

Emergency management is the integrated and coordinated set of measures and interventions aimed at ensuring relief and assistance to populations and animals affected by disasters and the reduction of their impact, including through the implementation of urgent interventions, the use of simplified procedures and information dissemination to the population. The nodal points of any emergency management are the activity and organization of coordination centers at various territorial levels. The **coordination centers** represent the physical place where the civil protection system carries out in a coordinated and structured way all emergency management and response operations. The activation of these centers determines a change in the working methodology: in emergency, to pursue the objective of protection and safeguard of the population, the Administrations work together organizing themselves by functions and objectives to pursue. This working method is carried out through the **"support functions"** system, as defined in the civil protection plans. The support functions represent the basic organization of each coordination center at all territorial levels (municipal, optimal context, provincial, regional, national) and are defined as specific areas of activity, functional to guarantee the choral management of the emergency context. The coordination centers implement the provisions of the civil protection plans, in which operating procedures are defined and shared to optimize alerting and activation of intervention capacity by the National Service. The goal of each center is therefore to coordinate and link civil protection activities. An example of a support function is the **"essential services" function**, which can be activated in the operational centers of the various territorial levels. This function has the objective of guaranteeing the functionality and, if necessary, the restoration of essential services (energy, gas, water, telephony, etc.), often interconnected with each other and of great importance for carrying out emergency activities. Based on the scale of an emergency, the various levels of coordination are activated according to the principle of subsidiarity, in order to support and integrate the response of the local system. On a national level, constant surveillance of the territory is ensured by the SSI-Italy's Situation Room of the Civil Protection Department, which operates on a 24/7 basis and is composed of representatives of the various Operational Structures of the system. SSI is responsible for: monitoring and overseeing the country to identify planned or ongoing emergencies and measure and monitor their progress; alerting and activating the various components and operational structures of the National Civil Protection Service participating to the emergency management. This task is carried out through the constant connection with the national operating rooms of the institutional rescue and/or public utility forces, with those of the Regions and the Autonomous Provinces, with the Territorial Offices of the Government-Prefectures, as well as with the monitoring central structures of the Bodies and Administrations that manage the networks and service infrastructures. In case of emergencies of particular intensity followed by the SSI, the civil protection system is activated by convening the civil protection Operational Committee, the highest strategic body in which representatives of the Bodies and Administrations that are part of the National Civil Protection Service are called to participate in the decision-making process.

2.1.1. Civil Protection/Emergency planning

The Civil protection planning is a non-structural prevention activity that increases responsiveness. The plan, according to the Italian regulations (DPCM 30/4/2021), is a tool that serves to increase risk awareness in ordinary time, to organize the pooling of resources, to build skills and professionalism, and to guarantee the link between different Administrations and Bodies. A civil protection plan is therefore not only the set of operational intervention procedures, but also the tool through which to define the organization of the structure needed to carry out civil protection activities: from forecasting to prevention, from emergency management to its overcoming. Among all the civil protection activities, emergency planning and management are those that most require sharing and connection between all the Components of the National Civil Protection Service and, as far as possible, the participation of the communities. This is the reason why the civil protection plan needs to foresee and plan consistent procedures and terminologies, shared and at the same time suitable for different territorial realities. The plans must be continuously updated in relation to the development of the territorial structure and changes in the expected scenarios. In addition, a plan must be flexible enough to be used in all emergencies, including unexpected ones. Furthermore, civil protection planning must necessarily be coordinated with the wider management and rehabilitation planning of the territory, within the context of a general vision of governance of the territory itself. All Administrations at different territorial levels must plan. Italian regulations provide for plans at municipal, optimal context, provincial, regional and national level. The concept of optimal context is a novelty recently introduced by the Civil Protection Code (2018) with the aim of establishing, on a geographic level and on a provincial basis, areas of organization of civil protection structures capable of optimizing resources and improving the efficiency of civil protection measures. Unless catastrophic events are so severe to cancel the territory's ability to react, the first response to an emergency must in fact be guaranteed by the local civil protection structure. The other plans must provide, according to the subsidiarity principle, for methods to support the activities put in place by the Municipalities in case of events of intensity and extent. In a plan, at the various territorial levels, the definition of operational strategies cannot be missing. They allow for: the organization of the structure for the performance of all civil protection activities; the ways to guarantee the activation and the connection for the information exchange between the various actors of the National Civil Protection Service and the definition of communication flows; the methods of periodic updating and revision of the plan and to guarantee information to the population, also during the event. In case of events that can be forecast, such as floods and partly tsunamis, the plan must also include the warning system of the structure and, according to the alerts issued, provide for increasing activations of the civil protection structure articulated in the operational phases of attention, pre-alarm and alarm, expected and defined in the civil protection plan of the various territorial levels (municipal, optimal context, provincial, regional and national). In particular, in each operational phase, a given degree of activation of the civil protection structure is provided, which allows to implement the necessary measures and contrast actions defined in the plan itself. Civil protection exercises are organized to test the effectiveness of a plan: simulations aimed at verifying the alert, activation and intervention procedures within the emergency coordination and management system, but also to make the population know both the risk to which it is exposed, and the intervention measures foreseen by the planning. Far from being a mere formal exercise, the civil protection plan constitutes the reference system, that is, the organization of the civil protection structures which must respond to a vast set of emergency situations. Civil protection planning is an activity that affects all territorial levels. At the national level, National Plans and National Rescue Programs are prepared for the management of events that may require the intervention of the entire National Civil Protection Service. The National Rescue Programs contain the intervention model for the organization of the operational response in the event or in view of national disasters where it is not possible to identify a specific reference scenario. This is the case of the seismic risk (Directive of the President of the Council of Ministers of 14 February 2014), for which it is not possible to define in advance neither the instant of the occurrence of the seismic event for which it is planned, nor the connected location and magnitude. A National Plan, on the other hand, in addition to describing the potentially affected territory, identifies the event scenario, the monitoring of the precursor phenomena of the event and the specific measures and operating procedures to be implemented.

Analyzing in more detail, the Italian regulations (DPCM 30/4/2021), the Article 2(2) introduces the hazard and risk scenarios as a forecasting activity that is functional for both alert system and civil protection planning purposes. The primary objective of each hazard and risk scenario, as part of a civil protection plan, is to define and guide decision-making activities aimed at implementing the strategic actions necessary to execute the plan itself such as the identification of operational centers and emergency areas.

Whenever possible, hazard and risk scenarios should be associated with predefined probabilities of occurrence referring to a predetermined time period, i.e., a return time or frequency as defined in reference standards, where issued, and historical events.

Several layers of information must be provided as outputs of the scenario activity for each type of risk.

For the hazard:

- delimitation of areas potentially affected by the phenomenon;
- identification of critical points (as recalled in the following for the floods);
- seismic microzonation and Emergency Limit Conditions (Condizioni Limite d’Emergenza, CLE), where existing;

Regarding the exposed elements, limited to the purposes of the BORSI2 Project, we mention:

a) delimitation of residential zones potentially affected by the phenomena;
b) census of the resident population and estimation of the floating population;
c) estimation of the number of people in socially fragile conditions and with disabilities (according to data submitted by the Regional Health Service);
d) location of strategic hospital and health facilities (e.g., hospitals, nursing homes, outpatient clinics Local Health Authorities), the headquarters of the Regions, Prefectures, Provinces, City Halls, and barracks;
e) location of relevant facilities such as public buildings, kindergartens and schools, public and private, of all levels, houses of worship, sports facilities and prisons;
f) location of major accident hazard establishments;
g) location of dams and hydraulic works of special interest;
h) identification of mobility infrastructure and essential services (power grids, water, telephone, ports, airports, roads);
i) delimitation of historic centers and aggregates;
j) delimitation of green, wooded and protected areas.

The article 18(1) of the Directive (2021) stipulates that civil protection planning must be aimed at "defining the operational strategies and intervention model containing the organization of structures for carrying out, in a coordinated form, civil protection activities and operational response for the management of planned or ongoing disaster events, ensuring the effectiveness of the functions to be carried out". Under this directive, therefore, the intervention model of planning at the various territorial levels consists of:

1) the organization of the civil protection structure, which must ensure the articulation of the exercise of the civil protection function at the territorial level, to ensure the effective performance of the activities;
2) the strategic operational elements of civil protection planning, which are the references for the implementation of the intervention model;
3) the operational procedures, which consist of the definition of the actions that the subjects participating in the management of the emergency at the different levels of coordination must put in place to cope with it, in adherence to what is established by the regional organizational and regulatory model.

For the purposes of this project, it is of particular interest to analyze point 2) referring to the municipal territory, since among others, it also identifies and describes the strategic elements/functions (more in general mentioned in the previous list from a to j) that will have to be present in the exposure model and for which we should prepare consequence and vulnerability models. Such elements are:

- **The operational coordination centers and operational rooms** (related to the previous point d). In the plan is identified the headquarters and the organization of the coordination structure, which together constitute the COC (Municipal Operations Center), in case of unusability of the headquarters of the COC, or difficulty of access to the same as a result of the event, it is appropriate, where possible, to provide in the plan one or more alternative locations also not permanent. For medium/large municipalities, with more than 100,000 inhabitants, it is useful to provide for the identification of operational centers, including mobile ones, distributed throughout the municipal territory, in connection with the COC;.
- **Emergency areas and facilities** are additional key strategic elements for relief, logistics, and population assistance activities (related to the previous point e and j), such as:
    - *waiting areas*: safe places of first gathering for the population; these can be squares, parking lots, and outdoor urban spaces;
    - *assistance areas and centers*: the former refer to field areas that enable assistance services to be offered in a short time; the latter are public and/or private covered facilities (e.g., schools,

exhibition halls, gymnasiums, military facilities), made temporarily receptive for assistance following evacuation. Also at the municipal level, other facilities that can provide rapid accommodation are those receptive facilities that should be surveyed in the ordinary period;
  - *rescuer and resource amassing areas*: places for the gathering of workers, vehicles and materials needed for relief activities in the municipal area. It is desirable, where possible, for these areas to be close to covered facilities that can accommodate rescuers and equipment, and to major road junctions;
  - *emergency landing zones*;
  - *areas for semi-permanent settlements*: for the housing needs of the population affected by serious seismic events. The identification of such areas takes into account the needs arising from the reference scenarios and includes an analysis of the safety conditions of the locations and accessibility, including for large vehicles. First and foremost, areas that do not require substantial urbanization interventions and those areas that are not urbanized but that allow, due to morphology and location, with respect to the infrastructure and service network, the completion of construction activities in a relatively short time with the use of extraordinary resources are to be surveyed;
  - *infrastructure and environmental services for emergency waste management*.
- **Accessibility.** The civil protection plan, for all territorial levels, contains an assessment of possible disruptions on the mobility system caused by events that would limit the usability of the land transport network. The primary objective is to identify the most effective measures to facilitate the movement and access of vehicles necessary to ensure rescue and assistance to the population, as well as the most effective ways to remove the population exposed to risk. In the aspects pertaining to viability management measures, the description of rail, air and sea accessibility is also reported with the identification, also with the involvement of the Managing Authorities, of the main vulnerabilities and any induced risks, where possible.
- **The territorial presidium** for flood, consists of the activity of monitoring the territory through direct and real-time observation of the occurrence of potentially dangerous precursor phenomena. The activity concerns: critical points or critical zones where, as a result of the event, situations of danger to public and private safety occur (e.g.: floodable underpasses, confluences of watercourses that may affect transportation infrastructure in the event of flooding, bridges with low light, man-made areas affected by landslides); observation points where controls can be carried out under safe conditions (for example: hydrometers, rain gauges or other points of visual control of the phenomenon).
- **Health service and care for people in socially fragile conditions**, with disabilities, and child protection.

2.2. Seismic risk assessment methods at urban scale

The main outcome of seismic risk assessment at the urban scale for the emergency management is the definition of impact scenarios, in terms of consequences of the considered seismic event(s) on people, buildings, strategic/relevant structures, and infrastructures. These scenarios are used within emergency management planning to define the resources needed to manage the emergency, and to identify operational centers and emergency areas.

The main indications to derive these scenarios are provided by recent National Civil Protection Guidelines in DPCM 30/4/2021. Further indications are provided by Guidelines issued by local (i.e., regional) authorities, that in several cases were issued before the above-mentioned National Guidelines but, generally speaking, are broadly consistent with them, and often provide more detailed indications. However, the indications provided by these (national and local) documents do not represent a sufficiently detailed source of information for all the phases of derivation of a scenario; several choices are up to the responsibility of the expert in charge of the redaction of the emergency plan. These issues will be discussed below.

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The scenarios have to include a description of the procedure and methodology adopted to derive them and an assessment of the consequences of the event(s) on people, buildings, structures and environment, along with their cartographical representation.

In the following, the steps and procedures needed to derive these scenarios are described in detail, in terms of hazard, exposure, fragility and consequence models, consistent with the above-mentioned documents and, when the indications provided by these documents are not sufficiently detailed, describing the most widespread, common approaches usually adopted.

If available, the CLE (*Condizione Limite per l'Emergenza*, Limit Emergency Condition) document has to be considered, too. The characteristics of this document are described in detail in the next Section.

2.2.1. Hazard model

Seismic scenarios provide a practical framework for representing the ground shaking anticipated from a specific earthquake impacting a given region. The ground motion associated with these scenarios can be evaluated empirically using regression models, numerically, or through a combination of both methods. To properly assess the magnitude and severity of the target scenario, a probabilistic approach is used. This involves selecting an event with a specified likelihood of ground motion being exceeded at a particular site within a given time frame, typically through the disaggregation of a probabilistic seismic hazard analysis (Bazzurro and Cornell, 1999). The likelihood threshold is determined in advance, based on various considerations such as potential impact and acceptable risk levels. The target ground motion intensity measure is often selected from peak ground motion parameters (e.g., PGA, PGV) or pseudo-acceleration from the damped response of single-degree-of-freedom systems across different periods. For instance, the Italian National Guidelines (DPCM 30/4/2021) specify a peak ground acceleration (PGA) with a 475-year return period, corresponding to a 10% probability of exceedance within 50 years, assuming a Poisson occurrence model. This data, officially mapped for the Italian territory by the National Institute of Geophysics and Vulcanology (INGV), is used in seismic design as prescribed by the National Technical Code (NTC, 2018). Such calculations are performed assuming standard rock conditions. However, to account for the variability induced by local geological effects - such as amplification due to soft sediments, resonance and basin effects, or topography - site-specific correction factors can be applied, often derived from seismic microzonation studies (Moscatelli et al. 2020).

Note that in some cases (e.g., the Campania regional Guidelines 2013) indications are provided to derive a further scenario for another event, too, i.e., a 98-year return period event, corresponding to a 40% exceeding probability in 50 years, assuming that a 475-year and 98-year return period events correspond to a national-level and a local-level emergency, respectively. The same return periods are often used in the context of Emergency Limit Condition, for applying the SMAV procedure (illustrated at §2.2.5), as specifically developed for assessing the operational level of strategic buildings.

2.2.2. Exposure model

The derivation of a given scenario leads to the assessment of the impact on people, buildings, strategic/relevant structures, and infrastructures. Therefore, the first phase of this procedure consists of the collection of information regarding the following system components, see also Figure 2.1:

- Census of the resident population, with the estimation of the floating population and of the number of people in conditions of social fragility and with disabilities (according to data transmitted by the regional health service).
- Delimitation of residential settlements potentially affected by the phenomena of interest.
- Location of:

  - strategic hospital and healthcare facilities (e.g., hospitals, nursing homes, local health authority clinics), regional offices, prefectures, provinces, municipalities, and barracks
  - relevant structures such as public buildings, nurseries, schools (public and private, of all levels), places of worship, sports facilities, and prisons
  - cultural heritage sites, such as museum hubs, cultural sites like museums, archives, and libraries
  - production and commercial structures, with reference to shopping centers and medium-large-scale production activities, agricultural and livestock farms, as well as kennels and catteries
  - industrial plants at risk of significant accidents
  - dams and hydraulic structures of particular interest
  - historical centers and aggregates
  - green, wooded, and protected areas
- Identification of mobility infrastructure and essential services (electric, water, and telephone networks, ports, airports, road networks).

Note also that some of these components may not be identified in all Municipalities.

Currently, we have national databases on schools, hospitals and bridges with information with different level of detail, e.g.:

for some bridges we know all the characteristics needed to elaborate a detailed model, for others only information for a simplified model and finally for some bridges we know only the position;
for many school buildings we know the structural typology, the number of floors and the construction period;
for many hospitals of the emergency network we know the structural typology, the number of floors and the construction period.

Base-level information regarding the population and the residential buildings is provided by ten-year ISTAT (*Istituto Nazionale di Statistica*, National Institute of Statistics) census data. These data are freely available and provide information on population and residential buildings aggregated at "census track" level, i.e., within roughly equally populated sub-municipal areas. The information of interest for a seismic vulnerability (and fragility) assessment provided by ISTAT are the number of storeys, the structural material (masonry or reinforced concrete) and the age of construction.

If the local administration can provide the expert with more detailed information, up to building-by building non-aggregated data – sometimes collected for real estate tax reasons, these data can be used.

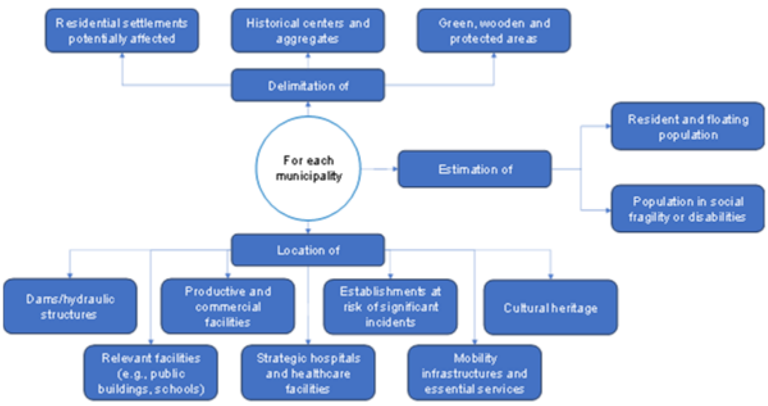


Figure 2.1: Identification of system components for each Municipality.

For single strategic/relevant structures and infrastructures, data must be collected by the expert, supported by the Municipal technicians.

As an example, Figure 2.2 depicts the number of residents for the census tracts in an area of Genoa municipality evaluated based on the ISTAT 2011 database.

Moreover, Figure 2.3 and Figure 2.4 illustrate, for the same area, the data concerning the structural typology (i.e. material) and age of construction as obtained respectively from a survey building by building (a) or from census ISTAT data. As aforementioned, usually municipality rely on census data while it is less common to have building by building data.

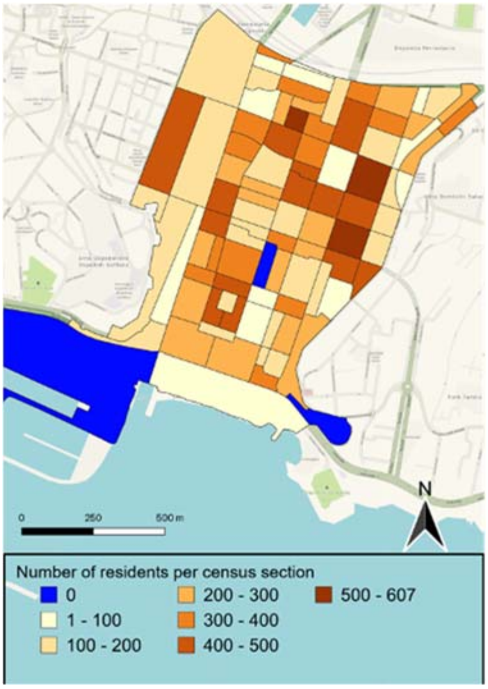


Figure 2.2: Distribution of the number of residents per census section (by way of example as extracted by ISTAT census data in an urban block of Genoa municipality).

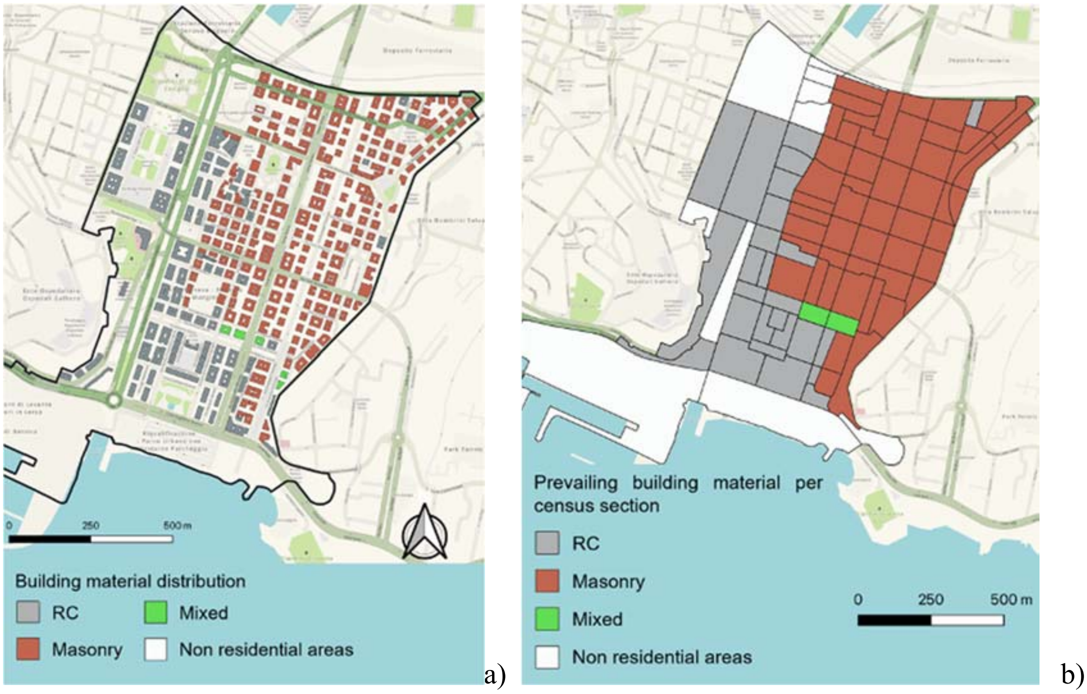


Figure 2.3: Distribution of the structural typology in terms of material (a) building by building or (b) per census section (by way of example as extracted by ISTAT census data in an urban block of Genoa municipality).

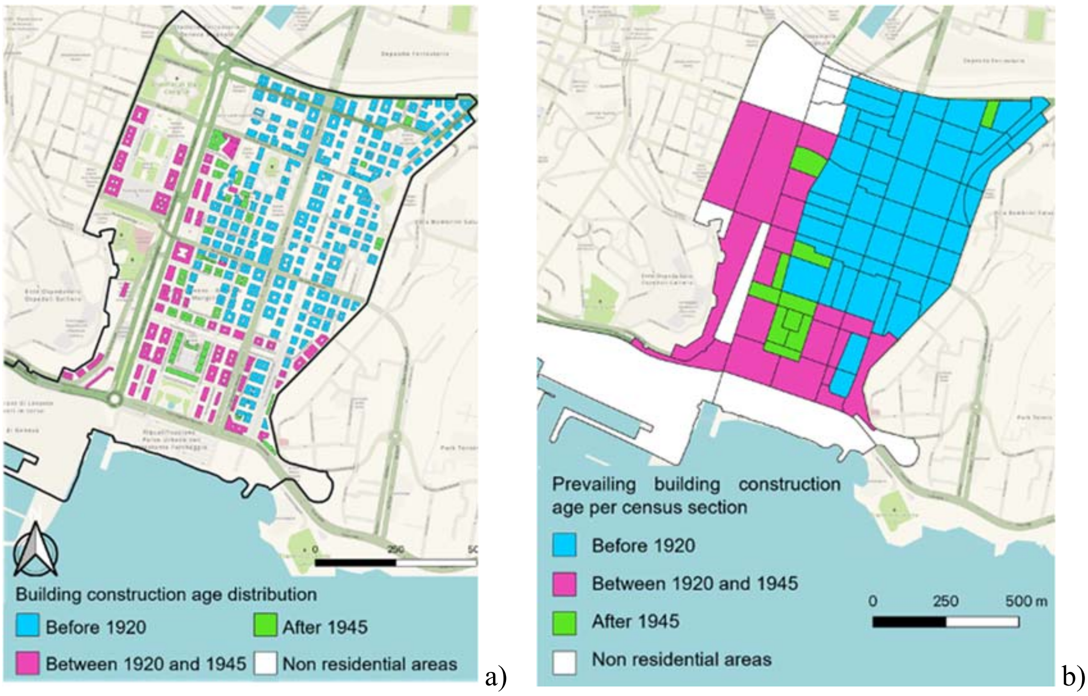


Figure 2.4: Distribution of the age of construction in terms of material (a) building by building or (b) per census section (by way of example as extracted by ISTAT census data in an urban block of Genoa municipality).

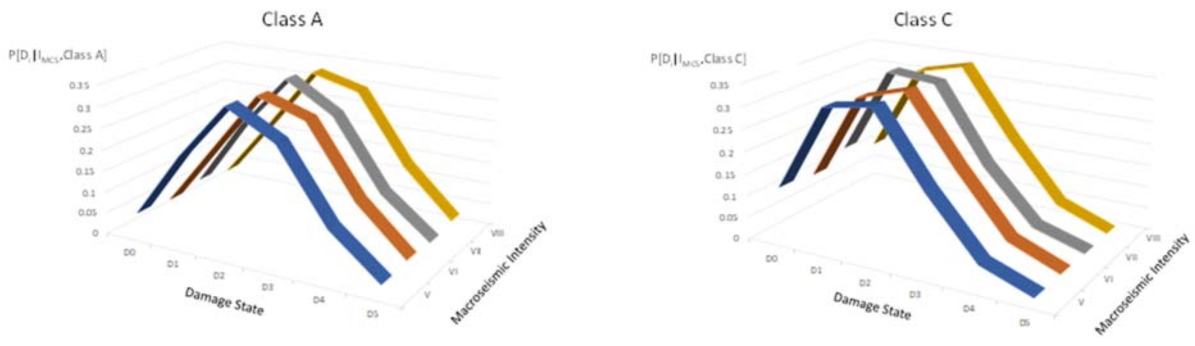
2.2.3. Vulnerability model

The assessment of the expected damage to the structures subjected to the seismic event is based on the application of a vulnerability and fragility assessment methodology, of course. From this point of view, there is a lack of specific, prescriptive indications in the Guidelines, and fragility models from literature have to be selected and adopted.

However, in any case, fragility models consistent with the available information level shall be adopted. If more detailed data about building stock is not available (likely, the most common case), ISTAT census data, aggregated at census track level, should be used. Hence, the vulnerability assessment has to be performed only based on buildings' number of storeys, structural material (masonry or reinforced concrete) and age of construction. Due to the limited amount of information available, a typical approach to vulnerability assessment is the classification of building stock into vulnerability classes. This classification can be consistent with the most widespread vulnerability models, e.g., EMS-98 (Grunthal 1998).

Even if simplified methods are used, compatible with large-scale low-information vulnerability assessment procedures, some working hypotheses are necessary to fill the gap between the available information level and the input data necessary to apply the model. One of the possible reasons for the adoption of these hypotheses is that census data are aggregated, therefore, if the goal is the determination of the number of buildings within a census tract with a specific number of storeys *and* with a specific structural material *and* with a specific age of construction, it is not possible based on census data only, but it is possible assuming – for example – that masonry buildings are always shorter and older than reinforced concrete buildings.

Many of the simplified large-scale vulnerability assessment methodologies are observational-based, and some of them are based on macroseismic intensity rather than instrumental intensity. In these cases, the hazard in terms of peak ground acceleration can be translated into the corresponding macroseismic intensity measure through appropriate empirical relationships. For instance, Figure 2.5 depicts the probability density functions derived for building classes A and C (EMS-98 scale) starting from the Damage Probability Matrix provided in Zuccaro and Cacace (2015). A classification of the building stock according to vulnerability classes consistent to the EMS-98 scale has been also recently done in the MARS project (Lagomarsino 2022, Lagomarsino and Masi et al 2021).



(a) (b)

Figure 2.5: Probability density functions derived from the Damage Probability Matrix for building classes (a) A and (b) C, defined according to the EMS-98 scale.

Finally, the outcome of the application of a fragility model for a seismic scenario has to be expressed in terms of expected damage to buildings (or, better, to groups of buildings), conditional on the seismic intensity defined by the hazard model. Different damage measures can be adopted, but a consistency with most widespread damage scales – such as, again, EMS98 – is desirable and usually pursued.

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Project co-funded by the European Union Civil Protection

Hence, assuming for example a 1-to-5 scale of Damage States, the outcome is typically represented by a damage index obtained as the average expected damage index and/or by the expected percentage (and therefore number, too) of buildings in each Damage State within each census tract.

Figure 2.6 illustrated the average damage index for the examined area in Genoa under a seismic action compatible with 475 years. The damage scale is from 1 to 5; the low values in this case are justified by the low seismic hazard of the area. Please consider that these figures are just to provide a graphical demonstration of possible achievable results.

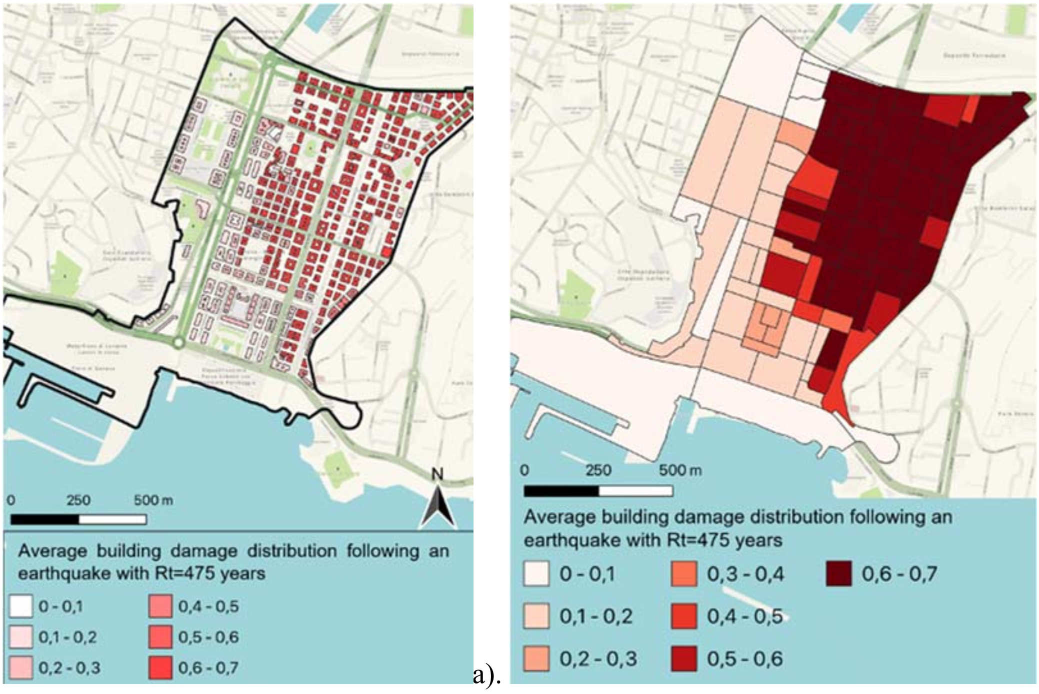


Figure 2.6: Damage distribution of buildings depicted at (a) building by building scale or (b) ISTAT census scale (the scale of damage is from 0 to 1).

For strategic/relevant structures or infrastructures, a single-structure, less approximate fragility assessment can be carried out, with more refined yet still simplified methods, whose development – especially for structures such as bridges – is currently ongoing. Also, in this case the output should desirably consist of a damage measure, rather than the information about the fulfillment (or not) of a conventional safety check. However, these single structure/infrastructure assessments are quite uncommon.

2.2.4. Damage and Impact Indicators

Once a fragility assessment is performed, its outcome can be used for the last step of the seismic scenario derivation procedure, i.e., the definition of the impact of the event, in terms of expected losses affecting population and functionality of buildings, structures and infrastructures. More specifically, the following data should be evaluated (see Figure 2.7):

- Deaths, injuries, homeless individuals.
- Collapsed, unusable, and damaged residential buildings.
- Functionality of:
    - hospitals

- strategic buildings, including emergency management centers
- relevant public buildings
- industrial plants at risk of significant accidents

– Functionality of infrastructures for mobility (such as the road system, including the study of interrupted routes and alternative routes) and related to essential services (with possible interruptions in the supply).

Furthermore, possible cascade events due to earthquake-induced hazards, such as landslides and tsunamis, should be assessed, as explicitly stated by some regional Guidelines, but – again – they rarely are.

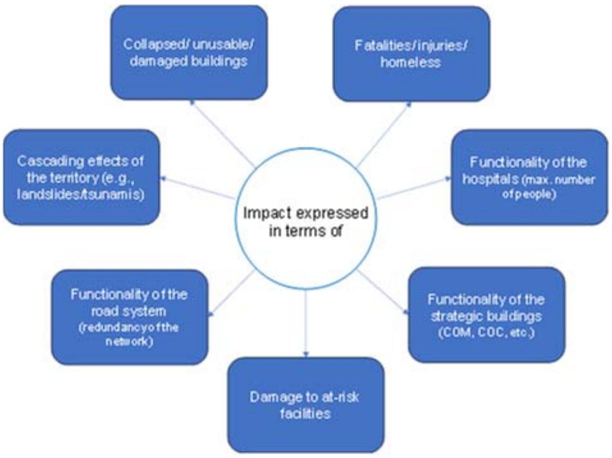


Figure 2.7: Representation of the impact for a Municipality and a given scenario.

The functionality assessment of hospitals, categorized by specialty, should be aimed at identifying the maximum number of people that can be assisted with existing facilities, treatment times, and the need for field hospitals.

To evaluate the above-listed data, loss models from literature, consistent with the adopted damage scale, should be used. This operation is quite straightforward for the estimation of direct losses affecting the population (i.e., deaths, injuries) and the residential building stock (i.e., buildings' usability), thanks to well-established loss models in literature, starting from the expected damage to these buildings. One of these models was proposed by Zuccaro and Cacace (2011a), as recalled later. This model provides the expected percentage of injuries and deaths within buildings' occupants, as a function of buildings' typology and Damage State, starting from the number of residents and accounting for the effective occupancy rate, too, and was validated on data from the 2009 L'Aquila event. The assessment of the functionality of strategic/relevant buildings and infrastructures for mobility can be carried out with reference to code-based serviceability Limit States, with a conventional yet generally conservative approach. The assessment of the functionality of infrastructures for services can be more challenging.

Other examples of the estimate of losses (also economic losses) at national scale – through models that can be used also at municipality scale – are the ones used for supporting the National Risk Assessment (i.e. Lagomarsino and Masi 2021 , Dolce et al. 2021).

By way of example, Figure 2.8 illustrated for the same area in Genoa the percentage of buildings expected to be unusable.

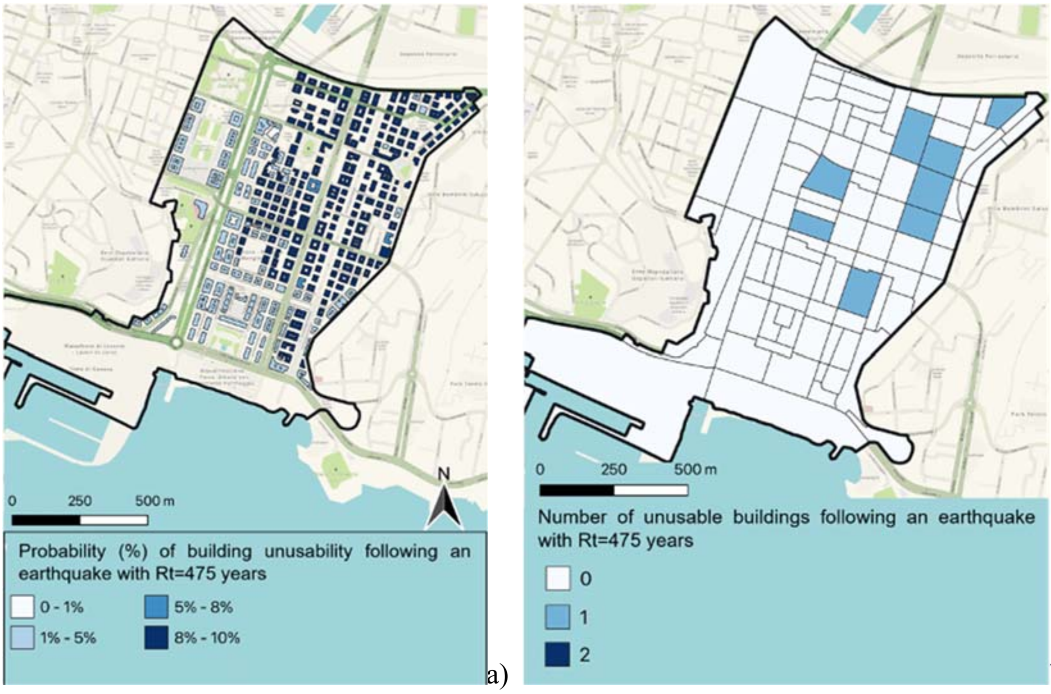


Figure 2.8: Probability (%) of unusable buildings depicted at (a) building by building scale or (b) ISTAT census scale.

2.2.5. Emergency Limit Conditions

The Italian Civil Protection Department outlined specific Limit Conditions (LC) for urban settlements (Dolce et al., 2019, and Bramerini et al., 2013), which were intended to specify the explicit target/objectives that mitigation plans should be defined accordingly in the course of various risk management cycle's phases (i.e., pre, post, and during disaster (Terzi et al., 2022). The LCs correspond to different conceptual thresholds. The conceptual thresholds set out by the LCs describe the physical and functional damage levels of the urban system and its constituent parts. Urban systems would lose a certain level of their functionality if any of the established LC thresholds were exceeded as a result of an earthquake (Figure 2.9). The main objectives of LCs are in line with the goals of specified limit states in Standards and Codes, but at a larger scale than that of a single building, i.e.: i) ensuring the safety of the settlement's residents' life; ii) protecting the buildings and infrastructures that compose settlement; iii) preserving the environmental and the social identity of the urban system (Cattari et al., 2024). Among these LCs, the Emergency Limit Condition (ELC) for an urban system corresponds to the condition in which the entire system suffers physical and functional damage enough to produce the interruption of almost all its urban functions (essential instead in the recovery phase), except for most of its functions strategic for guaranteeing the emergency operations and the connection and accessibility of the urban settlement with its surroundings. The objective of ELC is thus to ensure emergency management following a disastrous event.

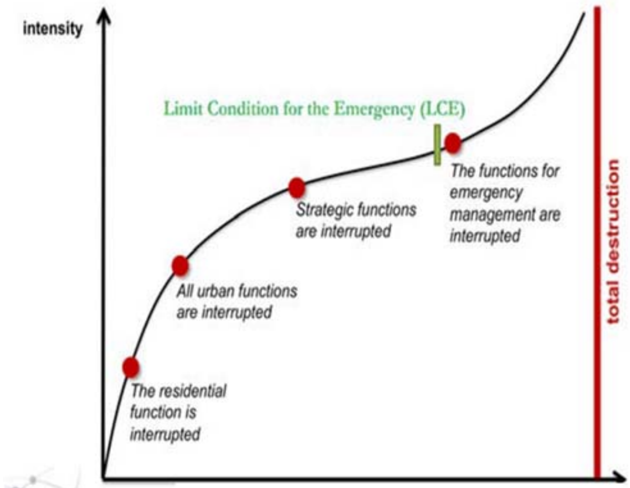


Figure 2.9: Loss of functionality of the urban system.

The Italian Civil Protection Department has already delineated the main components aimed to assure the operational level of the ELC, i.e.:

- critical elements identified in the contingency plan essential for emergency management (such as buildings and designated areas):
    - strategic buildings (ES), each associated with a specific strategic function (FS) crucial for emergency management (e.g., emergency coordination, medical assistance, operational intervention, emergency sheltering);
    - emergency areas (AE), including areas designated for various emergency purposes such as shelters and storage areas for materials and goods necessary for emergency management;
- the road network connecting critical elements, including roads providing access to the urban subsystem under investigation; road network (RA), defined by minimal road segments with consistent features, bounded by nodes positioned at access points to the system, strategic function locations, emergency areas, and standard road intersections;
-

Moreover, also the interfering buildings comprising all regular buildings situated along the aforementioned road network and emergency areas, whose collapse could impede the functionality of these strategic components (data collection regarding geometric and structural features are the same that required for strategic buildings) play a role in the operationality of the ELC system. Such interfering buildings are composed of structural units (US) and structural aggregates (AS), consisting of contiguous structural units whose vulnerability and anticipated damage may escalate due to adverse structural interactions.

Specific forms have been already outlined by the Italian Civil Protection Department to collect in a standardized way useful data to describe the features of all components above introduced (Bramerini et al., 2014). A specific form targeted to each of the components has been outlined. The forms comprise sections covering general information about the asset (such as location, address, and building identification), structural features (such as number of stories, vertical load-bearing structure, and structural damage) with a specific part related to other hazards (such as if a landslide interfere with the building, presence of active fault, and if the area is a prone flooded area), and specific characteristics (such as strategic function, construction period, and intended use). An example of the ELC for a portion of the Municipality of Genoa is provided in Figure 2.10.

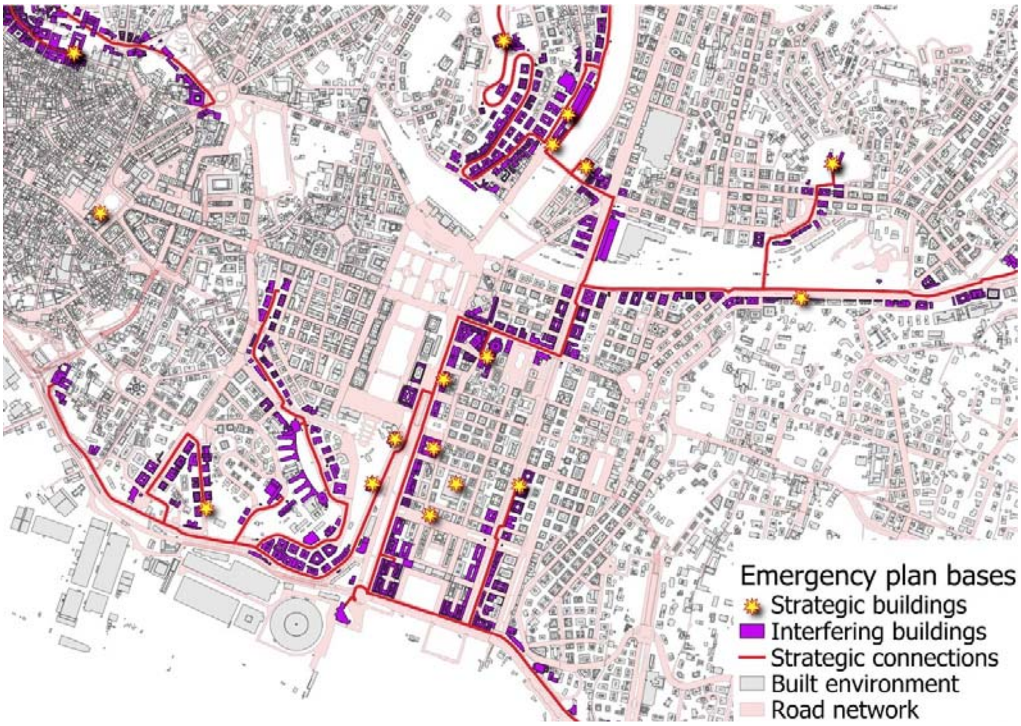


Figure 2.10: Schematic representation of the ELC system for a portion of the Municipality of Genoa.

As of today, the Italian Civil Protection Department requires municipalities to identify all components of the ELC and fill the forms for each element within the urban settlement. Subsequently, municipalities are asked to transfer all collected information into a specific software (SoftCLE). It's important to note that the ELC method doesn't require in a mandatory way for the administration a seismic assessment of the system, although some methods have been already developed that make use of the data collected to assess the performance of the system.

In addition, the National Department of Civil Protection extra developed two tools to supporting the planning and assessment of emergency system, namely the I.OPà.CLE method (Dolce et al. 2018) and SMAV method (Spina et al. 2021). However, the first is still in a test phase and up to now used essentially at national scale while both methods are not yet mandatory for municipalities. In the following a brief description of SMAV method is reported while I.OPà.CLE method is illustrated at §2.2.6.

The SMAV procedure (Seismic Model from Ambient Vibrations) is addressed to define the operational level of strategic buildings on basis of measurements acquired from Ambient Vibration Test (Spina et al. 2021). The model is based on the identification of the building experimental modal parameters from ambient vibration together with few information about its geometry and constructive typology. The dynamic response of the structure is obtained by a modal superposition where all the inertial properties are concentrated in the center of gravity of the floors or floor sections. The procedure can be used to support the identification of strategic structures to be included into the LCE system. The use of SMAV procedure is not yet mandatory at municipality scale.

2.2.6. Tool (platform) for seismic risk assessment at urban scale

I.OPà.CLE method (Indices for evaluation of the Operational efficiency of Limit Condition Emergency) was established by Civil Protection to have a tool capable of evaluating the physical efficiency of the ELC system. The ELC system, defined for numerous municipalities on a national scale, determines a standard procedure to identify the necessary component for the emergency plan operability. Instead, the role of the I.OPà.CLE method is to evaluate these components in the event of an earthquake to ensure their operability during the emergency phase. Up to now, this method has been tested by the National Department of Civil Protection and is not still a standard tool adopted by Municipality.

I.OPà.CLE method is basically aimed at supporting civil protection decision makers in evaluating emergency systems and establishing strategies and priorities concerning strengthening interventions at municipality level. The method provides an operational efficiency index ($I_{Op}[CLE]_T$) of the entire system, as the product of the subsystem indices relevant to Strategic Functions ($I_{Op}[FS]_T$), Emergency Areas ($I_{Op}[ARE]_T$) and Sheltering, and Infrastructural links ($I_{Op}[CO]_T$). The method has been specifically tailored for a minimum homogenous information level, obtained at municipal scale from the above mentioned LCE analysis, collected in the SoftCLE software, providing standard datasets to run probabilistic analyses. Concerning the hazard, two different seismic events with different return periods are usually considered in the I.OPà.CLE method: T = 98 and T = 475 years, respectively associated with exceedance probabilities of 40% and 10% in 50 years; moreover, also a T=0 is considered, i.e. related before the occurrence of the earthquake. Vulnerability models for the analysis of interfering or strategic buildings are based on damage probability matrices conditional upon macroseismic intensity; for the other components (emergency areas and infrastructure links) other approaches for calculating the operability index are described in Dolce at al. (2018).

By providing results at different levels (from individual elements to subsystems and whole system), I.OPà.CLE enables the user to easily identify the specific criticalities of the case under investigation, and hence to find out the most appropriate mitigation strategies and interventions for enhancing the contingency planning. A very low index can be produced either by a system with few low-performing elements or by one with several high-performing elements. From a probabilistic point of view the two systems are equivalent, while they are not from the point of view of potential criticalities of the emergency plan. In fact, such indicators have more functionality when used for comparative purposes to evaluate the system when intervening on the most critical elements, or when removing certain elements when the system appears to be redundant.

Since 2023, the I.OPà.CLE method has been implemented in an online platform for the exclusive use of the Italian Civil Protection Department. Figure 2.11 shows the Homepage of the platform and Figure 2.12 the page with the results.

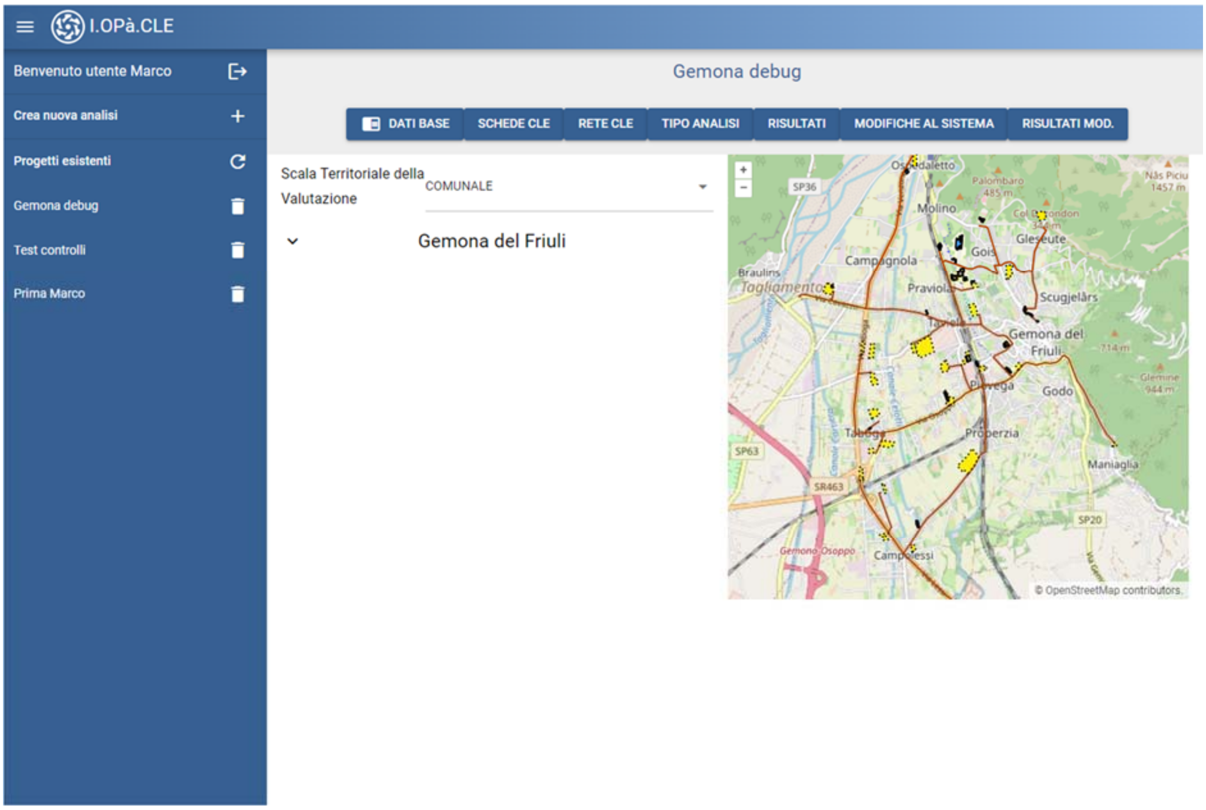


Figure 2.11: Homepage of the I.OPà.CLE platform.

Figure 2.12: Results page from the I.OPà.CLE platform.

2.3. Flood risk assessment at urban scale

The risks of negative consequences in case of floods could be reduced through both structural interventions such as embankments, reservoirs, draining channels, artificial canals cutting meanders, and non-structural interventions, such as safeguard rules on areas at risk, the alert system and emergency plans. The objectives of Boris2 project are addressed to the last two measures: the alert system (as framework) and the emergency plans, for its definition and development. Furthermore, this chapter introduces and describes some concepts and issues for a flood risk assessment evaluation at urban scale to implement in support of emergency management/planning. This type of analysis is developed in the prevention phase, pre-event, to produce scenarios to be used in time of event and with related alerting.

The alert system is a collection of procedures and activities that rely on probabilistic event forecasts and their potential impacts. This system activates the National Civil Protection Service to implement non-structural prevention measures, with a primary focus on protecting human life. The Civil Protection Department, along with the Regions and Autonomous Province, is responsible for managing the national alert system. The national alert system is the one for hydrogeological and hydraulic risk, defined by the DPCM 27/02/04, containing the "Operational guidelines for the organizational and functional management of the national and regional alert system for hydrogeological and hydraulic risks, for civil protection purposes". The management of the system is managed by the network of Functional Centers, subjects that develop real-time forecasting, monitoring and surveillance of events and assessments of the consequent effects on the territory. The network of Functional Centers is constituted by a CFC-Central Functional Center, at the Civil Protection Department, and by CFD-Decentralized Functional Centers, at the Regions and the Autonomous Provinces. Each Functional Center is responsible for collecting and distributing a range of data and information to the entire network of Centers. This data is sourced from various technological platforms and an extensive network of sensors located across the country, as: data collected by weather-hydro-pluviometric networks, by the national meteorological radar network and by the various satellite platforms available for Earth observation; hydrological, geological, geomorphological and territorial data deriving from the landslide monitoring system; meteorological, hydrological modeling, hydrogeological and hydraulic modeling. Based on the collected data and models, the Functional Centers conduct forecasting activities by generating expected probabilistic scenarios. They use this analysis to issue Bulletins and Warnings, detailing both the evolution of anticipated or ongoing phenomena and the assessed levels of criticality (including the type, extent, and severity of landslides and floods) within their jurisdiction. It is the responsibility of the Regions and Autonomous Provinces to issue alerts within their territories, using a color code system (Yellow, Orange, and Red) that reflects the forecasted risk level. Mayors then use this information to activate Civil Protection Plans, inform citizens of potential risks, and determine necessary actions to protect the population. The monitoring and surveillance phase, described above, aims to provide real-time information on the progression of an ongoing event through the collection, centralization, and sharing of data, as well as locally obtained non-instrumental information. To achieve this, monitoring and surveillance activities are complemented by on-the-ground surveillance, which is carried out through territorial safeguards organized at the regional, provincial, and municipal levels. This local surveillance gathers firsthand information on the actual evolution of the event and communicates it to the network of Functional Centers and relevant authorities via regional operating rooms.

Focusing on the emergency planning, the main indications to derive hazard and risk scenarios are provided by recent National Civil Protection Guidelines (DPCM 30/4/2021), where it is established that for hydrogeological, hydraulic and adverse weather hazards, also for the purpose of more effective alert system, it is necessary to develop the "event scenario" (DPCM 27/02/04). The event scenario should describe the phenomena that may occur in the area under consideration, defining their frequency and intensity, the areas affected, the directions along which trigger points can be expected to develop, and other information useful for understanding the essential characteristics of the phenomena. For the definition of the flood risk scenario at urban scale for the emergency management, it is necessary to refer to the following models.

2.3.1. Hazard model

In Italy the first reference for the flood hazard assessment is the hazard areas reported in the Hydrogeological Structure Plans (PAI), and in the Flood Risk Management Plans (FMPs) coordinated at the river basin district level. The maps contain the perimeter of the geographical areas that could be affected by the flooding of a watercourse according to the following scenarios:

- low probability of floods or extreme event scenarios;
- medium probability of floods;
- high probability of floods;

Indicating the following elements for each scenario:

- extension of the flood;
- water height or level;
- flow characteristics (speed and flow rate).

In this framework, the National Civil Protection Guidelines (DPCM 30/4/2021) establishes that, the main reference for the emergency management could be the highest hazard areas perimeter for the lowest return times (20 to 50 years), which correspond to the high criticality level provided by the warning system for hydrogeological and hydraulic risk. This guideline should be taken as a first scenario on which to develop planning, which needs to be completed for the other hazard scenarios corresponding to higher return times for which PAI/ FMPs provide scenarios of higher magnitude, but less frequent. Regarding hydraulic risk, the hazard mappings found in PAIs and/or FMPs may be insufficient because: (I) they typically only cover the main watercourses and parts of the secondary network; (II) they do not account for local flooding phenomena, such as those caused by the insufficiency of urban drainage systems; and (III) they are usually based on the assumption that hydraulic works are functioning perfectly, without considering the potential impacts of embankment failures. In this case, it is possible to identify areas of potential hydraulic/hydrogeological risk based on documents on past events and studies on possible local flooding and overflow mechanisms, in the possession of the agency concerned. In recent decades, urban flood hazards have been extensively studied, leading to the development and application of advanced numerical models to assess water depths and velocities during floods. As noted by Arrighi et al. (2013), flood propagation in urban areas is distinctly bidimensional, influenced by the complex interactions between floodwaters and the street/building layouts, particularly in densely built historic town centers. While 1-D numerical models are often considered sufficient for estimating flood water levels in rivers with regular flow patterns and for preliminary identification of inundation zones, more complex river geometries and detailed mapping of local parameters necessitate the use of 2-D models. In general, CIMA adopts the TELEMAC-2D model.

Despite, flood risk estimates only based on flood maps are reliable if the area of interest is relatively small (as the urban context object of the BORIS2 project), it is suggested to generate all possible flood events that can affect the area of interest with their probability of occurrence. The hazard maps provide water levels in flood prone areas for different return periods, but they do not represent flood events. It is necessary to generate all possible flood events that can affect the area of interest with their probability of occurrence. The aim of the flood events generation is the simulation of all the possible events that can affect different areas of the region with different intensities. To simulate possible flood scenarios the output of the in terms of discharges, in different locations of the river network, was analyzed to select independent flood events. The methodology that CIMA uses for the events generation relies on a multivariate statistical approach that takes in input the selected events and, by preserving their spatial correlation, it can simulate events not yet observed both in terms of intensities as well as geographical distribution. The approach used for the events generation covers all the possible range of intensities and spatial dependencies and assures that:

- the spatial correlation of small- and large-scale events is preserved in the simulated event set;

– the statistical properties of the observed events at each location is preserved in the simulated event set.

The event generation process consists of two components: the first one is the event definition and selection, and the second one is the probabilistic events generation. The event selection is based on a consolidated approach that balances the need of capturing small scale events and the limited computational resources during the flood generations process. The entire country is divided into hydrological units: the event selection process identified localized events affecting only one unit and more distributed ones affecting several units contemporary. These events, characterized by their maximum discharge over the event duration for each hydrological unit, were the basis for the probabilistic scenarios' generation. The probabilistic approach is based on a probability domain perturbation of the selected flood events via a multivariate gaussian distribution and uses a gaussian transformation in the probability domain to improve the representation of the tail dependencies and overcome boundary issues.

2.3.2. Exposure model

In the definition of the exposure model, it is necessary to recall two characteristics of the BORIS2 project: i) the urban scale; ii) the emergency management purposes.

The small scale of analysis, such as the urban context called in the following micro-scale, suggests that the exposure model could be defined in a very precise and local way starting from the localization of the building footprints. The built-up area exposure data are the main element for the people and economic evaluations. Three main categories of data are identified: (a) data regarding the geometrical features (as the built-up area extent, …), (b) the economic values and (c) the vulnerability characteristics (as the construction typologies data, occupancy type, number of stories, …). For each of these data, a series of different products can be used, which change in terms of resolution, both in terms of spatial scale and in terms of detail, according to the availability of country and municipality of the case study. The census section system is an optimal data source, offering a good balance between the aggregation scale of various socio-economic data and the spatial detail needed for urban micro-scale studies. Census section polygons form an irregular mesh that covers all areas with human activity, typically becoming denser where population density is higher. In Italy, for example, census sections often align with building blocks in densely urbanized areas. Every European country has a national statistics office that conducts censuses of population, housing, and commerce, making the micro-scale census section approach applicable across many countries.

For what concern the emergency management, as introduced in the §2.1, it is important to locate in the model traditional elements as residential buildings and population, and specific ones as:

- strategic hospital and healthcare facilities (e.g., hospitals, nursing homes, local health authority clinics), regional offices, prefectures, provinces, municipalities, and barracks;
- relevant structures such as public buildings, nurseries, schools (public and private, of all levels), places of worship, sports facilities, and prisons;
- dams and hydraulic structures of particular interest;
- Identification of mobility infrastructure and essential services (electric, water, and telephone networks, ports, airports, road networks);
- People in conditions of social fragility and with disabilities could be appropriate to include.

2.3.3. Vulnerability model

As stated in Arrighi et al 2013, flood damages are commonly classified into direct and indirect. Direct damages result from the physical impact of water on people and objects, while indirect damages stem from these direct impacts and occur outside the flooded area. These damages can be further categorized into tangible and intangible types, based on whether they can be quantified in monetary terms. Flood risk studies generally emphasize direct tangible damages because intangible damages—such as loss of life, disruption of public services, and trauma—are challenging to quantify. Damage models are typically developed at a macro scale (e.g., regional level with municipal details) or meso-scale (e.g., municipal level with raster mapping at approximately 100-meter resolution), utilizing land use databases and regional statistics. In contrast, recent studies focusing on micro-scale flood damage assessment face significant challenges due to their dependence on privately-owned economic data in addition to georeferenced land registry data.

Damage models are based on stage–damage curves to merge water level and land use maps or building footprint according to the scale of analysis. Libraries of stage–damage curves are available in literature (Huizinga et al. 2017, Scawthorn et al. 2006) or can be created, at meso- or micro-scale, collecting data after flood events or synthetically by experts.

For flood risk assessment in urban areas one crucial issue now is the pursuit of an adequate and significant scale of analysis supported by adequate information at the same level of spatial detail. The micro-scale approach is crucial, as it allows the specification of buildings and commercial characteristics that form the basis for assessing the similarities between distant urban areas. Although census databases provide extensive information, adopting a comprehensive quantitative approach at the micro-scale still should require on-site inspections. These inspections are crucial for gathering additional details about building characteristics and commercial activities needed to refine local stage-damage curves, particularly when such curves are based on literature. However, these inspections are often restricted to a limited number of representative samples for each category considered

It is also important to check for specific vulnerability models for those buildings defined as strategic for emergency management as introduced in the §2.3.2.

2.3.4. Damage and Impact Indicators

After applying the stage-damage function, percentage losses can be converted into economic losses using monetary value maps for each category. While direct monetary values are often unavailable at the micro-scale, proxy variables can be used to estimate these values from regional and sectorial economic studies. For instance, real estate market value may serve as a proxy for the value of structures and household contents, while annual business income can act as a proxy for commercial content value. However, these proxy variables are typically not accessible at the individual level (e.g., household or business) due to privacy concerns or data market value and are usually available only at a more aggregated level in various databases.

The physical impact on population, named also 'human impact', follows a slightly different approach, since the damage is not calculated as a percentage but just as an evaluation if the person is or is not affected by the hazardous phenomenon. Therefore, also the functions are slightly different. In the simplest case, the function is just a binary affected/not affected. A further detail allows us to classify affected people in different hazard zones. Four hazard zones (very high, high, moderate, low flood hazard) are defined based on the human instability in floodwaters, using available literature (Abt et al., 1989; Karvonen et al., 2000) together with expert judgments.

The resulting four flood hazard zones, considering different ranges of water depth (h) and water velocity (v) are:

- very high hazard zone, when $hv \geq 5\ m^2\ s^{-1}$ and $v \geq 2\ m\ s^{-1}$
- high hazard zone, when $h \geq 0.2$ m and $hv > 1.35\ m^2\ s^{-1}$
- moderate hazard zone, when ($h < 0.2$ m and $hv > 1.35\ m^2\ s^{-1}$) or ($0.5 > h \geq 0.2$ m and $v > 1$ and $hv < 1.35\ m^2\ s^{-1}$) or ($h > 0.5$ m and $hv < 1.35\ m^2\ s^{-1}$)
- low hazard zone, when ($h < 0.2$ m and $hv < 1.35\ m^2\ s^{-1}$) or ($0.5 > h \geq 0.2$ m and $v < 1\ m\ s^{-1}$

When information on water velocity is not available, similar zoning classification is performed only based on water depth information.

Obviously, the level of accuracy of the data on population influences the level of analysis that can be potentially developed. In fact, the availability of the simple spatial distribution of the population, without classification according to vulnerability-prone characteristics, would allow to perform a basic analysis, with the evaluation of people affected within the considered scenarios. If the population statistical distribution is added, instead, it could be possible to evaluate also the typical social-oriented impact indicators (e.g., number of children in school age affected). Whenever specific requests come from the stakeholders, ad hoc elaboration of the indicators could be developed, thus providing also a set of customized indicators.

2.3.5. Tool (platform) for flood risk assessment at urban scale

Rapid Analysis and Spatialisation Of Risk (RASOR) project (Arrighi et al., 2018) developed a platform to perform flood and multi-hazard risk analysis to support the full cycle of disaster management. This tool can be applicable at different scales, including the urban ones. In particular, RASOR uses a scenario-driven query system to allow users to simulate future scenarios based on existing and assumed conditions, to compare with historical scenarios, and to model multi-hazard risk both before and during an event.

At national level, flood hazard and risk maps are available for the entire country and they are, for example, viewable in the ***IdroGEO platform***. It allows the consultation, download and sharing of data, maps, reports, documents of the Italian Landslide Inventory - IFFI, the national landslide and flood hazard maps and risk indicators.

2.4. The Role of Seismic and Flood Risk Analysis in Effective DRM

Risk analysis plays a key role in the DRM process, because, with the derivation of impact scenarios, it allows for the quantification and spatial localization of impacts, that is, the expected consequences related to the occurrence of events associated with the considered hazards.

The definition of impact scenarios is part of the forecasting phase, aimed at providing the knowledge base for warning alert activities, if possible, and for the preparation of civil protection planning at the various territorial levels for all risks (see §2.1). More specifically, scenarios form the basis on which the "intervention model" must be developed, that is, the set of procedures to be activated in crisis situations for an imminent event or an ongoing event, aimed at providing assistance and overcoming the emergency, along with the identification of the subjects that need to be activated to perform the "functions" specifically aimed at managing the emergency.

However, the Guidelines for emergency planning do not always state in a very clear, unambiguous, and detailed way how these scenarios influence the emergency planning, that is, how the intervention model should be shaped based on the scenarios.

Certainly, a fundamental aim of scenarios is the definition of expected needs to manage the emergency. Based on these data, a comparison between needs and availability is performed, to be continuously updated even after the emergency plan is released, too. Furthermore, the choice of emergency areas within the Municipality must take into consideration scenarios' data, too.

Regarding seismic risk, the expected needs include first aid and health assistance (hospital beds – for specialty, possible need of field hospitals depending on the expected number of injuries), materials and vehicles, temporary housing (depending on the expected number of homeless).

Emergency management following a flood event, is certainly supported by an effective alert system that aims to reduce impacts. In this context, a risk assessment is an essential element, however, to know the likely system response in terms of infrastructure, both road and utilities, strategic buildings that must ensure the coordination and management of emergency and relief activities, buildings that are sensitive to large crowds. A good assessment of these elements in terms of damages and losses together with a risk evaluation of ordinary building is the first element of a reliable DRM procedure, that includes the emergency management.

2.5. Multi-risk assessment methods

Multi-risk evaluation is an innovative and increasingly used approach in risk assessments. However, the methods for using it are not yet widespread and employed, both for risk analysis and for assessments to support the emergency management. For the last issue, in Italy operational procedures have not been proposed until now. However, there is an initial consideration of the interaction of multiple hazards in the CLE form, described in the §2.2.5, where general information about the asset of the emergency system are collected. In particular, the data are related mainly to the seismic hazard, but there is a specific part on the connection between the asset with the other hazards as landslides and floods.

3. OVERVIEW OF DRM AT THE URBAN SCALE FOR SLOVENIA IN 2024

3.1. Procedural frameworks for DRM

Seismic and flood risk assessments for the purpose of emergency management in Slovenia are loosely prescribed by several regulatory documents. The main regulatory document addressing the assessment of natural hazards risks in general is the Decree on the Content and Elaboration of Protection and Rescue Plans (Official Gazette RS 24/12, 78/16, 26/19). Other documents regulating emergency management include the Protection Against Natural and Other Disasters Act (Official Gazette RS 51/06, 97/10, 21/18, 117/22), the Decree on the Organization, Equipment and Training of Protection and Aid Forces (Official Gazette RS 92/07, 54/09, 23/11 in 27/16) and others.

The Decree on the Content and Elaboration of Protection and Rescue Plans defines multiple levels of planning: the national (state) level, the regional level, the municipal level, and the organization level. The national plan is the fundamental plan, meaning that all other plans need to be consistent with it. It specifies which regions and municipalities are at risk and to what extent. The national plan, as well as the regional plan, are prepared by the Administration of the Republic of Slovenia for Civil Protection and Disaster Relief (hereinafter the CP). The regions referred to by the regional plans are not legal entities but represent the territories covered by the CP branch offices. Municipal plans are prepared by a body determined by the municipality mayor if this is required in the national plan. The organization plan is prepared by organizations with facilities that pose high environmental risks. However, this level of planning is not typical in the case of seismic risk management. On the other hand, it is worth mentioning that most of the activities of the CP are planned at the municipal level.

Each protection and rescue plan has a prescribed content. It should define the characteristics of the event; address the possibility of a chain event; present conceptual planning; define the trigger for the implementation and the resources necessary for the implementation of the plan; prescribe the organization and implementation of observation, communication, and alarming; define the powers and tasks of management and governance bodies; specify objectives of protection, rescue and assistance; propose guidelines for the protection of people and assets; and outline action plans of various forces participating in protection, rescue and assistance activities.

3.2. Seismic risk assessment methods at urban scale

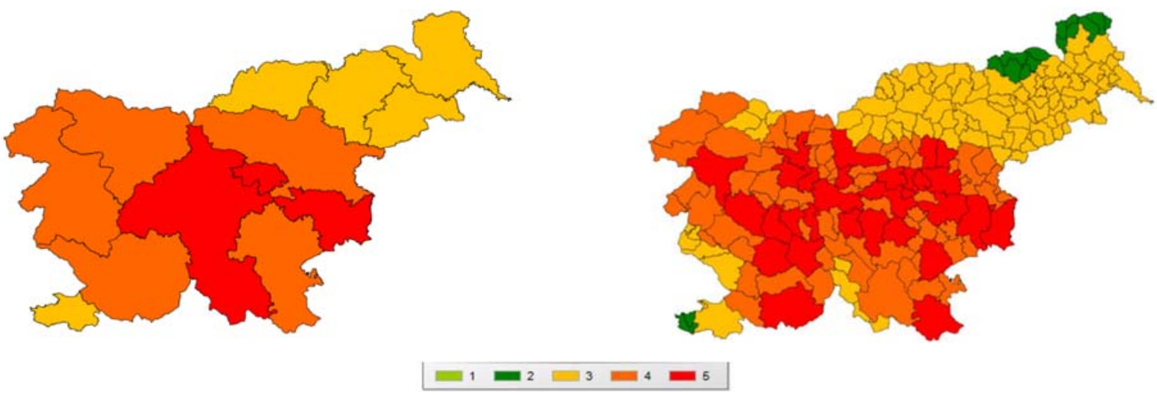
Seismic risk assessment for the purpose of emergency management is performed at the national, regional, and municipal levels, with the goal of complementing protection and rescue plans, which are also prepared at the national, regional, and municipal levels. The assessment reports at the national and regional levels are prepared by the Administration of the Republic of Slovenia for Civil Protection and Disaster Relief (hereinafter the CP), while the municipal reports are prepared by a body determined by the municipality mayor. Slovenia contains 13 regions, which are not actual legal entities but represent the territories covered by the CP branch offices. However, the municipalities are legal entities with administrative functions. There are 212 municipalities in Slovenia.

Seismic risk assessment reports vary in content and length. In general, the reports contain an explanation of basic concepts, present the causes of earthquakes, and describe past seismic events in Slovenia as a whole. These parts are quite generic. The parts that are more closely related to the territory analyzed include the information regarding seismic hazard, exposure, and fragility. The hazard is typically presented in the form of an EMS-98 intensity map corresponding to the 475-year return period. The exposure is described by the number of different types of assets, including buildings, infrastructure, population, animals, and cultural heritage facilities. In contrast, the fragility is often described only qualitatively, e.g., that buildings from a certain period are more vulnerable than other buildings. Moreover, the risk is often addressed only in the form of a discussion, giving subjective opinions on what would happen to different assets in the case of an earthquake.

The seismic risk assessment reports generally also include a determination of the risk class for regions and municipalities in the analyzed territory. For example, the national seismic risk assessment report defines the risk class for each region and each municipality in Slovenia, while a regional seismic risk assessment report defines a risk class for the region itself and each municipality in the region. The risk classes from the lower-level reports are consistent with the national report. The risk class for a region or a municipality is determined considering only the EMS-98 intensity and exposure of the population, which means that the seismic fragility of buildings and other units of the built environments is disregarded, which is considered a major limitation. An example of the risk classification for municipalities is presented in Figure 3.1. The risk classes of regions and municipalities are presented in Figure 3.2.

RISK CLASS	1 LOW	2 MODERATE	3 HIGH	4 VERY HIGH 1	5 VERY HIGH 2
DEFINITION	All residents of the municipality in the area of int. V EMS-98 or less	All residents of the municipality in the area of int. VI EMS-98	All or part of the residents of the municipality in the area of int. VII EMS-98 and no residents in the area of VIII EMS	All or part of the residents of the municipality (but less than 9000) in the area of int. VIII EMS-98 or higher	All or part of the residents of the municipality (but more than 9000) in the area of int. VIII EMS-98 or higher

Figure 3.1: Seismic risk classification criteria for municipalities.



(a) (b)

Figure 3.2: Seismic risk classes of (a) regions and (b) municipalities in Slovenia.

Some more refined seismic risk assessment reports also include scenario-based risk assessment. This is done, for example, in the national report (GRS, 2018) and the Ljubljana municipality report (MOL, 2015). In the scenario-based assessment, the scenarios are defined by an epicenter and epicentral EMS-98 intensity, and its results are presented in tables and maps. Moreover, this type of assessment utilizes quantitative fragility and consequence models in addition to the hazard and exposure models described above. All four models are presented in more detail in §3.2.1–3.2.4.

The national seismic risk assessment report, as well as the corresponding national protection and rescue plan, are publicly available. Such documents are also available at the regional level for all regions. In contrast, the documents at the municipal level are publicly available only for some municipalities (e.g., for Ljubljana).

It should be noted that, in addition to the seismic risk assessment presented above, an independent seismic risk assessment was conducted within a seismic stress test of building stock in Slovenia performed for the Government of Slovenia by the University of Ljubljana, Faculty of Civil and Geodetic Engineering (Dolšek et al., 2020) as a technical basis for the preparation of a resolution on strengthening earthquake safety in Slovenia, which was approved by the National Assembly of Republic of Slovenia in November 2023. The models developed and used by Dolšek et al. (2020) were also utilized in a cross-border risk assessment performed within the BORIS project (e.g., BORIS, 2022). An advantage of the seismic risk assessment used within the seismic stress test of building stock in Slovenia is that it uses a time-based approach rather than a return-period-based approach, contemporary seismic risk measures and systematically treats the effects of ground motion randomness and epistemic uncertainties. Moreover, the risk assessment by Dolšek et al. (2020) also includes a scenario-based approach, defining the scenarios by a magnitude and a hypocenter rather than an epicentral EMS-98 intensity and an epic enter (Babič et al., 2021). However, because the risk assessment by Dolšek et al. (2020) is not currently used by the CP, its models are not presented in the following subsections. More information regarding these models can also be found in Deliverables 2.1 and 2.2 of the BORIS project (BORIS, 2021a; 2021b).

3.2.1. Hazard model

For emergency management plans currently available in Slovenia, the seismic hazard model by Šket Motnikar and Zupančič (2011) is used. The model was developed based on a probabilistic procedure for spatial smoothing of seismic activity. It uses the EMS-98 intensity as the intensity parameter and is presented in the form of a seismic intensity map for a return period of 475 years (Figure 3.3a). The intensity values in the map were calculated for a grid of points spaced 10 km apart. The intensities were then interpolated over the whole mapped territory and rounded to the nearest whole number.

The model uses an intensity attenuation model, which predicts the intensity at a given location based on the epicentral EMS-98 intensity and epicentral distance. This attenuation model was developed based on 17 earthquakes from the Slovenian territory and is also used as the basis for scenario-based risk assessment in the more refined risk assessment reports. An example of intensity attenuation is presented in Figure 3.3b for the epicenter in Ljubljana.

The intensity map reflects the average ground type of the affected areas considered in the development of the intensity attenuation model. The ground type in those areas was classified as B and C according to the Eurocode 8 classification. To account for the actual ground type at a given location, the intensity from the map is subsequently increased or decreased if there is sufficient data. This is done, for example, in the Ljubljana risk assessment (MOL, 2015).

It should be noted that for the design and assessment of structures in Slovenia, a seismic hazard model for spectral acceleration is used. This model was recently updated (Šket Motnikar et al., 2022) and is harmonized with the ESHM20 model.

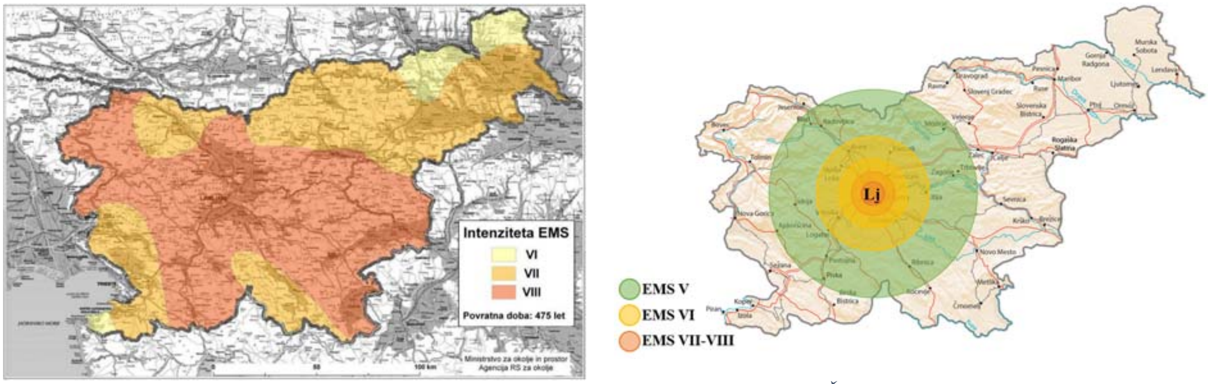


Figure 3.3: (a) An EMS-98 intensity map for Slovenia and return period of 475 years (Šket Motnikar and Zupančič, 2011) and (b) attenuation of the EMS-98 intensity based on a selected epicentral EMS-98 intensity in Ljubljana (based on GRS, 2018).

3.2.2. Vulnerability model

The seismic fragility (vulnerability) model used for emergency management in Slovenia was developed within the POTROG initiative (POTROG, 2013). The model is focused on buildings and uses the EMS-98 intensity as the intensity measure. Moreover, it considers the EMS-98 damage scale consisting of damage states D1–D5. In the model, the buildings are divided into six vulnerability classes from A to F. For each vulnerability class, a set of discrete fragility functions is defined and presented as tables displaying the percentages of the designated damage states for each degree of the EMS-98 intensity (Figure 3.4). For example, it is considered that 25 %, 35 %, 30 %, 10 %, and 0 % of buildings in vulnerability class B reach damage states D1–D5, respectively, if they are exposed to EMS-98 intensity VIII. The classification of buildings into fragility classes was made based on the so-called RAN-Z grade (between 0 and 10), which was determined using a neural network method (Peruš et al., 1995) that considers the year of construction, the number of stories, and the material of the load-bearing structure. The conversion between the RAN-Z grade and the vulnerability classes was defined based on engineering judgment following the guidelines from Grünthal (1998). The fragility functions (i.e., percentages of the damage states conditional to the EMS-98 intensity) were obtained directly from Grünthal (1998) with no additional numerical or empirical analyses for the Slovenian building stock.

	% po kategorijah poškodovanosti VIII EMS						**% po kategorijah poškodovanosti VIII-IX EMS**					
ranlj.	**0**	**1**	**2**	**3**	**4**	**5**	**0**	**1**	**2**	**3**	**4**	**5**
A	0	0	25	35	30	10	0	0	13	30	33	25
B	0	25	35	30	10	0	0	13	30	33	20	5
C	25	35	30	10	0	0	13	30	33	20	5	0
D	60	30	10	0	0	0	43	33	20	5	0	0
E	100	0	0	0	0	0	80	15	5	0	0	0
F	100	0	0	0	0	0	100	0	0	0	0	0

Figure 3.4: Fragility model used for emergency management in Slovenia: An example of damage-state percentages for vulnerability classes A–F and EMS-98 intensities VIII and VIII-IX (POTROG, 2013).

No fragility model for the infrastructure has been established. The exposed infrastructure is listed in the seismic risk assessment reports, but its damage and consequences due to earthquakes are not quantitatively assessed. Instead, the reports contain a discussion on what could happen to the infrastructure in the event of an earthquake based on the definition of EMS-98 intensity levels.

3.2.3. Exposure model

The seismic exposure model used in emergency management considers buildings, population, and infrastructure, but at different levels of detail.

The building data was obtained by the Surveying and Mapping Authority of the Republic of Slovenia and is provided in the Slovenian Real Estate Register (GRS, 2020a). The Real Estate Register was created in 2008 and contains building-specific information, e.g., the location of a building, the year of construction, the occupancy class, the net floor area, the predominant material of the load-bearing structure, the building value based on real estate mass appraisal procedure, the number of stories, the number of dwellings and the building height. It is publicly accessible when used to obtain information on individual buildings. However, only the buildings from the Real Estate Register that are also included in the POTROG database are considered in the exposure model. Buildings such as small auxiliary buildings, buildings built after 2009, and special buildings that would need an individual assessment are excluded. In the scenario-based risk assessment, each building is treated separately, but for the presentation of the exposure model, the building-specific data is aggregated. The aggregation is typically performed at the municipality level, with the exception of the Ljubljana assessment, where the data is aggregated at the school district level (MOL, 2015). Moreover, the dwellings are also treated separately in the scenario-based risk assessment, i.e., consequences are assessed separately in terms of affected dwellings, analogously to the consequence assessment for buildings. Furthermore, cultural heritage buildings are treated separately in some municipalities to evaluate the impact of earthquakes on the cultural heritage infrastructure.

The population data in the exposure model was obtained from the Central Population Register (GRS, 2020b), which is managed by the Ministry of Interior of the Republic of Slovenia. Based on the population data, two models of building occupancy have been developed, one representing the occupancy during the night and the other during the day (POTROG, 2015). In the scenario-based risk assessment, the number of residents in each specific building is used. However, for the presentation of the model, the data is aggregated at the municipality or school district level, analogously to the building data. Therefore, personal (non-aggregated) data from the exposure model is not publicly accessible but may be obtained only by state authorities and other users to perform prescribed tasks, manage databases, or conduct statistical, socio-economic, and other surveys. In addition, for the scenario-based risk assessment of the Ljubljana municipality (MOL, 2015), the civil protection units (members) are treated separately. By considering their address of residence obtained from the Central Population Register, the availability of each individual member in the case of a disaster can be analyzed.

The exposure model also includes the energy infrastructure facilities and the facilities on state roads of the analyzed territory. However, as explained in §3.2.2, these facilities are not analyzed quantitatively.

3.2.4. Damage and Impact Indicators

The damage and impact indicators are intended for use in scenario-based risk assessment. They are available for buildings but not for infrastructure.

The impact of earthquakes on buildings is based on their damage described by the EMS-98 damage scale, as explained in §3.2.2. Based on the damage states of buildings, the number of usable (non-damaged or slightly damaged), temporarily unusable (needing reconstruction), and permanently unusable buildings (intended for demolition or collapsed) are then calculated. Damage state D1 corresponds to usable buildings, damage states D2 and D3 to temporarily unusable buildings, and damage states D4 and D5 to permanently unusable buildings. Based on the number of dwellings in each building, the number of usable, temporarily unusable, and permanently unusable dwellings are also calculated. In some seismic risk assessment reports (e.g., the national risk assessment report), building damage is also used to estimate direct economic losses. In this estimation, it is assumed that the losses are equal to the worth of permanently unusable buildings. It should be noted that such a calculation of losses can be misleading because the direct economic losses after an earthquake depend on the repair and replacement costs of all buildings, including the buildings with minor degrees of damage, and because the worth of the building is not necessarily representative of the repair or replacement cost. It should also be noted that indirect economic losses are not considered in the loss estimation. Moreover, the impact of earthquakes on buildings is also expressed by the volume of debris. The calculation of debris volume is performed using two different approaches developed based on the FEMA (2007) methodology. In one approach, only the volume of structural elements is considered. In the other approach, the volume of empty spaces in the building is also considered. This impact indicator is typically not presented in the published seismic risk assessment reports but is included in the online platform presented in § 3.2.5. In addition, for 13 out of 212 municipalities, the model for the assessment of road transportability after an earthquake is also available. This model is based on the location of each building and the assumption that the debris of a building in damage states D4 and D5 blocks the roads at a distance equal to 10% and 33% of the building's height, respectively. For other damage states, it is assumed that the debris has no effect on road transportability.

The number of affected people is estimated from the number of damaged residential buildings. The number of people to be temporarily and permanently displaced due to the effects of an earthquake is estimated from the number of temporarily and permanently unusable buildings, respectively. Further, different approaches are used in different seismic risk assessment reports to assess the number of casualties. In the national report (GRS, 2018), the number of fatalities and injured people is calculated based on the number of people exposed to the event, using expert judgment and data from historical events. In contrast, in the POTROG report (2015), which is the basis for the seismic risk assessment in emergency management, a model by Zuccaro and Cacace (2011b) is used for this purpose. However, in some seismic risk assessment reports, even for Ljubljana (MOL, 2015), the number of casualties is not addressed. Moreover, in cases where civil protection members are treated separately, the availability of a member is determined based on the damage state of the building at the location of the member's residence. For damage state D1 and less, it is considered that the member is available for assistance; for damage states D2 and D3, it is considered that the member is partially incapacitated; and for damage states D4 and D5, it is considered that the member is fully incapacitated. The assessed availability of civil protection members in the case of an earthquake in Ljubljana with EMS-98 intensity VIII is shown in Figure 3.5.

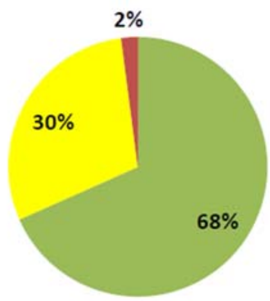


Figure 3.5: The availability of civil protection members in Ljubljana in the case of an earthquake with EMS-98 intensity VIII. Green indicates available members, yellow indicates partially incapacitated members, and red indicates fully incapacitated members (MOL, 2015).

It should be noted that the connection between impact indicators and emergency management condition needs is not evident from the seismic risk assessment reports, nor from the protection and rescue plans. The impact indicators are recommended for use in assessing the consequences of an earthquake after it has already occurred, while their role in the strategic planning of response prior to an earthquake disaster is not clearly foreseen.

3.2.5. Tool (platform) for seismic risk assessment at urban scale

Within the POTROG initiative, a platform has been developed, offering several different tools for the CP and the general public (Figure 3.6). The tools that are primarily intended for the CP include the following:

- An application for the assessment of consequences. This application uses the models described in §3.2.1–3.2.4. The user has to define the scenario by the epicentre and epicentral EMS-98 intensity. Based on this input, the application estimates the consequences at the level of the country, regions, and municipalities.
- An application for displaying building occupancy, considering the day or night scenario. This application is accessible only by the CP.
- An application for road transportability assessment for 13 municipalities. This application is accessible only by the CP.
- An application for describing building damage after an earthquake. This application provides a standardized form for describing building damage and enables the user to print the form and obtain existing building information without an internet connection. The POTROG webpage contains only information about the application, while the application itself can be obtained by the CP on a USB key.

All applications described above are intended for the CP response after an earthquake. They also offer valuable information for the preparation (pre-disaster) stage of risk management, but their use for this purpose is not straightforward. For example, it is not prescribed or recommended how to define the scenario for the consequence assessment that could serve as a basis for developing strategic decisions prior to a disaster.

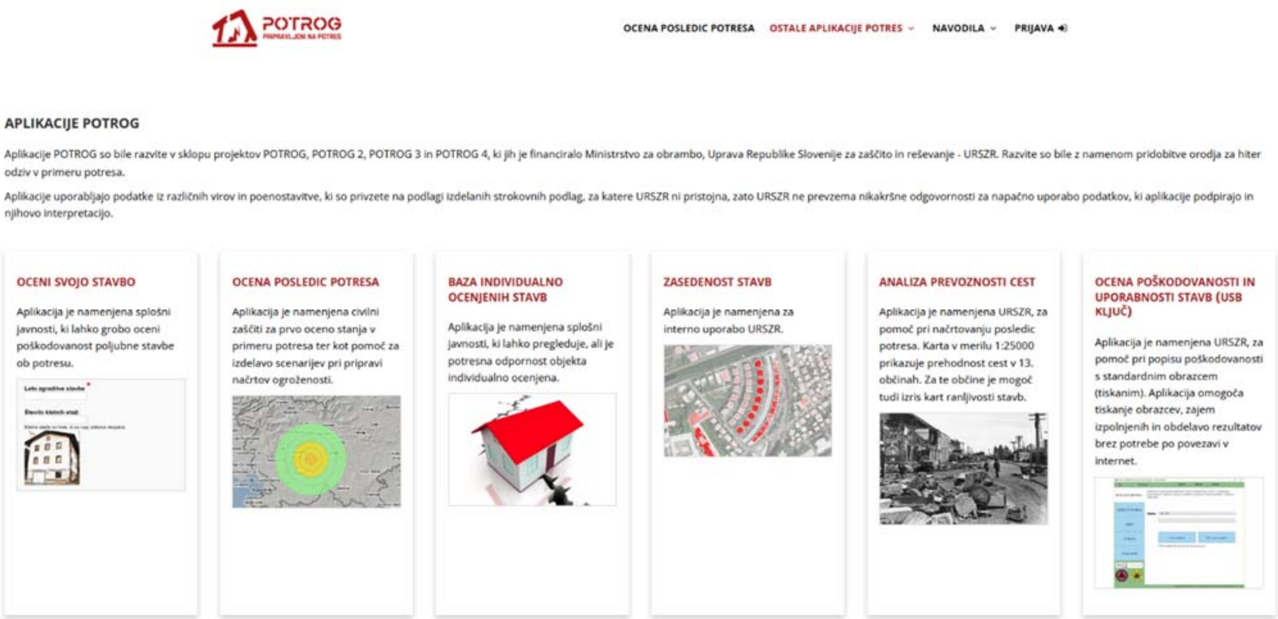


Figure 3.6: The online POTROG platform (POTROG, 2019).

3.3. Flood risk assessment methods at urban scale

Several regulatory documents that are used in Slovenia for emergency management in case of natural disasters are already presented in the introduction to Section 3. As a part of the first cycle of implementation of the EU Floods Directive, the Republic of Slovenia prepared and adopted a Preliminary Flood Risk Assessment and prepared an initial identification of the areas of significant flood impact for which detailed flood hazard maps have been prepared. Based on the initial analysis of flood impact indicators and exposure elements, preliminary flood risk maps have been made at a scale 1:50.000 as a basis for further preparation of the preliminary Flood Risk Reduction Plan. The second cycle of implementation of the EU Floods Directive (since 2016) was followed by the verification and possible amendment of flood hazard maps and flood risk maps for an updated set of Areas of Potentially Significant Flood Risk (MOP, 2019) and preparation of an update of the Flood Risk Reduction Plan (to be done by the end of 2021). In the scope of these activities, the upgraded methodology for preliminary flood risk assessment was prepared (IzVRS, 2018), which was based on the first methodology proposed in 2012 (IzVRS, 2012). There has been no specific flood risk assessment method developed at the urban scale.

Based on the Regulation on the content and preparation of protection and rescue plans (Official Gazette of the Republic of Slovenia, No. 24/12), considering the documents mentioned above, the classification of municipalities and regions (CP branches) into risk classes was prepared. In the hazard assessments, municipalities and regions were uniformly classified into five hazard classes. The flood risk assessment of municipalities for the needs of the hazard protection system was prepared by Slovenian Water Agency (hereinafter the DRSV) based on selected parameters and parameter indicators. The following parameters were considered to determine the risk: the presence of flood zones, the density of threatened areas and the number of people at risk. Determining the degree of potential flood risk of municipalities and their classification into risk classes strongly depends on the quality of the input data. Values of parameter indicators were calculated for each municipality. Six variants of considering indicators, choosing weights and determining risk classes were developed. According to the expert evaluation, consultations with local communities through their representative bodies and with CP branches, variant 6 was selected as the most appropriate one (Figure 3.7). Absolute and relative indicators of all parameters were selected, which means that the health of people and their property, infrastructure and economic activities, cultural heritage and the environment are taken into account. The presence of flood zones, the density of threatened areas and areas of significant flood impact are also considered. Based on the assessed flood risk class, the DRM plans at the municipal level had to be prepared with detailed instructions and procedures or emergency response during flood events.

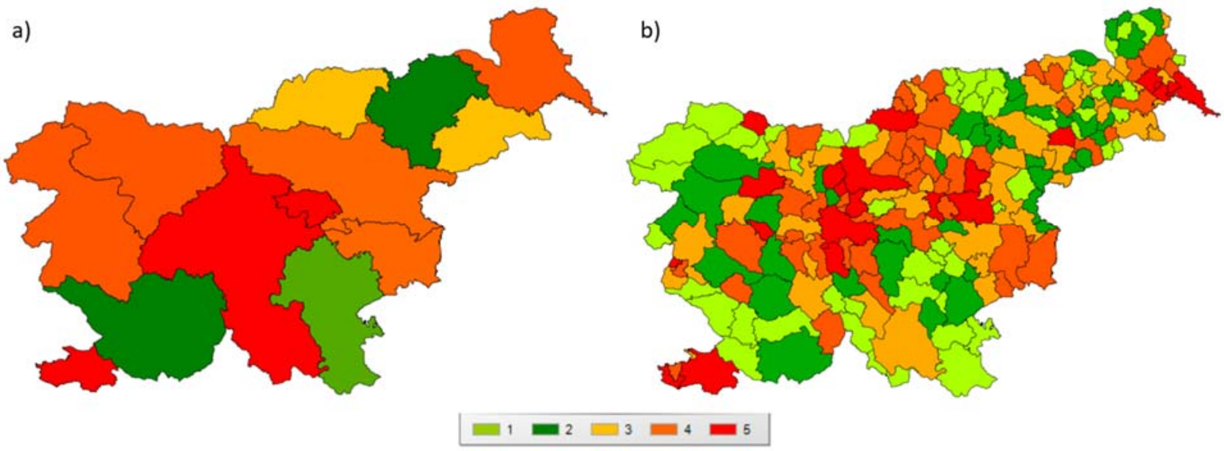


Figure 3.7: Flood risk classes of (a) regions and (b) municipalities in Slovenia.

The risk assessment of the regions (Figure 3.7(a)) was primarily determined based on the risk class of the largest number of municipalities within each region (Figure 3.8), but in most cases, the risk class of the region was by determined by considering additional criteria:

- if more than 1/3 of all inhabitants of Slovenia are in the region and they live in municipalities classified in the fifth risk class, the region is classified in the fifth risk class,

- if the dominant number of municipalities in the region is divided into several risk classes, the highest dominant risk class of the municipalities in the region is considered,
- the region can have a maximum of two classes lower risk than the municipality with the highest risk class risk in the region,
- if more than 15% of the municipalities in the region are in the fifth risk class, or if more than 20% of the population of the region live in municipalities that are in the fifth risk class, the region can have a lower risk by at most 1 class (fourth risk class).

1. Risk class	2. Risk class	3. Risk class	4. Risk class	5. Risk class
Majority of the municipalities in the region is assigned to first risk class	Majority of the municipalities in the region is assigned to second risk class	Majority of the municipalities in the region is assigned to third risk class	Majority of the municipalities in the region is assigned to fourth risk class	Majority of the municipalities in the region is assigned to fifth risk class

Figure 3.8: Criteria for classifying regions into flood risk classes.

3.3.1. Hazard model

The flood hazard assessment in Slovenia follows the general probabilistic approach where the flood hazard classes are defined based on the hydrologic and hydraulic modelling. In all, 10-, 100-, and 500-year flood return periods are considered in the calculations. The flood hazard maps should be generally prepared at the scale 1:5000 or higher scale. Detailed criteria for delineating the flood hazard classes consider the given discharge return periods, more specifically, for 100-year return period also water depth and water velocity is considered. The results of the flood hazard analysis are publicly freely available on Slovenian Water Atlas (ATLAS VODA (gov.si)). It is worth noting that after the devastating flood event in August 2023, the criteria for delineation of flood hazard classes are under revision and will probably be modified.

The Slovenian Environment Agency (ARSO) derived its own discharge warning levels which are specific for the selected flood monitoring stations operated by ARSO. The warning discharges at the specific water stations are not directly connected with the discharges considered for flood hazard classification. The warning by ARSO is issued for specific hydrographic areas covering a group of catchments, as can be seen in Figure 3.9.

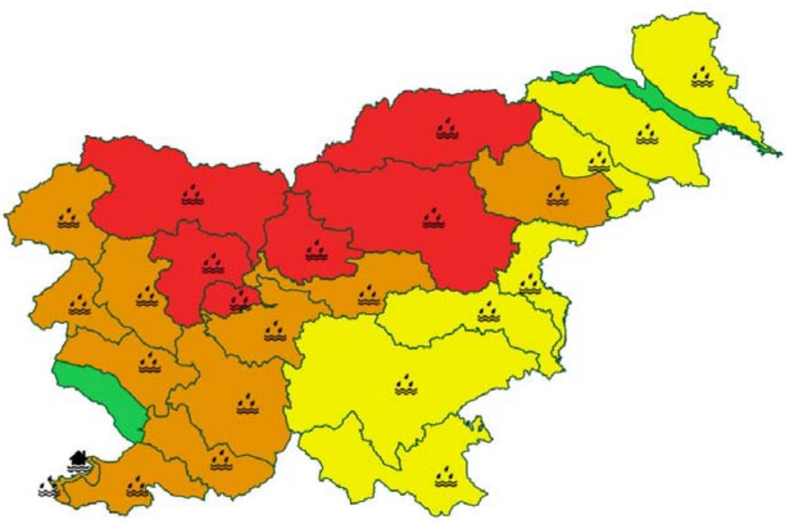


Figure 3.9: Example of flood warning issued by ARSO for specific hydrographic areas in Slovenia. Red colour: extensive and destructive flooding; orange: potentially severe flooding; yellow: spatially limited flooding; green: normal discharge conditions.

3.3.2. Vulnerability and exposure model

The preliminary flood risk assessment was prepared based on a methodology (IzVRS, 2012, IzVRS, 2018) which considered the following vulnerability and exposure elements:

- People's health: Vulnerability is related to the data on the location and density of permanent and temporary population. The layer is obtained from the Ministry of the Interior and contains point data on the number of people who permanently or temporarily reside at a given location.
- Social infrastructure: The impact indicator was created due to the awareness that general building and infrastructure data cannot be directly implemented for the most vulnerable infrastructure types during floods. Therefore, social infrastructure impact indicator was considered. The following elements of the social infrastructure were considered in this data layer: firefighters, hospitals and health centres, homes for the elderly, visually impaired and disabled, schools and educational institutions. Data were obtained from the Slovenian Business Register and analysed based on the Standard Statistical Classification of Economic Activities.
- Cultural heritage: Cultural heritage data is represented by two layers: the register of cultural heritage and a common layer which includes libraries, archives, museums and cultural centres. Layers of cultural heritage are obtained from the State register of cultural heritage by the Ministry of Culture. The impact element is further classified according to vulnerability assessments related to importance, namely state, municipal and other.
- Environment: This impact indicator was defined by including data describing several exposure elements: large-scale pollution facilities (according to IED, SEVESO and IPPC directive), industrial and municipal landfill areas, wastewater treatment plants; areas under environmental or other protection status (NATURA 2000, areas of special natural importance), and water protection areas at state and local level. Based on the potential impact of the exposure elements in view of flood vulnerability/exposure, special attention was given to assigning the weights.
- Economic activities: Due to wide variety of different economic activities and their variable vulnerability/exposure to floods, a set of the following exposure elements was suggested based on the classification of the activities from the Slovenian Business Register: (a) Health and care services, (b) Other economic activities, (c) Agriculture, hunting, fishing and forestry, (d) Mining, (e) Food, (f) Textile footwear paper, (g) Manufacturing industry, (h) Infrastructure, construction, trade, catering, and (i) Public administration.
- Infrastructure: The following types of facilities are defined as the infrastructure indicator: railways, roads, water supply, sewerage, gas and electricity (subgroups). For the infrastructure indicator, data are obtained from the Register of economic public infrastructure with a short description of the facility (classification by criteria).

Based on this classification, a weight value (from 1 to 5) was assigned. A value of 5 expressed the highest and 1 the lowest vulnerability. Estimates for railways and roads were given according to the type and importance of the infrastructure. For other infrastructure elements (water supply, sewerage, gas and electricity), the assessment was determined according to the type of element and how vulnerable the element is, when subjected to a flood event. All the listed impacts are shown separately in the maps, and then they were combined into a spatially processed combined flood impact (human health, economy, cultural heritage, environment and sensitive objects), as shown in Figure 3.10. To determine flood risk, vector grids of square cells with a side size of 75 meters were considered.

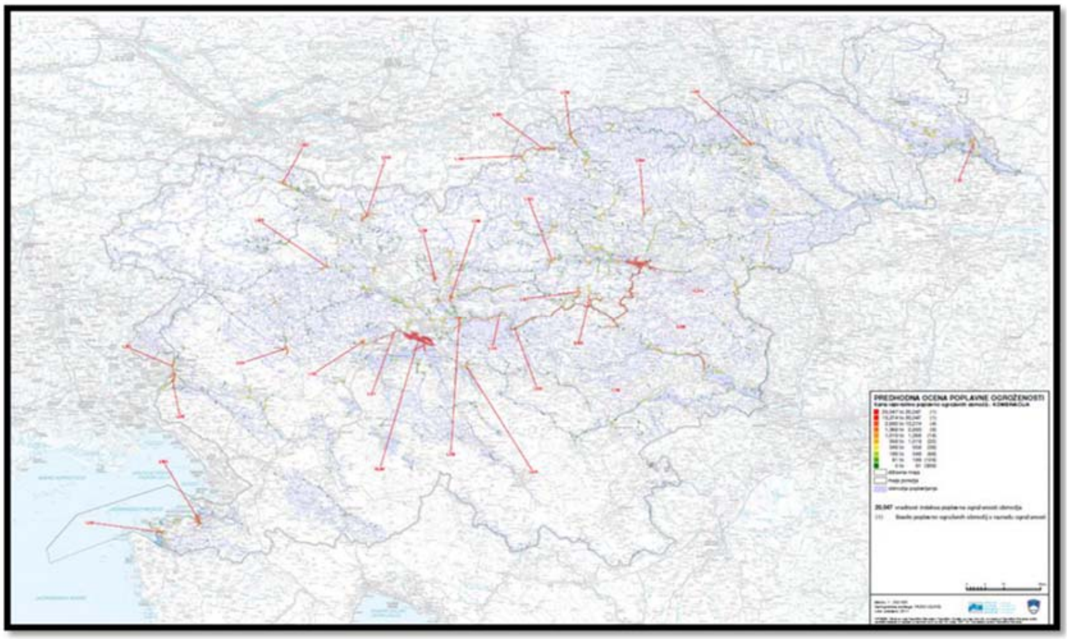


Figure 3.10: Flood risk assessment for the selected areas of potentially significant flood risk.

3.3.3. Damage and Impact Indicators

The damage and impact indicators are intended to be used in the scenario-based assessment of consequences by considering the floods return periods as described in § 3.3.1. Its estimation is based on the fact that flood damage is caused by a flood event, which is usually defined by water level and frequency of occurrence in a certain area. The assessment of damage and hazard potential in Slovenia was carried out for the needs of the Preliminary Flood Risk Assessment (MOP, 2019). It consists of three groups of parameters: probability, physical-social-economic and time group.

The damage potential in threatened areas depends on the period in which the inhabitants and other elements of the space are actually located in the area, their quantity, susceptibility to damage and market or social value. The duration of the flood is less important factor in the case of Slovenia, as water usually drains very quickly, therefore, the time required for restoration is a much more important factor, as quick restoration and damage repair also mean a smaller amount of damage potential. All these factors determine the amount of damage in the event.

The sizes of the damage potential were determined based on publicly available data, which may contain various elements:

– cultural heritage,
– social infrastructure,
– economic activities,
– environment,
– human health,
– infrastructure.

Spatial analysis was used to prepare the damage potential map, which shows the potential damage with values 1 to 10 assigned to individual 75 x 75 m cells. The area of the entire Republic of Slovenia was divided into an orthogonal grid of cells. Within each individual cell, the values of individual (sub)categories of damage potential were counted and integrated (Figure 3.11).

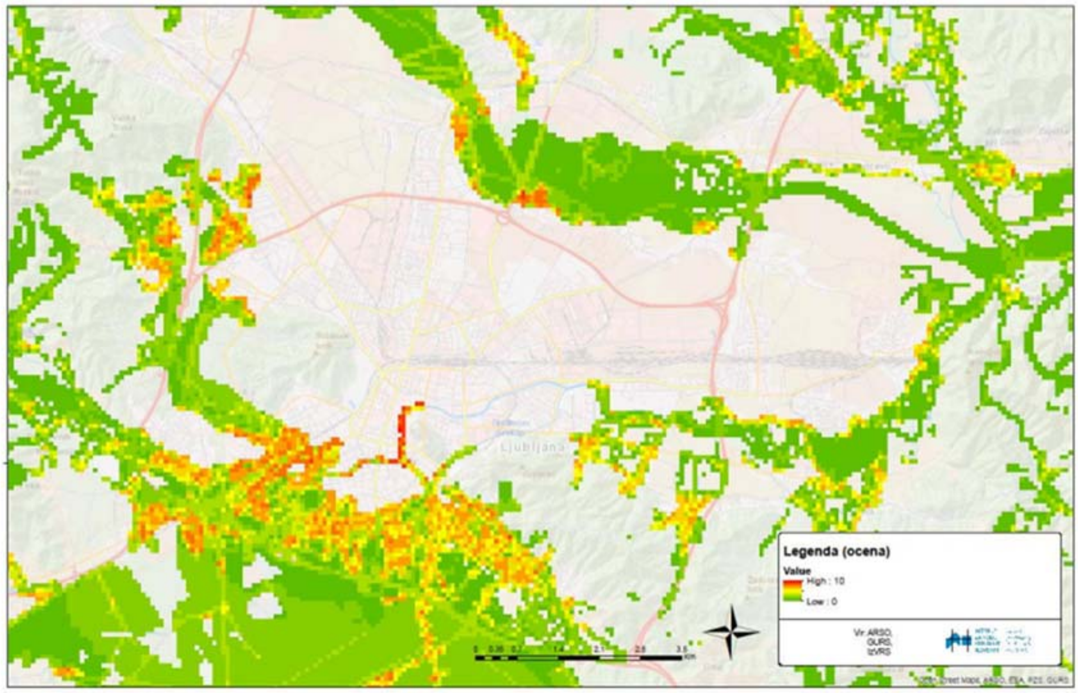


Figure 3.11: Selected detail of the damage potential map for the area around the city of Ljubljana.

3.3.4. Tool (platform) for flood risk assessment at urban scale

There are no tools (platforms) developed to specifically assess the flood risk at an urban scale in Slovenia. The flood risk assessment has been prepared on a national scale, and the results can be indirectly used also for the urban areas. The Faculty of Civil and Geodetic Engineering, University of Ljubljana, has developed KRPAN model (the methodology for calculation of flood damage and their analyses in Slovenian language (Sapač et al., 2021; Vidmar et al. 2019; Zabret et al., 2018). It represents an upgraded methodology primarily developed by IzVRS (2014) and an application that enables a set of support tools for the experts and decision-makers. It is GIS-based, however, some input data, such as population and number of vehicles, are averaged for individual spatial areas. Types of data used for the calculation of expected annual damage can be classified into 11 categories: cultural heritage, state roads, public infrastructure, agriculture, residential buildings, the environment, personal vehicles, economic activities, watercourse, settlement cleaning, and (temporary) alternative residence. For the calculation of expected annual damage, at least three hazard maps (three different return periods) are needed. The water depth is included in the calculation if available for the analyzed area, otherwise an average water depth is taken into calculation. The main purpose of KRPAN tool is to support project designers, engineers, and decision-makers in implementing proposed construction and non-construction flood protection measures in the economic and financial justifications. The KRPAN model can give an informative insight into the vulnerability of any selected area (predefined area or drawn manually in e.g., Google Earth and then uploaded to KRPAN). Still, this tool is not suitable for assessing damage to smaller areas, such as individual buildings, as data is aggregated for postal districts. However, it could be used for flood risk assessment on an urban scale.

3.4. The Role of Seismic and Flood Risk Analysis in Effective DRM

The seismic risk assessment in Slovenia, described in §3.2, impacts the DRM activities by defining the obligations regarding the preparation of regional and municipal protection and rescue plans via the risk classes of regions and municipalities (Figure 3.2), respectively. Regions and municipalities in risk classes 4 and 5 must prepare their own independent protection and rescue plans. For lower-risk classes, less detailed documents are required. This requirement follows an article from the Decree on the Content and Elaboration of Protection and Rescue Plans, which explicitly states that protection and rescue plans are necessary for municipalities with EMS-98 intensity VIII. It should be noted that protection and rescue plans have been prepared for all regions, even those with a risk class below 4, thus exceeding the requirements. It should also be noted that risk classification and subsequent requirements are based only on the EMS-98 intensity and exposure across the analyzed territory, as explained in § 3.2, while disregarding the seismic fragility and susceptibility to consequences of buildings and other units of the built environments, which is considered a major limitation.

Moreover, the impact of the scenario-based risk assessment on the protection and rescue plans is not clearly evident; the plans recommend using the results of the scenario-based assessment to assess the consequences after an earthquake already occurs but do not reveal if or how specific information from the risk assessment (i.e., expected consequences for a selected scenario) should be used in the strategic planning of response prior to an earthquake disaster. Therefore, while defining the obligations regarding the preparation of the protection and rescue plans, the risk assessment results are not clearly reflected in the content of those plans.

It is recommended that the strategic planning of response after an earthquake be updated with consideration of the seismic risk. To achieve this, the scenario-based seismic risk assessment used for emergency management should be upgraded to provide more informative and objective results. For example, the assessment should be based on the magnitude and hypocenter rather than on the EMS-98 intensity and the epicenter, and the uncertainties related to different steps of the risk assessment should be considered.

The flood risk assessment of the Republic of Slovenia is coordinated with the Ministry of the Environment, Climate and Energy, the Association of Municipalities of Slovenia, the Community of Municipalities of Slovenia, the Association of Municipalities of Slovenia and branches of the Administration of the Republic of Slovenia for Protection and Rescue (CP) which is responsible for DRM. In Slovenia, the DRM in case of different natural disasters is planned at the municipal level. The Regulation on the Content and Creation of Protection and Rescue Plans (Official Gazette of the Republic of Slovenia, No. 24/12) stipulates that individual risk assessment or their combined effects must show which municipalities are at risk from individual disasters and to what extent. For this reason, in recent years, several risk assessments prepared or obtained by the Administration of the Republic of Slovenia for Protection and Rescue have been revised and supplemented. In the hazard assessments, for the needs of the protection system against natural and other disasters, municipalities and other planning bodies were uniformly classified into five hazard classes. Due to the uniform concept, the same approach was also implemented in the Flood Risk Assessment of the Republic of Slovenia. In the fifth article of the same regulation, it is stipulated that municipal protection and rescue plans for individual accidents are prepared based on the risk assessments prepared or obtained by the Administration of the Republic of Slovenia for Protection and Rescue and based on the municipal risk assessments. In the case of floods, the provision of this article will be taken into account in such a way that, based on the findings of this risk assessment, the National Plan for Protection and Rescue in the event of a flood, as a basic plan, will determine the minimum obligations of the planning authorities in relation to the risk of flooding at lower levels, especially at the local level.

Regardless of the level of planning, in case of floods, the emergency response is based on hydrological forecasting. In Slovenia, ARSO monitors the hydrological situation and cooperates with neighboring countries in exchanging data on the water conditions in their territory. In the process of observing and predicting hydrological conditions, it issues hydrological warnings and uses the warning values that apply to the individual water gauging stations. The hazard level values are divided into four levels: green, yellow, orange and red. ARSO informs the Center for Information of the Republic of Slovenia (CORS) about any observed risk of flooding with a hydrological report and a forecast of high water (flood) conditions in graphic form, as well as a hydrological warning. The exchange of information and data on the risk of flooding between ARSO and CORS takes place according to the prescribed protocol.

3.5. Multi-risk assessment methods

No multi-risk assessment methods are used in the emergency management for the territory of Slovenia. The risk assessments address the possibility of chain events (e.g., floods due to earthquake-induced damage to the water supply networks). However, such events are merely discussed, and no quantitative risk assessment is provided.

4. OVERVIEW OF DRM AT THE URBAN SCALE FOR AUSTRIA IN 2024

4.1. Procedural frameworks for DRM

In Austria disaster management is basically a matter of federated states and thus regulated in nine different disaster relief acts. Even though there exist many similarities between those documents, they are also different in certain aspects. In general, the acts define the "Declaration of a disaster", meaning the conditions to call a scenario a "disaster" with all its legal consequences and responsibilities, and the "command and control structures on all levels", meaning the definition of all responsible stakeholders including their respective roles within the disaster management structure.

For further explication of the Austrian system the Province of Styria serves as example for all remaining federated states: Main responsible entity for provincial-wide disaster scenarios is the Office for the Regional Government of Styria – Department of Civil Protection and Defense. For all warning and alerting activities, it is supported by the National Alarm Center. The valid Disaster Act in Styria is (in German) LGBl. Nr. 62/1999 Stück 14 (Steiermärkisches Katastrophenschutzgesetz). Its content covers all responsibilities, the necessary actions to be taken in case of a disaster, all participating forces in disaster response and relief, the external Emergency Plans (focusing on enterprises dealing with CBRN-related substances), the duties of the population and the overall cost regulation for all related deployments.

The responsibilities in disaster management are defined according to the scale of the respective scenario. This means that small events not exceeding a certain municipality stay in charge of the mayor (and his crisis committee), events affecting two or more municipalities are a district affair and therewith taken care of the district commissioner. If two or more districts are affected the governor of the federated state becomes head of operation and thus leading the provincial crisis committee. Finally, all events affecting two or more federated states are managed by the Ministry of Interior, which is responsible for the coordination of National Crisis and Disaster Management (SKKM), Crisis Response, International Disaster Relief and Civil Protection, under command of the Interior Minister (see Figure 4.1). In all scenarios not exceeding provincial scope federal authorities only fulfill complementary tasks.

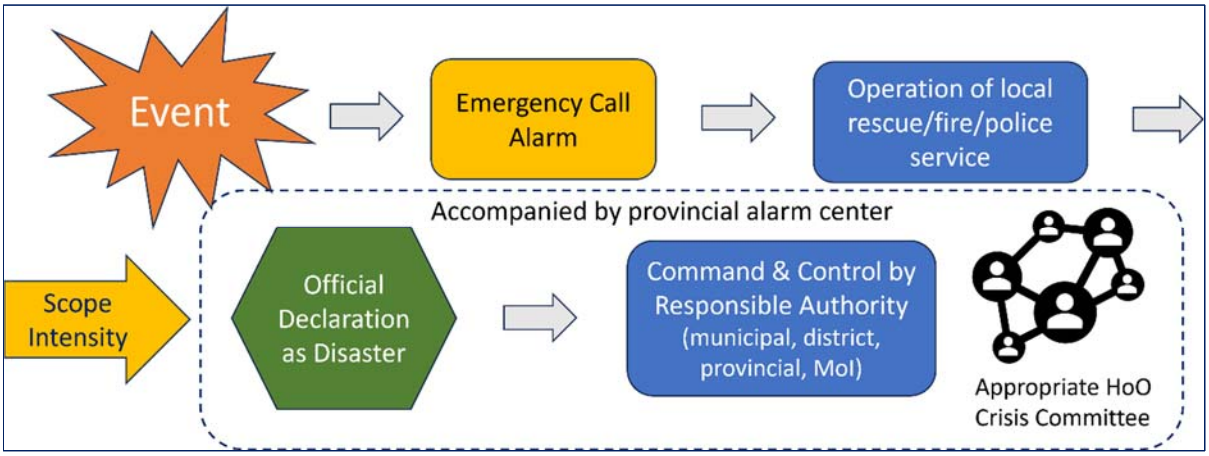


Figure 4.1: Disaster Management Process in Austria.

Major disasters of the last decades in Austria and abroad have demonstrated that disasters require overall coordination across and beyond the administrative competences of local and regional authorities. For this reason, in 1986 national crisis management at the Federal Chancellery was set up by the Federal Government.

Since May 2003 the coordination of national crisis management and disaster management as well as international disaster relief affairs falls within the responsibility of the Federal Ministry of the Interior. Based on the Ministerial Council Decision of 20 January 2004, the National Crisis and Disaster Management (SKKM) was reorganized. The most important innovation was the merging of coordination bodies, which had existed in different departments into one single new coordination committee chaired by the Director General for Public Security.

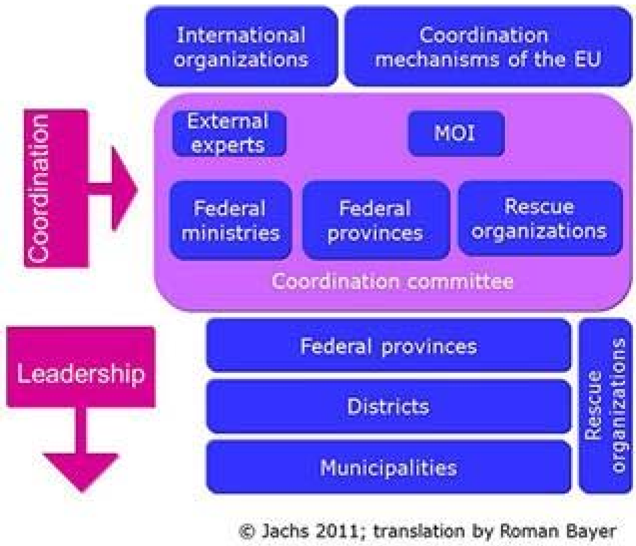


Figure 4.2: Coordination and Command and Control chart by SKKM, © Michael Felfernig, BM.I; Original in Siegfried Jachs: Einführung in das Katastrophenmanagement. Hamburg: Tredition 2011, p. 254.

The Federal ministries, Federal provinces, rescue organizations and the media are represented in this coordination committee. In case of major threats, the committee is responsible for the coordination and consultation regarding the necessary measures at the Federal and Provincial levels. The committee is active as coordinating body not only in case of disasters but also in basic planning. In consultation with the Federal provinces, eight expert groups have been set up for the basic planning, for example, for legal, technical, and operational matters.

The Federal Alarm Center (FAC), since January 2006 part of the Operations and Coordination Center (EKC), has been serving as 24/7-staffed information hub and national contact point. It is the point of contact for the Federal provinces, the neighboring countries, the European Union and International Organizations.

In the case of complex crisis and disasters, it is the task of the SKKM to ensure quick coordination between the federal authorities and the provinces. The current policy is provided by the SKKM-Strategie 2020 (Figure 4.2).

The SKKM ensures increased coordination between all players active in disaster management. It follows a holistic understanding, hence including not only operational organizations and public authorities in its management approach, but also science, economy and citizens. All those stakeholders have to be considered an taken care of to successfully meet the challenges of a disaster.

Every municipality in Austria has to prepare a disaster prevention plan and submit it to the relevant authorities. In particular, this should include the following, regardless of the respective federal state:

- An overview of the local conditions, including the (topographical) conditions and technical features of facilities that are important for disaster control

- Description of potential disasters, including areas at risk and the type of hazards to be expected in each case
- List (contact details) of the available alarm, communication, emergency and rescue facilities
- List (contact details), function and qualifications of persons authorized to issue orders and executive bodies
- List of equipment to be requested in the event of an emergency, its owners or authorized persons and the respective location of this equipment
- A list of the measures to be taken in the event of a disaster, in particular an alarm plan,
- Information on actions that need to be or can be taken in the case of a disaster in accordance with other relevant legal regulations.

These federal state-specific protection plans must be reviewed at municipal level as required, but at least every three years, and revised and updated if necessary. The emergency organizations (Red Cross, volunteer fire brigade, etc.) and civil defense associations, which are alerted in the event of a disaster on the basis of these plans, themselves prepare crisis/emergency plans for various scenarios such as floods or blackouts, which are also regularly trained.

Building on existing emergency management plans, process-related flood emergency management plans should be drawn up in order to be able to specifically orientate operational emergency planning to flood events. The use of hydraulic engineering plans, in particular hazard zone plans, flood risk maps, hydrological and hydraulic analyses, operating instructions for protective measures and hydropower plants, etc. are recommended as a basis for process-related flood emergency management plans.

4.2. Seismic risk assessment methods at urban scale

The Legal Framework of Austria's seismic risk assessment is controlled by Eurocode 8 (EN1998-1-1, 2004) which regulates "the design of structures against earthquakes". It also contains national annexes (ÖNORM EN 1998-1), which take into account regional characteristics such as the expected earthquake intensities and ground accelerations. The centerpiece of ÖNORM EN 1998-1 is the hazard map, which divides Austria into five hazard zones 0 to 4 (see Figure 4.3).

Based on the Probabilistic Seismic Hazard Assessment (PSHA) methodology, the seismic hazard map of Austria shows the 'horizontal reference ground motion' in accordance with the currently valid ÖNORM EN 1998-1. The seismic zonation is carried out based on ground motion values with a 10% probability of exceedance in 50 years, i.e. 475-year mean return period. Five hazard zones from 0 to 4 with different expected ground motions [m/s²] can be distinguished for Austria. The levels of potential building damage – from moderate to total destruction, following the concept of the European Macroseismic Scale 1998 (EMS-98) are expressed by the hazard zones as well as follows:

- Zone 0: (Grade I-VI) not perceptible to strong vibrations with possible minor damage to buildings
- Zone 1: (Grade VI) slight damage to buildings
- Zone 2: (Grade VII) medium building damage
- Zone 3: (Grade VII) severe building damage
- Zone 4: (Grade VIII-XII) severe building damage to complete destruction

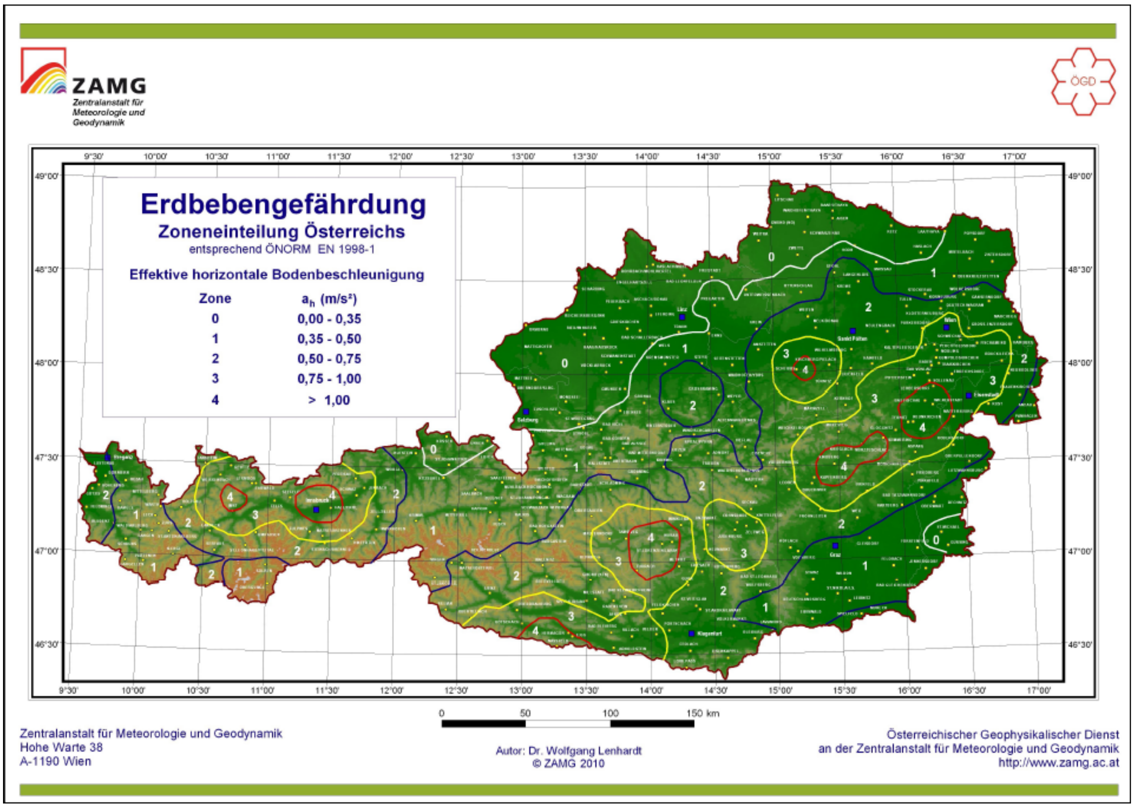


Figure 4.3: Nationwide seismic hazard map of Austria (URL-1).

According to ÖNORM EN 1998-1 building code, constructions in zone 4 must be designed to be particularly earthquake resistance as ground motions can exceed 1 m/s². Likewise, the ground and soil type have a significant effect on the strength of the possible earthquake. Consequently, seven ground types have been defined in the building code. Furthermore, detailed hazard maps for specific areas are available, and the annex of the building standards includes an index with exact seismic design values for some locations. The map resolution is two kilometers, as the localization accuracy of earthquakes is within this range. Therefore, in the transition areas, some locations are in the adjacent zone. In these cases, the reference ground peak acceleration a_{gR} determined for the particular location is valid. If a_{gR} is exactly at the zone boundary, the higher zone should be selected, and higher construction standards should be implemented. (BMLRT, 2024)

The hazard map (Figure 4.3) is also available online which gives an overview of the current seismic situation by additionally displacing the earthquakes recorded by network of GSA during the last 14 days. (BMLRT, 2024)

As earthquake-resistant building codes have to be reviewed every 20 to 30 years, improvements in the PSHA are made from an extended and updated earthquake catalogue, locally selected and developed ground motion models and the application of new calculation standards by Weginger et al. 2021. Briefly, the method combines the model of seismic zones with a geological fault zone model by considering a zone-free approach. The results include the maximum horizontal ground motion (PGA, m/s²).

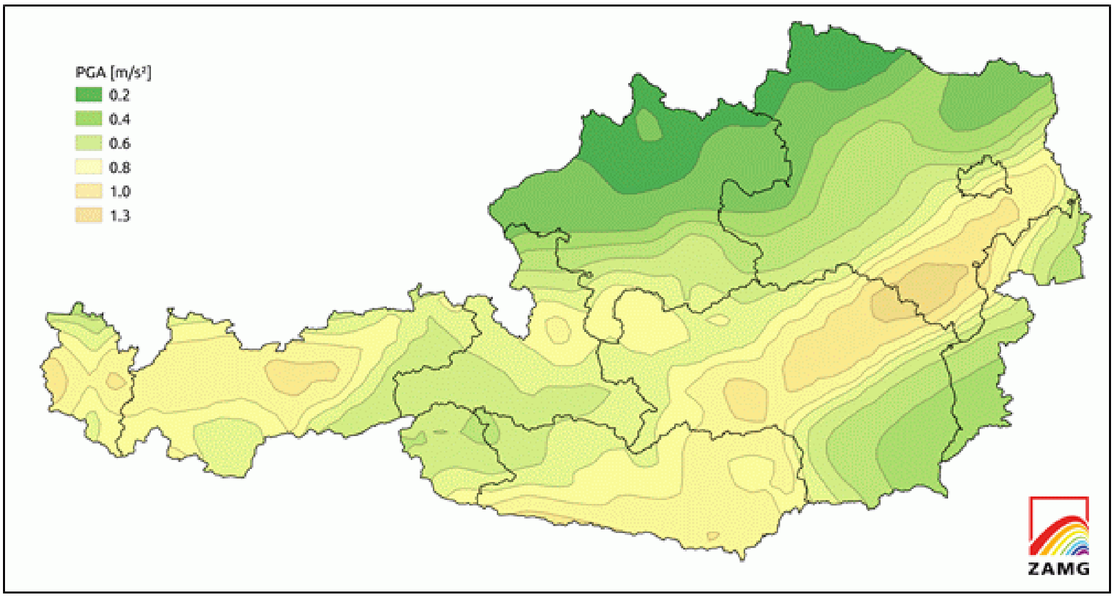


Figure 4.4: New nationwide seismic hazard map of Austria (URL-2).

The new seismic hazard map (Figure 4.4) provides a basis for the development of a new code for earthquake-resistant construction in Austria by the standardization committees of ÖNORM (Austrian Standards International). Until then, the current version of the hazard map (Figure 4.3) within ÖNORM EN 1998-1 remains fully valid.

In summary, Austria has a good overview of the seismic hazards thanks to

(i) the existing real-time monitoring (Figure 4.5)
(ii) the hazard maps, and
(iii) the building code by ÖNORM EN 1998-1

even if the seismic risk is currently not assessed in detail. Instead, Austria is focusing on implementing awareness-raising measures such as the earthquake handbook (Erdbebenschutz Ratgeber; BMI, 2021) by the Ministry of the Interior and the Civil Protection Federation or the visualization of the seismic hazard through the HORA platform (see §4.2.5, 4.3.3, 4.5). In addition, preparedness and training activities of the emergency services are performed on a regional level.

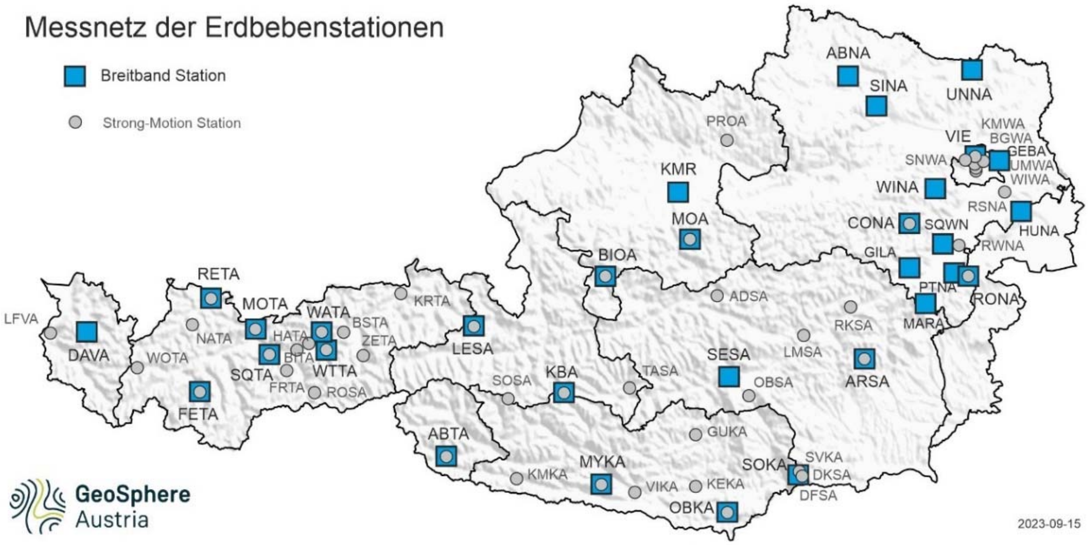


Figure 4.5: Seismological measurement network in Austria (URL-3).

4.2.1. Hazard model

The latest seismic hazard map of Austria from 2021 with a resolution of 2 x 2 kilometers (Weginger et al., 2019; 2021) shows the maximum horizontal ground motion with an occurrence probability of 10% in 50 years, i.e. 475-year mean return period (Figure 4.6). According to Weginger et al. (2019), the new approach combines the seismic zones model with a geological fault zone model, considering a zone-free approach. The improvements in the probabilistic seismic hazard assessment (PSHA) are based on:

1) revised Austrian Earthquake Catalogue (AEC)
2) additional monitoring data of the Austrian Seismological Measurement Network

With regards to the methodological improvements in the PSHA, these include (i) locally adjusted ground motion prediction equations (GMPE) computed by applying least-squares fitting to the local measurements, (ii) a neural network approach was implemented, and (iii) as a result, the final selection was made using statistical parameters such as log-likelihood and Euclidean distance domain. Verified calculation methods such as Bayesian Penalized Maximum Likelihood and modified Gutenberg Richter were used (Weginger et al., 2021).

In Austria, there is no calculation of seismic risk - Shake Maps are planned to further support the Emergency Management and the end-users, but by now not used to calculate risk.

The Shake Maps according to the USGS Earthquake Hazards Program – maps of fictitious earthquake – were introduced to the Austrian scientific community which show the possible effects of the ground motion as a degree of intensity according to the European Macroseismic Scale (EMS-98). Shake Maps provide near-real-time maps of ground motion and shaking intensity after significant earthquakes (URL-4). They are automatically generated within minutes after the occurrence of an earthquake. GSA has tested and recorded the USGS ShakeMap 4.0 (experimental code) based on the conditions in Austria (e.g. seismic geological amplification map) and are provided in terms of Intensity, PGA, PGV and PSA (Weginger et al., 2017a; 2017b). These Shake Maps are planned to further support the SKKM and the end-users, who will also be trained for better understanding.

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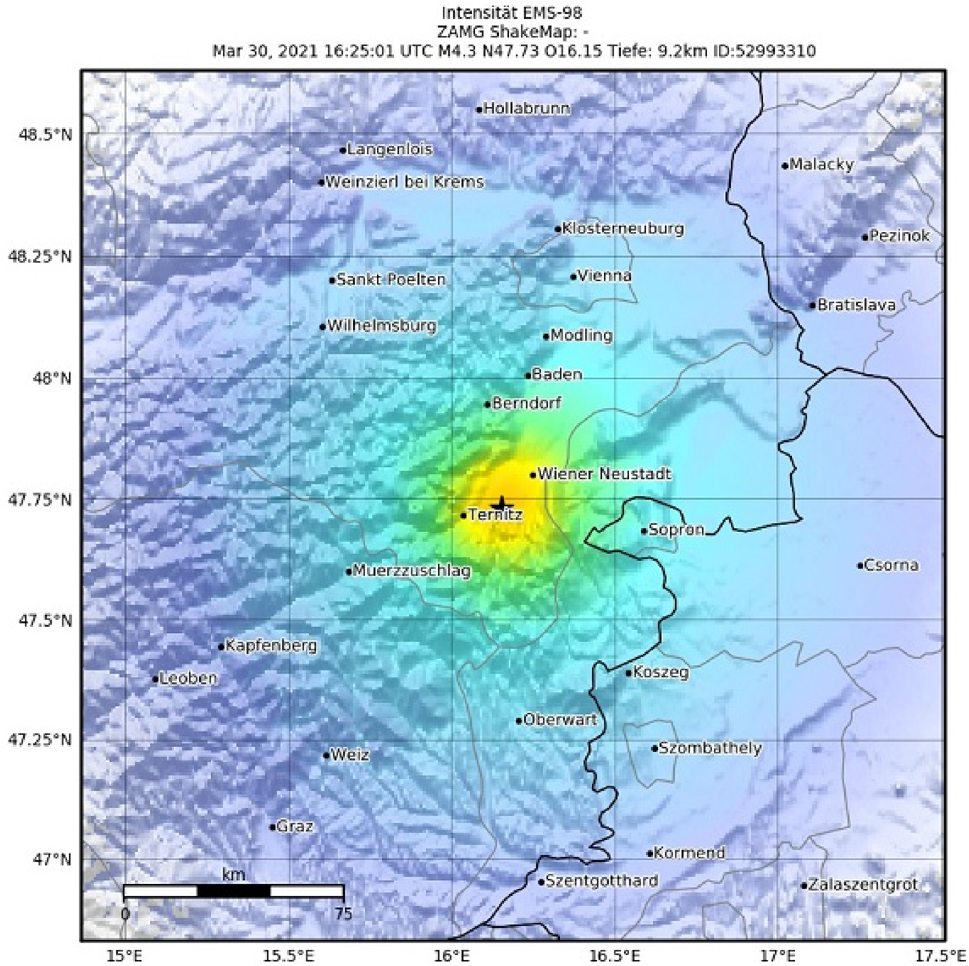

FÜHLBAR	nicht	schwach	leicht	deutlich	stark	sehr stark	häftig	extrem
SCHÄDEN	-	-	-	kaum	leicht	moderat	mod./schwer	Schwer
PGA(%g)	<0.06	0.21	0.81	1.97	4.82	11.8	28.7	70.1
PGV(cm/s)	<0.02	0.08	0.34	0.9	2.39	6.37	17	45.2
INTENSITÄT	I	II-III	IV	V	VI	VII	VIII	IX

Skalierung: Faenza and Michelini (2010, 2011) Version 1: Berechnet 2021-03-31T04:28:51Z
△ Seismische Station ○ Gemeldete Intensität ★ Epizentrum

Figure 4.6: An example of the ShakeMap in Austria (URL-4).

4.2.2. Vulnerability model

The concept of vulnerability is considered within the seismic hazard map (see Figure 4.3) by outlining the 12-step intensity scale, i.e. the European Macroseismic Scale EMS-98 (Grünthal, 1998). The most important features of the macroseismic scale are described in Figure 4.7. Isoclines - lines of equal earthquake intensity - are be used to delineate areas with different degrees of damage or perceptibility.

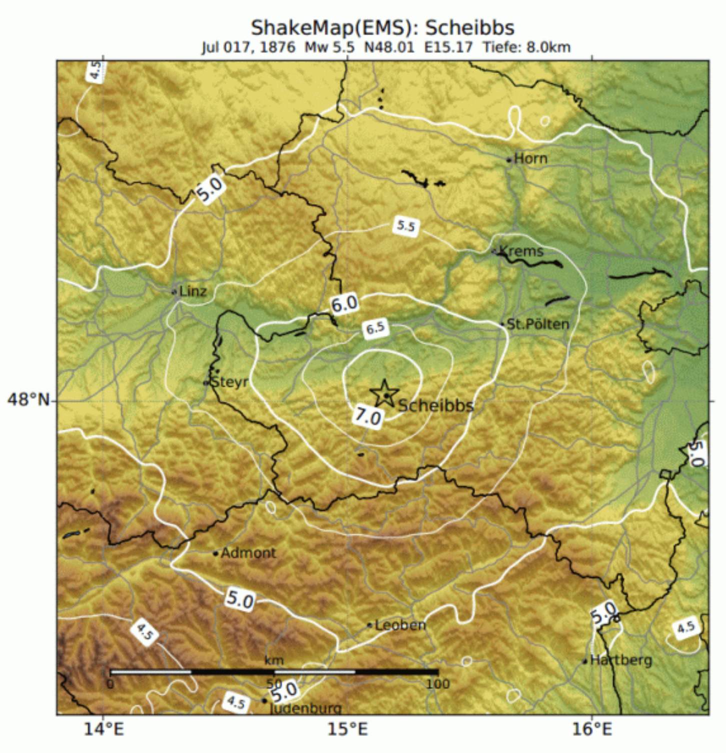

Figure 4.7: ShakeMap of an area in Austria with Isoclines according to the European Macroseismic Scale 1998 (EMS-98) (URL-5).

Currently, there is no vulnerability model in Austria in use, which assigns nationwide the vulnerability of buildings, infrastructure as well as the socio-economic and ecological vulnerability, required for a reliable seismic risk assessment. GeoSphere Austria is currently focusing on the collection of regional data information in an internal initiative called RiskLab to derive vulnerability models for Austria. This step has not yet begun and will require more time and resources. References and general vulnerability models can be found at: https://gitlab.seismo.ethz.ch/efehr/esrm20_vulnerability.

4.2.3. Exposure model

Within the unit of RiskLab, GeoSphere Austria is currently focusing on the collection of regional data information to obtain different types of exposure models for Austria. This step is still at an early stage with the goal to accurately estimate the potential losses and impacts of earthquakes by determining important exposure data, such as:

1) Population and building databases
2) Land use and infrastructure data
3) Geotechnical data
4) Economic and social data

As a reference and first approximation, European exposure data are available at: https://gitlab.seismo.ethz.ch/efehr/esrm20_exposure/. This public repository contains the data and resources used to develop the exposure models for the European Seismic Risk Model 2020 (ESRM20; Crowley et al., 2021).

Ad 1) Population and building databases:

Statistics Austria provides the “Adress-, Gebäude- und Wohnungsregister II (AGWR II)”, i.e. an address, buildings and dwellings register which combines the address register (AWR) and the building and dwelling register (GWR II) in Austria. The AWR enables the maintenance of an Austria-wide inventory of spatial address data down to the building level. In addition, addresses of apartments as well as structural data of buildings, apartments and other units of use are included in GWR II. Information on the number of full-time and other (secondary) residences is also included. The entire dataset is described in detail in the feature catalogue of Statistics Austria (Statistik Austria, 2022). The dataset is divided into a spatial dataset of address points and several content tables. The GWR II further provides data on the construction period, the number of storeys and the number of underground storeys. For older buildings, the construction period is specified by an interval of several years. For newer buildings (since 2000), the construction period corresponds to the year of construction. The construction method is understood to be a rough characterization with regards to the building material used: [ ] (not specified), [M] Brick construction, [B] Reinforced concrete frame, [S] Steel skeleton, [H] Wood frame construction. If there are multiple construction methods used, the predominant method is indicated. (Statistik Austria, 2022)

The *Federal Office of Metrology and Surveying (BEV)* of the Austrian Federal Ministry of Digital and Economic Affairs provides the dataset on the building stock. The BEV's digital cadastral map (DKM) is publicly available and is based on the analogue cadastral map (property database, coordinate database) and is constantly being improved by comparison with aerial image information such as orthophotos and other technical documents (site plans, as-built plans).

Ad 2) Land use and infrastructure

Land use and infrastructure data are currently being collected by GSA, including transport networks, utilities and communication systems, hospitals, dams and power plants, which can help identify critical facilities and infrastructure that could be damaged in an earthquake.

Ad 3) Geotechnical data

Geotechnical data are being collected by GSA such as soil types, liquefaction potential and slope stability are important for determining the extent of ground shaking and possible damage to buildings and infrastructure.

Ad 4) Economical and social data

Economic and social data are currently being collected by GSA, including the local economy, demographics and social vulnerability, which can provide insight into the potential economic and social impacts of earthquakes in the study area.

4.2.4. Damage and Impact indicators

In Austria, the population notices an average of 40 earthquakes per year - this corresponds to an average of about three earthquakes per month. Minor damage to buildings caused by stronger earthquakes is expected about every two to three years. Severe damage to buildings (intensity VIII on the EMS-98 scale) occurs much less frequently, and the average return period for such events is about 75 years. (BMI, 2021)

Earthquakes also have cascading effects, e.g. the failure of electricity and telecom communications and other important supply facilities (hospitals, fire brigades, and the like) as well as transport facilities (bridges, railways, airports, tunnel portals). In addition, landslides could affect important transport routes or important buildings are to be expected in areas where an intensity of degree VII (on the EMS-98 scale) is exceeded. (BMI, 2018)

In general, no standardized method is currently used in Austria to document earthquake damage or to convert damage into impact. The following procedures are currently applied:

(i) *Historical data* on certain events are collected and studied by the GSA.
(ii) *Different apps* and *tools* exist to collect events perceived by the public. The *QuakeWatchAustria App* (URL-6) enables to report noticed earthquakes and damage to GSA. It provides information about all earthquakes of the last hours, days and weeks worldwide using charts and maps, sortable by Austria, Europe, and the world. In addition, the app contains information on how to behave during earthquakes and on prevention/mitigation measures. The tool *Earthquake Report* provided by GSA enables the public to document earthquake damage to individual buildings. In detail, a short questionnaire is used to record the effects of earthquakes on people, objects, buildings and nature (see §4.2.5). (URL-7).

4.2.5. Tool (platform) for seismic risk assessment at urban scale

The following platforms/tools are applied:

1) **HORA** platform: Online since 1st June 2006: https://www.hora.gv.at, the digital hazard map informs the public about the risk posed by rivers, avalanches, earthquakes, hail, storms, lightning and snow loads. The seismic hazard map combines the hazard map and the information on current events during the last 14 days. (BMLRT, 2024)
2) **Erdbebenbericht** (earthquake report): Online on https://www.zamg.ac.at/cms/de/aktuell/erdbeben (URL-8), the questionnaire records the effects of earthquakes on people, objects, buildings and nature. With this questionnaire, people can document their personal perceptions by answering 17 short questions within a few minutes. This information is used for scientific purposes and subsequently for the Austrian civil protection.

In addition, all information about the Austrian seismological network, the hazard map and the current events as well as precise agR values are available under www.zamg.ac.at (GSA, s.a.).

4.3. Flood risk assessment methods at urban scale

To protect and prepare for flood events Austria follows an integrated flood risk management approach with an interdisciplinary program of measures along the risk cycle (see Figure 4.8). This includes precaution (e.ge. hazard zone planning), protection (protective measures and restoring), awareness-raising (information and education), preparedness (emergency management plans, flood forecast models, monitoring systems) and response and recovery (immediate measures, event documentation) (BMLRT, 2018).

Figure 4.8: Austria follows an integrated flood risk management approach along the risk cycle.

Austria flood risk management currently focuses on the following four objectives: avoiding new risks, reducing risks, strengthening resilience and increasing awareness.

From the perspective of flood risk management, emergency management with its instruments "warning", "alerting" and "operation" helps to strengthen resilience, and therefore needs the provision of underlying information such as flood hazard maps and flood risk maps.

As described in §4.1 the Austrian National Flood Risk Management Plan (RMP) is a strategic planning tool that is coordinated with all administrative areas and stakeholders responsible for flood risk management (BMLRT, 2021a).

The second Austrian RMP2021 (BMLRT, 2021b), valid from 2022-2027, was implemented in accordance with the requirements of Directive 2007/60/EC of the European Parliament and of the Council on the assessment and management of flood risks (EU Flood Directive) and implemented through the Austrian Water Rights Act (WRG1959). The responsible authority for the preparation and publication of the RMP2021 is the Federal Minister for Agriculture, Regions and Tourism. The EU Flood Directive was implemented in the first cycle using the following three work steps and expanded by the RMP2021 that summarizes all activities of the previous implementation cycle and gives an overview on the upcoming activities between (2022-2027). Besides options to reduce the flood risk and especially the residual risk during an event or failure of technical measurements are outlined.

In the first step, a preliminary flood risk assessment was carried out, with potentially significant flood risk areas (APSFR) being identified throughout the federal territory. Communities with more than 500 people potentially affected by flooding were prioritized as significant. Floods in areas that do not meet the significance criterion are assessed via regional and local planning instruments and are not part of the national flood risk management plan.

As a second step, flood hazard and flood risk maps were prepared for the more than 416 risk areas. The maps refer to flood events with different probabilities of occurrence (30, 100 and 300-year floods) and show flooded areas, water depths, flow velocities and the affected buildings, land use and critical infrastructure. Based on numerous modelling calculations, the 'affected population' indicator was defined as the main relevant parameter. The creation of supplementary hazard zone plans is not limited to risk areas, but they must always be created in these prioritized areas.

For the third step, the first version of the Flood Risk Management Plan (RMP), close coordination with the federal states followed, in particular with authorities in the field of spatial planning, regional planning, building regulations, civil engineering, disaster control and nature conservation. The flood risk management plan describes measures (structural and non-structural), explains the implementation process, and provides recommendations for action. Cross-border aspects were coordinated within the framework of the bilateral border water commissions and the international water protection commissions.

4.3.1. Hazard model

The Austrian flood hazard assessment follows a probabilistic approach by using hydrologic and hydraulic models and data from past events to consider the following different scenarios within the hazard and risk maps and to communicate flood risk.

- High probability of occurrence: 30-years return period;
- Medium probability of occurrence: ≥ 100- years return period;
- Low probability of occurrence/extreme flood: 300 years return period.

For every scenario three separate intensity classes (low, medium, high) of the process characteristics of water depth and flow velocity are defined:

- low intensity (water depth < 0.6m; flow velocity < 0.6 m/s).
- medium intensity (water depth between 0.6; 1.5 m, flow velocity between 0.6 and 2 m/s).
- high intensity (water depth > 1.5m and flow velocity > 2 m/s).

Hazard zone plans showing red, yellow and residual risk zones exist for torrential catchments as also for catchments in areas with potential significant flood risk (APSFR) and serve as basis for emergency management, spatial planning, zoning and awareness raising on household level. Additional surface runoff and flow path maps are available in some parts of Austria, especially focusing on the runoff behavior after pluvial heavy rain events in urban areas.

Hazard and risk maps as well as a catalogue of actions are available for all risk areas (APFSR), whereas the hazard maps show the flooded areas, water depths and flow velocities for 30-, 100- and 300-year events. Risk maps provide information on the number of people, land use class and infrastructure affected, as well as additional potential risks. The catalogue of actions contains the most effective combination of measures for the best possible flood management. If possible, more scenarios e.g. HQ10-HQ300 and one scenario that shows the consequences of a dam break, or an open dam is calculated.

All flood hazard maps are available online for the public on the water information platform (WISA, https://maps.wisa.bml.gv.at). For deeper insights also consider BORIS (2021a). Deliverable 2.1: Comparison of NRA.

As a hydrological overview, the Austrian Hydrographic Service runs the webGIS application eHyd (https://ehyd.gv.at/). eHYD provides current data from more than 700 precipitation, runoff and groundwater measuring sites and a survey of current water parameters. The presentation with the map “Pegel Aktuell” of the water levels at the Hydrographic Service's measuring stations is primarily intended to provide an overview of the latest discharge situation in Austria. Discharge categories and warning thresholds are categorized individually in each federal state for historical reasons. The classification of the current gauge map presents a visualization from low water to extreme high water reduced to a few categories by using colors and symbols (BML, 2022).

Forecast models that constantly calculate the current discharge situation and discharge forecasts for up to two days in advance are in use on almost every major watercourse in Austria. Responsibility for operation and the communication of flood information and warnings to the emergency services and the public is assigned to the provincial hydrographic services and adapted to the specific requirements of the country. The hydrographic services of Salzburg, Upper Austria and Lower Austria as well as Via Donau publish discharge forecasts for selected gauging stations constantly online. In all other federal states flood warnings are published in case of an event in the form of status que reports. If an emergency flood alert is set up in a federal state, a warning message appears on the eHYD portal.

4.3.2. Vulnerability and exposure model, damage and impact indicators

Regarding vulnerable and exposed elements and impact indicators, the Austrian focus lays on the visualization of potential impacts and affected assets through risk maps. For the preliminary flood risk assessment three types of risk maps were prepared by intersecting the potential flood inundation area of three scenarios (HQ30, 100, 300) with risk indicators at the scale of 1:25.000 (BMLRT, 2021b). These maps are available to the public via the Austrian Water Information System WISA. In detail the intersection that resulted in Risk Maps (see the following Figures) considers the following exposed elements within the inundation area:

- Population: the potentially affected people per cell are categorized into five classes (1-25, 26-50, 51-75, 76-100, > 100),
- Dominant land use: residential, agriculture, forestry and grassland, industry and commerce, water, development-related uses are visualized by color coding,
- Cultural heritage and infrastructure: Contaminated sites, industry, railway station, school, kindergarten, senior citizens' residence, swimming areas and hospitals are shown using icons on the maps,
- Protected areas: Water protection area, Nature Reserve, UNESCO World Heritage Site, NATURA 2000 area or one color for several protected areas in one place are also outlined by color coding.

The information on the number of potentially affected persons, i.e. those with a main or secondary residence or workplace in the area, is presented on the risk map in a grid with a cell size of 125 x 125 meters and with a color classification. Figure 4.9 is an example of a risk map that shows the people (raster) and infrastructure (icons) potentially affected. In yellow raster cells 1-25 people are potentially affected, whereas dark red stand for more than 100 people affected.

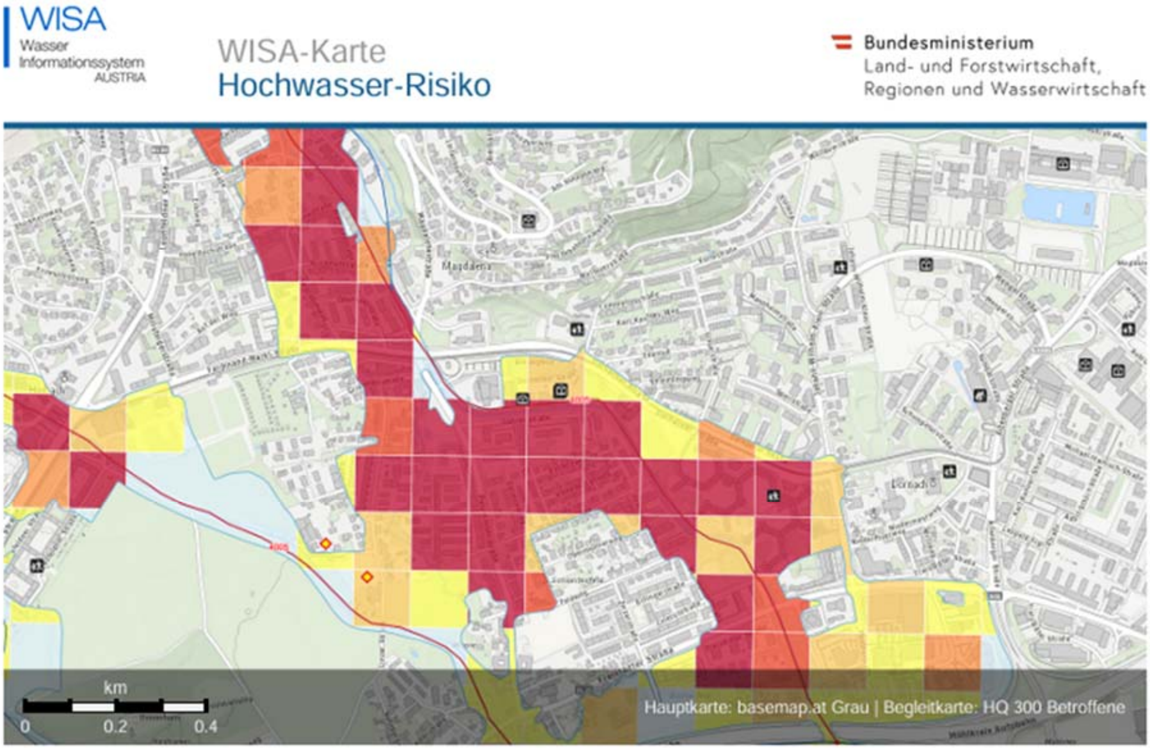

Figure 4.9: Risk map that shows the amount of people (raster) and location of infrastructure (icons) affected by a flood event (source:WISA,).

The following risk map in Figure 4.10 outlines the predominant use of the flooded areas (e.g. predominantly residential, industrial and commercial, urban uses, agricultural, forestry and grassland, water, transport areas), and the third Risk map Figure 4.11 focuses on the various protected areas and water protection areas within the potential floodplain.

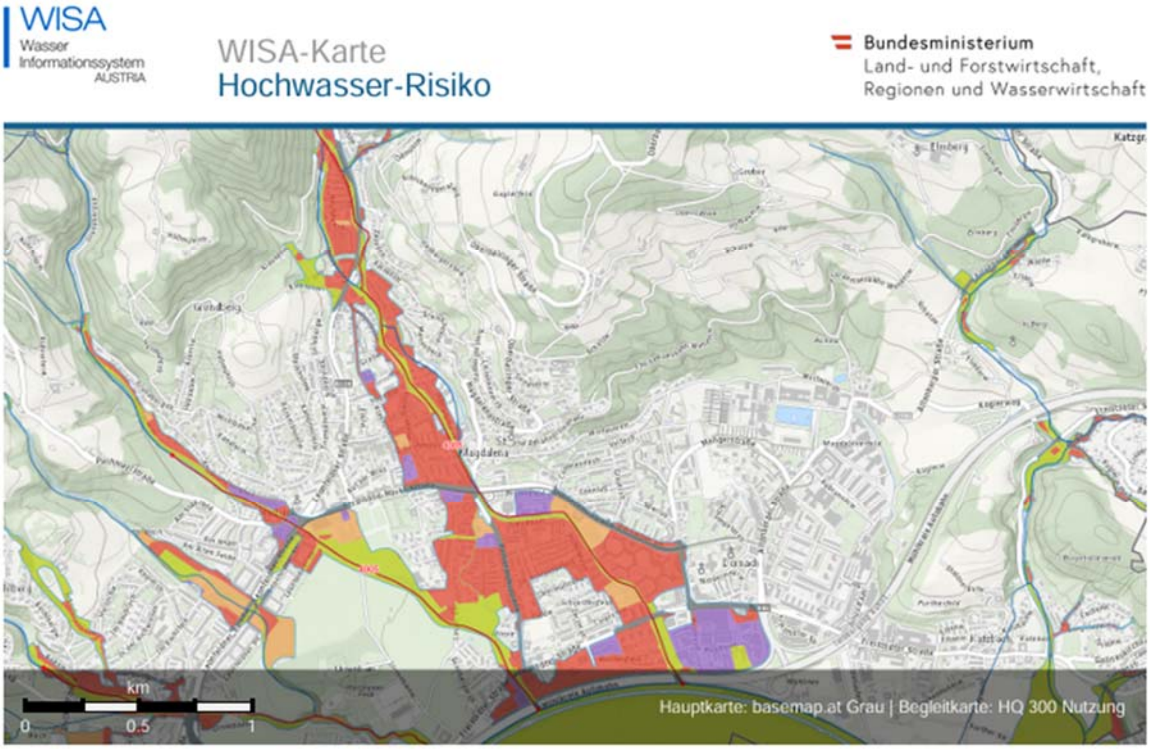

Figure 4.10: Risk map that outlines the predominant use of the flooded area (source: WISA).

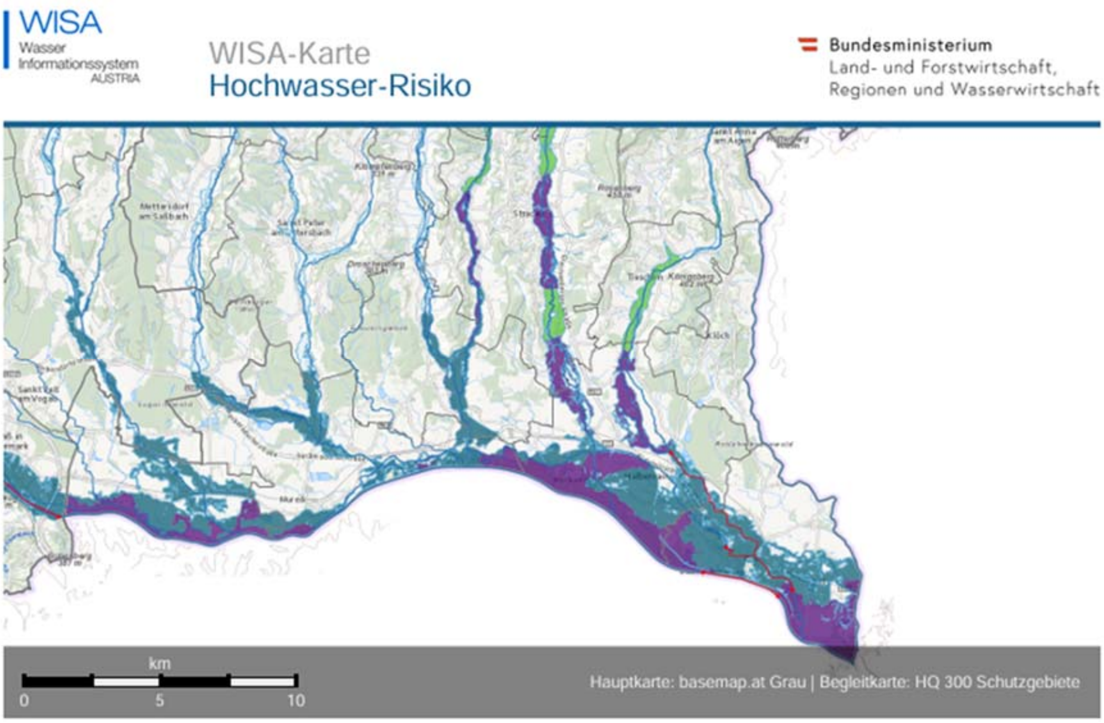

Figure 4.11: Risk map that outlines the protected areas (e.g. nature reserves) within the floodplain (source:WISA).

Currently no further vulnerability or damage potential assessment is applied for floods at national level, as the damage data are too heterogeneous to develop reliable damage curves. Instead, Austria is focusing on establishing a standardized and harmonized damage and event database for Austria (currently available as demonstrator version CESARE - CollEction Standardization and Attribution of Robust disaster Event information) in order ensure that damage functions can be created with the highest possible degree of accuracy in the future. In addition, after major floods, very detailed event documentation and analyses are conducted. The available exposure data for flood assessments is like the seismic as outlined in §4.2.

In terms of the consideration of uncertainty and the residual risk, it is the case that in Austria flood protection measures are mainly designed against a 100-year flood event and therefore a simulation of a scenario with a 300-year flood event or removal of all dam structures can be used to visualize the residual risk.

In the course of the Austrian National Flood Risk Management Plan (2021) which is a strategic, overarching planning instrument that is coordinated with the administrative authorities and stakeholders responsible for flood risk management short fact sheets with information on exposed elements were prepared (Figure 4.12). For each APSFR area, the fact sheet provides local information on the size of the exposed area, the main use of the flooded areas, the responsible flood risk management authority, the runoff peaks for the three scenarios and the number of potentially affected people and the related settlement area in hectares. In addition, the status of the implementation of water management measures and planned developments are outlined.

Figure 4.12: Flood risk in numbers: The visualization shows the number of exposed people and settlement area (ha) per flood scenario (HQ30, 100,300) that is used within the Flood Risk Management Fact Sheets to communicated to local authorities and emergency services. (Source:RMP2021).

4.3.3. Tool (platform) for flood risk assessment at urban scale

In Austria, no tools (platforms) exist that focus on urban areas and flood risk assessment. The flood hazard and risk maps are available for the entire Austria (urban and rural areas) and are available to the public. These maps and information are made available to the public via various communication tools/platforms:

The **online maps in water information system Austria WISA show the APSFRs and flo**odplains for HQ30, 100, 300, hazard maps with water depths and flow velocities, and risk indicators. The Risk maps show the potentially exposed elements of protection (people, environment, cultural assets and economy) under different hazard scenarios. Maps are available at: https://maps.wisa.bmlrt.gv.at/.

Natural Hazard Overview & Risk Assessment Austria (HORA) is a project by the Federal Ministry of Agriculture, Regions and Tourism together with the insurance companies. The HORA risk map (http://www.hora.gv.at) offers a quick and easy initial assessment of the personal risk situation through the collection of publicly available hazard maps and risk information on floods, avalanches, earthquakes, landslides, storms, lightning, hail and snow load. A new feature especially for flood risk is the HORA flood

3D representation (Figure 4.13), an object-centered risk visualization for the target group general public (municipalities, majors, emergency management authorities)). The application includes the possibility to visualize the effects of measures such as sandbags or building walls on the run-off behavior. www.hora.gv.at.

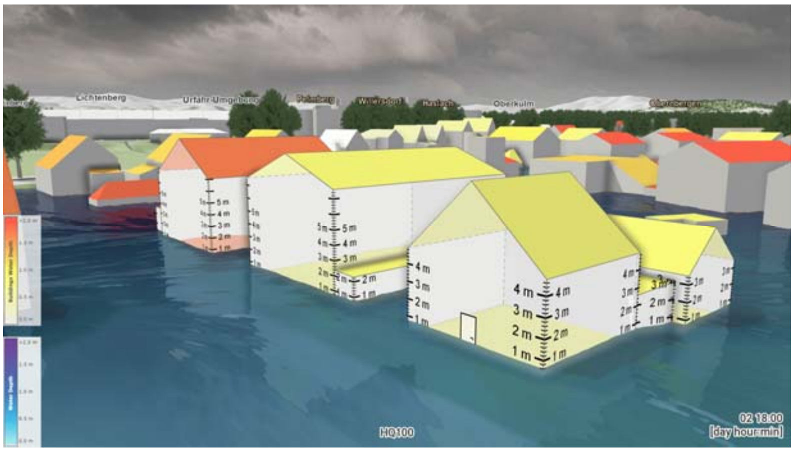

Figure 4.13: New 3D HORA tool to visualize flood scenarios object centered. source: vivris 2023.

The **GIS portal of the federal states and the intranet portal of the Departments of Civil Protection** provides information as overview maps, hazard maps, event registers, hydrographic information, lists of the respective crisis teams, the guidelines for leading emergency operations of the State Crisis and Civil Protection Management (SKKM) and all necessary forms and overviews.

Expert workshops along hazard catalogues and checklists are an established method of risk analysis. It is a qualitative method of (subjective) risk analysis that is in Austria applied if, due to a lack of data, quantitative indicators, etc., standardized (mathematical) approaches for scenario analysis are not available. Disaster management mainly relies on this method, providing the best outcome possible. The workshop targets are to define one or more scenarios, analyze the probability of occurrence and impact, identify the position on a risk matrix, assess the measures required to manage the risk and define further steps.

4.4. The Role of Seismic and Flood Risk Analysis in Effective DRM

The overall aim of emergency management is to prevent or minimize damage to people, animals, the environment and property. To analyze and plan for disasters, the first step is to identify the relevant hazards on the local level. For this step, the emergency management authorities in Austria use different planning tools and checklists to prepare on the local level. The objective of this checklists is to provide a quick and structured assessment of existing hazards and to identify further measures that can be tackled through the local disaster management and alarm plans. Disaster control authorities use hydraulic and hydrological information and the different flood hazard and risk maps and analyses for planning.

For example, if a hazard such as a localized extreme heavy rainfall event is classified as high in the federal state of Lower Austria, the local disaster management plans must be adapted, or a special alarm plan prepared (e.g. flood alarm plan for the Danube). The basis for this is provided by the Civil Protection Act. Supplementary alarm plans are mandatory in the transport sector for particularly vulnerable areas, e.g. road, rail and air transport.

The federal state warning centers (LWZ) are permanently staffed disaster control centers at federal state level. Their task is to warn and alert the population in the event of a disaster and to coordinate the emergency services in the event of major disasters in the respective federal state. The LWZ are in contact with the regional headquarters of the relief and rescue organizations as well as with the regional contact points of the respective neighboring states.

In addition, measurements of precipitation, temperature and groundwater levels are publicly available online. For example, the Styrian State Warning Centre (LWZ) visualizes hydrographs and as a "flood report" on its website.

As part of the revised Flood Risk Management Plan RMP2021, effort was given towards providing the map content in an understandable way for the interested public. The legend was simplified, some of the technical content of the maps was reduced and additional tutorials and definitions were added to the online platform. Further map content was generated that can provide additional planning information for particular sectors as for civil protection. As part of the implementation of the EU Floods Framework Directive, recommendations with appropriate pictograms were developed to visualize how a certain water level or flow velocity affects people, taking into account children, the elderly and vehicles.

- How do risk analyses shape the response and assistance strategies? (focus on urban/local level)
- **Expert workshops** along hazard catalogues and checklists are an established method of risk analysis. It is a qualitative method of (subjective) risk analysis that is in Austria applied if, due to a lack of data, quantitative indicators, etc., standardized (mathematical) approaches for scenario analysis are not available. Disaster management mainly relies on this method, providing the best outcome possible. The workshop targets are to define one or more scenarios, analyze the probability of occurrence and impact, identify the position on a risk matrix, assess the measures required to manage the risk and define further steps.
- How do risk analyses contribute to resilient rebuilding and recovery processes in your county (focus on urban level)
- The Role of Early Warning Systems and Forecasting, the effectiveness of early warning systems (relevant for floods)
- A central concern of Civil Protection and Disaster Management is the rapid transmission of a warning and alarm to the public in disasters or crises. Austria holds a well-developed warning and alarm system that is operated by the Federal Ministry of the Interior jointly with the offices of the provincial governments. Thus, Austria is one of the few countries that have a nationwide siren warning system. Currently the warning and alarm signals can be emitted by over 8,000 fire brigade sirens. In Vienna 165 civil protection sirens have been installed recently. Depending on the emergency, the signals can be activated centrally by the Federal Alarm Center at the Federal Ministry of the Interior, the provincial alarm centers of the federal provinces, or the district alarm centers.

4.5. Multi-risk assessment methods

A study assessing multiple risks in risk assessment at national, regional and local level has not yet been conducted in Austria and each risk is assessed individually. However, it is possible to access the different hazard assessments (for different processes) for a specific point/ any location on HORA or via the federal state GIS. The HORA Pass is a representation of the different hazards (flood, avalanche, earthquake, landslides, storm, lightning, hail and snow load) based on the information available on hora.gv.at for (see §4.2.5, 4.3.3), for a first assessment of whether there is a need for preparedness action on the household level, although no information on the exposure of the buildings is included. The Information can be displayed for any address in Austria and the area around, selected as a radius (in meters). In a clear and easy-to-understand overall presentation, the expected intensity as well as recommendations for to improve on the household level are provided via text explanations and a "multi-hazard" graphic (see Figure 4.14).

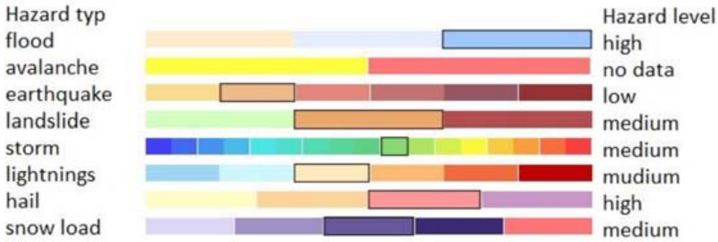

Figure 4.14: HORA PASS - Illustration of hazard levels (right column low/medium/high) per process/hazard type (left column) for a selected location.

For several years now, Austria has been successfully implementing another instrument at community level that takes multiple risks into account. The "Natural hazards and Climate Change - Preparedness check" is an innovative instrument to support municipalities in considering the local, individual risk to natural hazards and strengthen the risk prevention of communities. The aim of the Natural Hazards in Climate Change Preparedness Check is to raise awareness of local decision-makers for relevant local natural hazards and climate risks and to strengthen risk awareness and preparedness capacities within the municipality's area of responsibility. Experts with special expertise in the field of climate and natural hazards attend the community for the natural hazard check and assess on site which different hazards are locally relevant, which assets are exposed and how the local community can best adapt. This method is used to determine both the existing preparedness potential and the possible need for action in order to be better prepared for disasters and the challenges of climate change. https://www.naturgefahrenimklimawandel.at/.

Another instrument at the interface between risk management and civil protection/ disaster management is the Austrian Multi-Hazard Impact-based Advice Services Initiative. AMAS that is organized by GeoSphere Austria is an advisory service aimed at organizing partnerships of experts from all fields of hazards in the federal provinces with the aim of providing the best possible consultation to civil protection managers.

5. OVERVIEW OF DRM AT THE URBAN SCALE FOR TURKEY IN 2024

5.1. Procedural frameworks for DRM

With the aim of following an integrated disaster management approach and replacing disaster management carried out by multiple governmental bodies such as Prime Minister's Office General Directorate of Emergency Management of Turkey, Ministry of Public Works and Settlement General Directorate of Disaster Affairs and Ministry of Interior Ministry General Directorate of Civil Protection, Disaster and Emergency Management Presidency (AFAD) was founded in 2009 by the Law No. 5902 (Official Gazette of the Republic of Turkey, No. 27261) to conduct comprehensive disaster management processes and ensure coordination among relevant administrations, institutions and organizations. Turkey's first National Disaster Risk Assessment Report (AFAD, 2019) was prepared in 2019 for disasters induced by extreme natural events such as earthquakes, floods, forest fires, landslides, rockfalls and avalanches. According to the data recorded since the beginning of last century, earthquakes and floods have been the leading ones inducing disasters in Turkey (AFAD, 2022a).

Within the scope of the integrated disaster management approach, national and local plans shown in Figure 5.1 have been developed. Turkey Disaster Risk Reduction Plan (AFAD, 2022b) aims to (i) prevent physical, social economic, environmental, and psychological losses that may result from disasters or reduce their effects, (ii) establish durable, safe, well-prepared, sustainable and disaster-resistant living environments, and (iii) define the fundamental principles of disaster risk reduction works required to be prepared and implemented prior to disasters. The objective of the Turkey Disaster Response Plan (AFAD, 2022c) is to define the roles and responsibilities of working groups and coordination units that will serve in emergency response. While these two national plans are in action, Turkey Post-Disaster Recovery Plan is still under preparation.

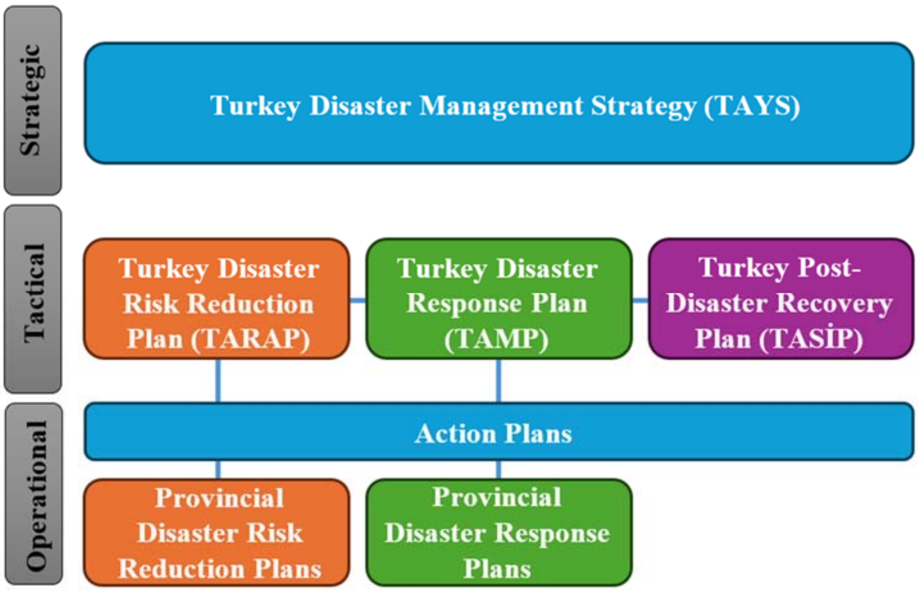

Figure 5.1: Disaster and emergency management system in Turkey.

In accordance with national tactical plans, operational disaster risk reduction and disaster response plans for each province (available at https://www.afad.gov.tr/il-planlari in Turkish) have been prepared. For districts with a population over 50,000, governors have the authority to establish District AFAD Centers. In such a case, a district response plan is prepared following the relevant provincial response plan.) have been prepared.

For districts with a population over 50,000, governors have the authority to establish District AFAD Centers. In such a case, a district response plan is prepared following the relevant provincial response plan.

A provincial disaster risk reduction plan consists of modules involving (i) up-to-date information about the province (geographical and general information, natural characteristics, socio-demographic characteristics, economic characteristics, states of transportation and infrastructure facilities, urbanization and settlement structure, possible hazards and disaster management applications), (ii) identification of hazards and risk assessment, (iii) current state assessment, (iv) disaster risk reduction actions, and (v) monitoring and assessing the plan. A provincial disaster response plan, on the other hand, reports the objectives and principles of disaster response plan, general information about the province, possible hazards and risks, organizational structure in disaster response and responsible authorities, monitoring and revising processes of the plan.

In case of an emergency, coordination at the local level is maintained by a committee headed by the Governor. Depending on the state of emergency, four response levels are defined ranging from “adequate local capacity” to “need for international support”. The response levels together with corresponding support scales are given in Table 5.1. Within the scope of the provincial disaster response plans, working groups (search and rescue, damage identification, infrastructure, transportation infrastructure, etc.) that will serve in case of an emergency are established by defining the primary responsible authority, supporting authorities, tasks and responsibilities of each working group.

Table 5.1: Disaster response levels (AFAD, 2022c).

Level	Scale	Impact	Event type and support scale
I	Slightly	Local capacity is adequate.	Provincial AFAD directorate
II	Moderately	Backup is needed from supporting provinces.	Provincial AFAD directorate + 1st group supporting provinces
III	Very	National support is required.	1st and 2nd group supporting provinces + National capacity
IV	Extremely	International support is required.	1st and 2nd group supporting provinces + National capacity + International capacity

Following the major Gölcük earthquake occurred on August 17, 1999, Compulsory Earthquake Insurance was developed by the state to cover dwellings against earthquakes and disasters directly caused by earthquakes such as fire, explosion, landslides and tsunamis. The Turkish Catastrophe Insurance Pool, established in 2000, is the public institution with a legal identity responsible for the acquisition of Compulsory Earthquake Insurance by the public, its implementation and its management in accordance with the Law No. 6305 (Official Gazette of the Republic of Turkey, No. 28296). No financial sanctions are imposed on those who do not have the compulsory insurance, however those without a valid insurance policy are not provided with services such as electricity, water and natural gas.

The Multi-Criteria Decision-Making (MCDM) method is employed to assess and analyze flood risk in a basin. Saaty (1980) introduced a theory for measuring tangible criteria, where the criteria's weight is assessed using pairwise comparison matrices. This method aids decision-makers by quantifying alternative priorities, making it a robust and versatile technique for setting priorities and enhancing decision-making processes.

The responsible institutions for flood risk at different levels are shown in Table 5.2 and the working groups defined by Turkey Disaster Response Plan (AFAD, 2022c) are shown in Table 5.3.

Table 5.2: Responsible institutions at national, regional, and provincial levels for flood risk in Turkey (Flood and Drought Management Department, 2022).

NATIONAL	REGIONAL	PROVINCIAL
Disaster and Management Presidency (AFAD)	Regional Directorates of State Hydraulic Works	Governors
Water Management Coordination Committee	Regional Directorates of General Directorate of Forestry	Provincial Directorates of State Hydraulic Works
General Directorate of Water Management		Provincial Disaster and Management Directorates
State Hydraulic Works		Local Administrations
Turkish State Meteorological Service		
General Directorate of Combating Desertification and Erosion		
General Directorate of Forestry		
Ministry of Environment and Urbanization		
Ministry of Health		

Table 5.3: Working Groups in Charge for Hazard-Based Plans (AFAD, 2022c).

Hazard Type	Working Groups
Earthquake	Communication, Transport Infrastructure, Security and Traffic, Fire and Hazardous Substances, Search and Rescue, Transport, Health, Evacuation, Placement and Planning, Infrastructure, Energy, Housing, Nutrition, Damage Detection, Debris Removal, Food, Agriculture and Livestock, Psychosocial Support, Burial, Working Groups Logistics, Resource Management, Technical Support and Supply, In-Kind Donation Storage Management and Distribution, Information Management, Evaluation, Monitoring and Strategy Development, Purchasing and Renting, Accounting Budget and Financial Reporting, Loss Detection
Flood	Communication, Transport Infrastructure, Security and Traffic, Search and Rescue, Transport, Health, Evacuation, Placement and Planning, Infrastructure, Energy, Nutrition, Damage Detection, Debris Removal, Food, Agriculture and Livestock, Working Groups Logistics, Technical Support and Supply, Information Management, Evaluation, Monitoring and Strategy Development, Loss Detection

Flood management is an area that requires many institutions and organizations carrying out different activities to act in collaboration. In addition, many institutions and organizations benefit from/are affected by flood management measures. All these groups constitute the stakeholders of flood management. Stakeholders are all persons, groups or organizations that have an interest in the issue. Stakeholders also include members of the

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public who are not yet aware that they will be affected (in practice this includes many citizens and small NGOs and companies). Although some of the stakeholders can be divided into those who manage/implement the measures and those who benefit from/are affected by the measures, most of them are in both groups. accordingly, the main stakeholders are generally grouped as follows (Flood and Drought Management Department, 2022):

- Settlement residents
- Public institutions (national, regional, local)
- Interest groups (chambers of commerce, forestry, agriculture, tourism, hunting, fishing, professional associations, etc.)
- Landowners/tenants
- NGOs (mostly nature conservation groups at local, regional, national or international level)
- The public affected by or interested in the relevant decisions

The roles of stakeholders may change during the implementation period. It is important to consider who will be needed, when, for what task and at what level. Stakeholders may be more willing to participate if they have a clear picture of what is expected of them and how much effort they need to make to participate (Flood and Drought Management Department, 2022).

Stakeholders' roles are summarized below.

- *Process initiators* are involved from the stage of developing or financing.
- *Shapers* strengthen, support or guide the emergency management plan in the early stages.
- *Informants* provide secondary data and information, organize focus groups, etc.
- *Centers* play a central role during the implementation. They can play several roles (shaper, informant, etc.) and can also act as an advisory group.
- *Reviewers* contribute to the final output (workshops, surveys, etc.).
- *Recipients,* although not involved directly, are assumed to have an interest in the results and are influenced by the process.
- *Reflectors* provide feedback on the results achieved and ideas for follow-up activities.
- *Indirectly affected ones* are those that are not directly involved but affected by the process or its results.

5.2. Seismic risk assessment methods at urban scale

Since Turkey is a seismically very active region, a plan referred to as the National Earthquake Strategy and Action Plan (AFAD, 2013) was put into action by AFAD in 2012. Within the scope of this plan, the active fault map of Turkey and the earthquake hazard map of Turkey were updated by the General Directorate of Mineral Research and Exploration and AFAD, respectively. Disaster risk reduction and disaster response plans for a province report the past seismic activity and assess the current seismicity of the province by considering the active fault map and the earthquake hazard map of Turkey.

Both probabilistic and deterministic approaches have been utilized for seismic hazard analyses. Within the scope of the risk reduction plan of a province, probable and worst-case earthquake scenarios have been developed by considering the seismic activity map of the relevant region and the active fault map of Turkey.

The criteria stated by the Turkish Building Earthquake Code (TBDY, 2018) together with those relevant to the province of interest have been considered as the primary factors in the seismic risk assessment. Seismic risk assessments for a province have been conducted district by district. As an example, the physical risk map and the results of the seismic risk assessment reported in the provincial disaster risk reduction plan of Istanbul are shown in Figures 5.2 and 5.3, respectively. The consequences have been published in terms of structural damage, loss of lives and injuries, and damage to infrastructure in the form of maps and/or tables. The objective is to identify districts with high risks so that disaster risk reduction and disaster response activities, and urban transformation works could be planned and implemented efficiently and effectively.

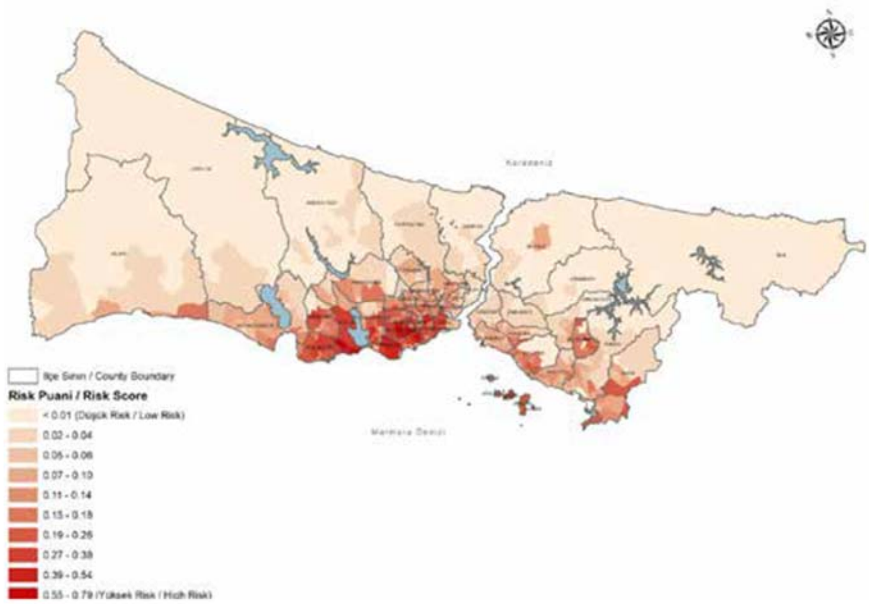

Figure 5.2: Physical risk map of Istanbul (Provincial AFAD Directorate of Istanbul, 2022).

Figure 5.3: Results of seismic risk assessment for Istanbul (Provincial AFAD Directorate of Istanbul, 2022).

5.2.1. Hazard model

The earthquake hazard map of Turkey, which was developed by considering probabilistic approaches and put into action in 2019, is shown in Figure 5.4. It provides peak ground acceleration values having a 10% probability of exceedance in 50 years, corresponding to a return period of 475 years. The map was prepared considering an average shear wave velocity (V_{s30}) of 760 m/s, but not taking into account the hazards caused by local soil conditions such as liquefaction, ground amplification, subsidence, etc. The data including peak ground acceleration, peak ground velocity, 5%-damped pseudo-spectral accelerations at 0.2 s and 1.0 s periods for different return periods (43,72, 475 and 2475 years) at grid points with spacing of 0.1° x 0.1° in latitude and longitude are also provided. A GIS-based interactive web application is publicly available to view and query earthquake hazard maps based on these data. The amplitudes provided by the earthquake hazard map of

Turkey can be converted to site specific amplitudes employing local site effect factors, which are functions of site classes and level of amplitudes, given by the seismic design specifications.

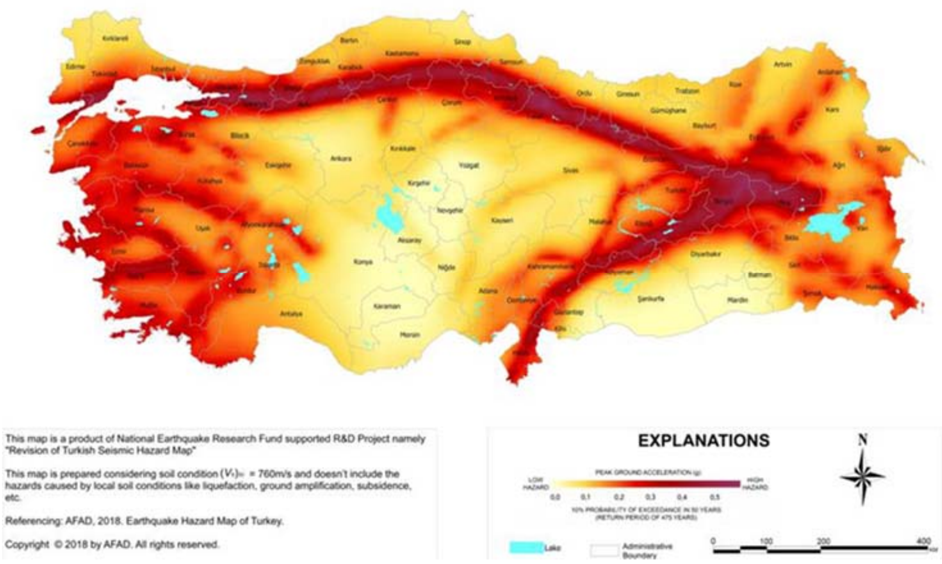

Figure 5.4: Earthquake hazard map of Turkey.

For scenario-based risk assessments, earthquake scenarios, which have been developed by considering the seismic activity map of the relevant region and the active fault map of Turkey, have been utilized to estimate peak ground acceleration, peak ground velocity, 5%-damped pseudo-spectral accelerations at 0.2 s and 1.0 s periods, and produce maps. The platform developed by AFAD allows multiple ground motion prediction models to be used by assigning weights to the models considered. First, estimates have been made and then soil amplification has been applied. The manual for preparing a provincial risk reduction plan (AFAD, 2020) requires considering at least two scenarios, one of which is a worst-case scenario, and the other is a probable scenario.

5.2.2. Vulnerability model

Structural damage is estimated by utilizing fragility curves defined for four damage states: slight, moderate, extensive and complete. Three main criteria considered in the vulnerability assessment are (i) local site condition, (ii) building inventory and stock, and (iii) distance to active faults. The platform developed by AFAD allows to define fragility curves in terms of seismic intensity, peak ground acceleration, peak ground velocity, peak ground displacement, spectral displacement etc. However, since the available building and population database used by the platform developed by AFAD contains only the number of buildings and population, spectral displacement and seismic intensity-based fragility curves, which are average curves for all buildings, are utilized in the analyses.

Provinces having more detailed building inventories may perform more elaborate analyses. For example, building inventory in Istanbul has been classified according to lateral structural system, building height and construction year, and then fragility curves have been developed accordingly. Using these curves, the number of buildings for each damage state has been determined and maps displaying building damage distribution across the province have been produced. The map showing the estimate of moderately damaged building distribution for a ground motion with a return period of 475 years in Istanbul is shown in Figure 5.5.

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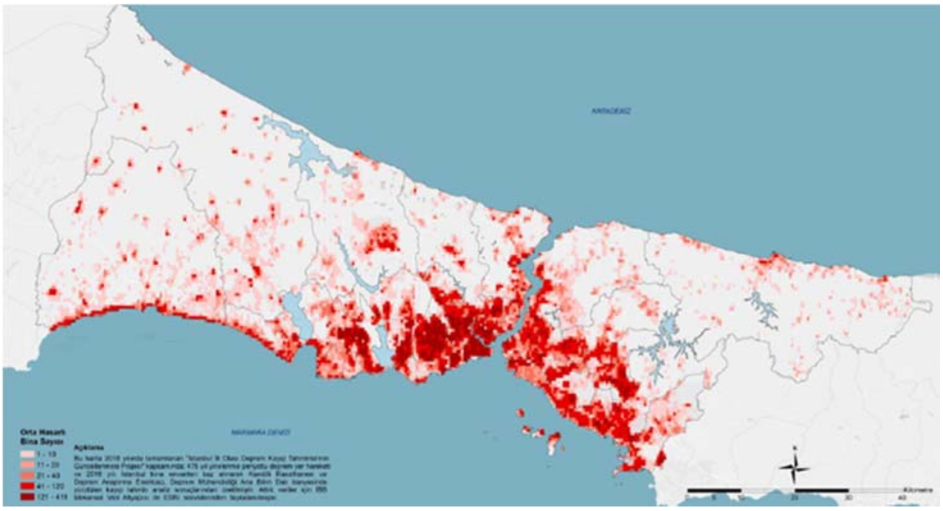


Figure 5.5: Moderately damaged building distribution estimate for a ground motion with a return period of 475 years (Istanbul, Turkey) (Cakti et al., 2019).

5.2.3. Exposure model

The general information about structure and infrastructure inventory of a province is reported in the form of tables and maps in the province disaster risk reduction plan, but the detailed data is not publicly available. The map showing the building stock map in Istanbul is shown in Figure 5.6 as an example. The detailed data used for risk assessment have been provided by municipalities. For instance, the inventory for Istanbul has been compiled mainly by using the resources provided by the Directorate of Geographical Information Systems of Istanbul Metropolitan Municipality. A cell network with a spacing of 0.005° x 0.005° has been established. Besides the buildings, the inventory involves data about day and night population, lifeline systems (natural gas, drinking water, wastewater and power lines) and transportation infrastructures.

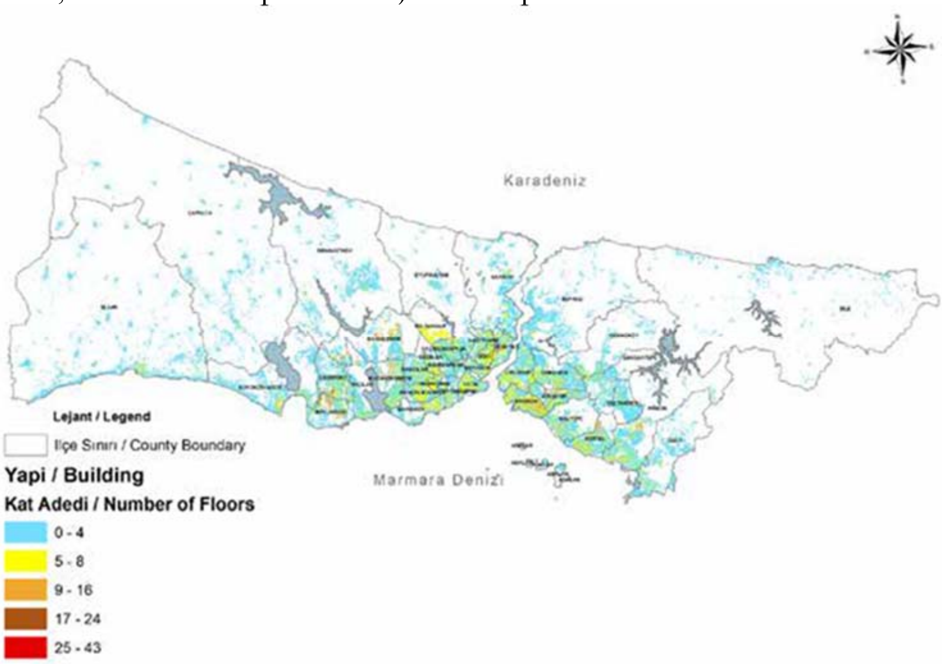


Figure 5.6: Building stock in Istanbul (Turkey) (Cakti et al., 2019).

5.2.4. Damage and Impact indicators

National Disaster Risk Assessment Report of Turkey (AFAD, 2019) defines three impact criteria represented by eight impact indicators (Table 5.4). The effects of the indicators are evaluated with a five-class system: limited, significant, severe, very severe and catastrophic. The following criteria are used:

1. *Human life and health*. Human life is invaluable. Loss of life, deterioration of health and displacement are seen as essential breaches of human rights.
2. *Economy and environment*. Economic loss can have devastating effects on the well-being of people. The same applies to environmental damage. The consequences can be long-term and hard to overcome.
3. *Society's functionality*. The value of families, communities, social networks and (historical) symbols are high for the functioning of people in a society. Society's identity is derived from shared artefacts and damaging these has a high impact on the well-being of people.

Table 5.4: Impact criteria and indicators (BORIS, 2021a).

Impact	
Criterion	**Indicator**
Human life and health	1.1 Number of fatalities
	1.2 Number of severely injured/ill
	1.3 Lack of fulfilment of basic needs
	1.4 Number of people who need to be evacuated
Economy and environment	2.1 Total economic impacts
	2.2 Impacts for nature and environment
Society's functionality	3.1 Disruption's to daily life
	3.2 Loss of cultural heritage
	3.3 Loss of reputation

The aforementioned indicators describe the general approach to be followed while carrying out a risk assessment. The manual for preparing a provincial risk reduction plan (AFAD, 2020) suggests using the platform developed by AFAD for calculations but it is not mandatory.

5.2.5. Tool (platform) for seismic risk assessment at urban scale

A platform referred to as Rapid Earthquake Damage and Loss Estimation System (AFAD-RED) has been developed for generating earthquake scenarios and estimating potential structural damage (slight, moderate, extensive and complete), the number of casualties, the need for temporary shelter service and serviceability of critical facilities (i.e. schools, hospitals, governorship buildings etc.), transportation systems (i.e. bridges, highways, railways etc.) and lifeline systems (i.e. natural gas, petroleum, drinking water and wastewater lines). It also produces maps for seismic intensity, peak ground acceleration, peak ground velocity, etc. The outputs are used as the basis for risk reduction, emergency response and recovery activities.

The system is integrated with the National Earthquake Observation System operated by AFAD. When an earthquake occurs, the system provides near real-time estimation of losses in the earthquake-affected region so that appropriate measures can be taken.

A web-based application referred to as Disaster Management and Decision Support System was developed to maintain an efficient use of resources in case of disaster and emergency. It constitutes the informatics infrastructure of Turkey Disaster Response Plan. AFAD-RED is compatible with the Disaster Management and Decision Support System, so Provincial AFAD directorates can easily integrate outputs from AFAD-RED into their works on the Disaster Management and Decision Support System. The Disaster Management and Decision Support System consists of three components:

- *Incident command system* is the component that makes it possible to manage the preparation, planning and intervention processes for the working groups defined in the Disaster Response Plan in an integrated manner.
- *Spatial information system* is intended to establish a sustainable disaster management system using geographical information system technologies. It is designed to make it possible to access accurate data rapidly before, during and after disasters, to produce new information from the data obtained and to take decisions quickly about the spatial queries and analyses to be carried out for the areas where disasters have occurred or may occur.
- *Recovery system* aims to make it possible to realize the recovery efforts carried out after disasters in an informatics environment with geographical information system support. This will make it possible to manage interrelated processes such as damage assessment, rights determination and site selection immediately.

5.3. Flood risk assessment methods at urban scale

In 2013, Turkey initiated the implementation and adaptation of the EU Floods Directive (2007/60/EC, available at https://eur-lex.europa.eu/eli/dir/2007/60/oj), involving the creation of flood hazard maps, flood risk maps, and flood risk management plans for river basins. The Ministry of Agriculture and Forestry's General Directorate of Water Management oversees the execution of the Floods Directive, with national legislation in place. The National Action Plan for EU Accession includes specific measures for flood management, and a by-law on the Preparation, Implementation, and Monitoring of Flood Management Plans was issued in 2015. The General Directorate of Water Management has been actively working to align with these objectives and actions.

The process of developing flood risk management plans for basins in Turkey involves several key steps:

a) Preliminary Flood Risk Assessment (PFRA).
b) Preparation of Flood Hazard Maps (FHM).
c) Creation of Flood Risk Maps (FRM).
d) Development of Flood Risk Management Plans (FRMP), which include risk management measures.
e) Revision of the existing Flood Warning System to a Flood Forecasting & Early Warning System (FF-EWS), expanding its coverage to the basin scale in accordance with the relevant articles of the Floods Directive.

5.3.1. Hazard model

The assessment of flood hazards in Turkey typically employs a probabilistic approach, categorizing flood hazard classes through hydrologic and hydraulic modelling with return periods of 50, 100, and 500 years.

Flood hazard maps are created, depicting the inundation area, water level or depth, and water velocity during floods for generally three return periods (Q_{50}, Q_{100}, Q_{500}).

Hazard rates are then obtained from these flood hazard maps, classified into four different classes (Table 5.5), utilizing the hazard rating formula: [water depth × (flow velocity + 0.5)] + Debris factor (van Alphen and Passchier, 2007; BORIS, 2021a).

Table 5.5: Criteria for determination of flood hazard classes (fluvial flooding) (BORIS, 2021a; 2021b).

Very High	**High**	**Medium**	**Low**
at calculated hazard rating > 2.50	at calculated hazard rating between 1.25-2.50	at calculated hazard rating between 0.75-1.25	at calculated hazard rating between < 0.75

Eight factors should be considered when evaluating flood risk management. These include aspects like the basin's hydrology and geography, vegetation density, terrain slope, past events, population density, existing flood defenses, and social and economic activities.

Two-dimensional hydrodynamic models are applied to numerical modelling of urban flooding. All activities outlined in this task must be conducted and presented within the GIS environment. In the PFRA study, past flood mitigation measures will be considered. Flood-prone areas should be displayed on both the map and in a list encompassing settlements, watercourses, agricultural, and industrial zones. The list should cover all evaluated areas, providing explanations for categorizing them as at risk or not at risk.

In Turkey, the General Directorate of Meteorology is responsible for installing and operating early warning systems for all types of floods. After the completion of the works that were conducted for the last few years, the Flash Flood Guidance System has been installed and taken into service. People must be informed without any bureaucratic procedures through the two-phased local instant flooding and storm announcements, which are termed as “Flash Flood Monitoring” and “Flash Flood Warning”. Furthermore, essential disaster response plans must be developed for each province, district and town, allowing the evacuation of dangerous areas within an hour, and practical applications related to these plans must be carried out regularly with the participation of the public. In Turkey, the General Directorate of Meteorology and the General Directorate of State Hydraulic Works have installed the Flash Flood Guidance System and the Flood Early Warning System for the rivers on the Turkey-Bulgaria border, respectively, while the pilot project on the Flood Early Warning System for Istanbul have been conducted by the Istanbul Metropolitan Municipality (IBB-AKOM unit). The Flood Early Warning System for Istanbul, which is currently active, is shown in Figure 5.7. All three institutions share their data and modelling outputs under the coordination of the General Directorate of Meteorology and continue their works on developing more effective and accurate early warning systems (Baris et al., 2020).

In addition to making flood forecasts and issuing early warnings, there are also applications such as issuing warnings based on hydraulic and meteorological measurements. It is based on assigning a hazard rating to the levels measured at Stream Gage Stations (SGS) or Meteorological Observation Stations (MOS) on the river based on past floods and/or previous hydraulic modelling studies. With this method, a warning is given when an alarm level is measured at an SGS/MOS. The disadvantage of the system is that there is no forecasting in advance, so a warning can only be given after the level is realized. In this method, some critical levels can be determined before the expected flood level and preliminary warnings can be given to be prepared. For example, while the alarm for the level determined for flooding is red, a yellow alarm, which means watch/wait, can be used for the critical level.

Figure 5.7: Flood Early Warning System Established by IBB-AKOM for testing purposes (Baris et al., 2020).

5.3.2. Vulnerability and exposure model

Analyzing flood exposure and vulnerability for flood risk assessment involves assessing potential negative impacts based on freely available spatial databases containing information about people, environment, cultural heritage, and economic activities (Table 5.6). The use of the Analytical Hierarchy Process is considered a typology for PFRA and Multi-Criteria Decision-Making Model.
The initial phase of the studies will involve assessing data needs using the information provided by the General Directorate of Water Management and the necessary datasets for preparing PFRA following EU practices. The end recipient will compile a list of datasets to be collected from relevant stakeholders for approval.

The study on data collection includes gathering, organizing, and evaluating all the necessary data. These data should encompass at least:

- adverse impacts of previous floods on human health, the environment, cultural heritage, and economic activities;
- characteristics such as topography, the course of streams and rivers, natural water retention areas, floodplains, soil types, and vegetation;
- overall hydrological and geological features of the basin;

- Information on using current human-made structures and natural features to reduce the impact of flooding;
- information on land use, including population, location of settlements, economic activity areas, strategic structures, cultural heritage buildings, and protected areas;
- the legal framework and current administrative structures for the preparation, prevention, and recovery phases.

The Flood Risk Pre-Assessment (FRPA), as per Article 4 of the EU Floods Directive (2007/60/EC, available at https://eur-lex.europa.eu/eli/dir/2007/60/oj), involves quickly scanning available data, including historical floods, meteorological and hydrological data, geological information, land cover, and soil maps, to determine and evaluate potential flood risks. Methods like the Alluvium Field Method are used to identify flood-prone areas. Additional data, such as development plans, schools, mosques, hospitals, flood control facilities, and industrial sites, are gathered for further analysis in flood management plans.

Digital Elevation Model is based on 1:25,000 scale topographic map data with 15-30 m resolution and can be reduced by 5-10 m with cross-sectional integration. However, the smaller width of the dikes means that higher resolution data (approx. 0.5-2 m). These data are also available from LIDAR type DEM or through detailed field measurements.

People exposed:
The assessment of the impact of floods on people is usually carried out by estimating the number of people likely to be affected within the boundaries of a flooded area. For this purpose, data on the size of the population available at different return periods are used to represent flood exposure. The spatial intersection of population data with the size of a given flood event gives an estimate of the population exposed to flooding. For a holistic assessment, ideal population data, such as spatially distributed address or postal code data, should be available. For the purpose of estimating the approximate number of people affected, the smallest spatial classification may be at the neighborhood level. Using the information for neighborhoods, a reasonable estimate of the actual number of people present in flood areas can be made.

The total number of people affected in a settlement *N* is calculated in a simple way.

$$N = \sum_{i}^{m} \frac{a_{fi}}{A_i} p \qquad (5.1)$$

where m is the number of neighborhoods, a_{fi} is the flooded area, A_i is the total area of a neighborhood of the city and p is the total population in that neighborhood.

Buildings exposed
Building data includes existing building types, zoning plans with data on existing and future construction works, and baseline maps. The data should also include information on the height of the highest level of buildings.

Table 5.6: Infrastructure classification according to the vulnerability (BORIS, 2021a; 2021b).

Essential infrastructure
Essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk.
Essential utility infrastructure which has to be located in a flood risk area for operational reasons, including electricity generating power stations and grid and primary substations; and water treatment works that need to remain operational in times of flood.

Highly vulnerable Police stations, ambulance stations and fire stations and command centers and telecommunications installations required to be operational during flooding. Emergency dispersal points. Schools, worship buildings, kinder gardens, age care and nursing homes Basement dwellings. Caravans, mobile homes and park homes intended for permanent residential use. Installations requiring hazardous substances consent. (Where there is a demonstrable need to locate such installations for bulk storage of materials with port or other similar facilities, or such installations with energy infrastructure or carbon capture and storage installations, that require coastal or waterside locations, or need to be located in other high flood risk areas, in these instances the facilities should be classified as "essential infrastructure")
More vulnerable Hospitals. Residential institutions such as residential care homes, children's homes, social services homes, prisons and hostels, worship buildings, kinder gardens, age care and nursing homes Buildings used for dwelling houses, student halls of residence. Non–residential uses for health services, nurseries and educational establishments. Landfill and sites used for waste management facilities for hazardous waste. Sites used for holiday and camping, subject to a specific warning and evacuation plan
Less vulnerable Buildings used for shops, financial, professional and other services.

5.3.3. Damage and Impact indicators

The primary goal of evaluating flood risk is to safeguard lives, guide flood management decisions, and reduce damage to private infrastructure, businesses, and economic activities. These measures target floods with specific return periods. The following criteria are taken into account in the flood risk assessment study:

- population affected by the flood;
- damage caused by the flood to the buildings and their contents;
- affected strategic structures and infrastructure;
- overall effects of the flood.

For each flood return period (Q_{50}, Q_{100}, Q_{500}) in flood-prone regions, nine maps were generated per study area using "Flood Inundation Maps" as outlined below:

- *Population Affected by Flood Maps*: These maps identify the population affected by potential floods, depicting low, medium, and high-risk areas for settlements. Additionally, the number of individuals exposed to floods will be calculated based on street-level data.
- *Flood Economic Damage Maps*: Economic damage within Q_{50}, Q_{100}, and Q_{500} flood-prone areas was assessed using flood damage-depth curves developed by the Directorate General of the Joint Research

Centre. This includes damage to buildings, commercial and industrial facilities, transportation, infrastructure like roads, and cultivated lands. These damage assessments are presented as layers in a GIS environment, categorizing risk levels as low, medium, and high. Furthermore, the annual expected average damage for Areas of Potential Significant Flood Risk was calculated and adopted to a GIS base map.

- *Flood Risk Maps (Combined Effect)*: For strategic structures, treatment plants, and buildings such as schools, hospitals, worship places, policlinics, childcare, and aged care homes, the flood risk may be higher. Residents in these areas can be more vulnerable during a flood event. Therefore, after consulting with stakeholders, a higher risk factor was assigned to these areas and risk maps were prepared accordingly.

No depth-loss function has been developed for floods in Turkey. For this reason, generally accepted depth-loss functions that are available in the literature and suitable for Turkey can be used (e.g. Figure 5.8).

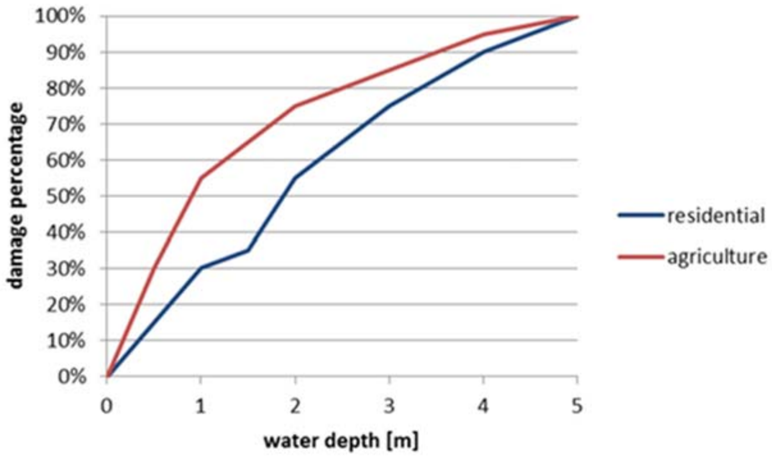


Figure 5.8: Loss Function for Building and Agriculture Categories (Huizinga, 2007).

5.3.4. Tool (platform) for flood risk assessment at urban scale

The Disaster Management and Decision Support System described in §5.3.4 is also used for flood risk assessment. It was designed to establish the information infrastructure and decision support system-centered management model needed for the pre-disaster risk reduction, preparation, and post-disaster response and recovery stages, and to ensure sustainable development. It is a software and data platform that provides access to accurate and valid disaster and emergency data, various reports, statistics, follow-up information, inquiries, analyses, etc. at any time, before or after a disaster (AFAD, 2022c).

5.4. The Role of Seismic and Flood Risk Analysis in Effective DRM

Turkey is vulnerable to the effects of earthquakes and flooding events. Climate change is expected to increase the impacts from flooding, especially at the urban level. However, potential catastrophic impacts from earthquakes will remain a significant threat, at least in the short-term. The World Bank (2019) indicates that Turkey is among the most exposed countries to disaster risk in the world due to its tectonic, seismic, topographic and climactic characteristics. Among these, seismic risk is identified as being the most critical. Turkey was ranked 30th among 192 countries in the 2022 World Risk Index, and in 2021 alone, there were 107 floods reported, 26 earthquakes between magnitudes 5.0-6.0 and three earthquakes that have magnitudes greater than 6.0 (Dilekli, 2022).

In terms of preparations, disaster resilience typically focuses on five core areas: risk identification; risk reduction; preparedness; financial protection; and resilient reconstruction (The World Bank, 2014). The latter of these core areas is in fact an opportunity to promote disaster risk management. This opportunity was recognized and adopted by the Sendai Framework, which stated that the recovery, rehabilitation, and reconstruction phases are a critical opportunity to 'build back better'.

Steps taken in Turkey specifically towards increasing resilience include the following: amending the building earthquake code; urban transformation policies and governmental mechanisms to replace non-compliant building stock; compulsory earthquake insurance to provide funds for rebuilding following earthquakes; critical infrastructure roadmaps prepared by Disaster and Emergency Management Presidency; and efforts towards the preparation of hazards maps for risk analysis (Dilekli, 2022). More specifically, the Disaster and Emergency Management Presidency has put in action two plans -Turkey Disaster Risk Reduction Plan (AFAD, 2022b) and Turkey Disaster Response Plan (AFAD, 2022c)- and finalizing Turkey Post-Disaster Recovery Plan at the national level. The latter action plan describes the interconnectedness of risk reduction and resilient rebuilding efforts. The main goals of the action plan are to: facilitate systematic and synchronous rapid action following a disaster; increase cooperation between involved stakeholders; efficient resource use via prioritization; and effective assessment of improvement activities.

5.5. Multi-risk assessment methods

A study assessing multiple risks in risk assessment at national, regional and local level has not yet been conducted in Turkey and each risk is assessed individually.

6. OVERVIEW OF DRM AT THE URBAN SCALE FOR MONTENEGRO IN 2024

6.1. Procedural frameworks for DRM

In Montenegro, the decision-making processes for seismic emergency management are spearheaded by the Directorate for Protection and Rescue of the Ministry of Interior. This directorate is responsible for proposing laws and strategic documents that govern disaster risk management. The foundational legal document is the Law on Protection and Rescue (Law, 2007), which outlines the framework for creating national and urban-level policies and strategies.

The national earthquake protection and rescue plan of 2018 (NEPARP, 2018) delineates various seismic risk reduction measures. These are categorized into preventive protection measures, urgent measures during the rescue phase, and long-term measures aimed at reducing seismic risk.

At the municipal level, the decision-making and responsibilities are detailed in protection and rescue plans. These plans are developed based on guidelines stipulated in the Rulebook on the content and methodology of preparation, the method of harmonizing, updating, and storing protection and rescue plans (Rulebook, 2017). Each municipality forms a Municipal Team for Protection and Rescue. This team includes the president of the municipality, the commander of the protection service, representatives from the Ministry responsible for protection and rescue operations, heads of local government bodies, responsible persons from relevant companies, and a representative of the Red Cross.

The Municipal Team for Protection and Rescue is tasked with managing and coordinating protection and rescue activities, organizing actions for protection and rescue, monitoring the organization of services in the municipality, issuing necessary orders and decisions, assessing threats from emergency states, and reporting to the Coordination Team. They are also required to cooperate with the Coordination Team and the Operational Headquarters, which operate at the national level.

Operational measures of protection and rescue from earthquakes are defined in the urban-level Protection and Rescue plans. For example, the management of evacuation actions involves the coordination and engagement of operational units, establishment of evacuation corridors, and engagement of necessary personnel and economic resources. Specific responsibilities for these actions are assigned to various entities including the Municipal Team for Protection and Rescue, the Police Directorate, the Army of Montenegro, protection and rescue services, transport companies, and the Red Cross.

Additionally in case of seismic event, evacuation maps are developed to guide the planning and execution of evacuation actions. These maps detail the directions of movement, locations for rescue, and positions of essential services like the police and health institutions. They also highlight sensitive areas such as gas stations, tunnels, and bridges, which are crucial from a planning, organization, and implementation perspective during an evacuation.

Municipal flood protection and rescue plans incorporate, for example, policies and recommendations regarding the return periods for the main design of hydro-technical infrastructure. The special part of these municipal plans outlines evacuation capacities and potential locations for accommodating displaced individuals during large-scale floods. Moreover, they detail activities to be undertaken after receiving flood warnings or extreme weather alerts, as well as strategies for protecting critical infrastructure. The plans also delineate the roles and responsibilities of various stakeholders, including local government bodies, companies, legal entities, and entrepreneurs, in implementing flood protection and rescue measures. Leadership and coordination mechanisms during flood protection and rescue actions are established, along with provisions for inter-municipal and international cooperation. Considering the fact that alerting citizens and the public about impending flood risks is a crucial aspect of DRM, the plans provide detailed instructions for this purpose.

Financial resources allocated for the implementation of the plan are also outlined. Furthermore, the plans include organizational schemes of operations at the municipal level, which ensure coordination and efficiency during emergency responses. Tables presenting an overview of human and material resources available from different responsible institutions, as well as contact information for members of the municipal emergency management team, facilitate effective communication and coordination.

6.2. Seismic risk assessment methods at urban scale

In Montenegro, the primary documents for seismic risk assessment at the urban scale are the Municipality Protection and Rescue Plans. These plans are developed in accordance with the guidelines outlined in the Rulebook on the Methodology for Developing Protection and Rescue Plans (Rulebook, 2008), which is issued by the Ministry of Interior's Department for Protection and Rescue. The creation and maintenance of these plans are the responsibility of local authorities. Despite establishing a framework for the content of the plans, the rulebook does not prescribe detailed methodologies for conducting seismic risk assessments. This is a primary reason for the variability observed in the plans across different municipalities.

Plans typically include detailed seismic hazard analyses, highlighting local and regional seismicity, geotechnical characteristics, and historical earthquake data. They also delve into risk assessments that evaluate the vulnerability of critical infrastructure, residential buildings, and key economic sectors to seismic events. Furthermore, the plans outline specific strategies and procedures for immediate response to seismic events, including the mobilization of rescue teams, first responders, and emergency services. In addition, some of the plans provide evacuation plans and routes tailored to the specific geographic and infrastructural characteristics of the municipality. This includes identifying safe zones, assembly points, and the most effective pathways for evacuation, identification and preparation of temporary shelter locations and relief facilities. Plans also include strategies for maintaining effective communication with the public before, during, and after a seismic event. This includes the use of various media and technology to disseminate critical information. Plans also delve into preliminary guidelines for restoring essential services and infrastructure following a seismic event, encompassing strategies for assessing damage, prioritizing recovery efforts, and mobilizing resources for rebuilding efforts.

The methodology employed for seismic risk assessment in these municipal plans typically involves scenario-based analysis and consideration of the maximum expected earthquake, utilizing available geological, infrastructural, and demographic data. However, the exact approach to quantifying risks and presenting results—such as potential damages, casualties, and economic impacts—differs among municipalities. In addition, the availability of these crucial documents to the public can vary.

Finally, it is essential to note that seismic risk in the Municipality Protection and Rescue Plans for urban areas in Montenegro is calculated and expressed quantitatively, focusing on the consequences of seismic events. This quantitative expression of risk encompasses various dimensions, including potential damages to infrastructure, economic impacts, and the anticipated effects on the population's well-being. However, an important aspect to highlight is that risk maps, which are valuable tools for visualizing and communicating seismic risk across different areas, are not developed within these plans. In the best-case scenario, the seismic risk is presented through risk matrices.

6.2.1. Hazard model

The Hazard Model for seismic risk assessment at urban level in Montenegro, particularly as applied in municipal protection and rescue plans, primarily utilizes a scenario-based approach rather than a probabilistic approach.

The intensity parameters used in seismic hazard models primarily include peak ground acceleration (PGA) and intensity on the EMS scale. If the PGA is used, empirical relations are developed to convert maximum ground acceleration to the equivalent earthquake intensity expressed on the EMS-98 scale for the purpose of further damage analyses. The spatial scale for hazard evaluation is addressed by calculating the distribution of intensities or accelerations across a network of points within the municipality. For example, in some cases, distributions are calculated on networks of points varying in scale, potentially from 20x20m to 80x80m . However, in some municipalities the scale is much bigger up to 1km.

In general, in Montenegro, two approaches when developing scenarios exists. First is based on the development of seismic scenarios linked to the concept of "credible ruptures" as opposed to "credible earthquakes." The application of this concept involved analyzing the seismic tectonic fault network and the character of active tectonic fault forms in the region. This led to constructing up to five synthetic, seismically active ruptures. These ruptures' dimensions, orientation, depth of seismically active zones, faulting mechanism, and seismogenic potential simulate real conditions and represent the basis for developing seismic scenario. By referencing empirical relationships on attenuation of peak ground acceleration (PGA) on bedrock (Akkar and Bommer (2010), Ambraseys et al. (2005), Berge-Thierry (2003), Joyner and Boore (1981), and Glavatović (1985)), calculation of the mean values of maximum acceleration for all possible hypocentre positions along the traces of all considered credible ruptures is done.

Following this, the process involves a detailed grid analysis where for each point within a dense network (typically 80x80m grid) covering the area, total maximum horizontal acceleration values are calculated. These calculations include the amplification effects of local soils. Subsequently, mean values of maximum acceleration and equivalent earthquake intensity (in decimal form) are computed based on mean value relations from literature (Gomez-Capera et al. (2020), Zare (2017), Faenza and Michelini (2010), Yaghmaei-Sabegh et al. (2011), and Atkinson and Kaka (2007)). Finally, the weighted average of earthquake intensity was calculated (weighting was done according to the number of grid points on a specific soil type) along with the corresponding integer values of earthquake intensity according to the EMS 98 scale. Based on the results for the local communities, the overall mean value of maximum intensity for the entire municipality was determined. The fault that yields the maximum intensity for the entire municipality is considered critical and is taken into further consideration.

The second approach to developing earthquake scenarios involves scaling up the magnitudes of previously occurred earthquakes to the maximum magnitudes expected for a region (expressed as the magnitude likely to occur with a 70% probability within 100 years). Depending on the municipality, between 2 to 6 scenarios are developed. The spatial distribution of expected accelerations for each scenario earthquake is empirically calculated for conditions of so-called basic rock, based on literature sources (Glavatovic, 1985). The calculations are performed over a large network of points spaced at 1 km x 1 km intervals. The selection of the critical scenario, which will be used for further calculations, is done by expert judgment taking into account the number of people affected and the strategic connections to other cities that are impacted. For the critical scenario, local soil effects are determined by identifying the geological structure and soil category, using constant values to multiply accelerations on rock. Finally, using the same literature as in the previous approach, accelerations are converted to the EMS-98 scale intensities for further calculations of damages.

6.2.2. Vulnerability model

Several models from the literature are used to assess the impact of the critical scenario on residential buildings in Montenegro. Currently, there is no unified approach or specific vulnerability model tailored to the characteristics of residential buildings in Montenegro. Plans for rescue and protection in certain municipalities often review multiple models from the literature and provide a comparative analysis of impacts using different models to estimate the possible range of effects. In addition to residential buildings, certain elements of infrastructure are also analyzed for potential damage using models from the literature.

Models used for residential buildings:

1. IZIIS Model (1984): Derived from the experience of the 1979 earthquake, this model has been converted into vulnerability functions for single and multi-family houses. The results are presented as the number of heavily damaged dwellings per the smallest census unit in the municipality, using Peak Ground Acceleration (PGA) as the intensity measure. This model does not distinguish between different materials or structural typologies.
2. EMS-98 Methodology: Based on the "mean damage ratio" and damage matrices (Tyagunov et al., 2006; Giovinazzi and Lagomarsino, 2004), this model categorizes dwellings/buildings into five damage grades (DG), from DG1 (minor damage) to DG5 (collapse).
3. Jaiswal et al. Model (2011): This model estimates the probability of building collapse within certain vulnerability classes (A to F) according to the EMS-98 scale, based on EMS-98 intensity measures. Results are presented as the total number of collapsed buildings, accounting for the distribution of buildings across vulnerability classes in Montenegro, as determined by the NERA project (Crowley et al. 2014).
4. WHE-PAGER Model (Jaiswal and Wald, 2010): A semi-empirical model developed under the Prompt Assessment of Global Earthquakes for Response project. It calculates the probability of collapse for specific building typologies based on EMS-98 intensity. While the PAGER model typologies do not exactly match the most common types in Montenegro, a correlation is established at an approximate level to align with the building typologies, according to NERA (2014).
5. Kappos Models (1998, 2007): Applied specifically to reinforced concrete buildings with infill walls, these models are used to calculate damages for this building category.
6. ATC-21-1 (1989) Methodology: This methodology assesses damages across eight residential building typologies differentiated by construction material/technology (wood, masonry, reinforced concrete, steel, and precast structures) and three ranges of story height (low, medium, and high rise)."

In addition to assessing the impact on residential buildings, seismic risk evaluations in some municipalities consider various infrastructural systems. This broader analysis includes roads, bridges, railways and railway stations, hospitals, water supply pumping stations, electrical transmission and distribution substations and lines, and facilities in ports and airports. For the analysis of these infrastructure systems, established models such as those from the Federal Emergency Management Agency (FEMA) and the Applied Technology Council (ATC), specifically the ATC-25 (1991) methodology, are employed. Plans for rescue and protection utilize digitized vulnerability curves based on the data provided in ATC-25 by employing a fourth-degree polynomial regression, which is executed in the form of:

$$\theta_k = \sum_{j=1}^{4} a_j \ I^{\,j} \tag{6.1}$$

Where θ_k damage grade of considered component k, a_j regression coefficient and I earthquake intensity on EMS-98 scale. Results are presented as damage level of considered components (in percentage) for the considered scenario.

6.2.3. Exposure model

In Montenegro, the exposure model at the urban level primarily focuses on residential buildings and population and in certain municipalities also includes various infrastructural elements. Population data are available from National Institute for Statistics (MONSTAT) as number of residents at census track i.e. settlements. The two main approaches regarding the buildings and infrastructure are employed as follows:

1. Exposure Model Including Residential Buildings and Infrastructure:

Since, there is no specific exposure model for Montenegro, or database on residential buildings, source of information is literature. In this approach model that is often deployed is NERA (2014) model for Montenegro. Details on the model (distribution in percentage of buildings in certain vulnerability classes and average number of dwellings per vulnerable class) are presented in table 6.1.

Table 6.1: Exposure model at urban level in Montenegro in use, NERA (2014).

Vulnerability class	Building typology	Distribution in percentage	Number of dwellings
A	masonry stone or adobe brick	4	1
	masonry wooden slab	6	1
	masonry RC slab	11	8
B	Confined masonry	9	4
	RC frame structures built before 1981	14.5	32
C	RC frame structures built after 1981	19.5	53
D	RC wall structures built before 1981	18.5	147
E	RC wall structures built after 1981	17.5	84

In this approach also elements of infrastructure are analyzed using vulnerability functions from literature (ATC-25, 1991). Components that are analyzed and form of data and availability are given in Table 6.2:

Table 6.2: Exposure model at urban level in Montenegro in use, NERA (2014).

Component	Data form and details	Publicly available
Roads	Map or tabular form of road lengths by sections	YES map of main roads
Bridges	major or regular bridges listed/ no details on structural typology	YES list of bridges
Railways and railway stations	presented on map or in tabular	NO
Hospitals	listed/ no details on structural typology	YES list of hospitals and capacities
Water supply pumping stations	listed or presented on map	NO
Electrical transmission and distribution substations	listed or presented on map	NO
Electrical transition and distributive lines	listed or presented on map	NO
Ports with cargo equipment	listed	NO
Airports	listed	NO

2. Exposure Model Based on Census Data and Expert Opinion:

This model utilizes census data, data collected on field (data on multi-family buildings) supplemented by expert opinion to quantify residential buildings, ensuring consideration of local insights and knowledge.

Infrastructure components (roads, railways, schools, hospitals, public institutions, sports facilities) are listed but not analyzed in detail.

6.2.4. Damage and Impact indicators

The lack of detailed data on the typology of buildings, their structural characteristics, spatial locations (due to the absence of any comprehensive database), population distribution within these buildings, and local geological soil characteristics outside the main urban areas of municipalities, makes it difficult to apply sophisticated numerical methods for an objective assessment of the potential consequences of earthquake scenarios. Consequently, the assessments carried out for municipalities in Montenegro are characterized by a lower level of reliability. To mitigate this limitation, a range of methods were applied simultaneously, providing a more comprehensive overview of the potential range of consequences.

Results from combining exposure and vulnerability models for residential buildings are presented in one of the following ways:

1. Number of heavily damaged buildings.
2. Distribution of the number of buildings across several damage grades (DS1 to DS5).
3. Number of collapsed buildings.

These results are expressed in absolute numbers as well as a percentage of the total residential stock.

For infrastructure, damage is presented as a damage grade, expressed as a percentage of the affected component.

For impact indicators following parameters are considered: economic losses and impact on people.

Economic losses are calculated using simple methodology based on the size of the gross national income, expressed through the gross income (budget) of the region/ municipality and function of losses (equation 6.2) (Chen et al. 1997).

$$GDP_{Loss} = GDP_{National} \cdot \frac{N\ of\ residents\ (region)}{N\ of\ residents\ (national)} \cdot \sum_{I_j} P(I_j) \cdot f(I_j) \tag{6.2}$$

Probability of occurrence of earthquake of intensity I_j for considered scenario taken as $P(I_j)=1$ and

$$f(I_j) = e^{8.837+1.4530 I_j - 0.0606 I_j^2} \tag{6.3}$$

Impact on people is determined by calculating the number of victims, injured people, people trapped by collapsed buildings and people that needs shelter.

For calculating number of victims following models are used:

1. ATC-13 (1985) model based on the distribution of residents in buildings with damages categorized in six damage grades. Predictions on the number of victims and injured are made by applying specific grades (percentage coefficients) to the number of residents living in buildings that are classified within certain damage grades, as determined in previously conducted damage analyses.
2. HAZUS99 1999, Coburn and Spence (2002) model based on the distribution of residents trough five damage grades. Number of victims and injured people is calculated in the same manner as in pervious method.
3. PAGER model, Jaiswal and Wald (2010) model where the earthquake mortality rate (ν) is defined as a function of the earthquake intensities level (expressed on the MMI scale) and total population exposed to the given earthquake intensity.
4. Samadijeva and Badal (2002) as well as Risk-UE (Vacareanu et al., 2004) models, which define the number of victims and injured people as the function of the magnitude of considered scenario earthquake and population density.

5. Tiedemann (1992) model which calculates the mortality rate for residents in buildings with different vulnerability classless (A-E) as the function of EMS-98 intensity.

For calculating the number of injured people also models 1, 2 and 4 are used.

For calculating the number of trapped people by collapses buildings Coburn and Spence (2002) model is in use. This model predicts the number of individuals trapped in rubble depends on the population residing in severely damaged buildings of a specific type (masonry or reinforced concrete structures), whether low-rise or high-rise, and the earthquake intensity as measured on the EMS-98 scale. The applied percentages are prescribed based on these factors.

The number of people that need shelter is calculated as number of residents (survivors) in heavily and very heavily damaged buildings.

The impact indicators calculated above are primarily used to assess locations and identify available spaces suitable for setting up shelters. These spaces may be open areas or existing facilities that can be adapted to accommodate people in need.

6.2.5. Tool (platform) for seismic risk assessment at urban scale

In Montenegro there is no tool or platform dedicated to seismic risk assessment at urban scale.

6.3. Flood risk assessment methods at urban scale

The relevant documents for flood risk assessment at the urban scale for emergency management in Montenegro are:

Disaster Risk Management Capability Assessment, European Commission—Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG ECHO), spanning 2022-2024, coordinated by the Ministry of Interior's Rescue and Protection Directorate (RPD) in Montenegro (DRMCA, 2023). This assessment offers a thorough examination of administrative, technical, and financial capacities concerning various risks, notably flood risk.

Law on Protection and Rescue (Law, 2007): This legislation serves as a comprehensive regulatory framework governing protection and rescue efforts at both national and local levels. It mandates risk assessment, management planning, and appropriate measures. The law encompasses natural disasters like floods, technical-technological accidents, and other emergencies, defining leadership, coordination, and essential elements for the functionality of the protection and rescue system.
Rulebook on the Methodology for Developing Protection and Rescue Plans (Rulebook, 2008): This rulebook outlines the methodology for creating and updating plans addressing protection and rescue from diverse disasters and accidents. It delineates the responsibilities of state bodies, local government units, companies, and other entities in developing municipal protection and rescue plans.

Municipal plans for protection and rescue: Compliant with the Rulebook, these plans comprise information on potential flood risk, protective measures, operational units, human and material resources, readiness implementation, mobilization methods, management responsibilities, intervention actions, safety protocols, risk mitigation strategies, financial resource allocation, public information dissemination, acceptance and provision of assistance from other municipalities or states, and necessary topographic maps and documents.

The methodology employed for assessing flood risk from the perspective of Emergency management (according to Municipal plans for flood protection and rescue (MPFPR)) is based on analysis of case studies - which represent descriptions of historic floods (with record hydrological data values – usually the flood 'intensity' is described through precipitation rate) that caused damages. If possible, analysis of these case studies may include maps of flood extent (Figure 6.1.), which are based on the field data (rather than hydraulic models) – and these may be regarded as a type of flood hazard map. The level of risk is not separately calculated (as low, medium or high), so the plans do not include any flood risk maps. For some case studies, if data is available, plans provide an overview of precipitation amounts for analyzed historical floods, with a comparative display of average precipitation quantities and deviations. Case studies usually include information regarding the consequences of flooding.

Figure 6.1: Flood extent from 2010 floods in Bar municipality (MPFPR Bar, 2019).

In some Municipal plans for flood protection and rescue, based on previous experiences, certain areas (settlements) in the analyzed municipality are identified as high-risk zones for floods:

first zone (the most endangered area, which typically floods first),

second zone, and

third zone (threatened by waters that accumulate in lower-lying areas of the terrain).

The number of buildings endangered by floods was considered a criterion for determining these high-risk zones. The first zone has the highest number of endangered buildings.

6.3.1. Hazard model

Based on multi-year research and analysis of extreme situations leading to river overflow and flooding of certain regions, Municipal flood protection and rescue plans analyze factors responsible for floods. These factors usually include rising lake levels, extreme rainfall lasting several days (that can be accompanied by strong winds), snowmelt, irregular watercourse maintenance, etc. Hazard analysis may additionally include a tabular overview of the heaviest rains in a certain municipality over 24 hours, 48 hours, and 72 hours, according to the records of the Hydro-Meteorological Institute of Montenegro. Sometimes, threshold rainfall values represented by the 10% largest quarterly rainfalls may be provided, meaning that their occurrence/exceedance may complicate the situation significantly in the field.

In a separate section of the plan, a hydrographic network of the municipality is analyzed – watercourses (as well as lakes and accumulations) that could cause floods in that municipality are identified and described and sometimes shown on a map (Figure 6.2). Torrential streams often lead to localized urban flooding, especially in the coastal municipalities. This is exacerbated by steep terrain gradients, extensive urban development, inadequate maintenance, and hydro-meteorological conditions. In the plans, torrential watercourses and settlements threatened by them are identified, as are erosion-contributing mechanisms.

In some municipal plans, maps of flood extents of analyzed historical floods are provided (Figure 6.3).

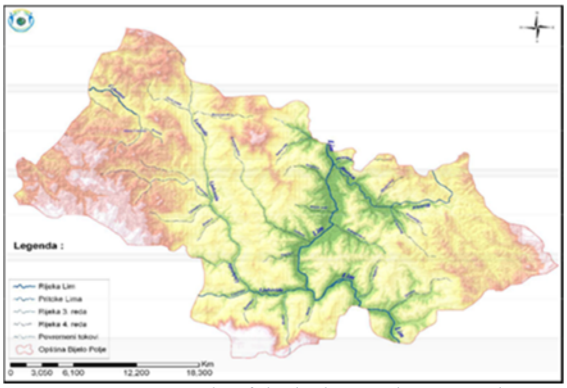
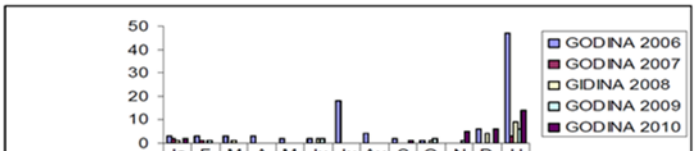


Figure 6.2: Example of the hydrographic network in Bijelo Polje municipality (MPPFR Bijelo Polje, 2013).

Figure 6.3: Flooded area during the December 2010 floods in Danilovgrad municipality (MPPFR Danilovgrad, 2014).

The frequency of occurrence and intensity of flooding is analyzed through available data from the Municipal Civil Protection and Rescue Service. For example, these data may represent the usual records of the Civil Protection Service regarding the number and type of interventions, location, and timing of events, which are regularly entered into the duty logbook, along with the number of deployed firefighters, vehicles, equipment, and resources. From the graphical representation given on Figure 6.4. It can be concluded that the critical months are November, December, and January, which are the months with the highest probability of flooding. Based on this observed data for the past several years, it can also be concluded that floods have become a common occurrence, causing significant damage in the municipality.



	Ja nu	F eb	M art	A pri	M aj	Ju n	Ju l	Av gu	S ep	O kt	N ov	D ec	U ku
GODINA 2006	3	3	3	3	2	2	18	4	2	1	0	6	47
GODINA 2007	2	1	0	0	0	0	0	0	0	0	0	0	3
GIDINA 2008	1	0	1	0	0	2	0	0	0	1	0	4	9
GODINA 2009	0	1	0	0	0	2	0	0	0	2	1	0	6
GODINA 2010	2	0	0	0	0	0	0	0	1	0	5	6	14

Figure 6.4: Graphical representation of flood events in Bijelo Polje municipality for 2006-2010. (MPPFR Bijelo Polje, 2013).

Even though hazard is not directly identified through the concept of return periods, the part of plans that concerns flood protection identifies the level of protection and priority in building construction related to the size of settlements, the value of industrial facilities, and agricultural areas. General criteria for ranking and adopting relevant design flow rates for flood protection systems are suggested with respect to the number of inhabitants and the nature of assets in the protected area. For example, for settlements with over 50000 inhabitants – the 200-year return period of design flow rate is recommended, whereas on the other hand, for agricultural areas without melioration systems, a 20-year return period is suggested.

Some municipal plans provide a tabular overview of maximal annual flow rates (of specific watercourses) for available years.

Emergency flood protection is organized and carried out depending on the hazard level. According to the degree of hazard of flooding, four levels of danger are determined:

- First, a further rise in the water level is expected when water begins to overflow from the riverbed.
- Second, when the overflowing water reaches the base of the embankments.

- Third, when the water level in the watercourse reaches 1 meter below the highest recorded water level, a further rise is expected, or when the protective embankment is saturated due to prolonged high-water levels.
- Fourth, when the water level in the watercourse reaches the highest recorded level, a further rise is expected or when the protective embankment is significantly saturated due to prolonged high-water levels.

6.3.2. Vulnerability and exposure model

Exposure data in Municipal plans may include, for example, a separate chapter that identifies and describes flood-prone areas (flooded sections of streams along with endangered settlements, number and type of endangered buildings, industrial facilities, and agricultural areas), as well as available photo-documentation of exposed risk assets. Sometimes, plans also provide a list of infrastructure (e.g. local roads) located in flood-prone areas and threatened by a certain watercourse. In some plans, maps show areas threatened by torrents and the locations of settlements and urban areas (as shown in Figure 6.5). A tabular overview of infrastructure threatened by torrents may be provided, as well as an overview of endangered settlements, the total number of inhabitants and households.

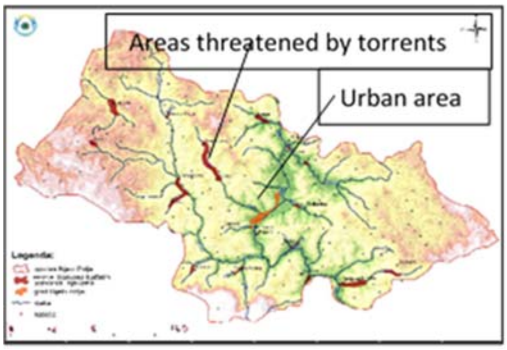


Figure 6.5. Erosive areas resulting from torrential flows in Bijelo Polje municipality (MPPFR Bijelo Polje, 2013).

Exposure data may also include lists of areas prone to flooding (in a specific municipality) and descriptions of endangered assets and risk facilities threatened by floods (e.g., agricultural land, roads, cemeteries, residential buildings, factories, tourist facilities, etc.).

Exposure is additionally described through tabular overviews of endangered populations and risk facilities (for different flood-prone areas). For residential buildings/houses, this information includes the location (settlement in the analyzed municipality), owner's name, total number of household members (children, adults, elderly), number of storeys, and presence of stable/garage/storerooms. For different risk objects (economic and non-economic facilities), the presence of industrial/healthcare/ touristic/ educational/ cultural/sports facilities is documented. The tables also include names of the watercourses that endanger a particular risk asset.

Plans usually include maps showing the locations of buildings, risk assets, and objects exposed to flooding (Figure 6.6 and Figure 6.7). Currently, no vulnerability curves are available, i.e., there is no established vulnerability model for buildings or infrastructure.

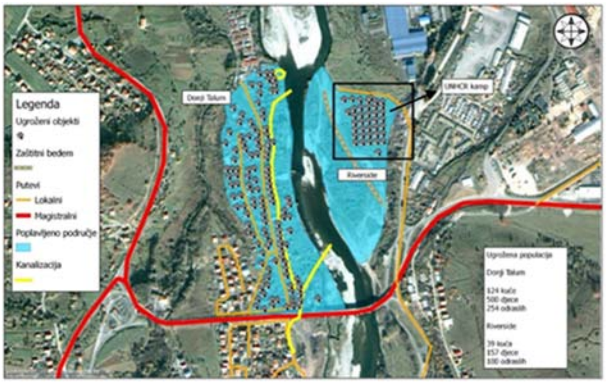


Figure 6.6: Map of facilities exposed to flooding in Berane municipality (MPPFR Berane, 2014).

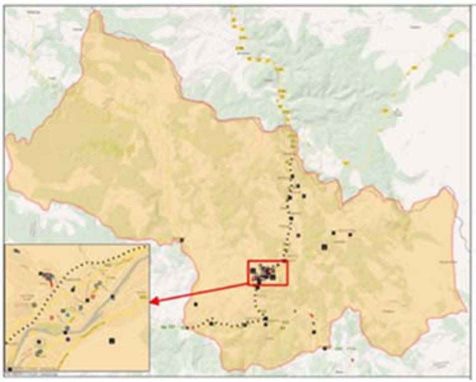


Figure 6.7: Map of exposed risk assets in Bijelo Polje municipality (MPPFR Bijelo Polje, 2013).

6.3.3. Damage and Impact indicators

The damage to structure and infrastructure is expressed in documented case studies. In addition to the comprehensive analysis of historic floods, the documented case studies provide a depiction of the aftermath, encompassing a range of consequences that illustrate the multifaceted impacts on infrastructure, communities, and the environment. These case studies delve into specific incidents, such as bridge failures and extensive damage to road infrastructure, including disruptions to transportation networks vital for urban and rural connectivity. They also highlight the challenges residential areas face, detailing the severity of damage inflicted upon housing facilities, the displacement of residents, and the ensuing humanitarian needs, as well as the number of evacuated people. General damage indicators are not defined.

Additionally, in some municipal plans, the immediate/direct consequences of more serious and larger floods are predicted, as are indirect/ induced consequences (rockslides, landslides). Furthermore, where available, the case studies provide valuable data on the economic toll of these floods, quantifying the total damage in euros.

Some case studies feature photo documentation to complement the narrative, offering visual context to the described consequences (Figure 6.8).

Figure 6.8: Flooded residential building in Bijelo Polje municipality (2010), the damaged road in Bar and Berane municipality (2010) (MPPFR Bijelo Polje, 2013; MPFPR Bar, 2019; MPPFR Berane, 2014).

6.3.4. Tool (platform) for flood risk assessment at urban scale

Flood warnings are issued by the Institute for Hydrometeorology and Seismology. In case of expected floods, the Institute informs the Ministry of Internal Affairs - Emergency Situations Administration about extreme meteorological conditions, and then the Administration further informs all local governments, municipal protection and rescue services, as well as all ministries, authorities, institutions and companies that are included in the protection system and rescue.

The Institute for Hydrometeorology and Seismology is responsible for monitoring and collecting meteorological data, including floods. Measuring stations were placed along the river courses, and responsible persons from the Institute for Hydrometeorology and Seismology collected up-to-date information related to the height of the river flow warnings (Figure 6.9).

These data and warnings are transmitted at the national level (MUP - Directorate for Emergency Situations) at the local level.

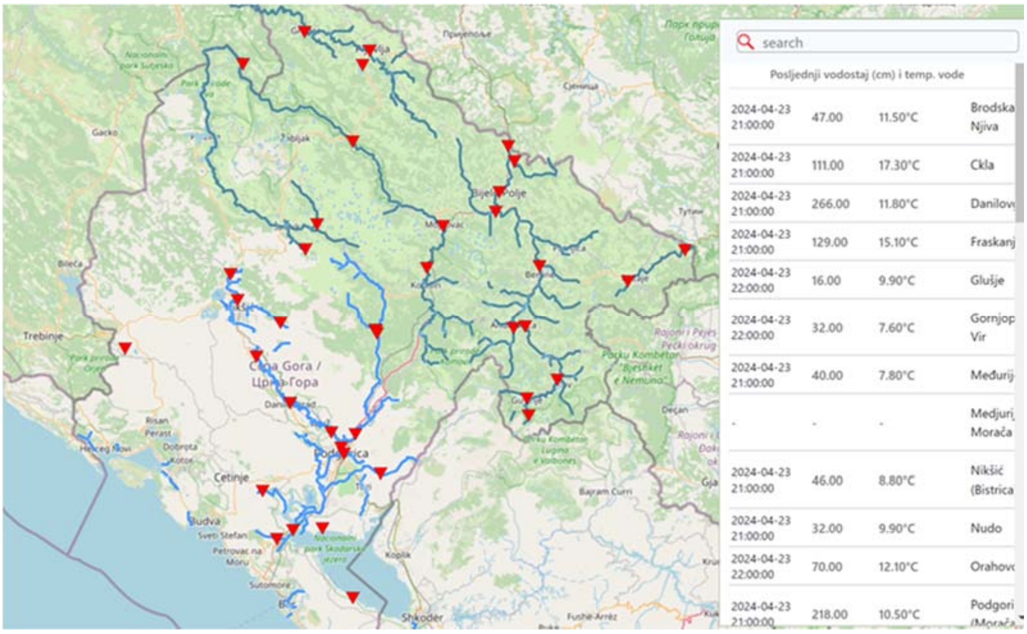


Figure 6.9: The Institute for Hydrometeorology and Seismology: Measuring stations (URL-9).

6.4. The Role of Seismic and Flood Risk Analysis in Effective DRM

In Montenegro, protection and rescue plans explicitly prescribe measures for each phase of DRM including prevention and preparedness, response, and recovery. Typically, these measures focus on residential buildings, infrastructure (roads, railways, hospitals and schools), and cultural assets. Although the prescribed measures often take on a declarative character with many general statements (e.g., emphasizing the need for spatial planning in accordance with risk assessment), there are instances where proactive measures are clearly based on risk analysis findings. For example, for some municipalities there has been identification of unstable terrains prone to landslides and rockfalls that potentially threaten infrastructure and evacuation routes, for which preventive actions are prescribed.

Regarding the response and assistance phase, the plans are not frequently focused on the conducted risk analysis. This might be due to the perception that risk analysis is a rough approximation of the consequence assessment, which often arises from limitations in the available data. In specific urban cores in Montenegro, protection and rescue plans comment on existing capacities for temporary accommodation and shelters based on risk assessment. In this sense, there is a reference to risk assessment, yet other response capacities such as human resources, protective and rescue equipment, and immediate post-earthquake communication equipment are generally listed without reference to specific needs. Often emergency management on the local level relies on support from the national level.

Immediate strategies for addressing the recovery after an earthquake in urban environments are often delineated in the plans, yet they lack a direct link to risk assessment findings. Despite evident shortcomings in capacities—e.g. capacities for restoring normal traffic flow and ensuring the usability of evacuation routes—there is no discussion of these needs relative to risk assessment outcomes.

Although local emergency management strategies in Montenegro are intended to incorporate insights from risk analyses, such as through the designation of evacuation routes, emergency communication systems, and community training programs, there often remains a gap in how these strategies are practically linked to the findings of risk assessments. These measures are outlined in municipal disaster management plans and are theoretically based on local seismic risk profiles. However, the actual integration and application of these risk analyses can sometimes be superficial, lacking depth in how they inform the strategic execution of these plans.

Flood risk analysis in Flood rescue and protection plans in Montenegro depicts case studies, as previously stated. No specific procedures or methodologies are employed for flood risk analysis on an urban level (since rescue and protection plans are done on a municipal level), and there are no adopted criteria for defining critical infrastructure.

The analyzed case studies do not directly impact the rest of the flood rescue and protection plans that deal with emergency response and capacities. However, by analyzing the case studies (which usually represent historic floods) and their impacts (if there is data available), authorities can identify vulnerable areas and prioritize resource allocation for mitigation measures. For example, detailed case studies on flood extent and consequences may help the authorities develop evacuation plans, establish emergency shelters, and even enhance early warning systems. In this way, it contributes to the overall preparedness of local authorities. Also, even though critical infrastructure is not explicitly defined, there is usually some available data on exposed infrastructure in general (the infrastructure in flood-prone areas is listed), and this may be helpful in the development of evacuation routes and procedures, ensuring swift and coordinated responses during flood events. By examining the causes and consequences of past floods, authorities can identify opportunities for infrastructure improvements, land-use planning, and community resilience-building initiatives. For instance, flood risk assessments may inform zoning regulations, building codes, and flood-proofing measures to minimize future flood damage. Furthermore, risk analyses help allocate resources for post-disaster recovery, such as housing rehabilitation, livelihood support, and ecosystem restoration.

6.5. Multi-risk assessment methods

No multi-risk assessment studies have been performed at the urban level.

7. COMPARISON OF RISK ASSESSMENT PROCEDURES AT URBAN SCALE

7.1. Comparison of seismic risk assessment procedures at urban scale

In the following tables, a comparison of seismic risk assessment procedures at urban scale in five beneficiary countries, is presented. Each elaborated component of risk analysis (hazard, vulnerability, exposure and damage and impact indicators) is compared as presented in Tables 7.1 to 7.4. Note that the parameters listed in the tables are those reported in the respective paragraphs for each country, and refer to the typical procedures adopted; these parameters do not necessarily reflect minimum standard requirements.

Table 7.1: Hazard assessment for seismic risk at urban level: comparison of practices in beneficiary countries.

Hazard assessment	Description	ITA	SLO	AUT	TUR	MNE
	Scenario(s) developed	✓	✓		✓	✓
	Hazard expressed in probabilistic manner	✓	✓	✓	✓	✓
	Return period:					
	T=475 years	✓	✓	✓	✓	
	Other periods considered	✓				✓
	Intensity measures:					
	I_{MCS}	✓				✓
	EMS-98		✓	✓		
	PGA	✓		✓	✓	✓
	PGV			✓	✓	
	PSA	✓		✓	✓	
	Local soil effects:					
	From available microzonation	✓			✓	
	Identified through soil category (A, B, C,…)		✓	✓		✓
	Topographically based	✓				
	Multi hazard scenario developed					

Table 7.2: Vulnerability model for seismic risk: comparison of practices in beneficiary countries.

Vulnerability model	Description	ITA	SLO	AUT	TUR	MNE
	For residential buildings:					
	Model based on EMS-98 scale (5 damage D1-D5, 6 vulnerable classes A to F)	✓	✓			✓
	discrete values		✓			
	curves	✓			✓	✓
	Additional model in use (e.g. empirical driven)					✓
	For infrastructure:					

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	vulnerability is analyzed					✓
	model from literature					✓

Table 7.3: Exposure model for seismic risk: comparison of practices in beneficiary countries.

Exposure model	Description	ITA	SLO	AUT	TUR	MNE
	Population					
	floating population number	✓	✓	✓	✓	
	vulnerable population	✓				
	civil protection members treated separately		✓			
	Scale of available data for population and buildings used in RA:					
	building by building			✓		
	sub-municipal (settlements, district)	✓	✓		✓	✓
	Available residential buildings attributes at sub- municipality scale:					
	number of buildings	✓	✓	✓	✓	
	number of stories	✓	✓	✓	✓	
	material	✓	✓	✓	✓	
	age of construction	✓	✓	✓	✓	
	number of dwellings		✓	✓	✓	✓
	occupancy	✓	✓			
	Infrastructure:					
	only listed		✓	✓	✓	
	listed with details on attributes	✓		✓		
	listed with details on capacities (hospital capacities, shelter capacities)					✓
	Types of infrastructure listed:					
	hospitals and health care	✓	✓	✓	✓	✓
	transportation network	✓	✓	✓	✓	✓
	schools	✓		✓	✓	✓
	public and strategic buildings	✓		✓	✓	
	cultural heritage	✓	✓	✓		✓
	sports facilities	✓		✓		
	green/protected areas	✓		✓		
	lifelines	✓	✓	✓	✓	✓

Table 7.4: Damage and impact indicators for seismic risk: comparison of practices in beneficiary countries.

Damage and Impact indicators	Description	ITA	SLO	AUT	TUR	MNE

	On people:					
	number of death and injured	✓	✓		✓	✓
	displaced	✓	✓			✓
	lack of fulfillment of basic needs				✓	
	people that need to be evacuated				✓	
	trapped by collapsed buildings					✓
	Economic losses	✓	✓		✓	✓
	Impact on buildings:					
	collapsed	✓	✓		✓	✓
	unusable	✓	✓		✓	✓
	damaged	✓	✓		✓	✓
	volume of debris		✓			
	Infrastructure					
	damage grade	✓				✓
	functionality of roads	✓			✓	
	functionality of hospitals	✓			✓	
	functionality of strategic buildings				✓	

7.2. Comparison of flood risk assessment procedures at urban scale

In the following tables, a comparison of flood risk assessment procedures at urban scale in five beneficiary countries is presented. Each elaborated component of risk analysis (hazard, vulnerability, exposure and damage and impact indicators) is compared as presented in Tables 7.5 to 7.8. Note that the parameters listed in the tables are those reported in the respective paragraphs for each country, and refer to the typical procedures adopted; these parameters do not necessarily reflect minimum standard requirements

Table 7.5: Hazard assessment for flood risk at urban level: comparison of practices in beneficiary countries.

Hazard assessment	Description	ITA	SLO	AUT	TUR	MNE
	Scenario(s) developed	✓	✓	✓	✓	
	Case studies developed			✓		✓
	Hazard expressed in probabilistic manner	✓	✓	✓	✓	
	Return period:					
	T=10, 100, 500 years		✓			
	Other periods considered	✓		✓	✓	
	Intensity measures:					
	Water depth	✓	✓	✓	✓	
	Water velocity	✓	✓	✓	✓	
	Flood duration					
	Multi hazard scenario developed					

Table 7.6: Vulnerability model for flood risk: comparison of practices in beneficiary countries.

Vulnerability model	Description	ITA	SLO	AUT	TUR	MNE
	For residential buildings:					
	Global models (HAZUS, JRC, …)	✓				
	Country specific model	✓	✓	✓	✓	
	discrete values		✓	✓		
	curves	✓			✓	
	Additional model in use (e.g. empirical driven)					
	For infrastructure:					
	vulnerability is analyzed		✓	✓	✓	
	model from literature	✓				

Table 7.7: Exposure model for flood risk: comparison of practices in beneficiary countries.

Exposure model	Description	ITA	SLO	AUT	TUR	MNE
	Population					
	floating population number		✓			
	vulnerable population	✓	✓	✓	✓	✓
	civil protection members treated separately					
	Scale of data for population and buildings used in RA:					
	building by building		✓			
	sub-municipal (settlements, district)	✓		✓	✓	✓
	Data on affected residential buildings				✓	✓
	Infrastructure:					
	only listed	✓	✓	✓	✓	
	listed with details on attributes					
	listed with details on capacities (hospital capacities, shelter capacities)					✓
	Types of infrastructure listed:					
	hospitals and health care	✓	✓	✓	✓	
	transportation network	✓	✓	✓	✓	✓
	schools	✓	✓	✓	✓	
	public and strategic buildings	✓	✓	✓	✓	
	cultural heritage	✓	✓	✓	✓	
	sports facilities	✓		✓		
	green/protected areas		✓	✓	✓	

Table 7.8: Damage and impact indicators for flood risk: comparison of practices in beneficiary countries.

Damage and Impact indicators	Description	ITA	SLO	AUT	TUR	MNE
	On people:					
	number of death and injured					
	displaced					
	lack of fulfillment of basic needs					
	people that need to be evacuated					
	Affected/not affected	✓	✓	✓	✓	✓
	Economic losses	✓	✓	✓	✓	✓
	Damage potential – discrete values		✓			
	Impact on buildings:					
	damaged					✓
	Infrastructure					
	damage grade					
	functionality of roads					✓
	functionality of hospitals					
	functionality of strategic buildings					

8. THE COMPARATIVE REVIEW OF THE NATIONAL INSTITUTIONAL AND LEGAL FRAMEWORK OF CIVIL PROTECTION SYSTEMS IN DIFFERENT COUNTRIES

This chapter compares the existing DRM frameworks in the five partner countries. For this, sub-chapters 1 and 4 of each country-chapter were reviewed focusing on existing decision-making processes, planning measures, responsibilities, policies, legal and institutional arrangements implemented by the relevant DRM actors. The aim of the comparative review is to present relevant aspects for the Emergency Management preparedness phase. As a conclusion, a number of recommendations for harmonization is also highlighted.

Based on the following four key aspects, similarities and differences between the partner countries are presented:

a. Coordination of responsibilities
b. Prevention, preparedness, and response plans
c. Role of real-time monitoring and warning and alerting activities
d. Tools and maps specifically used for emergency management.

8.1. Coordination of responsibilities

The disaster prevention and emergency management systems are based on different approaches and various planning levels. Some tasks are carried out at the national level, while other activities are handled locally, depending on the scale of the emergency. This is based on the different organization of responsibilities and participating organizations:

Country/scale	National Level	Regional Level	Local Level	Voluntary / Professional Involvement
Italy	National Civil Protection Service; SSI-Italy's Situation Room	Regional Operations Center (COR), for emergencies involving more than one province, chaired by the president of the region or his delegate	Municipality mayor who coordinates the Municipal Operations Center (COC)	National Fire and Rescue Service, the competence centers, the structures of the National Health Service, the structures responsible for the management of meteorological services at the national level
Slovenia	Administration of the Republic of Slovenia for Civil Protection and Disaster Relief	Administration of the Republic of Slovenia for Civil Protection and Disaster Relief (regional branches)	Municipality mayor and a body of experts established for this purpose	Voluntary non-government organizations (including voluntary fire brigades); professional civil protection units; duty units
Austria	National Crisis and Disaster Management / Ministry of Interior	Regional Civil Protection Department	Municipality mayor – head of crisis committee	Voluntary Fire Brigades; Voluntary Rescue Forces; Professional Responders (regional and national departments), civil defense associations
Turkey	Disaster and Emergency Management Presidency (AFAD)	Provincial AFAD directorate	Governor led crisis committee	Voluntary/professional non-governmental organizations, such as search and rescue teams, that are subject to the approval of AFAD and operates under the coordination of AFAD
Montenegro	Directorate for Protection and Rescue of the Ministry of Interior.	Regional coordination is not defined	Municipal Team for Protection and Rescue	Voluntary Rescue Forces, Voluntary Fire Brigades; Professional Responders (municipally and national units);

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				Professional rescue forces; Units for the protection and rescue of companies, other legal entities and entrepreneurs; Air forces for fire protection

In **Italy,** prevention activities are carried out by the National Service at various territorial levels. The operational structures of the National Service include various organizations such as the National Fire and Rescue Service, the competence centers, the structures of the National Health Service, the structures responsible for the management of meteorological services at national level. Coordination centers are the physical location where the civil protection system implements all emergency management and response activities. The activation of these centers leads to a change in common procedures, as in an emergency the administrations collaborate and restructure themselves according to tasks/functions and implement the civil protection plans. The aim of each center is therefore to coordinate and connect civil protection activities. Depending on the scale of an emergency, the various levels of coordination are activated according to the principle of subsidiarity, and, at the national level, continuous monitoring of the territory is ensured by the SSI-Italy, the Civil Protection Situation Centre.

In **Slovenia** the national risk assessment/ national plan defines obligations to draw up regional and municipal protection and rescue plans for the risk classes of the regions and municipalities. The national plan, as well as the regional plan, are prepared by the Administration of the Republic of Slovenia for Civil Protection and Disaster Relief. Municipal plans are prepared by a body determined by the municipality mayor if this is required in the national plan. The organization plan is prepared by organizations with facilities that pose high environmental risks.

The **Austrian** system is based on a federated states approach: Main responsible entity for provincial-wide disaster scenarios is the Office for the Regional Government - Department of Civil Protection. For all warning and alerting activities, it is supported by a National Alarm Center, which is stand-alone or affiliated with the regional fire-brigade. The content of the active disaster acts covers all responsibilities, the necessary actions to be taken in case of a disaster, all participating forces in disaster response and relief, the external Emergency Plans (focusing on enterprises dealing with CBRN-related substances), the duties of the population and the overall cost regulation for all related deployments.
The responsibilities in disaster management are defined according to the scale of the respective scenario. Starting from the mayor at the municipality level, via district commissioner and governor up to the Minister of Interior for nation-wide events. Those are handled under the National Crisis and Disaster Management (SKKM). In addition, International Disaster Relief and Civil Protection is under command of the Interior Minister. In all scenarios not exceeding provincial scope federal authorities only fulfill complementary tasks.

Turkey is relying on an integrated disaster management approach, which replaced disaster management carried out by multiple governmental bodies. The respective Disaster and Emergency Management Presidency (AFAD) was founded in 2009 to conduct comprehensive disaster management processes and ensure coordination among relevant administrations, institutions and organizations.
In case of an emergency, coordination at the local level is maintained by a committee headed by the Governor. Depending on the state of emergency, four response levels are defined ranging from “adequate local capacity” to “need for international support”. The disaster management is organized following those response levels (slightly, moderately, very and extremely). The primary responsible authority, supporting authorities, tasks

and responsibilities are defined and a working group is established depending on the certain scenario to be addressed. Responsible institutions for earthquake and flood risks at national, regional, and provincial level are defined by disaster response plans.

In Montenegro, the decision-making processes for emergency management are spearheaded by the Directorate for Protection and Rescue of the Ministry of Interior, which is responsible for proposing laws and strategic documents that govern disaster risk management (Law on Protection and Rescue outlining framework for creating national and urban-level policies and strategies.)

The Municipal Team for Protection and Rescue is tasked with managing and coordinating protection and rescue activities, monitoring the organization of services in the municipality, issuing necessary orders and decisions, and reporting to the Coordination Team. This team consists of the mayor, the commander of the protection service, representatives from the Ministry responsible for protection and rescue operations, heads of local government bodies, responsible persons from relevant companies, and a representative of the Red Cross. They are also required to cooperate with the Coordination Team and the Operational Headquarters, which operate at the national level.

8.2. Prevention, preparedness, and response plans

The preparation phase includes the development and coordination of disaster management plans at municipal, regional, and national levels. Although the terminology of the plans (civil defense and disaster management plans; evacuation plans) differ from country to country, the core elements and objectives of the plans are comparable. In most cases, the aim is to assess possible hazards/scenarios at the local level and then, in a next step, to list the necessary steps, operations, and contact persons. However, how detailed the plans are prepared and which aspects are focused on differs.

In Italy, for example, the detailed presentation of the people/elements at risk and the identification of strategically important elements and functions is very detailed. The Slovenian approach is to determine the level of detail of the plans on the basis of a national risk analysis. Austria intends to draw up specific civil protection plans for individual hazards.

The following paragraphs outline the key content and procedures of the individual plans in the partner countries.

The Italian Civil protection plan (Italian regulations - DPCM 30/4/2021 National Civil Protection Guidelines), is described as a tool that serves to increase risk awareness, to organize the pooling of resources, to build skills and professionalism, and to guarantee the link between different Administrations and Bodies. According to the specifications the plans should be very detailed and must be **continuously updated** in relation to the development of the territorial structure and changes in the expected scenarios. In addition, a plan must be flexible enough to be used in all emergencies, including unexpected ones. Within the plans **impact scenarios** (**hazard and risk scenario**s) need to be outlined with the main aim to define and guide decision-making activities intended to implement the strategic actions necessary for the implementation of the plan itself, such as the identification of operational centers and emergency areas. Several **different layers of information** must be compiled for each type of defined risk/hazard. The plans are intended to show information about the **exposed people, buildings and facilities**. Among the long list of exposed elements considered (see §2.1.1), it should be emphasized that information on **vulnerable groups** is also identified via an estimate of the number of people in socially weak conditions and with disabilities (according to information from the regional health service) or **particularly vulnerable sites** that pose a major accident risk or the location of dams and hydraulic structures. In addition, the plans also identify **strategic elements/functions including operational coordination centers and response areas, emergency areas and facilities like safe waiting areas, relief areas,** sites where workers, vehicles and materials can be assembled. Even areas for semi-permanent settlements for the housing needs of the population affected by severe earthquakes are shown. **Accessibility** is also an issue, and the plan includes an assessment of possible interruptions to the mobility system at all territorial levels resulting from events that would limit the usability of the land transport system. Of particular interest is the identification **of potentially dangerous areas** due to flooding (e.g. floodable passages). **Points of observation** are furthermore defined in order to enable monitoring under safe conditions (e.g. hydrometers, rain gauges or other points for visual monitoring of the phenomenon).

In Slovenia, **national and regional plans** are prepared by the Department for Civil Protection and Disaster Relief. The approach here is to start from the national risk assessment that determines for which regions and municipalities protection plans need to be compiled and to what level of detail. Risk class 4 and 5 regions and municipalities are obliged to create individual protection and rescue plans. In addition, plans must be drawn up for companies with a high potential environmental risk.
The **protection and rescue plans** need to include the characterization of the event and to address the possibility of chain events. The framework conditions regarding conceptual planning, activation of the plan as well as required resources and instructions for the organization of communication and alerting. The responsibilities involved and their scope of action are also defined, and the action plans of the various forces involved in the protection, rescue and relief measures are outlined.

Every municipality in Austria needs to draw up a **disaster prevention plan** that needs to be revised at least every three years. The plans should include an overview of the local conditions, including the topographical conditions and technical features of facilities that are important for disaster control. Besides a description of potential disasters, including areas at risk and the type of hazards to be expected in each case is the basis to develop contact details of relevant available alarm, communication, emergency and rescue facilities and information on the function and expertise of the responsible persons and executive bodies. The plans also include a list of equipment required in the event of an emergency (e.g. excavator) and a person to contact to request the resource. One important part is the overview of the measures/interventions to be taken in the event of a disaster, in particular, the existing alarm plan.
Building on existing plans, **process-related flood emergency management** plans should be drawn up in order to be able to specifically orientate operational emergency planning to flood events. The use of hydraulic engineering plans, in particular hazard zone plans, flood risk maps, hydrological and hydraulic analyses, operating instructions for protective measures and hydropower plants, etc. are recommended as a basis for process-related flood emergency management plans.
The **emergency organizations** (Red Cross, volunteer fire brigade, etc.) and civil defense associations, which are alerted in the event of a disaster on the basis of these plans, themselves **prepare crisis/emergency plans for various scenarios** such as floods or blackouts, which are also regularly trained.

Within the scope of the **integrated disaster management approach**, national and local plans have been developed in Turkey. **Turkey Disaster Risk Reduction Plan** aims to prevent/reduce losses that may result from disasters, tries to establish durable, safe, well-prepared, sustainable and disaster-resistant living environments, and define the fundamental principles of disaster risk reduction required to be prepared prior to disasters. The objective of the **Turkey Disaster Response Plan** is to define the roles and responsibilities of working groups and coordination units that will serve in emergency response. Turkey Post-Disaster Recovery Plan is still under preparation.
In accordance with national tactical plans, operational disaster risk reduction and **disaster response plans for each province** have been prepared. For districts with a population over 50,000, governors have the authority to establish District AFAD Centers. In this regard a district response plan is prepared following the relevant **provincial response plan**.
A provincial disaster risk reduction plan consists of modules involving (i) up-to-date information about the province, (ii) identification of hazards and risk assessment, (iii) current state assessment, (iv) disaster risk reduction actions, and (v) monitoring and assessing the plan. A provincial disaster response plan reports the objectives and principles of disaster response plan, general information about the province, possible hazards and risks, organizational structure in disaster response and responsible authorities,

In Montenegro, protection and rescue plans explicitly prescribe measures for each phase of DRM including prevention and preparedness, response, and recovery. Typically, these measures focus on residential buildings, infrastructure (roads, railways, hospitals and schools), and cultural assets. Although the prescribed measures often take on a declarative character with many general statements (e.g., emphasizing the need for spatial planning in accordance with risk assessment), there are instances where proactive measures are clearly based on risk analysis findings.

The national earthquake protection and rescue plan of 2018 delineates various seismic risk reduction measures. These are categorized into preventive protection measures, urgent measures during the rescue phase, and long-term measures aimed at reducing seismic risk.
Operational measures of protection and rescue regarding earthquakes are defined in **the urban-level Protection and Rescue plans**. Specific responsibilities for these actions are assigned to various entities including the Municipal Team for Protection and Rescue, the Police Directorate, the Army of Montenegro, protection and rescue services, transport companies, and the Red Cross.
Municipal flood protection and rescue plans incorporate, for example, policies and recommendations regarding the return periods for the main design of hydro-technical infrastructure. Municipal plans also outline evacuation capacities and potential locations for accommodating displaced individuals during large-scale floods. The plans also delineate the roles and responsibilities of various stakeholders, including local government bodies, companies, legal entities, and entrepreneurs, in implementing flood protection and rescue measures.

The plans include organizational schemes of operations at the municipal level (decision-making and responsibilities), which ensure coordination and efficiency during emergency responses. Tables presenting an overview of human and material resources available from different responsible institutions, as well as contact information for members of the municipal emergency management team, are also part. Leadership and coordination mechanisms during flood protection and rescue actions are established, along with provisions for inter-municipal and international cooperation.

8.3. Role of real-time monitoring and warning and alerting activities

Italy:

Regarding floods, the national alert system is ruled by the DPCM 27/02/04, containing the "Operational guidelines for the organizational and functional management of the national and regional alert system for hydrogeological and hydraulic risks, for civil protection purposes". The management of the system is ensured by the Civil Protection Department and by the Regions and Autonomous Province, through the Centers for Forecasting and Surveillance network. They develop real-time forecasting, monitoring and surveillance of events and assessments of the consequent effects on the territory. In particular, each Center is responsible for collecting and distributing a range of data and information to the entire network of Centers. This data is sourced from various technological platforms and an extensive network of sensors located across the country, as: data collected by weather-hydro-pluviometric networks, by the national meteorological radar network and by the various satellite platforms available for Earth observation; hydrological, geological, geomorphological and territorial data deriving from the landslide monitoring system; meteorological, hydrological modeling, hydrogeological and hydraulic modeling. Based on the collected data and models, the Functional Centers conduct forecasting activities by generating expected probabilistic scenarios. They use this analysis to issue Bulletins and Warnings, detailing both the evolution of anticipated or ongoing phenomena and the assessed levels of criticality (including the type, extent, and severity of landslides and floods) within their jurisdiction. It is the responsibility of the Regions and Autonomous Provinces to issue alerts within their territories, using a color code system (Yellow, Orange, and Red) that reflects the forecasted risk level. Mayors then use this information to activate Civil Protection Plans, inform citizens of potential risks, and determine necessary actions to protect the population. The monitoring and surveillance phase, described above, aims to provide real-time information on the progression of an ongoing event through the collection, centralization, and sharing of data, as well as locally obtained non-instrumental information. To achieve this, monitoring and surveillance activities are complemented by on-the-ground surveillance, which is carried out through territorial safeguards organized at the regional, provincial, and municipal levels. This local surveillance gathers firsthand information on the actual evolution of the event and communicates it to the network of Functional Centers and relevant authorities via regional operating rooms.

Regarding earthquakes, real-time earthquake monitoring and warning is governed by a comprehensive national framework that defines the regulations and guidelines for seismic monitoring and warning. The National Institute of Geophysics and Volcanology (INGV), as one of the Competence Centre for the Italian Civil Protection System, is the primary institution responsible for these activities. In collaboration with other research institutes such as the National Institute of Oceanography and Experimental Geophysics (OGS), the National Research Council (CNR) and various Italian universities, the INGV operates an extensive network of seismic stations throughout the country.
The INGV continuously collects and analyses seismic data in real time and quickly calculates the magnitude, location and potential ground motion distribution of the event. As soon as the INGV detects an earthquake that exceeds certain thresholds, it triggers an automatic alarm system that transmits warnings to the Department of Civil Defense (DPC). The DPC then assesses the situation and activates the emergency protocols if necessary. Coordination with regional and local authorities ensures that these alerts are immediately communicated to the public through various channels, including mobile notifications and media broadcasts. For seismic events with a magnitude of $Ml \geq 2.5$, the INGV issues automatic, unverified reports that are later updated with verified data from on-duty seismologists. Special protocols apply to volcanic areas, where lower magnitude thresholds are set, and additional monitoring of seismic swarms is carried out to assess possible volcanic activity.
In addition, the INGV provides the DPC with detailed reports and weekly bulletins containing earthquake data, seismotectonic information and shake maps, among other important information. These documents are made available to the public via the INGV website on seismic events and serve to support ongoing emergency management and long-term planning. In the event of significant seismic events, INGV forms a crisis team to coordinate emergency measures and ensure a rapid and effective response.

Slovenia:

For floods, the National Meteorological Service ARSO informs the Information Centre of the Republic of Slovenia (CORS) about every observed flood risk with a hydrological report and a flood forecast in graphical form as well as with a hydrological warning. The immediate measures taken in the event of flooding are based on hydrological forecasts and an evaluation using four levels.

There is no real-time warning system for earthquakes. This can be attributed to the fact that the seismic hazard in Slovenia is controlled by earthquakes with distances up to 20 km, for which real-time warning system is less effective.

Austria:

For over thirty years, Austria has had a warning and alert system covering all municipalities with around 8,300 civil protection sirens. The 'AT-Alert' population warning system, which is based on the mobile radio technology 'Cell Broadcast', is currently being implemented as a supplement. The aim of this new additional warning channel is to reach as many affected people as possible directly via their mobile phones in the event of an emergency. AT-Alert will therefore be used nationwide. Alerts can be sent out for any event if the responsible authority decides that this is appropriate in the context of imminent or developing emergencies or disasters. Some examples of possible situations requiring an alert are

- (Life-) threatening natural hazards (severe weather such as storms, extreme heavy rainfall, extreme flood risk, extreme snowfall, very high avalanche risk, extreme forest fire risk, ...)
- (Life-threatening) technical hazards (accidents involving radiological, biological and chemical substances, such as gas leaks, chemical leaks, explosion hazards, but also hazards from fumes, ...)
- (Life) threatening police situations

The individual federal states and municipalities are responsible for flood warning. Hydrographic services are responsible for monitoring and are connected to the state warning centers in the individual federal states. In the event of imminent flooding, the state warning centers are informed, which then initiate the required emergency measures and activate the warning of the population via the warning and alarm system. A state website provides an overview of the situation at the watercourses and the current flood stage (1-3), and additionally shows whether the water level trend is rising, stable or declining.

There are no particular warnings or alarm plans for earthquakes, a warning is communicated via civil protection alarms in the event of an emergency. Geosphere Austria provides a map and list showing the earthquakes registered by the seismic station network in Austria over the last 14 days.

Turkey:

In Turkey, the Flood Forecast and Early Warning System (TATUS) is being operated under the umbrella of the Ministry of Agriculture and Forestry. The data and modeling for the TATUS are provided by the General Directorate of State Hydraulic Works using the Flood Early Warning System (TEUS) module. In this context, water levels in riverbeds are monitored through Level Observation Stations, which are established on streams that pass through settlements and pose flood risk and will provide real-time data. When the critical water level is reached, the data is transferred to AFAD and the General Directorate of Meteorology, which are responsible for flood warnings. Warnings and alerts are issued by the General Directorate of Meteorology using a four-colored (green, yellow, orange and red) evaluation system to make people and responsible authorities understand the situation better. The TATUS is aimed to be established throughout the country by the end of 2028.

An earthquake rapid response and early warning system for Istanbul is being developed through a collaborative study conducted by the Istanbul Metropolitan Municipality and Boğaziçi University Kandilli Observatory. There is no early warning system for earthquakes throughout the country.

Montenegro:

In Montenegro the plans addressed include detailed instructions for alerting citizens and the public about impending flood risks, as this is a crucial aspect of DRM. Moreover, they detail activities to be undertaken after receiving flood warnings or extreme weather alerts, as well as strategies for protecting critical infrastructure. Flood warnings are issued by the Institute for Hydrometeorology and Seismology, which monitors and collects meteorological data, including flood-related information. In the event of anticipated floods, the Institute notifies the Ministry of Internal Affairs - Emergency Situations Administration, which then alerts local authorities, municipal protection services, and relevant ministries, institutions, and companies involved in flood response.

In case of an earthquake The Ministry of Interior, specifically the Directorate within the ministry responsible for protection and rescue services, receives information about the occurrence of an earthquake from the Institute of Hydrometeorology and Seismology through its Emergency Call Center 112. According to a pre-established standard operating procedure, the ministry prepares a notification that informs all members of the protection and rescue system. This information provides operational units with the initial inputs needed to begin rescue actions and provide assistance to the affected and injured population. Operational units in the field, on the other hand, will send feedback to the Municipal Protection and Rescue Team and the Operational Headquarters, based on which information is prepared for the public.

8.4. Tools and maps specifically used for emergency management

This chapter draws attention to different tools and applications that are currently only used in individual countries.

Italy

CLE (Condizione Limite per l'Emergenza, Limit Emergency Condition) The Italian Civil Protection Agency has specific limiting conditions (LC) for urban settlements during an earthquake event in order to define risk management tasks in the individual phases. The LCs correspond to different conceptual thresholds demonstrating how urban systems lose a certain level of functionality as a result of an earthquake. The aim of the LC is to ensure emergency management after a disaster event (see §2.2.5). Further the I.OPà.CLE method (Indices for evaluation of the Operational efficiency of Limit Condition Emergency) is a tool capable of evaluating the physical efficiency of the CLE system aiming at supporting civil protection decision makers in evaluating emergency systems and establishing strategies and priorities concerning interventions at municipality level (from individual elements to subsystems and whole system).

For the case of floods there is no tool used for emergency management in Italy.

Slovenia

Tools used in emergency management differ with respect to the type of hazard. For emergency management related to seismic hazard, the POTROG platform is used. Within this platform several tools are available, including an application for the assessment of consequences, an application for displaying building occupancy, an application for road transportability assessment (available for 13 municipalities), and an application for describing building damage after an earthquake. The POTROG platform is intended for the CP response after an earthquake. It also offers valuable information for the preparation (pre-disaster) stage of risk management, but its use for this purpose is not straightforward.

For the case of floods there is no tool used for emergency management in Slovenia.

Austria

As the Austrian federated states are mainly responsible for disaster management, represented in the various Disaster Acts, some of them also use stand-alone solutions to support the response process. In this context, for example the Styrian Department of Civil Protection and Defense uses the so-called FÜIS, an Executive Information System, to manage all participating disaster response forces with one software-tool. The main benefit of this application is to collect all information necessary for efficient and successful deployment on one platform in relation to a map of the affected area. This includes information about residential areas, critical infrastructure and industry dealing with hazardous material. Furthermore, the current location of all participating units is visualized with information about their certain capacities. This together with information about scope and intensity of the respective disaster event creates a performant operational picture for continual deployment planning. The data and all changes throughout the process are visible for all response organizations in real-time, so the activities of each organization can easily be adjusted to optimize the joint response effort. Similar software solutions, which can also be used with handhelds like cellphones and tablets, are in use in other federated states as well.

Turkey

The platform Rapid Earthquake Damage and Loss Estimation System (AFAD-RED), developed for generating earthquake scenarios and estimating damage and impact indicators, is integrated with the National Earthquake Observation System operated by AFAD and it can be used to provide near real-time estimation of losses in an earthquake-affected region so that appropriate measures can be taken. It is compatible with the Disaster Management and Decision Support System, which is a web-based application developed to maintain an efficient use of resources in case of disaster and emergency, so Provincial AFAD directorates can easily integrate outputs from AFAD-RED into their works on the Disaster Management and Decision Support System. The system consists of three components: incident command system, spatial information system and recovery system. The application is also used in case of floods.

Montenegro

For some municipalities evacuation maps especially for earthquake events are developed to guide the planning and execution of evacuation actions. These maps detail the directions of movement, locations for rescue, and positions of essential services like the police and health institutions. They also highlight sensitive areas such as gas stations, tunnels, and bridges, which are crucial from a planning, organization, and implementation perspective during an evacuation.

Regarding floods, there is currently no specific platform that can be used for emergency management (except the website of the Institute for Hydrometeorology and Seismology which only provides measured hydrometeorological data), however, depending on the municipality, Municipal Protection and Rescue Plans may contain various appendices: a map of flood-prone locations within the municipality; a map indicating the position of significant structures (health facilities, schools, transportation infrastructure, municipal buildings, evacuation locations, etc.), and similar items.

8.5. Recommendations for harmonization of national systems

- Nationwide templates for the development of disaster management plans and intervention maps should be provided.
- Harmonization of templates, guidelines and terminology across national borders leads to an improved exchange during preparation and the emergency.
- The content of the plans differs depending on the region and country. This is due to the various hazard processes. A harmonization can be achieved, however, in that the following contents are systematically included in the plans: Territory description, identification of hazards and risks and definition of risk/impact scenarios with different levels of information/identification of critical points/exposed elements/objects.
- In order to be able to present this content as intended, data is required. This calls for the standardised collection and availability of data as well as the harmonization of individual datasets.
- Emergency management requires the development of operational strategies and intervention options in order to be able to react efficiently to situations in the event of a crisis and to facilitate the prioritization of resources.
- Specialized tools for emergency management such as LCE might be of interest to other countries/ processes. An exchange across process boundaries and country borders would be beneficial.
- Continuous evaluation, revision and updating of plans, procedures, responsibilities and maps as well as corresponding training and exercises are essential.

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