Inception Report

Regionally consistent risk assessment for earthquakes and floods and selective landslide scenario analysis for strengthening financial resilience and accelerating risk reduction in Central Asia (SFRARR Central Asia disaster risk assessment)

FINAL VERSION

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RED – Risk Engineering + Development – Pavia, Italy

Revision History

Version	Date	State	Initials	Changes
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Executive Summary

Central Asian countries, which includes Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan and Uzbekistan (Figure 1), are known to be highly exposed to natural hazards, especially floods, earthquakes and landslides. According to the country risk profiles developed by the Global Facility for Disaster Reduction and Recovery (GFDRR)[1], the annual average population affected by floods in these countries is almost one million (the majority of which located in Uzbekistan and Kazakhstan) and the annual average population affected by earthquakes is almost two million (the majority of which located in Uzbekistan and Tajikistan). Disasters have affected more than 2.5 million people and caused losses in excess of US$ 1.5 billion in the last 20 years (EM-DAT[2]). Landslides can also cause significant loss of life and trigger disruptions to transport networks, especially in the mountainous areas of Uzbekistan, Tajikistan and Kyrgyz Republic. Climate change, urbanization and population growth are expected to exacerbate natural risks in the future.

To face these challenges, the European Union, in collaboration with the World Bank and the GFDRR, has started a programme for "Strengthening Financial Resilience and Accelerating Risk Reduction in Central Asia" (SFRARR). The overarching objective of the programme is to improve financial resilience and risk-informed investment planning, aiming to advance disaster and climate resilience in Central Asia. The target countries of this programme are Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan. The programme spans from July 2019 until 31 December 2023. The operational components of the programme are:

i. Quantifying regional disaster risks and capacity building on risk identification
ii. Establishing fundamental awareness and capacities for financial resilience at national and regional levels
iii. Exposure mapping for improved risk analysis, disaster risk management and awareness.

A probabilistic risk assessment is required to attain the goals of the programme and to start a strategic discussion with the relevant stakeholders. The probabilistic risk assessment should be consistent across multiple hazards and asset types, to allow for coherent and consistent strategic financial solutions across geographical areas and across economic sectors. The current experience and expertise of regional institutions and governments in Central Asia is still not sufficient to carry out such assessments by themselves and need to be further strengthened.

Within this framework, the World Bank has commissioned the present project to a consortium formed by RED (Risk, Engineering and Development, Pavia, Italy), OGS (National Institute of Oceanography and Experimental Geophysics, Udine, Italy), ERN (Evaluación de Riesgos Naturales, Mexico City, Mexico), UNESCO Chair (UNESCO Chair on Prevention and Sustainable Management of Geo-Hydrological Hazards of the University of Florence, Italy), AKUA (Akua Capital, Mexico City, Mexico), and a wide range of locally-based research and engineering institutions (LLP "Institute of Seismology" of the Science Committee of the Republic of Kazakhstan, Institute of Seismology of the Academy of Sciences of Uzbekistan, Tashkent State

[1] https://www.gfdrr.org/en/disaster-risk-country-profiles

[2] https://emdat.be/

Transport University, Institute of water problems, hydropower and ecology, National Academy of Sciences of Tajikistan, Institute of Seismology of the National Academy of Sciences of Kyrgyz Republic and consultants from Turkmenistan). The current project will build on risk assessment and risk management concepts to provide an improvement in the understanding of how natural disaster risk (flood, earthquake and landslide risk) affects the population, the building stocks and, in general, the economies of Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan and Uzbekistan. The overarching objective of this project is to provide the World Bank and the local governments with a reliable tool that can be used in the framework of their wider disaster risk management strategies. An additional objective is to increase the understanding of natural risks among the technical and scientific communities of the five countries and build natural hazard and risk assessment capacity through an ensemble of regional workshops to be carried out within the framework of the project.

Figure 1. Countries target of this project.

The risk assessment will inform the World Bank's engagement activities on emergency planning and their disaster risk management activities. However, it must be noted that this assessment will not have sufficient detail to inform planning and design of specific risk management infrastructure; rather, the output information will inform and enable the World Bank to initiate a policy dialogue.

This report summarizes the outcomes of the inception phase of the "***Regionally consistent risk assessment for earthquakes and floods and selective landslide scenario analysis for strengthening financial resilience and accelerating risk reduction in Central Asia***" project, including the desktop study/literature review and an overview of the methodology to be followed during the project. In particular, the report includes the following topics:

- Background information on hazards and risk in Central Asia;
- Review of previous national and regional hazard and risk assessment and disaster risk management activities;
- Technical description of the methodologies, including earthquake and flood hazard assessment, exposure development, earthquake and flood vulnerability assessment, earthquake and flood risk assessment and landslide scenario assessment;
- Structure and content of capacity building workshops;
- Workplan of the activities.

Index

Index of Figures

Index of Tables

1 Introduction

Central Asia is subject to frequent natural disasters including earthquakes, floods and landslides. Furthermore, climate change and a growing population and urbanization have contributed to an increase in the frequency and severity of related losses caused by natural disasters in the last two decades (Pollner et al., 2010; Reyer et al., 2017; Yu et al., 2019). Natural disasters can affect different countries at the same time, for example, the periodic seismic events in the Ferghana Valley (Namangan oblast of Uzbekistan) involve Uzbekistan, Kyrgyzstan and Tajikistan (Bindi et al., 2014). The transboundary nature of many of these events requires a regional and shared approach to support, plan and coordinate Disaster Risk Management (DRM) and Disaster Risk Financing and Insurance (DRFI) strategies. Currently, the availability of risk information for DRM and DRFI activities remains variable across the region and has largely been generated in previous projects with a focus on a single country, rather than with regional consistency in mind. Moreover, few of these studies have quantified disaster risk, and, to the authors' knowledge, none have done so for the whole region using probabilistic methods applied with the sufficient fidelity required to robustly inform the development of DRFI solutions. A regional approach can significantly benefit each country by providing common analytics and metrics, training and sharing of knowledge and technology, and co-development of solutions for national and regional/transboundary risks. The development goal of the project is to improve financial resilience and risk-informed investment planning towards building disaster and climate resilience in Central Asia.

Specifically, the project has two main objectives:

1. Conduct probabilistic disaster risk assessment for earthquake, fluvial and pluvial flood, and landslide for the World Bank and national governments to consider engagement in the region on DRFI solutions, and to inform DRM/DRR activities. The risk assessment will be regionally consistent in its methodology and output metrics. The models developed should comprise the necessary model components and uncertainty quantification of a catastrophe loss model in order to inform dialogue on the development of DRFI solutions and to be used to potentially structure and operationalize such solutions
2. Build capacity of local experts, institutions, and research groups with a role in DRM and emergency planning on exposure mapping and development/use of disaster risk information and its components. Capacity building should occur throughout the project with local technical experts participating in the project as partners and as members of a regional scientific and technical working group. Training on exposure mapping are important components of this capacity building.

The project is organized in tasks listed herein in Table 1. Each task will be presented in more detail in the following sections.

Table 1. Project's tasks list

TASK #	TASK NAME	
T1	Inception report	
	T1.1	Inception report preparation
T2	Earthquake hazard assessment	
	T2.1	Data collection
	T2.2	Modelling
	T2.3	Validation and model output
T3	Fluvial and pluvial flood hazard assessment	
	T3.1	Modelling
	T3.2	Data Collection
	T3.3	Validation and model output
T4	Development of an exposure dataset	
	T4.1	Methodology
	T4.2	Validation
	T4.3	Modelling output
T5	Development and validation of physical vulnerability or fragility relationships and casualty relationships	
	T5.1	Methodology - flood
	T5.2	Methodology – earthquake
	T5.3	Validation
	T5.4	Modelling output
T6	Earthquake and flood risk assessment to support Disaster Risk Management and Financing activities	
	T6.1	Methodology
	T6.2	Validation
	T6.3	Modelling output
T7	Landslide scenario assessment	
	T7.1	Methodology
	T7.2	Validation
	T7.3	Modelling output
T8	Capacity Building and Knowledge Transfer	
	T8.1	Planning of the capacity building activities
	T8.2	Participation to project inception workshop (W1)
	T8.3	Interim workshop on hazard modelling (TW2)
	T8.4	Interim workshops on exposure mapping (TW3 – TW7)
	T8.5	Interim workshop on vulnerability analysis (TW8)
	T8.6	Interim workshop on risk modelling (TW9)

	T8.7	Participation to final project workshop (W10)
T9	Final reporting	
	T9.1	Final reporting

The project started on October 31st, 2020 and will be completed by July 29, 2022 with the delivery of the final report (Deliverables D9a and D9b).

2 Background information on hazards and risk in Central Asia

Central Asia is highly exposed and vulnerable to a broad range of natural hazards which frequently result in economic and human losses. Geographically, Central Asia is a vast and diverse region including high mountain chains, deserts and steppes. Large transboundary river systems are present such as the Amu Daria and Syr Daria as well as major water bodies such as the Caspian and Aral seas and the Balkhash lake. About 70% of the region is classified as agricultural land with wheat, cotton and livestock being the main commodities. Central Asia also experiences very large temperature fluctuations, which are expected to increase due to climate change. The effects of a changing climate are already visible today, with noticeably higher temperatures and an increase in extreme weather events frequency and severity in recent decades (Hydrometeorological Service under the Cabinet of Ministers of the Republic of Uzbekistan, 2009; Ministry of Environment Protection Kazakhstan, 2009; State Agency for Hydrometeorology of Tajikistan, 2009; State Agency on Environment Protection and Forestry under the Government of the Kyrgyz Republic, 2009). Over the course of 80 years, all countries have seen an increase in annual average temperatures that significantly exceeds global trends. The countries of Kazakhstan, Kyrgyzstan, and Tajikistan experienced the highest temperature increase in the winter period, while in Turkmenistan and Uzbekistan the most significant changes were observed in the summer and autumn months. Even if a regional clear trend in precipitation was not observed, precipitation variability and the frequency of intense rainfall events have consistently increased in all countries, especially in the mountain areas where two-thirds of the region's population is concentrated. Future projections estimate an acceleration of climate change in Central Asia, with increased temperature and more intense and variable precipitation by 2030[3].

The population of Central Asia is steadily growing and recently exceeded 72 million people (ESCAP, 2019), the most populated country being Uzbekistan, followed by Kazakhstan. However, population density is unevenly distributed in the region: almost 50% of the population is concentrated in few densely populated cities, while rural areas have very low population density (Seitz, 2019).

The residential building stock is constituted by 6 main building typologies identified and characterized during past projects in the area, and in particular the SENSUM project (http://www.sensum-project.eu/) and the EMCA (The Earthquake Model Central Asia) project (Wieland et al., 2015). Wieland et al. (2015) also provide specific figures of the residential building stock distribution in Central Asia. Unreinforced masonry buildings are widely present both in rural and urban areas (in particular in Turkmenistan). Multi-storey masonry buildings are widely present only in urban areas, reaching more than 40% of the overall inventory, on average. In particular, the countries with a higher percentage of masonry buildings in urban areas are Turkmenistan and Kazakhstan. Rural areas are characterized by a strong presence of adobe/earthen buildings (more than 50% on average, but with peaks of more than 70% in Uzbekistan). Reinforced concrete buildings are very common in urban areas (more than 40% on average). Strategic buildings in the

[3] First and second National Communication on Climate Change under the UNFCCC (see previous reference)

region include schools, hospitals and healthcare facilities, airports, communication and production sites.

Central Asia also hosts approximately 200 hydro-power dams (UN, 2007), most of them constructed between the 50s and the 80s, which represent a strategic national asset. Natural and human-made water basins are both used for hydro-power production and for irrigation. In fact, some areas of Central Asia (in particular Uzbekistan and Kyrgyzstan) have a strong agricultural production (mostly rice and wheat), which covers about 19% of Central Asian GDP, and is, therefore, of major relevance for national economies (Lerman, 2013).

In addition, Central Asia is undergoing a strong development of energy and transportation infrastructures, both due to national development plans and international initiatives. In particular, the Belt and Road Initiative, announced in 2013, involves the construction of new railways and energy pipelines (mostly oil and gas) (Figure 2 left and right panel respectively). Kazakhstan, in particular, invested about $30 billion on infrastructure development, transport and logistics assets. Turkmenistan, less interested by the initiative, hosts the Turkmenistan–Afghanistan–Pakistan–India Pipeline (TAPI), constructed between 2015 and 2019, while the Pakistani segment is still under construction.

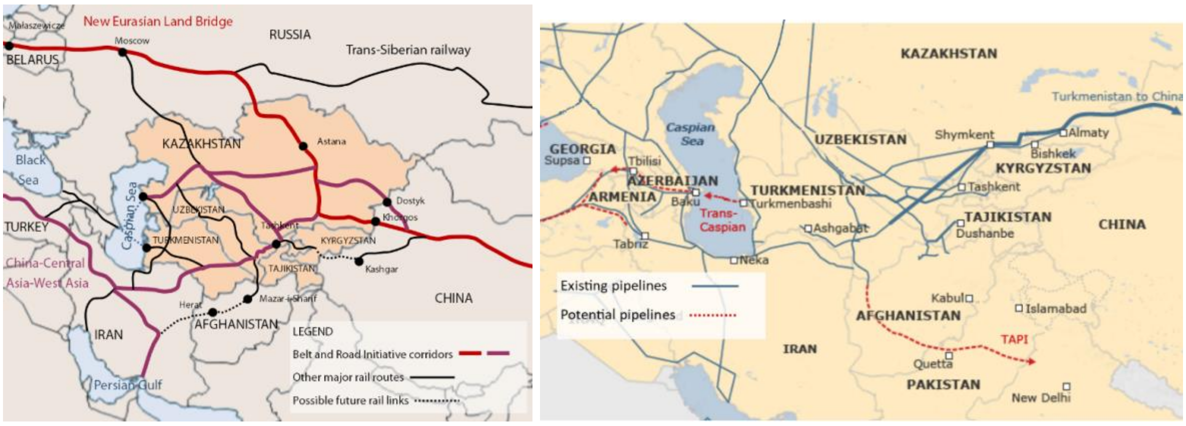

Figure 2. (left) Current and new railway routes in Central Asia and (right) current and future energy pipelines in Central Asia. Source: European Community (2019).

Thus, Central Asia has a heterogeneous distribution of assets, including residential buildings, strategic buildings and infrastructures, transportation assets, production sites and crops, that are potentially exposed to hazard associated with different perils.

Although poverty rates have fallen in Kazakhstan, many people remain vulnerable to significant economic volatility (Seitz, 2019). Poverty incidence remains high in Tajikistan (over 50% of the population), Kyrgyzstan (almost 40%), Uzbekistan (almost 30%), and Turkmenistan (over 20%). Moreover, rural poverty remains above the national average (including around 20% in Kazakhstan) (Thurman, 2011). This situation is reflected in high economic, social and infrastructure vulnerability. Several natural risk studies are focused on this region generating a variety of information unfortunately very often fragmented at spatial scale level. In 2008 the Global Facility for Disaster Reduction and Recovery (GFDRR, 2008) presented a simplified quantitative risk assessment to determine the social, economic and urban loss potential and the likelihood of occurrence of different hazards in each country of Central Asia. Results from GFDRR (2008) show that the dominant cities for social vulnerability are Tashkent, Uzbekistan; Almaty and Astana, Kazakhstan; Bishkek, Kyrgyzstan; Dushanbe, Tajikistan; and Ashgabat, Turkmenistan.

In terms of seismic hazard, Central Asia, with the exception of a large part of Kazakhstan, is classified as a highly seismically active region. Large historical earthquake events have occurred, mostly caused by thrust and reverse-faults generated by the collision of the Eurasian and Indian plates (Ullah et al., 2015). Such compressional regime was responsible for the development of the Cenozoic belts of Tien Shan and Pamir, which accommodate great part of the regional deformation (e.g., Abdrakhmatov et al., 1996; Zubovich et al., 2010) and where most of the seismicity occurs, often with earthquakes of magnitude larger than 7. Notable examples are the Verny (Ms = 7.3, 1887), Chilik (Ms = 8.3, 1889), Kemin (Ms = 8.2, 1911), Chatkal (Ms = 7.5, 1946) and Suusamyr (Ms = 7.3, 1992) earthquakes (Abdrakhmatov et al., 2003). The Kyrgyz Republic alone has been hit by 18 destructive earthquakes in the last 50 years, with up to 6.4 billion USD of potential economic losses estimated to be exceeded on residential buildings with a 10% probability in the next 50 years (Free et al., 2018, Figure 3). This seismically active region formally separates the more stable regions of the Tarim basin to the south and the Kazakh platform to the north, where a more moderate intraplate seismicity is observed, still capable of generating significant earthquakes. Seismic activity is also observed in south-western Turkmenistan, to the border of Iran and the Caspian Sea, and it is worth mentioning the large destructive earthquake of 1948 in Ashkabad (M=7.3). While most of the regional seismicity occurs within the first 40km of the crust, deep earthquakes have also been observed down to 300km depth in the Pamirs-Hindukush area (King et al., 1999). Although reverse and thrust source mechanisms are dominant due to tectonic regime, strike-slip and normal mechanisms (or a combination of them) are also present.

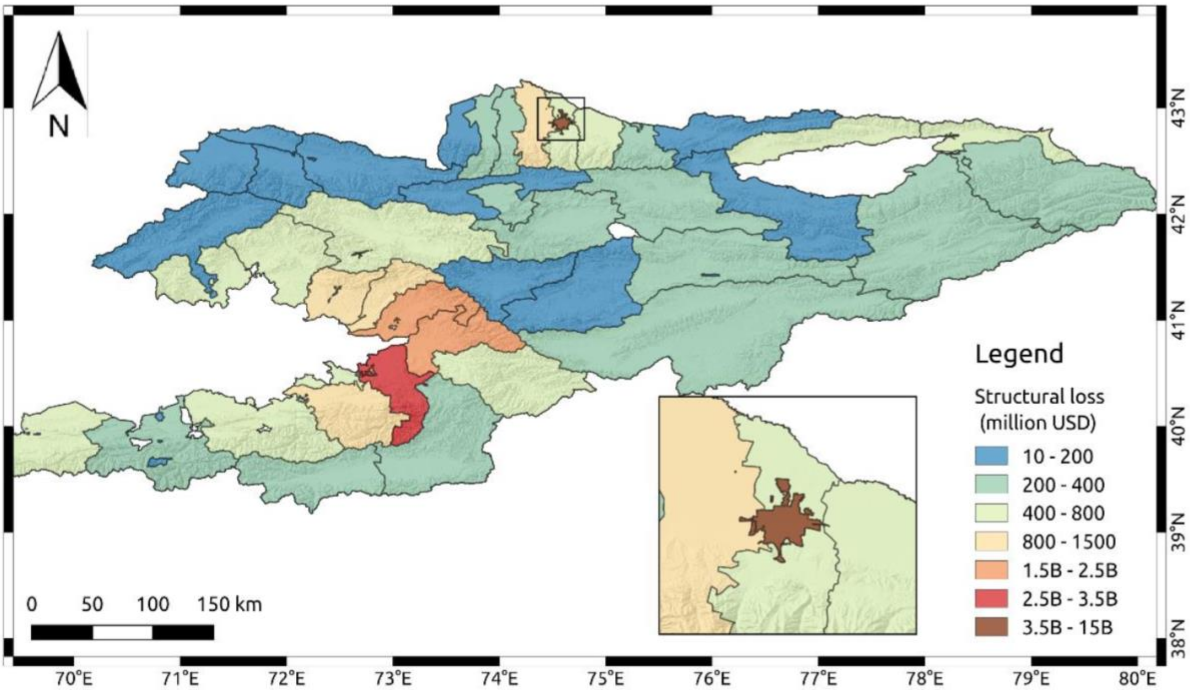

Figure 3. Monetary mean loss map (in US dollars) with 10% probability of exceedance in 50 years for residential buildings of the Kyrgyz Republic (from Free et al., 2018)**.**

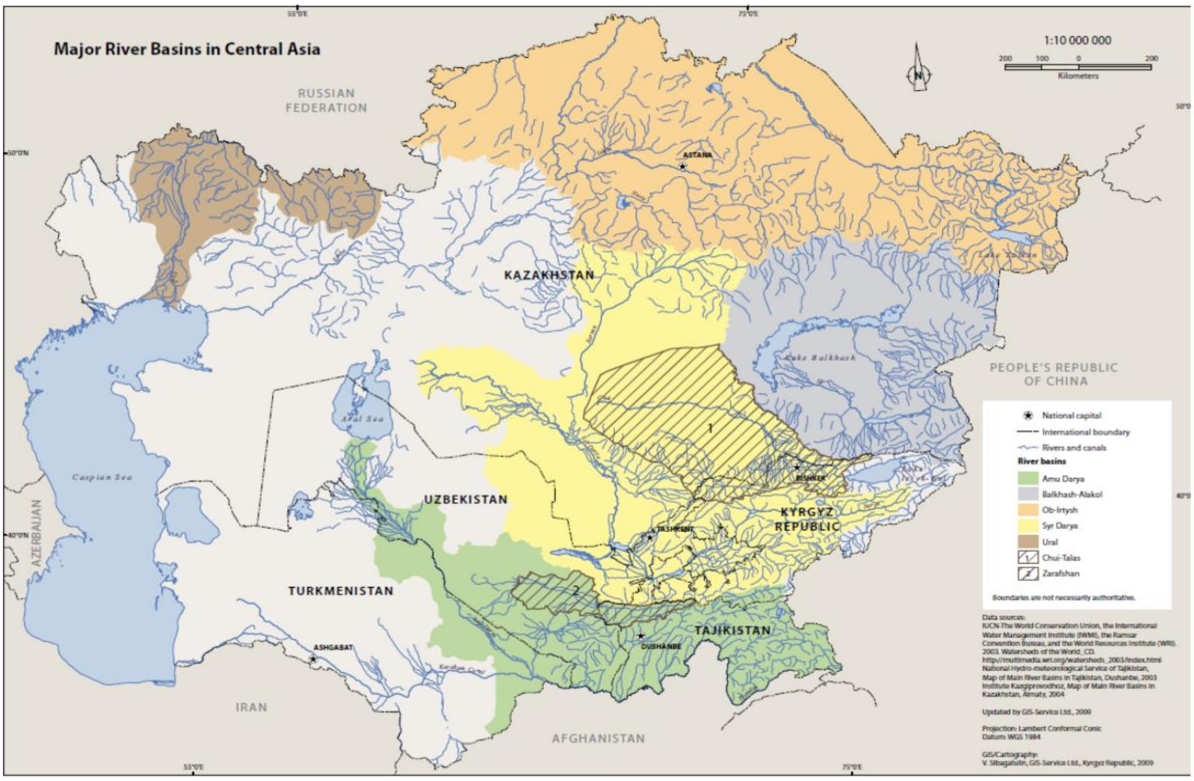

Figure 4. Map of Central Asia with major river catchments and their topography (from Mirzabaev, 2013)

Flood hazard is also significant in the region. According to a recent analysis provided by the Central Asia and Caucasus Disaster Risk Management Initiative (CAC DRMI, 2009), in the period between 1988 and 2007 floods were the most frequent natural disaster, followed by earthquakes, landslides, avalanches, and drought. Floods were second for number of deaths and amount of population affected (1,512 and 19% respectively). Collectively, floods inflict the second highest overall economic losses ($52 million), surpassed only by earthquake (an annual average of $186 million). At the local level (e.g., in Tajikistan), flood is sometimes the dominant risk in terms of economic losses. Considering the deteriorated protection infrastructure and vulnerabilities in several sectors, floods cause considerable damage to housing, infrastructure, and agriculture (Libert, 2008).

For the purpose of this study, we distinguish two common types of flood: fluvial flood which occurs when excessive rainfall over an extended period of time causes a river to exceed its capacity, and pluvial flood, which occurs when heavy rainfall creates a flood event unrelated to an overflowing water body. The mountainous areas of Tajikistan and Kyrgyzstan are particularly impacted by pluvial flooding caused by intense heavy rains, which are known to trigger disastrous mudslides. Fluvial flooding, on the other hand, is typical of the lowland areas. In the past 20-30 years, flood events have become more frequent in Central Asia, mainly due to both a more pronounced seasonal hydrological variability and a significant increase in extreme events in the largest river basins of the region: the Amu Darya and Syr Darya (whose catchments are shown in Figure 4). Since transboundary river systems in Central Asia are highly regulated, flooding on most large rivers is often exacerbated by the difficulties of cooperation concerning reservoirs' operation and maintenance (UNECE, 2007). Higher temperatures triggered by climate change are expected to significantly exacerbate flooding risk by increasing the flood duration and shifting the peak of flood periods. Notwithstanding the general uncertainty in the available climate projections, all analyses predict more severe floods, with higher water levels and runoff than at present (Executive

Board of the International Fund for Saving the Aral Sea Regional Center of Hydrogeology, 2009). The areas most impacted by flood in each country according to the GFDRR (2016) are briefly presented hereafter:

Kazakhstan presents an extensive network of rivers such as the Syr Daria, Ural, Irtysh and Tobol and several large lakes including the Caspian Sea, the Aral Sea and the Zaysan. Flood disasters are frequent, with the south-western provinces of Atyrauskaya and Kyzylordinskaya registering the highest economic losses (GFDRR, 2016).

The largest floods in the Kyrgyz Republic usually affect the broad alluvial plain of the Chu River, where the cities of Bishkek and Tokmak are located. Other high-risk areas include the middle reaches of the Naryn River (the largest in the country), the Talas River valley and the eastern and northern lowlands near Lake Issyk-Kul (including the city of Karakol). Altogether 182 towns and villages in Kyrgyzstan are at risk from river floods (Thurman, 2011).

Tajikistan is highly exposed to flood hazard given the complex topography, the highest rainfall levels in the region, and a large number of glaciers (CAC DRMI, 2009). The floods can also be caused by outbursts from mountain lakes. Tajikistan's Lake Sarez is considered potentially dangerous: the lake formed in 1911 following a great earthquake which triggered a series of landslides along the slopes of the Bartang, Tanimas and Murghab valleys (Oldham, 1923). Floods occur most frequently in the Zerafshan, Pyanj, and Vakhsh River basins with the southern province of Badakhshoni Kuhi being the most affected in terms of economic losses (GFDRR, 2016).

Turkmenistan's major rivers are the Amu Daria, the Murghab and the Tejen. Floods are common in the watersheds of the Atrek and Siraks rivers, notably where the Siraks border Iran. The eastern province of Chardzhou is the most affected in terms of economic losses (GFDRR, 2016).

In Uzbekistan the Amu Daria and Syr Daria are the country's two major rivers. Uzbekistan is vulnerable to floods mainly caused by snowmelt run-off or severe storms; very large floods are typically caused by the outbreak of mountain lakes. The eastern province of Andijan is the most affected in terms of economic losses (GFDRR, 2016).

Furthermore, one should consider that flood is also a trans-boundary hazard and as such can affect simultaneously, due to the river's path, different countries like Kyrgyzstan Tajikistan and Uzbekistan.

Following earthquakes and floods, landslides are the third most prevalent natural hazard in Central Asia (CAC DRMI, 2009), mostly affecting the mountainous areas of Tien Shan, Trans-Alay Range, Pamir and Altaj (Figure 5).

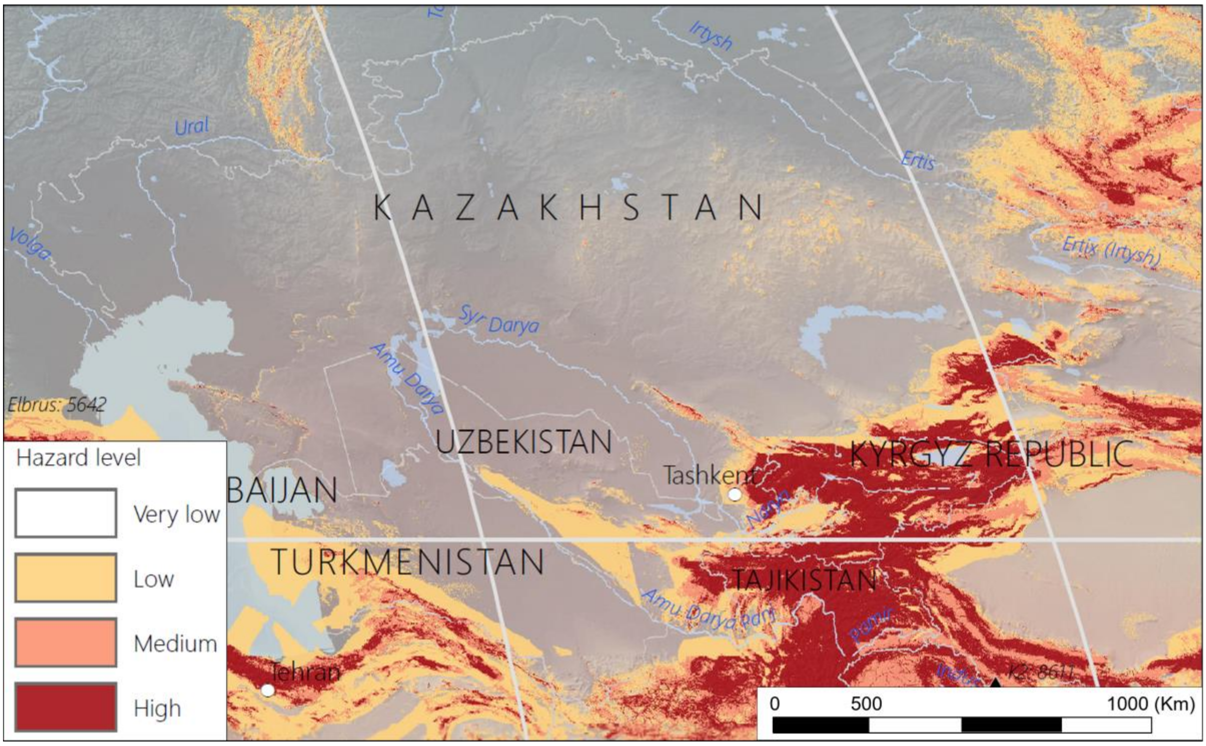

Figure 5. Landslide Hazard Map of Central Asia and the Caucasus (extracted from World Bank, 2020a).

During the last 20 years (1988-2007) out of 177 reported disasters 13% were landslides, causing 700 deaths (Table 2), while in the same period economic losses have been as high as $150 million, including damage to infrastructures, settlings and agricultural/pasture lands, as well as displacement of the population (GFDRR, 2009).

Table 2. Landslide Hazard Statistics (1988-2007). Source: Risk assessment for Central Asia and Caucasus (UN ISDR, 2009).

Country	No. disasters/year	Total no. of deaths	Deaths/year	Relative vulnerability (over total population) (deaths/year/million)
Kazakhstan	0.05	48	2.40	0.16
Kyrgyzstan	0.30	238	11.90	2.27
Tajikistan	0.50	339	16.95	2.51
Turkmenistan	n.a.	n.a.	n.a.	n.a.
Uzbekistan	0.15	75	3.75	0.14

Landslides phenomena in Central Asia include rockslides/avalanches, rotational/translational slides and mud/debris flows (often involving loess), which are often triggered by natural events such as earthquakes, floods, rainfall and snowmelt (Behling et al., 2014; Golovko, 2015; Havenith et al., 2015a, 2015b, 2006; Kalmetieva et al., 2009; Saponaro et al., 2014; Strom and Abdrakhmatov, 2017).

Glacial lakes outburst flood (GLOF) phenomena, caused by the breach of natural glacial dams, often result in large scale catastrophic mud/debris flows. In the past few decades, the number and intensity of landslides have grown owing to climate change and the increase of the anthropic pressure, due to several factors such as the uncontrolled land and water use, the rising of the water tables (often induced by the increase of irrigation), deforestation, mining and excavation activities.

Due to their large size and impact, most of the occurring landslides have profound transboundary implications. Tajikistan and Kyrgyzstan are the countries most impacted by landslides: in Tajikistan around 50,000 landslide were mapped, 1,200 of which threaten settlements or facilities (Thurman, 2011); Kyrgyzstan has been affected by 5,000 landslides, of which 3,500 at various levels of activity are located in the southern portion of the country (the Ferghana Valley) (Pusch, 2004). Almaty province in Kazakhstan, Tashkent, Samarkand, Surkhandarya, Kashkadarya Provinces of Uzbekistan, and Ahal Province of Turkmenistan are also exposed to landslides (World Bank, 2006).

3 Review of previous national and regional hazard and risk assessment and DRM activities

In order to address risks posed by natural hazards, governments and the international community have undertaken an increasing number of initiatives in recent years. Part of the effort was dedicated to developing and implementing regional Disaster Risk Reduction (DRR) strategies (UNDRR, 2019): during the Second World Conference for Disaster Risk Reduction in 2005, Central Asia countries joined other 168 nations in the effort to initiate the Hyogo Framework for Action (HFA), a key goal of which is to develop and strengthen institutions' efforts, mechanisms and capacities to build resilience to hazards. As part of this effort, in 2010 UNDP launched the project "Enhancing Disaster Risk Reduction Capacities in Central Asia" under the Disaster Preparedness ECHO programme (DIPECHO). This project fostered the establishment of a Central Asia regional center focused on disaster preparedness and response coordination, which was inaugurated in 2016 in Almaty, Kazakhstan (Central Asia Centre for Emergency Situations and Disaster Risk Reduction). In 2019, a Regional Platform meeting was held in Dushanbe, Tajikistan, to discuss a plan of action for implementing the Sendai Framework for Disaster Risk Reduction which had been adopted at the Third World Conference on Disaster Risk Reduction in 2015. In 2018, the second Central Asia and South Caucasus (CASC) Sub Regional Platform approved the Yerevan Declaration which include political commitments to implement the Sendai Framework, specifically, the participating countries undertook the adoption of local and national DRR strategies by 2020. Concurrently, a series of initiatives were devoted to risk assessment with the goal of developing the countries' risk profiles and related databases on natural hazards.

Risk assessment is a data intensive analysis process that relies on the availability of a wide range of data from different sources in order to characterize each risk component (hazard, exposure and vulnerability). This premise poses inevitable challenges in terms of data reliability, proper documentation and compatibility in terms of format, scale and resolution. In Central Asia we can identify two main challenges regarding data: first the availability and accuracy of the data depend on the monitoring system's conditions. In this sense, while seismic hazard monitoring was better maintained and recently saw some upgrades to digital equipment, hydrologic data has been particularly affected by the deterioration of the monitoring network which in some areas has seen a consistent decrease in the number of meteorological stations and hydrological posts since the 1990s (Thurman, 2011). Remotely sensed data can partly compensate (e.g., TRMM, IMERG) and recent initiatives are addressing the modernization of hydromet services in Central Asia (e.g., the CAHMP project, Masud, 2016) but significant gaps will likely remain. A second challenge is represented by the need for cooperation and data sharing among the different countries in Central Asia in order to guarantee coherence in the analysis of hazard at the regional level.

An overview of previous risk assessment studies organized by component is reported in the following sections.

3.1 Hazard

Earthquake hazard in Central Asia has been assessed comprehensively in several national and international studies. A first attempt of regional homogenization came from the Global Seismic Hazard Assessment Program (GSHAP) (Giardini et al., 1999), aimed at establishing a common framework for the homogeneous evaluation of the seismic hazard at global scale. In this frame, a new seismic zonation was proposed for the Central Asia (Ulomov et al., 1999) and from that a first probabilistic seismic hazard model in macroseismic intensity was produced. In 2012 the project USTC EMCA ("Earthquake Model of Central Asia") aimed at the development of a new comprehensive seismic hazard and risk model for Central Asia, as part of the global earthquake hazard and risk model under development at the GEM Foundation. Several datasets were assembled and released, including a homogenized seismic catalogue and a new earthquake source zonation model. Outcome of the projects have been documented in several publications, such in Bindi et al. (2011, 2012) and Ullah et al. (2015).

Several studies at national level followed the aforementioned regional project USTC EMCA, as in Ischuk et al. (2014, 2018) for Kyrgyzstan, Tajikistan and Eastern Uzbekistan, Silacheva et al. (2018) and Mosca et al (2019) for Kazakhstan. A probabilistic earthquake hazard analysis of Kyrgyzstan was carried out by Abdrakhmatov et al. (2003), in terms of both peak ground acceleration and Arias Intensity, followed by a more comprehensive model developed within the Central Asia Seismic Risk Initiative (CASRI) (Abdrakhmatov, 2009) also including fault traces. Seismic hazard studies of Uzbekistan have been done within the framework of national programs, such as in Abdullabekov et al. (2002, 2012), Artikov et al. (2018, 2020). As well, research on seismic hazard in Turkmenistan has been conducted by the Institute of Seismology and Atmospheric Physics of the Academy of Sciences in the frame of regulatory acts (see Ministry of construction of Turkmenistan, 2017). In 2013 the Ministry of Education and Science of the Republic of Kazakhstan requested the development of probabilistic maps of the general seismic zoning of the Republic of Kazakhstan and seismic microzoning of Almaty city. The maps have been developed by the Institute of Seismology of Kazakhstan with participation of other relevant institutions and are at the stage of implementation in the construction practice. A package of maps of general seismic zoning is then included in the national Code of Rules No 2.03-30-2017 "Construction in seismic zones". The development of regulatory documents based on the package of maps of microzonation of Almaty was launched in 2020 by the Kazakh Research Institute for Construction and Architecture. The Institute of Seismology (IS), the Seismological Experimental and Methodological Expedition (SEME), the Kazakh National Data Center (KNDC) and the Institute of Geology, Earthquake Engineering, and Seismology under the Academy of Sciences of the Republic of Tajikistan are currently participating to the ongoing ISTC Project "Central Asia Seismic Hazard Assessment and Bulletin Unification" (CASHA-BU).

Flood hazard studies for Central Asia are usually included in more comprehensive risk studies (see Section 3.4). A study on flood hazard of the territories in the Esil Water Management Basin in Kazakhstan was conducted in 2019 (Plekhanov and Medeu, 2019). In Kyrgyzstan, a catalogue of historical floods and hazard maps is managed by the Ministry of Emergency Situations of the Kyrgyz Republic (MES). There are various global flood hazard assessment models that provide hazard maps at various resolutions and considering different return periods. Some examples are the Catchment-Based Macro-scale Floodplain (CaMa-Flood) model (Yamazaki et al., 2011), the Centro Internazionale in Monitoraggio Ambientale and United Nations Environment Program (CIMA-UNEP) model (Rudari et al., 2015), the European Centre for Medium-Range Weather Forecasts (ECMWF) model (Pappenberger et al., 2012), the Global Flood Risk with Image Scenarios (GLOFRIS) model (Ward et al., 2013) which is implemented in the Aqueduct Floods platform (Ward, P. J. et al., 2020), the Joint Research Centre (JRC) model (Francesco Dottori et al., 2016) based on the Copernicus Global Flood Awareness System (GloFAS) (Alfieri et al., 2013), and the Fathom Global Ltd model (Sampson et al., 2015). For these models, the corresponding flood hazard maps resolution at the equator vary between ~90 m (Fathom Global Ltd, CIMA-UNEP), ~540 m (CaMa-Flood, ECMWF), and ~900 m (GLOFRIS, JRC GloFAS) (Bernhofen et al., 2018).

Since the early '90s landslide monitoring and research in Central Asia has declined and is currently outdated (Thurman, 2011), thus, given the increased anthropogenic pressures and the impact of climate change, the available landslide hazard analysis needs an increased support and additional research.

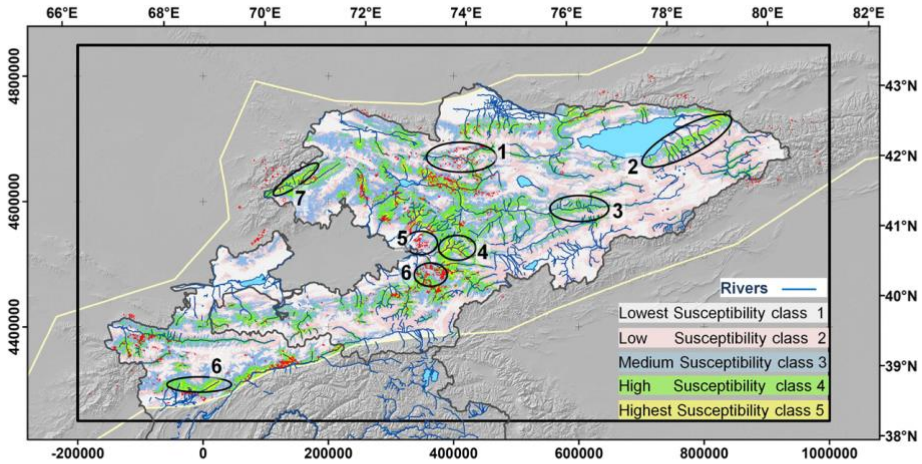

Figure 6. Kyrgyzstan landslide susceptibility map (from Havenith et al., 2015b).

Therefore, in this context several projects have tried to fill this gap, providing important information for landslide assessment, such as landslide losses estimations, location, type, triggering/reactivation dates, inventories and hazard maps (Figure 6, Table 3), as well as geological maps, fault and peak ground acceleration maps, platforms to retrieve open disaster risk data and overviews on seismic risk reduction strategies. Among the regional studies on landslide hazard developed at regional level it is worth mentioning:

- Disaster Risk Management and Climate Change Adaptation in Europe and Central Asia, developed by the World Bank - Global Facility for Disaster Reduction and Recovery (Pollner et al., 2010).
- Disaster Risk Reduction, 20 Examples of Good Practice from Central Asia, developed by the European Union, International Strategy for Disaster Reduction ISDR (European Commission Humanitarian Aid, Civil Protection, 2006).
- Science for Peace Project (983289) 'Prevention of landslide dam disasters in the Tien Shan, LADATSHA'. 2009–2012, NATO Emerging Security Challenges Division[4]
- PROGRESS (Potsdam Research Cluster for Georisk Analysis, Environmental Change and Sustainability). German Federal Ministry of Research and Technology (BMBF)[5].

[4] https://www.nato.int/cps/en/natohq/88111.htm

[5] https://www.gfz-potsdam.de/en/section/remote-sensing-and-geoinformatics/projects/closed-projects/progress/

- Tian Shan-Pamir Monitoring Program (TIPTIMON). German Federal Ministry of Education and Research (BMBF)[6].

Table 3. Example of landslide inventory from Havenith et al., 2015a, showing landslide surface area, thickness and volume.

Numb.	Landslide	Coordin.	Shown in	Area (10^3 m^2)	Calc. max. thickn. (m)	Prev. vol. estim. (10^6 m^3)	Reference	Calc. vol. (10^6 m^3)	Agreement
V01	Suusamyr landslide, C. Tien Shan	42.207°N, 73.610°E	See ref.	126.90	20.1	0.75	Havenith et al. (2003)	0.85	Accept.
V02	Okuli loess flow, Gissar	38.480°N, 68.620°E	Fig. 8a	2027.00	45.3	20.00	Ishihara et al. (1990)	30.60	Overest.
V03	Kainama loess flow, Alay	40.275°N, 73.565°E	See ref.	151.30	13.9	0.40	Danneels et al. (2008)	0.70	Overest.
V04	Koytash landslide, Maily Say	41.290°N, 72.480°E	See ref.	277.80	30.6	3.00	Authors prev. estimate	2.83	Accept.
V05	Tektonik landslide, Maily Say	41.285°N, 72.480°E	See ref.	326.00	18.1	2.00	Authors prev. estimate	1.97	Accept.
V06	Kochkor Ata loess flow, Maily Say	41.260°N, 72.555°E	Fig. 6a, b	968.50	20.0	10.00	Roessner et al. (2005)	6.46	Underest.
V07	Isolith landslide, Maily Say	41.280°N, 72.470°E	See ref.	112.90	20.6	0.60	Authors prev. estimate	0.78	Accept.
V08	Yasman loess flow	39.175°N, 70.750°E	Fig. 7a, b	33,143.10	21.3	245.00	Evans et al. (2009)	235.22	Accept.
V09	Bielogorka Rock avalanche 1, N Tien Shan	42.635°N, 74.280°E	See ref.	1075.60	48.4	20.00	Havenith et al. (2003)	17.35	Accept.
V10	Bielogorka Rock avalanche 2, N Tien Shan	42.640°N, 74.290°E	See ref.	863.80	38.9	10.00	Havenith et al., (2003)	11.19	Accept.
V11	Ananevo rockslide, NE Tien Shan	42.805°N, 77.630°E	Fig. 8d	720.80	76.5	15.00	Havenith et al. (2003)	18.38	Accept.
V12	Kemin rockslide, NE Tien Shan	42.720°N, 76.205°E	Fig. 8e	750.10	68.8	15.00	Authors prev. estimate	17.21	Accept.
V13	Kara Suu rock avalanche, C. Tien Shan	41.570°N, 73.220°E	See ref.	3735.50	106.0	280.00	Strom (2010)	132.00	Underest.
V14	Karakol rockslide	41.650°N, 72.660°E	See ref.	2786.70	126.5	300.00	Strom (2010)	110.00	Underest.
V15	Belaldy rock avalanche (partial dam)	42.060°N, 73.280°E	See ref.	906.10	62.5	40.00	Korjenkov et al. (2004)	18.87	Underest.
V16	Sary-Chelek rockslide, west. Tien Shan	41.850°N, 72.000°E	See ref.	43,567.10	531.0	6000.00	Strom (2010)	7711.28	Accept.
V17	Beshkiol rockslide, central Tien Shan	41.400°N, 74.480°E	See ref.	56,059.40	588.6	10,000.00	Strom (2010)	10,998.66	Accept.
V18	Khait rock avalanche, S Tien Shan	39.185°N, 70.880°E	Fig. 7c	5747.60	41.5	75.00	Evans et al. (2009)	79.57	Accept.
V19	Iskander Kul rockslide, SW Tien Shan	39.080°N, 68.420°E	Fig. 4	17,063.80	196.5	1000.00	Strom (2010)	1117.95	Accept.
V20	Aini rockslide dam (remaining part)	39.380°N, 68.540°E	Fig. 4b	592.40	36.5	20.00	Strom (2010)	7.21	Underest.

3.2 Exposure

Exposure assessment in Central Asia has been performed within specific risk assessment projects, mostly developed for a single risk. In particular, a number of past projects were focused on seismic risk at national scale (e.g., JICA, 2009 for Kazakhstan; World Bank, 2017 for Kyrgyzstan). Based on country-specific studies produced within these projects (e.g., Pittore et al., 2020; Wieland et al., 2015), a regional-scale exposure database in Central Asia has been developed in the context of developing global seismic risk assessment platforms (e.g. Silva et al., 2020). The exposure dataset is based on 2015 estimates, which are derived using a methodology based on census data, remote sensing and building inspections performed during the EMCA project (2011-2014) and the "Seismic Risk Estimation in the Kyrgyz Republic" (2014-2017) World Bank project. The database contains the number of buildings in each building typology (associated to a specific taxonomy developed by GEM) average floor area, cost per unit and per square meter. In addition, the database contains estimates of day and night buildings occupancy. The data are provided on a variable-resolution grid constituted of Voronoi polygons defined based on the population density. However, this database includes information on exposed residential buildings but does not include other typologies of exposed assets (e.g., strategic, industrial and commercial buildings, transportation network, and infrastructures).

The transportation network has a very strategic role in the region, in particular for commerce. Transportation network data (location, type) are available from the OpenStreetMap layers and, in some cases, from regional/national reports. Road network density is, on average, very low in Kazakhstan (3.6Km/100Km²), slightly higher in Turkmenistan, Kyrgyzstan and Tajikistan (12.5,

[6]https://www.gfz-potsdam.de/en/section/lithosphere-dynamics/projects/past-projects/tiptimon/

18.1, 19.3 Km/100Km², respectively) and quite high in Uzbekistan (43.2 km/Km²). The railway network has also undergone a strong development, particularly under the Belt and Road initiative. During the World Bank project "Seismic Risk Estimation in the Kyrgyz Republic" (2014-2017), a methodology was defined in order to assess expected impacts also on roads and railways (including bridges), based on remote sensing data and field inspections (Free et al., 2018). This method can be applied to other countries and the results for Kyrgyzstan can be a starting point for the development of regional-scale exposure layers.

Despite the strong effort devoted to disaster risk reduction in the region, at the moment, no regional exposure assessment study exists that collects all the exposed assets into a regionally-consistent dataset. In addition, very few open datasets are available on strategic assets (e.g., infrastructures, industrial facilities) considered in disaster risk reduction studies. The development of a comprehensive exposure dataset is therefore very challenging but also strongly needed. There are, nonetheless, many regional and global datasets that can contribute to the development of a comprehensive regional-scale exposure layers. Global-scale datasets (e.g., OpenStreetMap layers) contain useful information on the location of such assets but the information contained therein needs to be analyzed, validated and homogenized before being integrated in a regional-scale exposure database.

Finally, there is a number of ongoing projects focusing on the identification and classification of other typologies of exposed assets such as schools in Kyrgyzstan (e.g., the World Bank ERIK project[7], started in 2018), and critical infrastructures in Tajikistan[8] (2017-2023). The Consortium will liaise with the World Bank team to establish a connection with the respective contact persons for the above-mentioned ongoing projects, in order to explore synergies and, if possible, to include additional data into the exposure layers.

The exposure development task will benefit from the wide knowledge developed in recent years by scientists in research centers and public institutions and by practitioners in the region. The great knowledge of these experts on location, type, and relevance of the exposed assets has only been partially grasped during the past projects in the area. The consortium has collected the existing exposure datasets at global, regional and national scales of interest for the exposure development. Table 4 summarizes the information collected so far at global, regional and national scales. The references included in the table are also mentioned in Section 4.3 where their usage for the exposure development is described in detail.

[7] https://gpss.worldbank.org/en/projects/enhancing-resilience-kyrgyzstan-erik

[8] https://projects.worldbank.org/en/projects-operations/project-detail/P158298

Table 4. Available data reports and past/current projects identified by the consortium at global, regional and national scales. References in the table are available in the References section. Text marked with an asterisk, *, refers to data for which information is available, but the data have not yet been retrieved or quality-checked. Such activities will be performed during the course of the project.

CATEGORY	TYPE	FEATURES	GLOBAL DATA	REGIONAL DATA	NATIONAL DATA				
					KAZ	KYR	TAJ	TUR	UZB
BUILDINGS	Residential	Location, type	OpenStreetMap; World Housing database	Lang et al., 2018; EMCA exposure layers, (Pittore et al., 2020; Wieland et al., 2015)	Committee on Statistics of the Ministry of National Economy of the Republic of Kazakhstan can provide information on building stock.	Pittore et al., 2016; World Housing database (http://db.world-housing.net)			Local partner can provide information on location of main waste dumps*
	Commercial		OpenStreetMap						
	Industrial		OpenStreetMap; USGS dataset of mines and industrial sites (2015)			Radioactive waste sites location (UNISDR report, 2010)			
	Schools		OpenStreetMap; Global Library of School Infrastructure (GLOSI)			WB projects "Seismic performance-based assessment of school infrastructure in the Kyrgyz Republic" and "Enhancing Resilience in Kyrgyzstan"; School location available at http://geonode.caiag.kg	Location available at https://geonode.wfp.org (2018)		
	Healthcare		OpenStreetMap			Hospitals location available at http://geonode.caiag.kg			
	Strategic		OpenStreetMap			Fire stations location available at http://geonode.caiag.kg			
POPULATION		Density, age, gender	WorldPop database (2020); GRUMP database; Facebook High Resolution Settlement Data	EMCA exposure layers (Pittore et al., 2020)	Census data*	Census data*	Census data*		Census data*
TRANSPORTS	Roads	Location, type	OpenStreetMap (OSM); GRIP global roads database		Committee of Roads of the Ministry of Industry and Infrastructure Development of the Republic of Kazakhstan can	WB Project 'Measuring Seismic Risk in Kyrgyz Republic' (2017); Road network available from CAIAG geonode (http://geonode.caiag.kg/)			Local partners can provide information (but a special permission might be necessary)*
	Railway		OpenStreetMap						

	Bridges		OpenStreetMap		provide information on transportation system (and recent projects)	Location available from CAIAG geonode (http://geonode.caiag.kg/)			
	Airports/airstrips		OpenStreetMap; Global airports database (https://www.partow.net/miscellaneous/airportdatabase/)						
INFRASTRUC-TURE	Energy	Location, type	World Bank data portal	Raimondi, 2019; World Energy Council, 2007); Sternberg et al., 2017)	*Local partner can provide location of main power plants**		*Information must be requested to the specific government office indicated by local partner**		
	Water-related	Location, type	World Bank data portal; Global Reservoir and Dam (GRanD) database (Lehner et al., 2011); Unesco AQUASTAT dataset	Information on main central Asian dams in UN report (2007); Water supply studies e.g., Lemenkova (2012)					Rakhmatullaev et al., 2010; Local partner can provide information and location of main dams*
	Communication	Location, type	World Bank data portal	Regional report UNESCAP (2020)					
AGRICULTURE	Crops	Crops distribution, yield, price	FAOSTAT; JRC project ASAP (https://mars.jrc.ec.europa.eu/asap/download.php)	Crop Dominance database (Teluguntla and Yadav, 2015)		WB report 'Second On-farm Irrigation Project' (Meerbach, 2013)	Crop distribution available at https://geonode.wfp.org		Kasimov (2013)
REPLACEMENT COSTS			HAZUS Framework	FAOSTAT (Statistics available at regional and national scale)	WB project "Strengthening Catastrophe Risk Transfer Supervision"; *Local partner has provided information on average construction costs for residential buildings**	WB Project "Measuring Risk in Kyrgyz Republic" (2017)	Information must be requested to the specific government office indicated by local partner*	Local consultant can provide estimates*	Local partner can provide estimates, in particular for railways*

2080 PROJECTIONS	Population	Global projections up to 2100	Gao, 2020; Gao and O'Neill 2020; NASA SEDAC dataset; International Institute for Applied Systems Analysis (IIASA) dataset	Pedde et al. (2019)	
	GDP		GDP projections from NASA SEDAC dataset; International Institute for Applied Systems Analysis (IIASA) dataset		
	Urbanization		Li et al. (2019);	Jing et al. (2020)	
	Transportation				
	Commercial		Global freight ITF report (2019)		

This project will devote considerable effort into gathering missing information and including it into a comprehensive regional database. The exposure development will start from the existing available data (which, as stated earlier, have a variable resolution for different countries). Global and regional datasets will be cross-checked with available information at the local scale, with the paramount contribution of local partners. Discrepancies and data gaps will be identified, and further analyses will be performed (e.g., using remote sensing data) also with the support of the local experts. Particular attention will be devoted by the team with the key contribution of the local partners to the estimation of unit replacement costs for buildings belonging to the different exposed assets. Results will therefore combine regional, national and local datasets and the available outputs of past projects in order to fill the identified gaps. The classification of exposed assets into broad categories valid for the entire region can contribute to the purpose of regional risk assessment and put the basis for other future developments.

3.3 Vulnerability

Regarding structural vulnerability to earthquake, in 2020 the World Bank performed a seismic risk assessment for seven classes of multi-family buildings in Europe and Central Asia countries (Albania, Bosnia & Herzegovina, Bulgaria, Croatia, Hungary, Moldova, Montenegro, North Macedonia, Romania, Serbia, Slovakia, Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, Uzbekistan, Armenia, Azerbaijan and Georgia, World Bank 2020). Due to the lack of information for some building typologies, the vulnerability models employed were obtained by merging loss models from various sources. Figure 7 shows the classes of multi-family buildings studied, as well as a relative classification of their seismic vulnerability (World Bank 2020b[9]).

At the national level, in 2017, a seismic risk assessment was carried out for the Kyrgyz Republic (Word Bank, 2017). For that purpose, fragility functions for residential buildings and transportation infrastructure were developed. These functions were derived from a vulnerability index based on empirical methods that consider parameters such as: type of building, local characteristics, a parameter that reflects the quality level and their seismic resistance, number of stories and structural characteristics. The empirical formulation proposed by Lagomarsino and Giovinazzi (2006) was employed to transform the vulnerability indexes into fragility curves. Figure 8 (left panel) shows an example of the fragility curves for several structural typologies, in terms of Peak Ground Acceleration (PGA), developed in this WB 2017 project.

In Kazakhstan, a set of seismic vulnerability functions for different buildings (masonry, wood, reinforced concrete, and unfired brick), developed using the HAZUS-MH methodology (Federal Emergency Management Agency and National Institute of Building Sciences, 2003), in combination with the information obtained from a JICA study (JICA & AKIMAT, 2008), was employed to examine the potential losses that earthquakes might cause in Kazakhstan (World Bank, 2010). The resulting vulnerability functions for different structural typologies are shown in Figure 8 (right panel).

[9] https://openknowledge.worldbank.org/handle/10986/34439

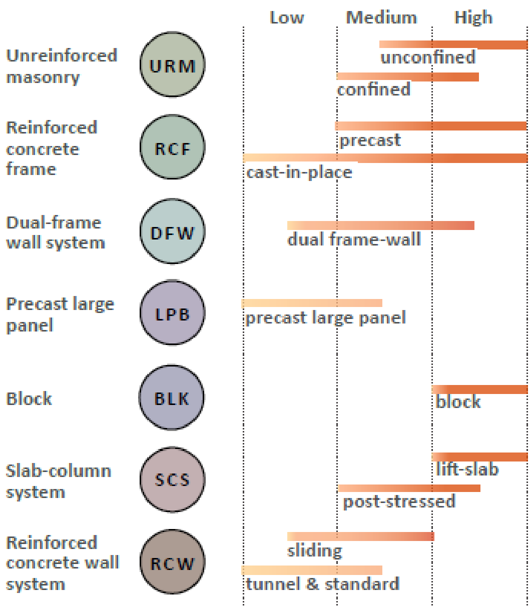

Figure 7. Multi-family building types considered in the WB study and their relative earthquake vulnerability (World Bank 2020)

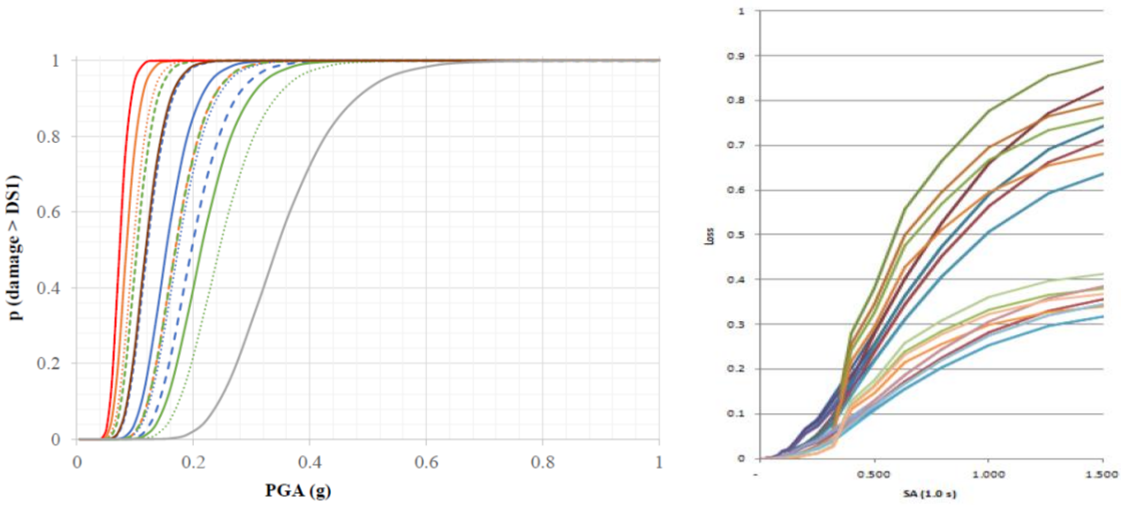

Figure 8. Example of (left) fragility functions for building typologies in Kyrgyz Republic associated with negligible to slight damage level (Word Bank, 2017); and (right) vulnerability functions developed for different building types in Kazakhstan (World Bank,2010)

To the authors' knowledge, there are no data or information available for Uzbekistan and Turkmenistan related to the structural vulnerability of built stock due to earthquakes.

Social and economic flood vulnerability studies at the regional scale exist in the area, although quantitative structural and non-structural building and infrastructure flood vulnerability studies specific for the target countries are lacking. The following project reports can be mentioned:

- Risk Assessment for Central Asia and Caucasus. Desk Study Review. International Strategy for Disaster Reduction. World Bank, (CAREC, 2008).
- Europe and Central Asia Country risk profiles for Floods and Earthquakes. GFDRR. World Bank (GFDRR, 2016).

- Natural Disaster Risks in Central Asia: A Synthesis. UNDP/BCPR, Regional Disaster Risk Reduction Advisor, Europe and CIS UNDP (Thurman, 2011).

To the authors' knowledge, no national-scale flood vulnerability studies are publicly available at national level in the region.

3.4 Risk

In 2009, the Central Asia and Caucasus Disaster Risk Management Initiative (CAC DRMI) estimated flood and earthquake risk profiles at the country, sub-regional and regional level based on historical data from the period 1988-2007 (CAC DRMI, 2009). The report estimates risk based on historical information for events that have impacted the region over the period 1988 to 2007 (20 years). Historical events were gathered from international databases such as CRED EM-DAT, Dartmouth Observatory, ADRC, OCHA, and the World Bank. Risk was quantified as directly based on historical losses and not following a fully probabilistic approach. More recently, The World Bank and the Global Facility for Disaster Reduction and Recovery (GFDRR) produced flood and earthquake risk profiles for Central Asia at the provincial and country level (GFDRR, 2016). Results in terms of number of affected people and GDP were estimated for different return periods (2, 5, 10, 25, 50, 100, 250, 500, and 1,000 years) and as annual averages using 40 years of climate simulations and extreme value analysis. An example of flood risk profile map is shown in Figure 9.

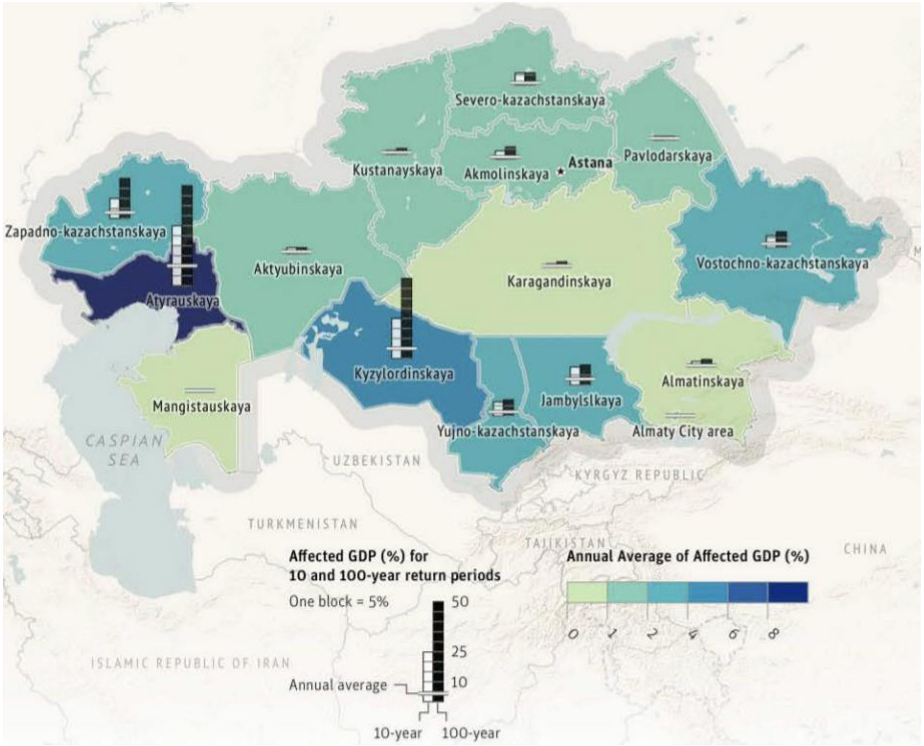

Figure 9. Impact of flooding on Kazakhstan provinces' GDPs presented in the GFDRR study (2016).

Previous flood risk assessment studies were also conducted at the national scale, in most of the cases, flooding is treated in conjunction with other perils in multi-hazard studies. In Kazakhstan, the Institute of Geography and Water Security LLP issued the Atlas of Natural and Technogenic Hazards and Risks of Emergencies in 2010. The Atlas includes 108 maps of natural hazards and risks at various scales. In 2019 one of the biggest regional conferences on DRR was held in Dushanbe, Tajikistan[10], to discuss a plan of action for implementing the Sendai Framework which had been adopted in 2015 at the Third World Conference on Disaster Risk Reduction.

In the Kyrgyz Republic, several projects have been carried out or are currently ongoing, such as the World Bank and MES project: "Enhancing Resilience in Kyrgyzstan" (2018-2025), the Situation analysis of disaster risk assessment in Kyrgyzstan (UNDP, 2014), the In depth review of Disaster Risk Reduction in the Kyrgyz Republic (UNISDR, 2010) and a recent pilot-study of multi-risk assessment in the Alay valley (Umaraliev et al., 2020). In Tajikistan, in 2005, the Information Management and Analytical Centre (IMAC) of the Committee of Emergency Situations and Civil Defense (CoESCD) was established with the support of UNDP. The Centre manages an electronic database of disasters occurred in the territory of Tajikistan including information on data, type, location, as well as economic losses. Among the previous studies and projects on flood hazard and risk, it is worth mentioning The "Khatlon Province Flood Management Project" (2007-2015), which was funded by the Asian Development Bank with the goal of developing an operational and sustainable flood management system in the country's poorest and most populated province of Khatlon (Asian Development Bank, 2015); a 2020 study offering an assessment of the districts most affected by flood risk in the lower Pyanj (M.S. Saidov, 2020); a nation-wide risk assessment within the project "Multi-hazard Risk Assessment at District Level in Tajikistan" (2018-2020) currently conducted by the Asian Institute of Technology (AIT) and the University of Twente with the support of UNDP; a review of emergency situations, including floods, was redacted in 2018 (Committee on emergency situations and civil defense under the government of the Republic of Tajikistan, 2018); and the UNDP project "Strengthening Disaster Risk Governance in Tajikistan" (2016-2019). In Turkmenistan, few previous projects on flood risk assessment have been carried out and the National report on emergency situations, 1994 (Department for the Turkmenistan State Commission for Emergency and Situations, 1994) is the main reference in this topic. To the authors' knowledge, previous national studies on flood risk assessment are not publicly available for Uzbekistan. However, many documents have been gathered regarding mudflow risk, which seems to be the major weather-related risk in the country.

In terms of seismic risk, in 2017 the World Bank launched the report titled "Measuring Seismic Risk in Kyrgyz Republic. Seismic Risk Reduction Strategy"(Word Bank, 2017). The portfolios included in the analysis were residential buildings, schools, hospitals, fire stations, transport infrastructure (roads and bridges). For each portfolio, the following analyses were developed:

- Scenario earthquake risk results for 12 deterministic events: the results are presented in terms of economic losses and fatalities. For residential buildings the number of collapses is also provided. In the case of transport infrastructure, the number of fatalities were not computed. The selected earthquake scenarios for analysis are distributed across the country, with magnitude between Mw= 6.7 to 8.3. The expected economic losses are very large, potentially in the order of many billions of USD and thousands of casualties.

[10] *Regional Conference on Disaster Risk Reduction and Implementation of the Sendai Framework for Disaster Risk Reduction* (Dushanbe, 21 August 2019). https://www.undrr.org/news/regional-conference-disaster-risk-reduction-implementation-sendai-framework-disaster-risk

- Probabilistic risk assessment: the results reported are average annual economic losses associated with earthquake damage and average annual fatalities. For transport infrastructure these results are not provided. The probabilistic risk results show that Kyrgyzstan is exposed to a severe level of seismic risk, with expected annual losses ranging up to 4% of GDP for the individual asset portfolios and expected annual fatalities of up several hundred.

In 2009, the Government of Japan, through JICA implemented "The Study on Earthquake Disaster Risk Management for Almaty City in the Republic of Kazakhstan" (JICA, 2009). One of the project's main objectives was to prepare a Disaster Risk Management Plan for Almaty City through Disaster Management Maps. The project analyzed three major earthquakes that inflicted significant damage to Almaty City in the past 150 years. The deterministic earthquake scenarios were: 1887 (M7.3): Verny earthquake; 1889 (M8.3): Chilik earthquake and 1911 (M8.2): Kemin earthquake. The results from those deterministic scenarios were represented in risk maps, providing the foundation for formulating the Earthquake Disaster Risk Management Plan for Almaty City. For each of the three deterministic earthquake scenarios, the report provides estimations and general maps with the distribution of damage to buildings, population (casualties), bridges, lifelines and roads. For example, in the case of buildings, the worst-case scenario is the Verny earthquake (1889-M8.3), where 33% of all individual residential houses in Almaty city would be heavily damaged or collapsed. A probabilistic risk assessment was not developed for Almaty city in this project.

4 Technical description of the methodologies

4.1 Earthquake hazard assessment

4.1.1 Introduction

For the purpose of developing a comprehensive risk model for Central Asia, first a probabilistic seismic hazard assessment (PSHA) will be carried out for the Central Asia region during Task 2. The analysis will be conducted using state-of-art methodologies and analysis tools, using the most complete and up to date information available for the territory. The study will benefit from the collaboration and continuous interaction with the local experts, those within the consortium and potentially others, who will provide the necessary support in term of datasets, local knowledge and expertise.

At a first stage, a PSHA will be carried out at regional level. After validation of the PSHA results, the developed earthquake source models and ground motion prediction models will then be used for the calculation of specific hazard-compatible earthquake scenarios, possibly consistent to known historical events, at five target sites (one per country) selected as representative of key urban areas for the subsequent risk analysis.

4.1.2 PSHA Workflow

The Probabilistic Seismic Hazard Assessment (PSHA) for Central Asia will be carried out following the methodology proposed by Cornell (1968) but using the methodological formalism of Field et al. (2003) as implemented in the OpenQuake engine (Pagani et al., 2014), an open source seismic hazard and risk calculation software developed, maintained and distributed by the Global Earthquake Model (GEM) Foundation.

PSHA allows quantifying probabilistically the chance of exceeding levels of ground motion at a site due to different earthquake sources, each with defined characteristics and seismogenic potential. More specifically, at any arbitrary observation site of the study region, the assessment is thus done by evaluating the ground motion level (for a set of different ground motion intensity measures) that is expected to be exceeded with given probability and within a fixed observation time (e.g., 50 years).

With respect to previous hazard models developed for the region (see e.g., GSHAP, EMCA), an enhanced source model will be developed combining direct modelling of active faults with a distributed seismicity representation. The advantage of such hybrid source model is a more realistic representation of the spatial pattern of seismicity, which is hardly replicable just using standard (homogenous) source zones.

In order to perform PSHA, the following steps will be followed:

1. Gathering of the available seismological and seismotectonic information from previous studies and past projects, including datasets and tools
2. Dataset integration and homogenization (earthquake catalogue, active fault database)
3. Implementation of the earthquake source model (distributed source zones and finite faults)
4. Seismicity analysis (occurrence rate estimation, maximum magnitude, definition of dominant faulting style, etc.)
5. Characterization of the ground motion prediction model
6. Hazard calculation and verification

Methodological assumptions related to the selected modelling strategies, together with a discussion on their relative advantages and limitations, will be described in the technical report (deliverable D2a) due by the end of Week #41 on 13th August 2021.

4.1.3 Data Gathering and Calibration datasets

In a first phase, all existing information from the scientific literature and past studies available for the target regions will be collected and reviewed, including geological and seismotectonic interpretations, existing seismicity analyses and previous earthquake hazard assessments from past projects (e.g., GSHAP, EMCA) and published studies (e.g., Abdullabekov et al., 2012; Ischuk et al., 2018; Silacheva et al., 2018). Subsequently, we will focus on identifying the available instrumental and historical earthquake catalogues from different sources, as well as earthquake bulletins from permanent local and regional seismic networks (e.g., data from the Institute of Seismology of Kyrgyzstan, the Seismological Bulletin of Turkmenistan), temporary networks (e.g., TIPTIMON network, Schurr et al., 2012), complemented with data from national or global reporting agencies (e.g., ISC, IRIS, Harvard GCMT catalogues). Whenever possible/accessible, the most recent raw historical, archaeological and paleoseismological information from local regional studies will also be collected and reviewed (see e.g., Grützner et al. 2016a, 2016b).

4.1.3.1 Earthquake Catalogues

The main notable examples of compilation and unification of earthquake catalogues in Central Asia were carried out within the framework of the international projects CASRI (from historical time up to 2005) and EMCA (up to 2009, Mikhailova et al., 2015). Subsequently, the available information was supplemented with new data from SEME and KNDC for Kazakhstan and adjacent territories, with the goal of supporting the development of a new national seismic zonation model and the seismic microzonation of Almaty. A revision of the EMCA catalogue (thus data before 2009) is required. In particular, earthquake epicenters and the magnitude conversion relations used to build the catalogue, including a description of the intensity in moment magnitude (Mw), must be verified in light of the most recent studies. Data after 2009 may be inconsistent across catalogues from neighboring countries in Central Asia, due to different development of the observation networks and the use of dissimilar processing techniques. We envisage a deep revision of the datasets from local reporting agencies, that will lead to a harmonization of location and magnitude estimates. Particular attention will be given to the removal of spurious events, such as man-made explosion.

It must be noted that since 2018 the IS-SEME together with KNDC and the local partners from Tajikistan and Kyrgyzstan have been involved in the ISTC Project "Central Asia Hazard Assessment and Bulletin Unification" (CAHA-BU), presently ongoing but close to finalization. Access to datasets developed along the project might be granted upon request, and the possibility of accessing the project results will thus be investigated by the consortium. A catalogue of earthquakes in the territory of Uzbekistan and adjacent regions for the historical and instrumental period of time (up to 2020) is available from the Institute of Seismology of the Academy of Sciences of the Republic of Uzbekistan, which is a partner of the consortium and will support the development of the task. The catalogue is compiled using energy class K to represent magnitude of local and regional earthquakes. Additional data compilations including recent events are available from literature and will be reviewed, such as the work done by Ullah et al. (2015) and A. Ischuk et al. (2018).

4.1.3.2 Fault Databases

Complementary to earthquake catalogue information, regional data on known active faults will be identified, collected and reviewed. This will include information on fault geometry and tectonic style, either from field studies or indirect geophysical analysis, and the associated seismic productivity. As a starting point, we will use (and subsequently extend) the active fault database developed by the Global Earthquake Model foundation (GEM) as part of the GEM's Global Active Faults project. At present stage, the database already integrates most of the information available for the territory from previous studies but is nonetheless presently quite heterogeneous when comparing the different covered sub-regions, as the level of detail varies considerably depending on the availability of the input sources and the level of involvement achieved with local scientific contributors. In fact, the GEM dataset is incomplete in Central Asia, since GEM is mostly based on existing literature review and, to some extent, on previous regional projects. The information for the different entries needs careful verification; in particular, activity rates obtained from slip rates, when available, have to be tested against observed seismicity (through seismic moment balance verification), as well as their associated uncertainty, which is presently loosely constrained. Information on fault segmentation is almost missing, which has an important impact on the largest magnitude event expected from a fault system.

Along with the GEM database, a useful compilation of local fault information is available from Mohadjer et al. (2016), which published an online catalogue of faults including slip rates, and the Active Fault Database of Eurasia published by Bachmanov et al. (2017). Additional data are available from Ischuk (2006) and Ischuk and Mamadjanov (2014) for Tajikistan. In Uzbekistan, the Institute of Seismology of the Academy of Sciences has produced map of active faults and seismogenic zones (Ibragimov, at al., unpublished). In Turkmenistan several geological maps containing fault information were produced and are presently owned by the governmental organization "Turkmengeologiya". Access to this data could be granted through the Academy of Sciences of Turkmenistan. A map of active faults is available at the Institute of Seismology of Kazakhstan. The map of seismogenic zones of the Republic of Kazakhstan is part of the package of general seismic zoning included in the Code of Rules No 2.03-30-2017 and described in the literature in Timush et al. (2012).

Special attention will be given to the possibility of using the available geodetic information to constrain regional strain rates in a systematic matter and using homogenous methodological approaches. If available, geodetic monitoring data (GPS, GNSS) will also be gathered, in order to retrieve regional velocity fields (e.g., Zubovich et al., 2010), to subsequently derive the strain rates of the main fault lineaments.

4.1.3.3 Dataset Homogenization

Homogenization of the input datasets is definitely one of the most critical and challenging steps of the analysis, due to the unavoidable variable quality, completeness and reliability of the datasets required to build the model. Although several homogenization strategies are readily available (e.g., Weatherill et al., 2016), the most suitable approach must be defined on a case by case basis, and only after critical analysis of the available data. Hence, it cannot yet be explicitly defined at this early stage of the project.

In this study, a top-down approach will be implemented for the homogenization of each dataset. This approach entails defining an initial structure based on the most uniform and non-conflicting information available across the region (e.g., fault traces, general faulting styles) and progressively introducing more granular and detailed information, selected and ranked by reliability and significance to the hazard assessment. Multiple representations or interpretations of a single item -not resolvable by the analysis- will be identified and explicitly considered in the analysis. Such epistemic uncertainty will be then propagated in the hazard calculation (using logic tree or by means of parametric distributions) in OpenQuake.

However, given the impossibility to produce fully homogenous sets of data for the whole Central Asia region, due the expected heterogeneity of the available information, we will investigate the possibility of introducing a classification system that will help identifying regions with data of different levels of fidelity, and, thus, where the final results of the analysis may be less robust and potentially biased.

4.1.3.4 Delivered Datasets

Two main datasets will be delivered by August 13th, 2021, at the end of week #41 (Deliverable D2b):

- An updated earthquake catalogue will be produced by cross-border harmonization of the different datasets and data sources. The catalogue will be delivered in moment magnitude (Mw) by using existing or developing ad-hoc appropriate conversion relations. A declustered version of the catalogue will also be produced, in order to fulfil the main assumption of Poissonian occurrence used in standard PSHA.
- A database of the retrieved seismogenic (active) faults will be produced. For each fault, a minimum information regarding geometry and faulting style will be provided. Accessory information such as strain rates (total) or the coupling coefficient will be included, if available.

We envisage the development of dynamic datasets (both catalogue and faults), which can be easily maintained and subsequently extended whenever new information becomes available. By the end of week #41, August 13th, a second report will be delivered summarizing characteristics of the two datasets, which will be used for calibration and validation of the earthquake hazard assessment.

4.1.4 Earthquake Source Modelling

The earthquake source model will be derived from the analysis of the available datasets. Nonetheless, existing regional source zonation models from past hazard studies will be taken into high considerations.

The source model to be developed within the project will consist in a combination of distributed seismicity sources and finite faults. The former component will be calibrated on occurrence analysis of the available earthquake information from published studies, earthquake catalogues (from local, regional and global reporting agencies) and historical sources. The latter component will be calibrated on information from geological literature, field studies and geodetic analysis, depending on the accessibility of data.

The distributed seismicity model will consist of a standard seismogenic zonation, using area sources of homogeneous seismicity, combined with a more sophisticated smoothed seismicity approach. Earthquake occurrence rates of each zone will be initially characterized by identifying the most appropriate occurrence model that best explain the observed data, whose completeness will be preliminary accessed. Faulting style, dominant rupture mechanism and hypocentral depth distribution will then be defined from seismotectonic considerations, as well as a set of hypotheses related to maximum expected magnitude based on the analysis of the seismogenic potential. In a second step, a smoothed-like seismicity model will be derived from the homogenous area sources using the methodology proposed by Poggi et al. (2020). Such methodology allows a more realistic representation of the variability of seismicity across the study area, by redistributing the annual occurrence rates of the homogenous source zones depending on the spatial probability pattern of the observed events.

Finally, the available seismogenic structures identified in the active fault database will be translated into a finite fault source model. Occurrence rates of the different faults will be derived from standard seismicity analysis of the local earthquake catalogue and, when available, from interpretation of the slip rates from geodetic analysis, e.g., using the Youngs and Coppersmith (1985) formulation and more recent refinements.

To depict the epistemic variability associated to the different modelling choices, the developed complementary source models (distributed seismicity and finite faults) and the corresponding ground motion models will be combined within a logic-tree calculation structure, whose results will be analyzed statistically.

4.1.5 Ground Motion Model Selection

The calibration of the ground motion prediction model represents a major issue in the hazard analysis. Although few studies have been performed for the area, there is a general lack of usable models for the prediction of a complete set of the target response spectral accelerations. To overcome this limitation, a set of external ground motion prediction equations (GMPE) have to be used. A pool of candidate equations will be compared depending on:

- Performance with respect to the available ground motion observations, when available.
- Characteristics of the calibration dataset and compatibility of target tectonic setting.
- The suitability of the functional form (availability of the information required for the predictor variables, consistency of the output with respect to hazard assessment requirements).

The availability of waveform data to be used for calibration purposes appears presently limited. The analogue strong motion network (IS-SEME) covered the south-east part of Kazakhstan. It was implemented after 1980 and operated until the late 90s, with fewer earlier records, consisting of 28 regional sites and 8 sites in Almaty. The digital strong motion network, with 15 accelerographs, has been operating in the Almaty region since 2000. A few additional KNDC stations are also available, mainly located in lower seismicity regions. Within the CAHA-BU project the available recordings have been reviewed, including some analogue records of engineering interest digitized for the purpose. So far, 27 records appear suitable for GMPE validation, but as for the case of catalogue, access can be granted upon request. A good set of analogue accelerograms, also digitized within the CAHA-BU, is available for Tajikistan. The Institute of Seismology of the Academy of Sciences of the Republic of Uzbekistan has also few digital recordings in the range of magnitudes M = 3.0-6.5 that need review and could be potentially used to calibrate the ground motion model. As well, permission to access the waveforms from the Institute of seismology and atmospheric physics of the Academy of Sciences of Turkmenistan will be requested. Finally, additional accelerometric recordings might be obtained from the ACROSS Central Asia Strong Motion Network developed and maintained by GFZ in cooperation with CAIAG (Parolai et al., 2017).

In order to account for the variability of the tectonic environments across the region, a strategy for ground motion modelling regionalization will be used. The strategy consists in selecting appropriate ground motion prediction equations that are representative of each tectonic condition in the study area. The selected GMPEs are then used simultaneously by means of a logic tree approach but using different weight combinations in separate branches for the different sub-regions. The big advantage of such a procedure is that it yields smooth and regionally-variable ground motion predictions, thus avoiding sharp variations between neighboring tectonic environments. In this project we target using a minimum of 3 complementary GMEs. The selection will be performed by direct comparison with the actual ground motion recordings - when/where available- or alternatively by using more general selection criteria e.g., as described in Cotton et al. (2006).

4.1.6 Hazard Calculation and Validation

Several annual probabilities of exceedance (PoE) of the ground motion will be considered, corresponding to average return periods of 5, 10, 25, 50, 100, 250, 475, 500, and 1,000 years, assuming a Poisson occurrence model. Ground motion at the investigated sites will be represented in term of peak ground acceleration (PGA) and 5%-damped response spectral acceleration at several oscillatory periods (e.g., 0.5, 1, 3 and 10 seconds, mostly depending on the limitations imposed by the selected ground motion prediction model). Hazard results will be additionally provided in macroseismic intensity (MSK scale), using appropriate conversion relations, for better comparison with previous hazard studies.

Hazard calculation will be performed for a site grid of 25km (or lower) spacing using OpenQuake engine, an open source seismic hazard and risk calculation software developed and maintained by the Global Earthquake Model (GEM) Foundation. The use of the OpenQuake software is advantageous in that it allows a transparent verification of the calculation procedures, ensuring therefore the reliability and reproducibility of the output results. For each site of the calculation grid, a set of hazard curves will be computed for each target ground motion intensity measure type (PGA, SA). Hazard maps and Uniform Hazard Spectra (UHS) will be then derived for the return periods of 5, 10, 25, 50, 100, 250, 475, 500, and 1,000 years.

4.1.7 Seismic hazard disaggregation and controlling scenarios at key locations

Additional to the probabilistic hazard analysis, which is a must to perform regional loss and risk modelling, a set of regional earthquake scenarios will be identified and considered for five target sites (one per country) representative of key urban areas in the region.

The controlling scenarios for each site will be defined both on the basis of the available historical earthquake record and through disaggregation analysis of the developed probabilistic hazard model. Disaggregation allows quantifying and separating out the relative contribution of the different seismogenic sources of the hazard model, for the different return periods and ground motion intensity types, thus allowing the proper identification of the controlling earthquake at each geographical location.

In practice, a set of five major events e.g., with magnitude larger than 7 and documented impact on structures and population of the territory, will be identified from the assembled earthquake catalogue. Notable examples that will be reviewed are the Verny (Ms = 7.3, 1887), Chilik (Ms = 8.3, 1889), Kemin (Ms = 8.2, 1911), Chatkal (Ms = 7.5, 1946), Suusamyr (Ms = 7.3, 1992), Isfara-

Batken (Ml=6.3, 1977), Khait (Ml=7.4, 1949), Karatag (Ml=7.5, 1907) earthquake events. Nonetheless, the selected historical events must be consistent with the results of the disaggregation analysis to be fully representative of the seismic hazard expected for the region, and thus they should be identified only after the setup of the probabilistic hazard model and its consequent validation.

For each identified controlling scenario, then, a target location of strategic, economic and political relevance will be identified, e.g., within the highly populated areas of the major cities and capitals. Finally, for each selected target site, a set of stochastic ground motion fields will be generated, including the calculation of the corresponding ground motion fields for different ground motion intensity types and uncertainty levels. About 100 stochastic models will be calculated for each site, to fully explore the epistemic and aleatory variability of the ground motion prediction model. If available, site specific information (e.g., Vs30 maps, geotechnical or geophysical studies) will be included, in order to properly depict the variability of the ground motion in relation to the specific local geological conditions.

4.1.8 Output Summary

During the project, three major datasets and four activity reports will be delivered by the end of week #41, on August 13th:

- An Mw-homogenized earthquake catalogue for the target region (including a declustered version) and a database of potentially seismogenic faults, in plain text tabular format (e.g., csv) (Deliverable D2b).
- Hazard model input files (source model, logic-trees) in OpenQuake (xml) format, and calculation outputs, including hazard curves, uniform hazard spectra and hazard maps. Calculation output will be delivered in text format (e.g., csv) and/or in an open geospatial layer format (for maps) (Deliverables D2b and D2d).
- Stochastic event sets and associated ground motion realizations for the selected target sites in plain text tabular format (e.g., csv) (Deliverable D2c).
- Four main activity reports covering the following aspects (Deliverable D2a):
    - i. hazard modelling strategy and assumptions in relation to the existing information and the available calibration data
    - ii. the harmonized input datasets assembled for the calibration of the hazard model
    - iii. main features of the implemented hazard model and presentation of the results of the analysis
    - iv. discussion on the reliability, usability and potential limitations of the results.

4.2 Fluvial and pluvial flood hazard assessment

4.2.1 Introduction

Despite the aridity of large areas in some of the target countries, natural phenomena linked to extreme precipitation can cause billions of dollars of damages every year. A robust estimation of possible loss due to flood is necessary for developing and implementing successful DRM strategies. To reach this goal, during Task 3 the consortium will assess fluvial and pluvial flood hazard to be used as input to Task 6. A hybrid stochastic and physically-based approach will be adopted, taking into account the scale of the phenomenon, the data available (both input data and calibration/validation data) and potential future modification to the hazard triggered by climate change.

4.2.2 Fluvial flood hazard assessment

4.2.2.1 Modelling approach

The fluvial flood hazard assessment will be carried out by means of a physically-based numerical modelling toolset and a stochastic catalogue of flood footprints, i.e., a dataset containing a collection of flood footprints caused by flood events, either historical or synthetically generated (but consistent with the historical ones).

The numerical modelling toolset will be composed of two elements: the hydrological model (TOPKAPI) and the flood model (CA2D).

TOPKAPI. The TOPKAPI (Ciarapica and Todini, 2002) hydrological model is a well-established, cutting-edge tool derived upon the assumption that the horizontal flow at a point in the soil and over the surface can be approximated by means of a kinematic wave model. The model was first developed around 20 years ago, and then constantly updated to keep up with the latest advances in the field. The TOPKAPI model requires as input both precipitation and temperature meteorological data, plus a description of the soil characteristics that can be derived from the land use (to derive crop factors and surface roughness) and soil type maps (to derive permeability and depth).

The consortium holds an internal version of the TOPKAPI model, which will be set up at the catchment scale that optimizes its performances in terms of computational times over the wide area object of the study. The model will be run with a daily time step. At this stage it is not possible to estimate the final spatial resolution, which will depend on the data obtained during the project and will eventually be a result of the trade-offs between computing requirements and accuracy of the results. However, it is foreseen that it will be between 250 m and 1 km, adopting a higher resolution for very steep mountainous areas. The model will be applied to all major catchments in the countries of study, including transboundary catchments (Figure 11).

CA2D. CA2D (Dottori and Todini, 2011) is a full physically-based flood model specifically designed for high-performance computing applications, based on the ©(CA) approach and the diffusive wave equations, specifically designed to simulate flood inundation events involving wide areas. The model is based on the state-of-the-art of large-scale flood modelling and has been tested extensively on several case studies. The CA2D model has an internal preprocessor that allow the user to provide as input only the Digital Elevation Model and the roughness map. The network (comprising nodes and links) is automatically generated, and specific conditions (such as flood protections) can be included where present. In addition, input meteorological data must be provided in the form of hydrographs at specific points and/or of rainfall maps.

The consortium holds an internal version of the CA2D model, which was implemented in C++ programming language and fully parallelized (including GPU parallelization) to improve its performances in terms of computational times. Again, at this stage it is not possible to estimate the final spatial resolution, which will depend on the data obtained during the project and will eventually be a result of the trade-offs between computing requirements and accuracy of the results. However, it is foreseen that it will be between 90 m and 500 m and will make use of the MERIT digital elevation model, whose resolution is 90 m. The model will be applied to selected fluvial floodplains where exposed assets are located.

The two models are linked together as shown in Figure 10: we expect using the TOPKAPI model in the upstream part (slopes greater than 1%) of each catchment to represent the hydrological processes that contribute to the flood formation. The hydrograph at the closure of the upstream catchment provided by TOPKAPI will be used as input to the CA2D model to represent the routing in the channels with slopes lower than 1% and to the 2D inundation processes to derive flood footprints in terms of water depth and flow velocity.

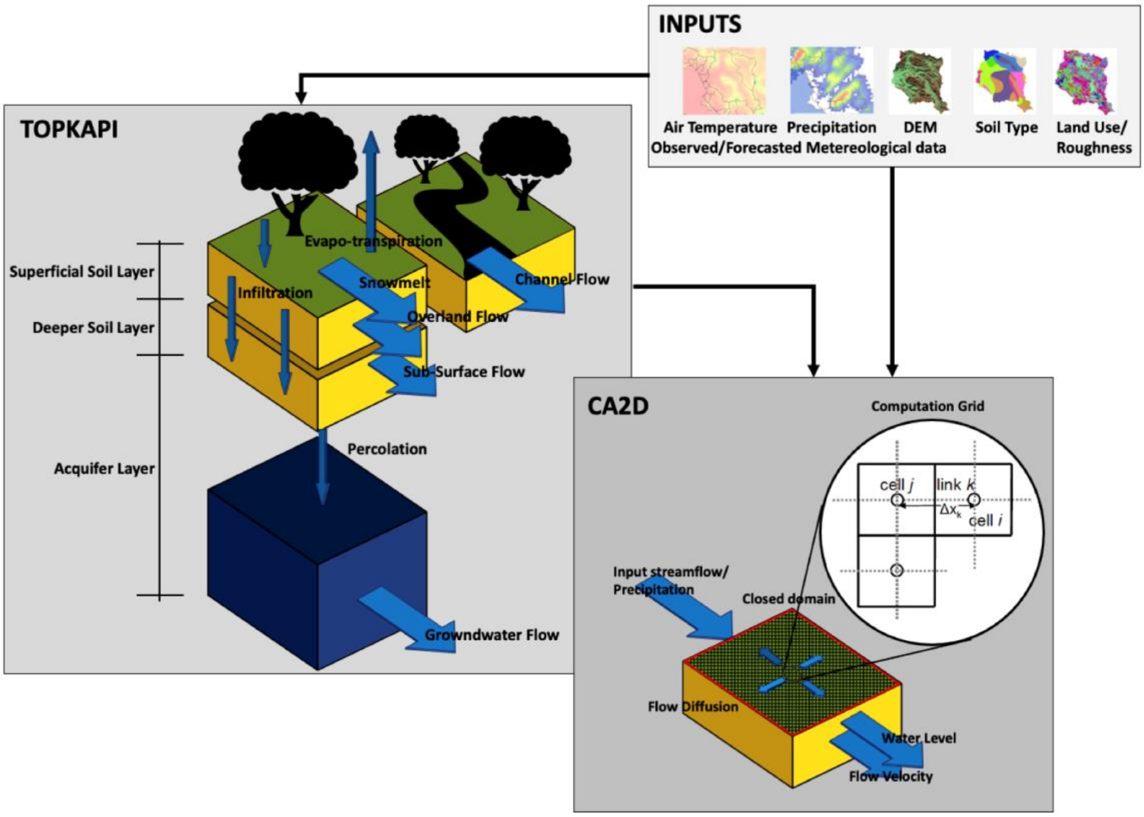

Figure 10. Flood hazard modeling diagram

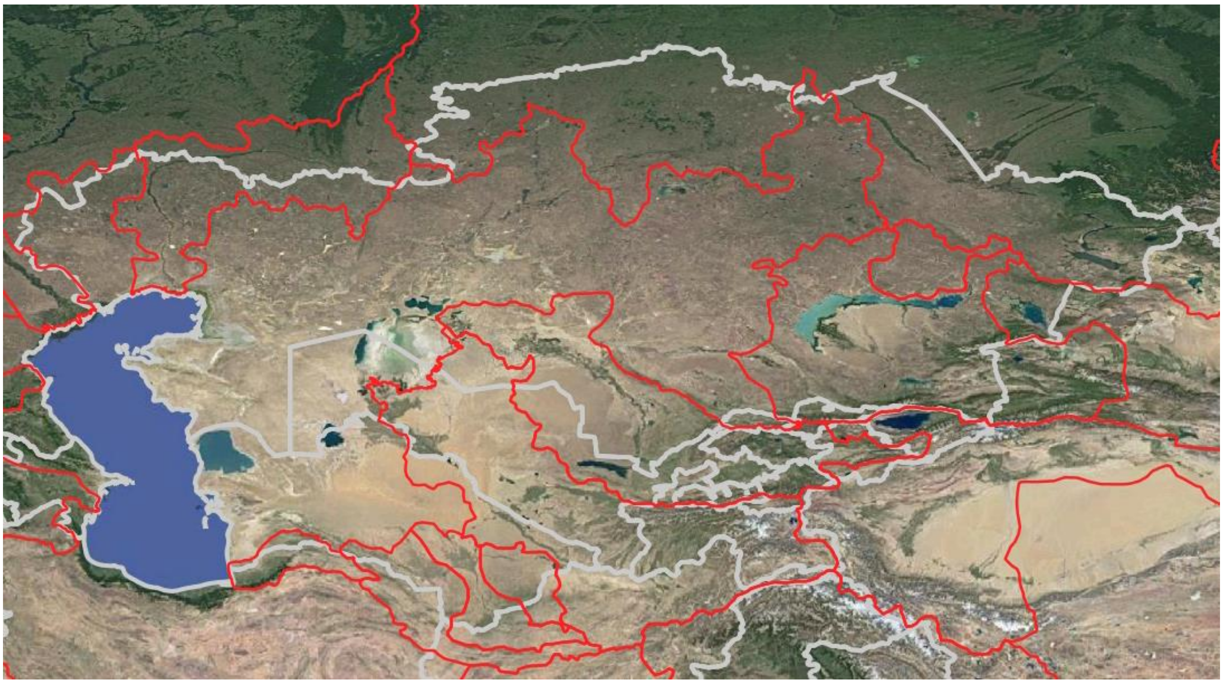

Figure 11. Major river basins (in red) and countries of study (in grey).

The hazard maps at different return periods will be derived through the generation of a 10.000-year stochastic catalogue of flood footprints with the following steps as described in Figure 12:

- Flow time series will be collected and processed, eliminating outliers and filling gaps, whenever possible. Flow time series can be both observed and simulated, however, where discharge data are not available. The extreme distributions of discharge at selected river sections will be derived using the hydrological model TOPKAPI fed with precipitation data from IMERG and reanalysis (see Section 4.2.2.3).
- Distributions of flow extreme values (for example, Gumbel and Generalized Extreme Value - Gumbel, 1958) will be fitted on the flow records and on the simulated flow time series, to estimate low-frequency flow values.
- Given the extent of the area and the scarcity of data, a regionalization procedure will be put in place to estimate the extreme value distributions at ungauged river sections, by combining the output of the hydrological model with the extrapolation of the distribution parameters obtained where data are available.
- To ensure spatial coherence in the stochastic catalogue, the spatial correlation of the river flow at all the gauged sections will be determined by computing a cross correlation matrix on all the available (observed/simulated) flow time series.
- The obtained stochastic set of discharge will be used as input to the CA2D model in order to obtain a corresponding stochastic set of flood footprints. The stochastic event set of flood footprints will be finally used to derive the hazard maps over the region.

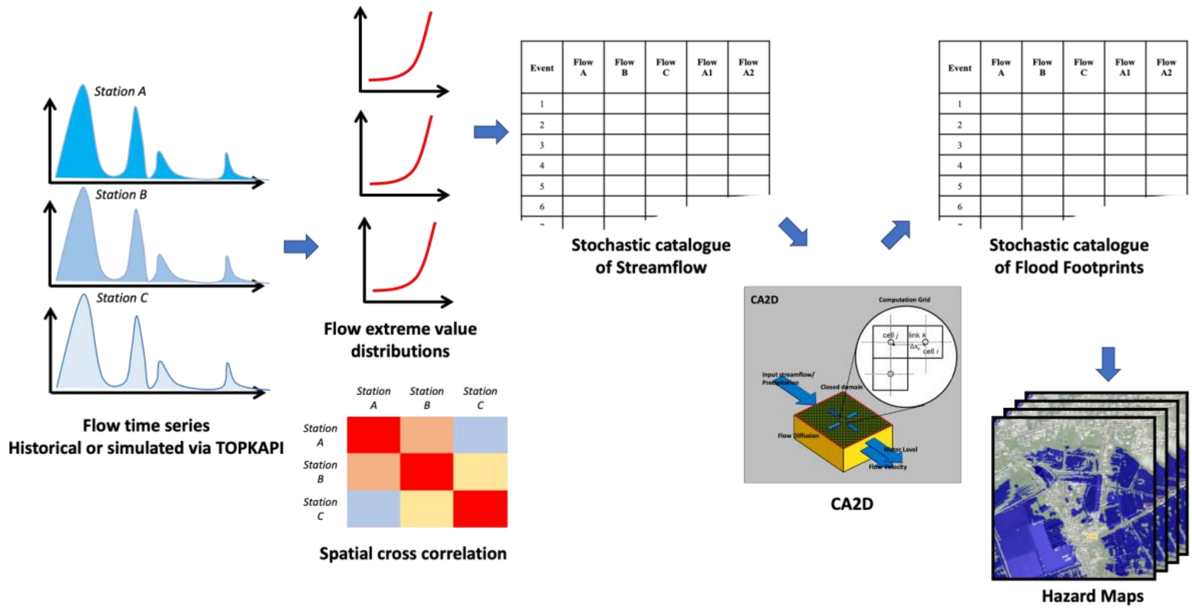

Figure 12. Components required to derive the flood hazard maps

The proposed modelling approach, which leverages on the use of satellite data available in real time (e.g., IMERG, CMORPH, CHIRPS) and of a hydrological/hydraulic modelling chain calibrated using historical observed data, is potentially suitable for the implementation of Disaster Risk Financing applications based on parametric triggers (e.g., CCRIF for the Caribbean and Central America regions, ARC for the continent of Africa).

4.2.2.2 Flood defenses and reservoirs

The role of the defensive protections is crucial in reducing fluvial flood hazard. However, availability of precise data regarding flood protection levels is very limited and uncertain. The consortium will collect all available flood protection data from local partners and will provide a description of information availability, flood protection standards compliance, and perceived quality/condition of structures.

However, based on our preliminary analysis, we expect that assumptions on flood protection levels will have to be made for specific areas. These assumptions will be based on the correlation between the flood protection levels, where available, and the protected exposure (mainly population). Based on this correlation, protection levels will be assumed where data are not available based on the level of protected exposure. A function of the level of protection on exposure will be estimated based on the data available for the countries of Central Asia. If no data specific for the region are available, we will rely on the expertise of the local partners and on available data from similar countries.

Similar assumptions will be made for the operation of reservoirs. The TOPKAPI model includes a specific module for managing reservoirs based on known operation strategies and/or volume/level curves, which will be derived/calibrated using historical data, if available.

4.2.2.3 Input data

The TOPKAPI hydrological model requires daily or sub-daily precipitation and temperature records as input data. With the aim of obtaining a homogeneous and regionally-consistent assessment, the consortium will focus on spatially-distributed global datasets to be used as input to integrate the ground data available from historical observation recorded by rain and temperature gauges.

The global datasets that the consortium will use to integrate the ground data from available stations are listed as follows:

- IMERG (Integrated Multi-satellitE Retrievals for GPM). IMERG is based on a relatively recent algorithm which is applied to the passive microwave GPM (Global Precipitation Measurement) satellite constellation imagery, combined into half-hourly 0.1°x0.1° fields (around 10x10 km at the equator) and covering the entire world. The product is available in real time, with a short latency time (4 hours after observation time for the "early" version, 14 hours after observation time for the "late" version). Despite the relatively recent launch date of the GPM satellites (2014), NASA was able to obtain IMERG-consistent precipitation estimates starting from June 2000, based on remote-sensed imagery obtained by the TRMM (Tropical Rainfall Measuring Mission) satellites, which were the precursors of GPM.
- Climate reanalysis. Reanalyses are gridded observational dataset of climatic variables over extended periods without gaps developed using a fixed version of data assimilation algorithm and climate model code. Some examples are shown in Table 5. Reanalysis datasets can contain useful variables such as predominant wind speed direction, mean wind speed, average temperature

Table 5. Reanalysis products.

Name	Institution	Coverage period
ERA-40	ECMWF	1957 - 2002
ERA-Interim	ECMWF	1979 - 2018
ERA-5	ECMWF	1950 - present
Reanalysis 2	NCEP-DOE	1900 - 2010
CFSR	NCEP	1979 - present
MERRA	NASA	1979 - 2016
MERRA-2	NASA	1980 - present
JRA-55	JMA	1958 - present

The TOPKAPI model also requires spatially-distributed information for the characterization of the river catchments. Local datasets for the Central Asia region or specific countries developed during previous projects will be used where available; in addition, the following global datasets will replace missing local information:

- Soil characteristics. The FAO/UNESCO soil map of the world will be used (resampled at the resolution of the simulation).
- Land use. The Global Land Service map of the Copernicus service (European Union) will be used (resampled at the resolution of the simulation).
- Elevation. The MERIT-Hydro 90m digital elevation model will be used (resampled at the resolution of the simulation).

The CA2D uses flow time series as input, which will be produced by the TOPKAPI hydrological module. The flood model also needs a detailed digital elevation model to define the boundary conditions of the domain. The consortium will use the MERIT DEM (Karnieli et al., 2010) together with MERIT Hydro (Yamazaki et al., 2019). MERIT Hydro is a new global flow direction map at 3 arc-second resolution (~90 m at the equator) derived from the latest elevation data (MERIT DEM) and water body datasets G1WBM, GSWO (which stand for Global 1 arc-second Water Body Map and Global Surface Water Occurrence respectively and were developed by the same authors as MERIT) as well as OpenStreetMap. MERIT Hydro, which was produced at the University of Tokyo, uses a new algorithm to extract river networks near-automatically by separating actual inland basins from dummy depressions caused by the errors in input elevation data. MERIT Hydro improves on existing global hydrography datasets in terms of spatial coverage and representation of small streams, mainly due to increased availability of high-quality baseline geospatial datasets.

The regional risk analysis will make use of data from several sources (gauges, remote sensing and reanalysis) not all available in real time. Parametric insurance, however, requires that the real time reliable data used as basis for identifying the triggering mechanism be consistent with the data utilized in the risk analysis. This consistency will be achieved through the homogenization (bias correction and probability density function matching) of precipitation and temperature data and the validation of the output of the hydrological model against historical records of flow observations.

Given the relatively short record available from IMERG (about 20 years) and the goal of obtaining long return period hazard maps, we will consider the possibility to extend the IMERG dataset using re-analysis data during the development of the project. The extension will be based on bias correction and probability density function matching techniques similar to those used for the homogenization process.

4.2.2.4 Validation data

Calibration and validation for the hydrological model will be performed based on the historical discharge data and particularly on the hydrograph of extreme events. The hydrological model will be considered validated if discharge peak and volume associated with the hydrograph can be estimated with a MRE (Mean Relative Error) equal to or lower than 15%.

Calibration and validation for the hydraulic 2D model will be performed based on water level and, if available, flood footprint area. The hydraulic model will be considered validated if the MRE of the maxima water levels of the events is within 15% or by visual comparison of the flood footprint maps when location and extension of the flood areas have a good degree of agreement. If observed flood footprint maps are available and reliable, a quantitative comparison will also be performed by computing the overlapping area between simulated and observed flood area. In this case the hydraulic model will be considered validated if the mean ratio between the overlapping area and the simulated flood area is greater than 80%.

As potential source of validation data, the Global Runoff Data Center lists around 200 flow stations in the area, 180 of which have more than 10 years of data (although very few of them include data from the past two decades). The country-based partners of the consortium will assist the hydrological modelers in retrieving all available flow gauge data, including but not limited to the data from the stations listed by the Global Runoff Data Center (Figure 13).

Another methodology that is being widely used for flood model validation involves satellite-derived flood footprints. A growing number of satellite products is currently being produced and employed in the disaster risk management sector. One of these products is the Synthetic Aperture Radar (SAR), which, notwithstanding some limitations (e.g., in urban areas) has been extensively used in the last decade for post-event flood detection. One of the most common SAR products used for flood detection is Sentinel1. Sentinel1 is a constellation of two satellites launched by the European Space Agency (ESA) in 2014 and 2016, respectively. Flood footprints will be extracted from Sentinel1 images for selected historical and realistic regional flood scenarios (see Section 4.2.4) and their extents compared to the results of the simulations (Figure 14).

The final results of the flood hazard module (i.e., maps of the likelihood of the flood depth to exceed certain thresholds) can also be validated by comparing them with other studies and data sources. Such as GLOFAS (Global Flood Awareness System), which provides a map of the 100-year flood at the global scale, and the GAR15 (Global Assessment Report 2015) flood hazard maps (Figure 15).

Additional sources for validation to be considered are the GLOFRIS global flood model; Dartmouth Flood Observatory and Fathom Global 90m flood maps.

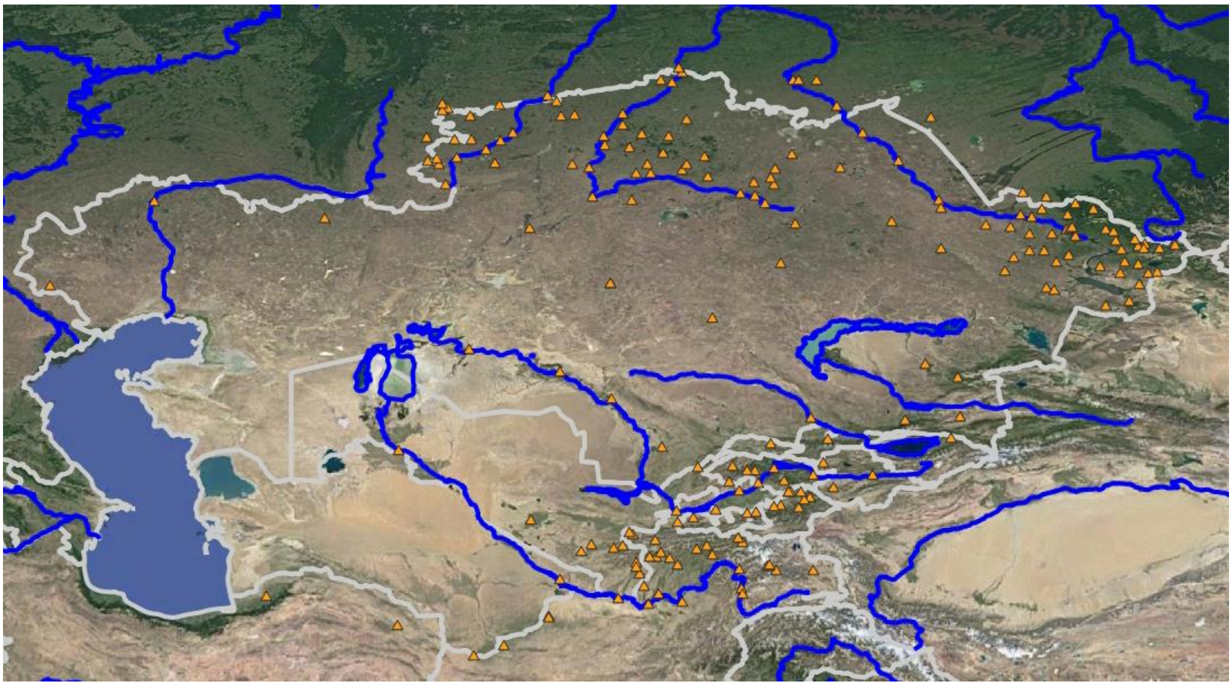

Figure 13. Flow gauge stations according to the Global Runoff Data Center.

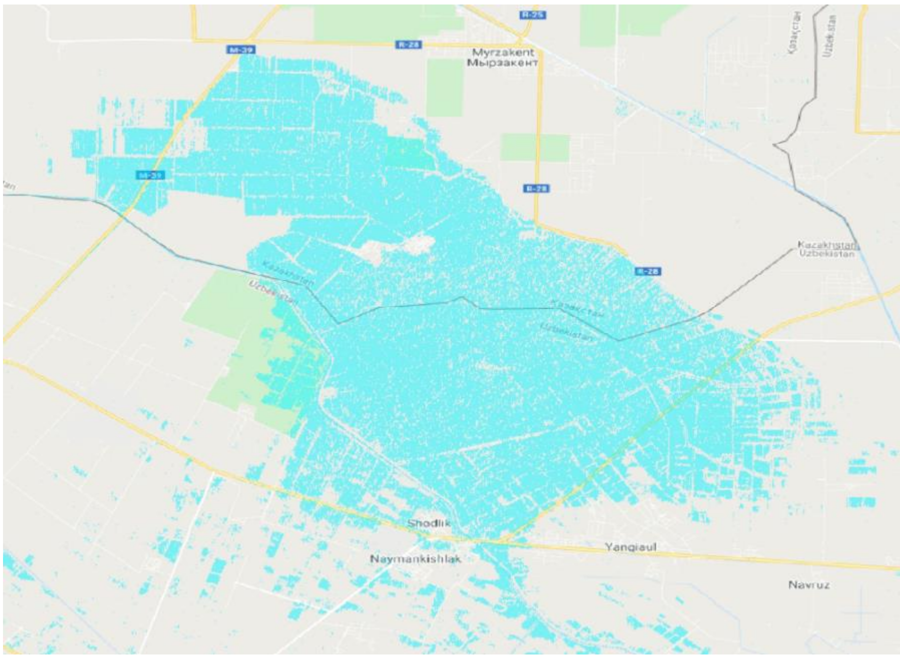

Figure 14. Flood footprint extracted from Sentinel1 images corresponding to the May 2020 flood event caused by the failure of the Sardoba Reservoir Dam, which flooded an area located on the border of Kazakhstan and Uzbekistan and forced evacuation of more than 70,000 people (elaboration made by RED).

Figure 15. 100-year flood footprint extension according to GLOFAS (https://www.globalfloods.eu/glofas-forecasting/).

4.2.3 Pluvial flood hazard assessment

4.2.3.1 Modelling approach

Due to limitations in the resolution and the scale of the region to be covered, the flood hazard assessment described in the previous section mainly covers fluvial floods, i.e., inundations caused by medium to large-sized rivers, while localized heavy precipitation bursts and flash floods might not be accurately reproduced. This is a crucial issue for several areas of the region, which are characterized by short and intense floods, such as the mountainous areas of Tajikistan and Kyrgyzstan, that may trigger catastrophic mudslides as often observed in the past.

In order to assess pluvial flood hazard, in Central Asia, the consortium will adopt the hydraulic model CA2D. In this application, the CA2D model will be fed with extreme precipitation events synthetically generated based on the Intensity Depth Duration curves (IDDc) derived from ground stations observations or from remotely sensed data where the former are not available. Spatial correlation will be taken into account through the definition of a cross-correlation matrix estimated on the historical rainfall intensity time series. The infiltration rate will be estimated by means of a simplified Hortonian model where the soil coefficient will be obtained as a function of the land use and soil type classes used in the TOPKAPI configuration for fluvial flood as described in the previous section. This will ensure that the model is calibrated and validated specifically for the study area. Excess of rainfall will be routed using the model propagation equations and water depth in the model domain will be finally computed. The effect of the urbanized area will be informed by the local partners. Where information on the urban drainage system is not available, the simulation will assume null infiltration rate, essentially assuming an impermeable surface.

The CA2D model will simulate all the synthetic rainfall events generated in the IDDc and will build a stochastic catalogue of flood footprints due to pluvial hazard, which will be used to derive the hazard maps at different return periods.

4.2.3.2 Input data

The global satellite-based IMERG (Integrated Multi-satellitE Retrievals for GPM) product will be used as the input of the pluvial flood hazard assessment, which will also take into account the precipitation values used as input in the modelling chain previously described for assessing the fluvial flood hazard. As mentioned, IMERG is based on a relatively recent algorithm that is applied to the passive microwave GPM (Global Precipitation Measurement) satellite constellation imagery, combined into half-hourly 0.1°x0.1° fields, covering the entire world. IMERG and IMERG-consistent precipitation estimates are available since June 2000. In case IMERG will not provide the necessary accuracy to the modelling tool in the target areas, the consortium will explore the possibility of using alternative datasets, such as CMORPH (rainfall rate estimation dataset obtained from satellite images elaborated by NOAA through the Climate Prediction Center's Morphing Technique) or CHIRPS (Rainfall Estimates from Rain Gauge and Satellite Observations, developed by USGS and CHC).

The regional risk analysis will make use of data from several sources (gauges, remote sensing and reanalysis) not all available in real time. Parametric insurance, however, requires that the real time reliable data used as basis for identifying the triggering mechanism be consistent with the data utilized in the risk analysis. This consistency will be achieved through the homogenization (bias correction and probability density function matching) of precipitation data.

Given the relatively short record available from remote sensing and the goal of obtaining long return period hazard maps, we will consider the possibility to extend the IMERG dataset using re-analysis data during the development of the project. The extension will be based on bias correction and probability density function matching techniques similar to those used for the homogenization process.

4.2.3.3 Validation data

The model will be validated by comparing its results with any available record of flash flood. The consortium will collect rain gauge measurements or even anecdotal evidence of rainfall events, if available. Rain gauge data will be collected from local meteorological agencies and water authorities and from international networks of rainfall data (e.g., the US NCEP's Climate Data Online portal or KNMI's Climate Explorer portal. Alternative satellite rainfall products, such as the Climate Hazards Center InfraRed Precipitation with Station data (CHIRPS), which is s a 35+ year quasi-global rainfall data set, which incorporates 0.05° resolution satellite imagery with in-situ station data to create gridded rainfall time series for trend analysis and seasonal rainfall monitoring.

Rainfall validation data will also be retrieved from a variety of sources (see some examples in Table 6).

Table 6. Main sources of hydrometeorological information in the Central Asian countries.

Kazakhstan	Institute of Hydrogeology and Geoecology
	Kazakh National Hydromet Service
	Regional Center of Hydrology
Kyrgyz Republic	The agency on hydrometeorology under the Ministry of Emergency Situation of the Kyrgyz Republic ("Kyrgyzhydromet")
Tajikistan	Institute of Water Problems, Hydropower Engineering and Ecology of Tajikistan
	Tajik National Hydromet Service
Turkmenistan	Turkmen National Committee of Hydrometeorology
	Institute of Seismology and Atmospheric Physics of Turkmenistan
Uzbekistan	Center for Hydrometeorological Service of Uzbekistan
	Scientific Information Centre of the Interstate Coordination Water Commission
	Khorezm Rural Advisory Support Service

Re-analysis of climate data will also be used for validation purposes. Data from the numerical weather prediction model COSMO-CA (Central Asia) could also be employed if made available by the corresponding institutions.

4.2.4 Selected scenarios at key locations

Historical flood scenarios will be selected to validate the model outputs, while realistic scenarios will be identified to assess potential floods that have not happened in the past but may affect the region in the future.

Historical flood observations are usually not recorded systematically, although for some extensive flood events reconstructions might have been carried out. The team will count on local experts in the consortium and will interact with members of the RSTC both for the identification of these studies and their interpretation and re-analysis in light of the obtained results.

In this phase we have identified a series of potential candidate scenarios:

Historical scenarios.

- The catastrophic Panj River flood that hit the Hamadoni district in Tajikistan (M.S. Saidov, Yu.N. Pilguy and L.V. Davlyatshoeva, 2006).
- The 2008 flood that hit the Ordabasy, Aryss, Saryagash districts in South Kazakhstan, at the border with Uzbekistan. One of the most severe floods ever registered in the area, it caused the displacement of more than 13,000 people.

Realistic scenarios.

- Three realistic flood scenarios considering different return periods for key locations selected based on their flood risk profile from previous studies (e.g., GFDRR 2016). These may include Atyrauskaya region in Kazakhstan, Talas region or the Jalal-Abad region in Kyrgyzstan, Badakhshoni Kuhi region in Tajikistan, Chardzhou region in Turkemnistan and Andijan region in Uzbekistan.

4.2.5 Uncertainty assessment

Uncertainty estimation is a fundamental feature for a proper interpretation of the results. A quantitative estimation of the uncertainty will be possible only if enough historical data is available. This sort of estimation will quantify the errors between observed and simulated variables (precipitation, discharge, water depth) and will infer their statistical distributions. Confidence intervals for different quantiles will be associated to the simulated variables.

A qualitative estimation of the uncertainty will weigh the different sources of uncertainty in relative terms based on data quality and process assumptions in order to rank them from the most to the least influencing.

Uncertainty sources considered will include:

- input data (precipitation and discharge);
- synthetic generation of rainfall or discharge;
- hydrological modelling;
- hydraulic modelling;
- defense simulation.

Uncertainty will be presented by confidence bounds associated to the hazard and risk curves. Regarding the hazard, for example, discharge hazard curve with confidence intervals will be presented, estimated analytically by fitting a known distribution (e.g., GEV) to the observed discharge. Regarding risk, approximated confidence intervals along with the exceedance probability curves, obtained by combining hazard uncertainty and vulnerability uncertainty, will also be estimated.

4.2.6 Climate change impact analysis

According to the available literature, aridity is expected to increase in the future across the entire Central Asian region, especially in the western parts of Turkmenistan, Uzbekistan, and Kazakhstan (Lioubimtseva and Henebry, 2009). Temperature increases are expected to become particularly high in summer and fall, accompanied by decreases in precipitation. This can trigger a decrease in runoff and total water availability. However, little is known about the expected variations in extreme rainfall and flow. In this assignment, the consortium will make use of climate projections resulting from climate modelling experiments available for the region (for example from the Climate Model Intercomparison Project in its versions CMIP5 and CMIP6 or the Coordinated Regional Climate Downscaling Experiment CORDEX). These climate projections will be employed, selecting realistic Representative Concentration Pathways to be agreed with the World Bank (for example, RCP4.5 might represent the "business-as-usual" scenario), to estimate seasonally-variable change factors for precipitation and temperature, which can be employed to alter the inputs of the model and estimate potential future flood hazard. In the Change Factor methodology (Diaz-Nieto and Wilby, 2005), a baseline climatology is first established for the site or region of interest, and then changes in one or more variables of interest (e.g., average precipitation, monthly precipitation, seasonal patterns, average flow) are calculated based on the results of a climate model (or an ensemble of them). These changes can then be applied to the stochastic catalogues of fluvial and pluvial flooding so to estimate a range of potential future impacts of climate change on flood hazard. This methodology is relatively simple and is particularly suitable for areas such as Central Asia where downscaled high-resolution projections are lacking.

In order to produce hazard maps for the selected climate change scenario, the same modelling approach described in Figure 12 will be applied but in this case after replacing the observed input data with those provided by the selected climate projection.

4.2.7 Modelling outputs

The flood hazard assessment report (Deliverable D3a) is due by the end of week #41, on August the 9th 2021. The report will include a description of the adopted flood hazard assessment approach, an inventory of data sources, an inventory and description of hazard assessment outputs, and the validation of the hazard outputs. These consist of hazard curves, hazard maps and hazard profiles.

Other three outputs are due by the same date: tabulated flow gauge data, rainfall gauge data and a flow hydrograph data summary of the climate reanalysis (Deliverable D3b); tabulated stochastic event set including all rainfall and flood event parameters (Deliverable D3c); and the spatial distribution of flood depth for different return periods for fluvial and pluvial flood, for climate conditions in 2020 and 2080, and scenario footprints for selected events (Deliverable D3d).

4.3 Development of an Exposure dataset

The aim of this component is to develop, under Task 4, a comprehensive and regionally consistent exposure dataset, which will be used together with the output of Tasks 2, 3 and 5 as input to Task 6. The exposure dataset developed under Task 4 will be used as input for both earthquake and flood risk assessment. The differentiation of impacts of the different hazards to the exposed assets will be obtained through the use of the specific vulnerability curves developed under Task 5.

The consortium can offer a long-standing and well-established expertise in large-scale exposure database development and will rely on a strong network of local project representatives for the collection of data. The development of the exposure dataset will be performed in three phases: data collection, data processing and validation. Local partners will participate to the three phases and interact with the exposure development team. In addition, they will be involved and trained during the capacity building workshops in order to be able to autonomously develop and update the exposure layers in future (See Section 5 for details on the capacity building strategy).

4.3.1 Methodology

4.3.1.1 Data collection

Exposure data is crucial for a correct development of damage and risk assessments. The consortium will collect all available data and information and build up regional exposure datasets to be used in the subsequent risk assessment (e.g., population density, buildings distribution, location of strategic infrastructures). The availability of some data at national scale (e.g., location of industrial sites and energy production sites) has to be formally agreed with other institutions (e.g., governmental agencies, ministries) and cannot be yet guaranteed. This document describes the available data and the exposure assessment methodology. It also mentions the data that might be available in future and their possible use in the exposure development. The consortium will include in the final exposure development report an inventory of additional data identified and collected during the project, specifying their availability and any access /usage restrictions.

4.3.1.2 Exposure assessment

This section describes the methodology adopted in order to extract the relevant information for each exposed asset and build up a usable and cross-border consistent exposure dataset. The methodology is strictly dependent on the data available. Here we describe the data that will be used and the information that will be extracted. Should additional and more specific data arise, they will be included in the methodology when possible, in order to enhance the outcomes of the assessment.

4.3.1.2.1 Building stock

Urban exposure will be estimated at different spatial scales. At regional scale, using land use data (e.g., Global land cover from the Copernicus service), it is possible to identify urbanized areas and associated building density. Then, exposure will be defined at aggregated level, based on a combination of medium-resolution satellite data and ancillary census data, if available.

Specific methodologies will be applied in order to classify the different building types, in particular:

Residential buildings. Exposure datasets developed during the EMCA project are already available for the five Central Asian countries (https://github.com/GFZ-Centre-for-Early-Warning/EMCA-Exposure, Pittore et al., 2020) and contain occupants and construction types based on the GEM taxonomy. Datasets are derived from a combination of remote-sensing and ground observation data (e.g., the ones collected during the SENSUM project**,** http://www.sensum-project.eu/), and aggregated using neighboring polygons defined based on the population (Pittore, 2016). The main building typologies are the ones defined in the EMCA project using the GEM taxonomy. Such typologies will be adopted for the Central Asian region and validated based on local experts' knowledge of the residential buildings stock. The building typologies will also be compared with those identified by Lang et al. (2018). In addition, the final exposure dataset will include attributes relevant in order to tackle other risks (landslides, floods). In case additional data are available at higher resolution (e.g., for cities such as Almaty in Kazakhstan), those will be included in the regional exposure dataset.

Schools. Number and location of schools will be extracted from OpenStreetMap layers. Local partners may provide the number and the location of some of them, but the availability of such information has yet to be confirmed. Information on school typologies will be extracted from the findings of previous or ongoing projects in the study area (e.g., the World Bank projects "Seismic performance-based assessment of school infrastructure in the Kyrgyz Republic", "Building Technical Capacity in Central Asia to Design Risk-Informed Public Infrastructure Investments at Scale" and "Enhancing Resilience in Kyrgyzstan" - ERIK). Schools location is available for Kyrgyzstan (http://geonode.caiag.kg/layers/geonode:kyrgyz_schools_utm43_v01) and Tajikistan (https://geonode.wfp.org/layers/geonode%3Atjk_schools_sm2018). In particular, the consortium will contact the team of previous World Bank projects and, if possible, access the data in order to grasp the latest available knowledge. Global datasets (Global Library of School Infrastructure) and tools (GLOSI library, available at: https://gpss.worldbank.org/index.php/en/glosi/library) will be also consulted. The findings of such projects will be used to classify the schools in the other countries of the study area. School typologies will be extended to the other Central Asian countries with the support of local partners, who will validate the typologies with relation to their country. The consortium will make every possible effort to identify the relevant features of the main school typologies (age, height, construction material).

Healthcare facilities. Number and location of hospitals for each country will be provided by local partners when available or extracted from the findings of previous projects in the study area. Online sources (e.g., http://www.londonnews247.com/list-of-world-hospitals/) might be used after being validated with the local partners. In particular, the location of hospitals is available at national scale for Kyrgyzstan (http://geonode.caiag.kg/layers/geonode:kyrgyz_hospitals_utm43_v01). The consortium will make every possible effort to identify the relevant features of the main hospitals (age, height, and construction material for each building, occupants for the entire hospital).

Industrial buildings. The USGS global database collects the main mineral mines and industrial sites in Northern and Central Eurasia. The database contains the sites coordinates and their main features (e.g., construction age, commodity, type of activity, capacity, status). This information will be complemented with information at a national scale, when available. Industrial buildings are included in OpenStreetMap layers as land use polygons. OSM does not contain additional information on industrial buildings features (e.g., age and material). The analysis will be complemented with information at a national scale, when available, and validated with local partners, in particular for areas of interest.

Commercial buildings. Commercial buildings are included in OpenStreetMap layers and are organized into different categorizes (e.g., supermarket, cafe, restaurant). The consortium will gather the information of OSM (which might have a variable coverage for different countries/areas). Should no information be available for some areas, the percentage of commercial buildings will be associated to urban areas based on the information collected for the other countries. OSM does not contain additional information on commercial buildings features (e.g., age and material). The analysis will be complemented with information at a national scale, when available, and validated with local partners, in particular for areas of interest (e.g., capital cities).

4.3.1.2.2 Population density and demographic attributes

Population count is available at national scale on a grid of 3-arc resolution provided by the WorldPop population mapping project (https://www.worldpop.org/geodata/listing?id=29) for the year 2020. In addition, the NASA SEDAC data center provides population data (count and density) aggregated at sub-national level and for urban and rural areas (e.g., GRUMP database, available at: https://sedac.ciesin.columbia.edu/data/collection/grump-v1, 30 arc-second resolution). Another global population dataset is Landscan, which contains population count at 30 arc-second resolution (https://landscan.ornl.gov/documentation). Finally, the Facebook High Resolution Settlement Data (HRSL) provides overall population density and population counts for different age/gender classes at 1 arc-second resolution (e.g. https://data.humdata.org/dataset/kazakhstan-high-resolution-population-density-maps-demographic-estimates for Kazakhstan). The above-mentioned data sources can be compared in order to identify areas where there is a strong discrepancy (and where local data and/or validation exercises are required) and build a reliable high-resolution dataset. Since the Facebook HRSL provides population density and gender/age attributes and has the highest resolution (approximately 30m), it will likely be used as a starting point. The Facebook HRSL indicators will be cross-checked with the national and sub-national demographics extracted from other datasets. In particular, the Facebook HRSL population data can be aggregated at different administrative units (e.g., region/city) and compared with the same-level demographic indicators that have lower resolution (e.g., in the GRUMP or WorldPop). This exercise can be performed using spatial analysis tools and comparing the raster layers (aggregated at the same resolution) in order to identify the areas of greater discrepancies. Where we will find substantial agreement between the datasets, the Facebook HRSL will be included as is in the population exposure layer. However, in areas where there may be strong discrepancies, those will be identified by spatial analysis and corrected based on additional data (e.g., national census) with the support of local experts.

Demographic attributes (gender, age) will be extracted from the latest available data sources (e.g., national census data at national or sub-national level). National census data will be analyzed and the percentage of population by gender and age will be applied to the total population at the highest available resolution. For example, the Kyrgyzstan census data (https://unstats.un.org/unsd/demographic/sources/census/wphc/Kyrgyzstan/A5-2PopulationAndHousingCensusOfTheKyrgyzRepublicOf2009.pdf) allows to extract the percentages of age and gender classes for each Kyrgyz region in 2009, while more recent data are available here: http://www.stat.kg/en/opendata/. Similarly, demographic data are available at national scale for the other countries: Tajikistan (https://www.dhsprogram.com/pubs/pdf/FR341/FR341.pdf), Uzbekistan (https://stat.uz/en/181-ofytsyalnaia-statystyka-en/6383-demography), Turkmenistan (http://www.citypopulation.de/Turkmenistan.html) and Kazakhstan (https://stat.gov.kz/census/national/2009/region).

The EMCA exposure layers mentioned in the previous subsection provide gridded residential building occupancy data. The demographics obtained from the national census and/or the aforementioned global population datasets will be then applied to the building occupancy data. One approach is to distribute the population age and gender based on the percentages extracted from census data. Other approaches will be considered based on the available data. Should additional and more precise data be available, the consortium will include those into the exposure dataset when possible.

4.3.1.2.3 Transport infrastructure

Transportation data will be retrieved from open source datasets (e.g., Open Street Map, GRIP global roads database). Studies on the transportation system at regional and national scale will be also taken into account (e.g., Chen and Fazilov, 2018; Bazarbekova, 2018). Transportation assets will be categorized based on the outcomes of the World Bank assignment 'Measuring Seismic Risk in Kyrgyz Republic' (Word Bank, 2017), that assigned broad structural categories to roads and bridges based on open-source data (OpenStreetMap). Such categories will be validated and adapted to the different context of the other Central Asian countries. In particular, the following methods will be employed for:

Roads. The OSM layers have been retrieved and allow us to identify the road locations and type. In addition, the GRIP layer has been retrieved (https://www.globio.info/download-grip-dataset) and provides road density and road types based on several data sources. This allows us to compute the total length of roads for each road type and for specific areas. Road types (e.g., primary, secondary) will be analyzed together with local partners in order to identify their specific features (e.g., width, pavement material) which will be then validated via indirect inspection (e.g., aerial images, Google maps images) when possible.

Railway. The Central Asian railway network will be included in the exposure layers[11]. The OSM layers in the area contain the railway network and bridges. Specific information on the railway typologies will be provided, when possible, by local partners (in particular TSTU, former TashIIT for Uzbekistan). Digital maps of the network will be retrieved, when possible, or assembled based on the available information.

Bridges. The location of bridges will be identified based on OSM, the digital elevation model and the map of main rivers. Broad bridge material categories (concrete, steel, other) will be defined similarly to what proposed by Free et al. (2018) based on the information available in OSM. Partial results of this analysis are available for Kyrgyzstan from the CAIAG geonode (http://geonode.caiag.kg/). The bridge width will be inferred by the category of road where the bridge is located (e.g., if the bridge is located on a highway, the bridge will be wider). The bridge length will be inferred, when possible, from OSM layer. A small number of bridges located on relevant transportation infrastructures will be identified with the help of local partners and their characteristics will be inferred from aerial/satellite photos, if available.

Belt and Road. Special attention will be devoted to the transportation infrastructures that belong to the Belt and Road initiative and their main junctions or critical nodes. Based on the most recent Belt and Road existing and planned projects[12], the consortium will include the existing infrastructure into the exposure layers and include them into the exposure dataset. The infrastructures planned or under-construction will be inserted and labelled accordingly.

Airports and airstrips. Existing airports and airstrips will be gathered from existing open databases (e.g., https://www.partow.net/miscellaneous/airportdatabase/, https://openflights.org/data.html, https://ourairports.com/data/) and added to the exposure layers. The airport features (e.g., construction type, occupants, type of use) will be also collected when available. Effort will be prioritized to retrieve the information for the most important airports in the region.

4.3.1.2.4 Industrial sites

The consortium will identify the most relevant industrial activities that can contribute to increase disaster impacts (e.g., mines) and gather their main characteristics (e.g., construction age, material,

[11] https://www.unescap.org/resources/trans-asian-railway-network-map

[12] https://merics.org/en/analysis/mapping-belt-and-road-initiative-where-we-stand

type of activity, type of infrastructures related to the industrial sites). The location of main mineral mines and industrial sites can be gathered from a report provided by USGS (2015) and the associated dataset (https://pubs.usgs.gov/of/2010/1255/). Additional information on the location and type of mines is available in a report by Zoï Environment Network (2012). This information will be validated with local partners and integrated with information at national scale, when available. Satellite images (e.g., Landsat and/or Sentinel-2, having a resolution of 30 and 10 meters, respectively) will be used to infer the presence and characteristics of industrial sites in areas of interest. Other types of industrial plants will be taken into account based on the available data provided by the local partners. Waste storage sites location is very difficult to gather for most countries. However, radioactive toxic waste sites location for Kyrgyzstan is available from the UNISDR report (2010).

Should specific assets location not be available, other (more general) information (e.g., generic areas, number of items per area) will be used.

4.3.1.2.5 Supply infrastructure

Since most data on supply infrastructure might not be available in a georeferenced format, maps will be assembled based on the available information. The location of assets will be retrieved to the best possible resolution also based on existing datasets, e.g., the World Bank portal (https://www.worldbank.org/en/data/datatopics/infrastructure). The status of the infrastructure (active/inactive) will be checked with local partners. Should specific assets location not be available, other (more general) information (e.g., areas, number of items per area) will be used.

Energy and water-related infrastructures. Special attention will be devoted to:

- Power generation facilities will be collected for each country based on available data at regional scale (e.g., Raimondi, 2019; World Energy Council, 2007), national scale (based on national agencies data), and local scale (provided by local partners). Should data be available on power plants and network rehabilitation (e.g., https://www.adb.org/projects/43150-012/main#project-pds) they will be collected and included into the exposure layers.
- Oil and gas pipelines: The location of main oil and gas pipelines will be retrieved from available online sources (e.g., in Sternberg et al., 2017; https://geopoliticalfutures.com/central-asia-pipelines/#&gid=1&pid=2). Such data will be validated with local partners and finally georeferenced.
- Dams and water reservoirs, whose location, age, height, usage (hydropower or irrigation) and storage capacity are available in the Global Reservoir and Dam (GRanD) database produced by NASA (Lehner et al., 2011). The type, age, height and volume of main central Asian dams are provided in the annex of a specific UN report (2007). Main dams' location and use/capacity are provided by Unesco AQUASTAT (http://ihp-wins.unesco.org/layers/geonode:dams_centralasia). Specific studies are available at a national scale (e.g. Rakhmatullaev et al., 2010 for Uzbekistan). All the available information sources will be compared, combined together and validated with the help of the local experts. Dams and water reservoirs play a relevant role also for flood protection and for agriculture. Main dams' location is available from the NASA dataset, which includes dams age and main use (hydropower, floods, irrigation). The dataset contains also details on the reservoir capacity, which have been mentioned in the report. As for flood protection infrastructure, OpenStreetMap provides a classification of waterways that include canals

and small ditches. However, the coverage might be limited. Local partners will contribute to identifying areas where major flood protection infrastructure is present.

Water supply infrastructure. When possible, the location of the main water supply facilities and infrastructures will be gathered based on national maps and the support of local partners. Such data will be complemented with existing reports and studies at regional (e.g., Lemenkova, 2012) in order to identify the areas where main water supply infrastructure is present. Information on the main Central Asian water basins (http://www.cawater-info.net/bd/index_e.htm) will be used to identify the areas of higher water consumption and infer where the water supply infrastructure is present.

Communication infrastructure. Few information has been found so far. The available information will be extracted by regional reports (e.g., UNESCAP, 2020) and enriched with information from local partners. In order to estimate the total length of communication lines in urban areas, in absence of other data we will assume an average lines length per unit area. Due to the limitation of the available data, specific analyses for the main communication facilities in each country will be performed only if enough data are available.

4.3.1.2.6 Commercial agriculture

Crops spatial distribution will be extracted from the Crop Dominance database (https://lpdaac.usgs.gov/products/gfsad1kcdv001/, Teluguntla P. G. and Yadav, 2015) produced for Central Asia at the resolution of 1km. The dataset is available for the nominal year 2010, produced *a posteriori* based on the elaboration of remote sensing data collected between 2007 and 2012. Recent changes in land use will be discussed with the local partners and, if necessary, modifications will be applied. Crop Dominance information will be complemented with national datasets (e.g., FAOSTAT, http://www.fao.org), national agricultural production data, local partners knowledge and recent aerial images when available. In particular, efforts will be devoted to distinguishing the wheat and cotton crops, which both belong to the class 'Irrigated Mixed Crops 2', based on national agriculture statistics and local partners' feedback. One example of valuable information is the work of Kasimov (2013) on the value chain of cotton industry in Tajikistan.

Crops annual yield, area harvested, and production quantity will be extracted based on an average of the most recent available decade (2008-2018) yielding datasets available from the FAOSTAT website (http://www.fao.org/faostat/en/#data/QC). Finally, the growing season will be extracted from the crops calendar produced by the JRC project ASAP (https://mars.jrc.ec.europa.eu/asap/download.php) in order to account for the time differences during the year (planting, growth and harvesting period)

Data produced during past projects related to agriculture and irrigation in the region will be collected whenever possible (e.g., Meerbach, 2013).

4.3.1.2.7 Replacement costs

Replacement cost estimates will be collected from previous studies in the area or estimated based on the available data. Local partners will support the consortium to gather construction costs for each country and for specific asset types, when possible. Replacement costs for other considered assets can be inferred by scaling the collected replacement costs accordingly. As a last resort, we propose to base our estimates on construction costs from areas with similar socio-economic settings (e.g., Russian federal administrations having similar characteristics).

Buildings. The replacement cost report produced within the World Bank project "Measuring Risk in Kyrgyz Republic" was based on the construction cost declared by international construction datasets. However, to reliably estimate replacement costs for each country and its specific socio-economic settings, such estimates will be validated together with the local partners, who can retrieve average building costs and/or involve local practitioners. The outcomes of the World Bank project 'Strengthening Catastrophe Risk Transfer Supervision', developed in Kazakhstan (2010), will be also taken into account. Finally, and particularly for flood damage assessment, construction costs estimates need to account for the value of non-residential objects (in particular, the buildings' content) (Merz et al., 2010). The relation between content and building value will be addressed during the project based on the information collected by local partners and experts. Content replacement costs are usually assumed as a percentage of the building value. However, such percentage can be very high in case of industrial and commercial activities. Estimates of content value/cost in relation to different lines of business are available from different disaster loss assessment frameworks (e.g., HAZUS). The ratio between building value and content value can be inferred from such databases. Ratios will then be adjusted based on the Central Asian regional and national economy (e.g., GDP) and on the input of local partners, who will provide useful insights on specific assets' values.

Crops. The yielding and price estimates collected from the above-mentioned sources (see previous sections) will be used to calculate the expected value produced for the area unit. Crops price will be extracted from the FAOSTAT database that contains monthly and yearly produced price index (http://www.fao.org/faostat/en/#data/PP) for the time interval 2004-2016. The FAOSTAT contains also other price indicators that can be used to complement the analysis (http://www.fao.org/prices/en/). The Crop Dominance classes include multiple crop types. Should it not be possible to differentiate specific crops, the average of the crops prices in each class will be used as reference. The prices time variability will be also taken into account by using the average price and yield in the time period between 2010 (year for which the crop dominance map is available) and the year for which the most recent yield and price data are available (e.g., for Tajikistan, wheat price data on FAOSTAT are available between 2010 and 2019). Note that the FAOSTAT database can contain some gaps. Data produced during past projects related to agriculture and irrigation will be collected whenever possible (e.g., https://documents.worldbank.org/en/publication/documents-reports/documentdetail/604041468273032016/kyrgyz-republic-second-on-farm-irrigation-project-p096409-implementation-status-results-report-sequence-11). A global dataset of irrigated land is provided by Siebert et al. (2015) and allows the identification of the main areas in each country where irrigation systems are deployed. The replacement cost will then be assumed as a fraction of the total crop price for the area unit.

Transport infrastructure. Replacement costs will be defined based on the building costs retrieved from international construction datasets or, if possible, from recent infrastructure projects in the region. Local partners (in particular TSTU, former TashIIT for Uzbekistan) may provide estimates for the construction costs of railways, bridges, roads and other transportation-related assets, which could be used as a starting point to estimate the costs for the other countries (to be validated with the help of other local representatives). Maintenance and repair costs will be accounted for, when possible. Special attention will be devoted to the identification of the influence of railway features on costs in the particular context of Central Asia. Replacement costs will be differentiated based on the aforementioned railway, road and bridge types (4.3.1.2.3). Results will be compared with those provided by Free et al., 2018 for Kyrgyzstan.

4.3.1.2.8 2080 projections

The assignment requires to provide projected population and building stock in 2080. Three socio-economic scenarios will be defined based on shared socio-economic pathways (SSPs), GDP and population projections and urban growth modelling. SSPs are scenarios defined in order to assess the future socio-economic development under different conditions (e.g., fossil-fueled development, energy consumption). Each SSP is associated to a narrative that describes the expected socio-economic changes and to a set of projected indicators (e.g., projected population, GDP, urbanization rate). An overview of the SSPs and their implications can be found in Riahi et al. (2017). The consortium will consider three SSPs scenarios: SS1 (sustainability), SS4 (inequality) and SS5 (fossil-fuel development). The SSPs have been selected based on the narratives proposed by Pedde et al. (2019) specifically for Central Asia:

a) SSP1: *"This scenario is characterized by cooperation between nations in the region and between external actors. [...] Countries start to collaborate effectively thanks to the establishment of an effective supervisory intergovernmental body in key common policy areas such as energy diversification, water policy and food production. Population grows steadily. Thanks to effective long-term oriented governance, larger shares of the population have access to resources and global markets. […]"* (Pedde et al. 2019).

b) SSP4: *"This scenario is characterized by large and growing inequalities particularly within countries, with a powerful elite established in all countries of Central Asia. These strong and connected elites ensure a high level of stability within and across countries through international connections and collaborations. […] The elite is furthermore responsible for effective management of migratory fluxes with China and Russia; establishment of common environmental standards across Central Asia; cross-regional cooperation related to infrastructural projects; water management; and exploitation of natural resources. [...]"* (Pedde et al. 2019).

c) SSP5: *"The global scene is characterized by a positive attitude to competitive markets, innovation and participatory societies to produce rapid technological progress and development of society. As a result, the economic development is generally good and international trade is intensified. Partly this is driven by exploitation of fossil fuel resources. There is also a lack of environmental concerns in the world and the lifestyle is 'globalized' with high material consumption. The implementation of the Sustainable Development Goals (SDGs) has been relatively successful with regard to reducing inequality between countries, but less successful with regard to environmental issues. Also, in Central Asia, there is a competitive economic development largely based on the fossil fuel industry. The region experiences a boom and there is an inflow of investments and people, partly reinforced by an international development of increased international mobility and opening of labor markets. Also, the agricultural sector has seen a good development of its productivity, partly due to improved technologies within this sector. However, the environment in Central Asia pays a high price for the development, and governments mainly focus collaboration on issues that are of importance for the economic development."* (Pedde et al. 2019).

The projections for 2080 will be based on the following steps:

1. Projected population and GDP. 2080 projections provided by International Institute for Applied Systems Analysis (IIASA) based on the five SSPs for the Asia region will be used as a starting point. The dataset includes projections of the main indicators for fixed years in the period 2005-2100. At regional scale the variables include population, GDP, built-up

area and cropland available for the 5 SSPs. For single countries, the basic variables (population, other demographic variables, GDP) are provided. GDP and population projections are also available from the NASA SEDAC dataset for the time period 1900-2100 (Gaffin et al., 2004) and can be used to compare the outcomes.

2. Projected national urban growth. Urban growth will be extracted from the results of Li et al. (2019) who provides projected urban area growth per year and country for the time interval 2020-2067 and for the five SSPs. The growth rate for the remaining years (2067-2080) will be estimated by applying the average growth rate in the final decade of Li's dataset (2057-2067). These values will be also compared and complemented with the ones provided by Jing et al. (2020) for the countries of the Belt and Road region. The extracted urban area growth rate will be assumed valid for the urban areas within the country (i.e., the main cities).
3. Projected changes in residential building stock. The present residential building stock (defined in the previous steps of the exposure assessment based on Pittore et al., 2020) will be used as a basis for estimating the building stock based on the projected urban/rural growth. It will be assumed that future residential buildings belong to the recently constructed typologies contained in the exposure dataset developed by Pittore et al. (2020). The recently constructed building typologies will be characterized based on the analysis of the residential building stock in the exposure layers. While no information is available on the age of residential/commercial buildings, some building typologies are currently in use while others are being gradually abandoned. As a starting point, the consortium will use the data collected in the World Housing Encyclopedia, available mainly for Kyrgyzstan (http://db.world-housing.net/list/?country=Kyrgyzstan). The age filters will allow to identify images of older and more recent building types. The projected building stock will be constituted of building types that are recent and/or widely used in the area. The consortium will interact with local partners in order to validate this selection against the building stock in each specific country. When possible, specific analysis will be done separately for urban and rural areas within each country, in order to account for the different urban/rural development patterns. This is also valid for rural areas that are expected to be urbanized by 2080. Residential buildings in rural areas will also be estimated according to the projected rural growth based on the same assumption, but excluding obsolete building typologies (e.g., adobe). These assumptions will be discussed with local partners and strategies might be differentiated at a national scale. The number of commercial buildings will be increased proportionally to the increase of residential buildings estimated under each scenario. Industrial buildings will be increased in number in the areas where development is expected (to be identified with the help of local partners, e.g., in main cities and around infrastructures such as the belt road).
4. Projected changes in transportation. The assumption will be made that areas with expected urbanization or critical infrastructures are associated with a subsequent increased transportation and infrastructure system. The results of Meijer et al. (2018) can be used in order to estimate the total road length in 2080 based on the projected GDP and population. Global freight projections can be also extracted from the ITF report (2019).
5. Identification of future urban/rural areas. In order to distinguish between rural and urban areas, the consortium will use digital maps of population counts for urban/rural areas and urban land fraction in 2080 available for different SSPs (Gao, 2020; Gao and O'Neill, 2020). Based on the spatial distribution of urban/rural areas, the consortium will identify the areas

with expected population growth and urbanization in the region. In this phase, it will be paramount to interact with local experts and territorial planners to identify the areas undergoing strong development in each country and discuss the projections.

6. Projection of replacement costs. For each of the selected scenarios, the projection of the replacement cost for buildings will be estimated by correcting the present replacement cost based on specific projected indicators (GDP, population, inflation) for each country.
7. Production of the projected exposure layers. The expected changes in urban land extension, population, road infrastructure and replacement costs will be applied to the identified urban and rural areas. The exposed assets number/density will be increased based on the identified trends. Final exposure layers will reflect the expected exposure in 2080 under the different scenarios considered.

4.3.2 Validation

Exposure datasets collected will be validated by the consortium team at regional and national scale. Sub-national and local-scale validation will be a relevant part of the objectives of the five exposure workshops (Section 5). Targeted validation exercises will actively involve local communities (practitioners, university students). In particular, remote-sensing data will be used to extract the most relevant exposure assets in specific target areas (e.g., identification of industrial areas based on satellite images such as Landsat and Sentinel-2). Higher-resolution images can be used to validate and infer the characteristics of specific features (e.g., road or bridge type). Finally, workshop participants will be encouraged to provide their own data (e.g., building images) that can be used to for the training activities. Results of the validation process will be collected into the Interim exposure development report, underlining the main differences and discussing issues and open challenges.

4.3.3 Modelling outputs

The exposure development report (Deliverable D4a) is due by the end of week #61, on December 30th, 2021. The report will include a description of the employed methodologies and the main bottlenecks and the challenges identified by the team during the exposure data development. The document will also provide indications on the maintenance actions required to keep the exposure dataset up-to-date (ex. how to update the database, how often, using which data sources) and on the tools to be used for this purpose (e.g., GIS tools, inspection forms). The document will not exhaustively describe all the existing procedures to update the exposure layers, but it will include the most relevant ones, for which instructions will be given during the capacity building workshops (Section 5).

Another output consists of the geospatial data layers with metadata (Deliverable D4b, due by the end of week #61, on December 30th, 2021) for all the exposed assets identified, in a format compliant with the technical requirements listed in the Terms of Reference and with the GFDRR Risk Data Schema. Exposure layers will be produced in the form of shapefiles representing the location of the exposed assets and the exposure fields required for the risk analysis, in the format required by the Annex 1 of the TOR. Special care will be taken in complying with all the licenses and policies of the different data sources.

4.4 Development and validation of physical vulnerability or fragility relationships and casualty relationships

A vulnerability function provides a relationship between a hazard intensity measure and the expected loss for a specific exposed asset, while fragility functions are probability distributions that are used to indicate the probability that a component, element or system will be damaged to a given or more severe damage state.

Physical vulnerability, fragility and casualty relationships will be built under Task 5 to provide inputs to Task 6 to perform a consistent risk assessment for both earthquake and flood hazards. The relationships for the two perils will be developed in parallel, leveraging on the consolidated consortium experience and considering available data in literature, local databases and previous projects mentioned in Section 3 combined with findings from Task 4 regarding the assets information gathered during the development of the exposure dataset.

4.4.1 Flood vulnerability

The flood vulnerability component provides a probabilistic relationship between the flood depth or the rainfall intensity and the loss ratio expected by a specific asset at that site. The model reflects the large size of the structure inventory and the lack of data to fully characterize each building individually by considering classes of structures rather than individual buildings. These classes cover all the structures of the building exposure database, including residential, commercial, industrial and public buildings, road and rail transport networks and crops.

The flood risk will be assessed by means of vulnerability functions (also known as damage functions), which relate the flood depth/rainfall intensity computed by the pluvial and fluvial flood hazard model with the level of damage and/or with the fatalities corresponding to a certain event. The granularity and complexity of the vulnerability functions is strictly linked to the granularity and level of detail of the exposure database (see Section 4.3 for more details).

Three families of flood vulnerability functions will be developed:

1. Population vulnerability functions: curves that relate flood depth and/or the flood extension with number of people affected
2. Direct damage vulnerability: curves that relate flood depth with the level of direct damage in different categories of building, infrastructure and crop, depending on the characteristics of the asset
3. Indirect damage vulnerability: curves that relate flood depth with the economic consequences on productive sectors (i.e., costs of downtime/business interruption).

4.4.1.1 Fluvial flood vulnerability

Regarding fluvial flood direct damage vulnerability, a fully-customizable, validated, cutting-edge methodology for fluvial flood vulnerability estimation called INSYDE (F. Dottori et al., 2016) will be employed. This methodology is component-based and mechanism-based, i.e., it can produce vulnerability functions by considering different components of the assets and different damage mechanisms. This methodology is fully adaptable to the amount of information available for the project. The results will be a set of spatially-distributed relationships that allows determining the level of damage depending on the flood depth. This will in turn allow the production of a damage map corresponding to any flood event, in a swift, computationally straightforward manner. Vulnerability functions will be developed and calibrated on the data available and then incorporated into the loss computations. These vulnerability curves will include direct damage on structure and content of the buildings.

Existing vulnerability relationships will be used for curve validation and comparison, and, when needed to complement curves developed within the framework of this project. In particular, the Global Flood Depth-Damage functions developed by the Joint Research Centre of the European Commission (Huizinga et al., 2017) will be considered (see example in Figure 16). These curves are based on an extensive literature survey and the estimation of maximum damage values based on construction cost surveys from multinational construction companies. The curves are also harmonized globally using statistical regressions with socio-economic World Development Indicators. The Standard Method 2004 Damage and Casualties Caused by Flooding report (Kok et al., 2004) will also be used for the same purposes.

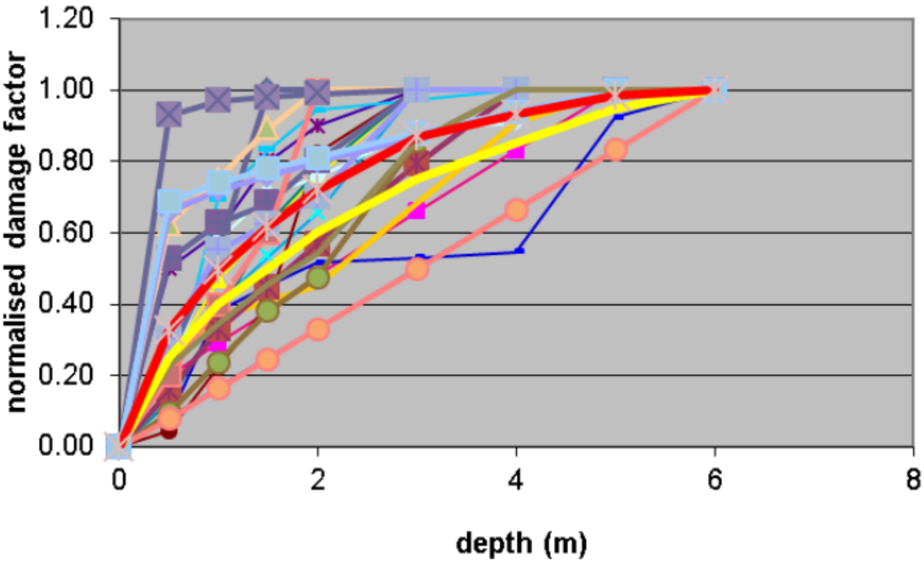

Figure 16. Example of existing damage functions for different types of residential buildings in Asia from Huizinga et al., 2017.

Regarding fluvial flood population vulnerability, the number of persons affected by a flood will be estimated based on underlying population maps, used for the development of exposure database. Life loss will be evaluated through flood depth/velocity relationships derived from stability analysis, such as Milanesi et al. (2016). It is important to note that, given the large uncertainty of these methodologies, a calibration will be needed to adjust such curves based on the fatalities caused by historical floods in the region, such those listed in Section 4.2 among the five key scenarios selected.

4.4.1.2 Pluvial flood vulnerability

Vulnerability functions of high-resolution state-of-the-art catastrophe models used for insurance purposes are typically built based on asset-level damage observations and their corresponding measure of event intensity (e.g., flood depth). Vulnerability curves are obtained fitting several pairs of asset-level damage vs intensity points, disaggregated by line of business, occupancy, building material, etc. This is not feasible within the framework of this study, due to the lack of data at such detailed level (i.e., hundreds or thousands of damage ratio observations at the asset level, for several types of building and infrastructure), at least according to the team's knowledge. This methodology is also undesirable within the framework of this study, given the purpose and scale of the risk model, which will be used to guide national and sub-national disaster risk management policy (as opposed to asset-based risk assessment for insurance purposes).

Given the above, pluvial flood vulnerability will be determined following a statistical approach. The vulnerability curves will be represented by a parametric mathematical function and its parameters will be selected in the calibration procedure based on historically recorded rainfall accumulation and historical event losses. Statistical (as opposed to physically-based) vulnerability functions will be developed for pluvial flood, this approach is a necessary simplification, given that rainfall intensity and level of damage do not show a clear correlation (such as the one between flood depth and level of damage) since damages are mostly caused by consequent events induced by the precipitations such as mudflows, landslides, and flash floods. It is therefore impossible to derive physically-based pluvial flood vulnerability functions using rainfall intensity as the intensity measure.

Construction typologies, occupancy classes, building code requirements, construction practices and other parameters affecting the vulnerability will be taken into account considering the information provided in the exposure database (see Section 4.3 for more details).

4.4.2 Seismic vulnerability

4.4.2.1 Physical vulnerability functions

From a seismic engineering point of view, a vulnerability function represents the expected loss in a building of a given construction type selected according to specific structural characteristics (material, number of floors, age, etc.) for different levels of ground motion intensity imposed by an earthquake motion. The first step in the development of earthquake vulnerability functions requires the identification and classification of the main structural and construction characteristics of the exposed assets. For this project, using the input information from the exposure database developed during Task 4 (see Section 4.3 for more details) building classes will be identified (or, more in general, structure classes for other assets, such as bridges) based on construction material, structural system, building occupancy, height, and building code, as the main characteristics that have an impact on the structural behavior under earthquake excitation. Then we will develop a vulnerability function for each one of such class. For this purpose, it is possible to use reference information that has been obtained in previous risk assessment projects. For instance, the earthquake vulnerability functions for buildings in Kazakhstan developed by the World Bank in 2010 (World Bank, 2010), or the set of earthquake fragility curves and the vulnerability index for buildings, roads and bridges developed by the World Bank in 2017 for the Kyrgyz Republic (Word Bank, 2017), might be used as a base reference for estimating the physical vulnerability of the exposed assets in the target countries.

The earthquake vulnerability functions are a probabilistic representation of loss that provides information about the expected value and its dispersion. To develop these earthquake vulnerability functions, the following steps will be carried out:

1. Definition of a seismic intensity parameter that better correlates with the structural damage of each specific building typology. In this case, the considered hazard intensity measure (IM), will likely correspond to the spectral acceleration associated with the fundamental vibration period representative of each building typology. Other IMs, such as the average spectral acceleration in a relevant oscillatory period range will also be evaluated.

2. Definition of the structural characteristics that best represent the non-linear behavior, such as inter-story height, number of stories and spans, use and location of the structure, as well as material properties. The Consortium is well aware that this information is difficult to gather; therefore, local partners' support will play an important role in identifying building codes, experimental test results, approximate year of construction for the building stock, among other information.
3. Computation of non-linear analyses to estimate the structural response. These analyses might be static with incremental monotonic lateral loads or incremental dynamic analysis.
4. Development of a damage model to obtain a relation between the structural response and the expected loss. As the structural vulnerability will be defined in terms of the repairing/reconstruction cost ratio, a damage index will be computed and associated with the physical damage using information available in the literature.
5. As the last step, the expected loss computed in the previous point will be associated with the corresponding hazard IM that produced the already computed structural response. Besides, the vulnerability functions will be calibrated and validated with information from available reports of field surveys of previous earthquake events, available results from previous vulnerability studies developed in the region, and disaster loss databases.

4.4.2.2 Human vulnerability functions

The human losses (fatalities and injuries) due to earthquakes have decreased over time in many countries because of the development of new building codes, which include stricter design specifications, reflected in the improvement of safety and reliability that the structures provide. However, the need to model the economic and life consequences of disasters induced by natural hazards has led several researchers to develop methodologies for the estimation of the number of human losses after an earthquake (D'Ayala et al., 1997; Guettiche et al., A., Guéguen, 2017).

For this project, a novel methodology that combines fragility and vulnerability approaches with statistical data (Reinoso, E., Jaimes, M., Esteva, 2017) will be employed. The steps in this methodology are:

1. Identification of the type of structure to link with a fragility curve associated with collapse damage state. The IM, in this case spectral acceleration, will be computed.
2. The number of possible victims during an earthquake depends on the time and day the earthquake occurs, for this purpose, it is necessary to estimate the number of people inside a building at the time of the earthquake. Then, such occupancy number will be computed, through an occupancy rate included into the methodology, which estimates the number of occupants inside the buildings considering two cases: seismic events occurring during the day and during the night.
3. A fatality rate and entrapment rate will be selected from the research performed by Reinoso, E., Jaimes, M. and Esteva (2017), considering the number of people trapped or deceased and the number of occupants of a collapsed building, taking into account the structural type and a specific collapse mechanism for each structural type, for example the pancake type for flat slab structures and the overturning of the façade for masonry structures, and other factors such as occupants behavior, number of stories (or building height), type of contents and type and velocity of the collapse (Reinoso, E., Jaimes, M. and Esteva, 2017). Based on the aforementioned assumptions, it is important to point out that the uncertainty in mortality rates due to different failure modes for a single structures is not taken into account in this approach.

4. Non-structural components and contents inside buildings can produce injuries and human fatalities during earthquakes, even if the structure does not collapse. For that, a fatality rate due to damage associated with non-structural components and overturned contents, as a function from expected damage conditional to the structure's survival, is employed. This expected damage can be obtained from fragility functions.

4.4.3 Validation

The vulnerability curves will be validated by comparing the loss model results with the economic losses caused by historical events, where available. Therefore, a consequence database of historical events will be compiled. The consortium has a long experience in consequence database development and is fully aware of the issues and limits of existing catalogues. The consequence database will include information on all historical events that caused damage or affected part of the population of all the target countries. A review of scientific studies and historical studies on frequency, severity, and spatial distribution of events affecting the target countries will be carried out starting from the projects and information mentioned in Section 3, but additional information will be searched for during the development of the task. Where possible, the impact will be disaggregated geographically (by region, country, etc.).

4.4.4 Modelling outputs

The technical report on vulnerability (Deliverable D5a) will be completed by the end of week #61, on December 30th, 2021, including the description of existing structural vulnerability and fragility relationships and casualty estimation relationships and existing gaps in vulnerability information and the development process. Moreover, an inventory of data sources, validation process and all relationships applied during the risk assessment will be provided.

4.5 Earthquake and flood risk assessment to support Disaster Risk Management and Financing activities

This section describes the approach that will be followed for a probabilistic estimation of risk due to earthquakes and floods in Central Asia for both the 2020 and 2080 exposure cases and for the five selected earthquake and flood scenarios, to be developed under Task 6. The methodology for risk estimation will use as an input the results of Tasks 2, 3, 4 and 5. Landslide risk will be analyzed during Task 7 (see Section 4.6 for more details) through a scenario-based approach and will not be included in the probabilistic estimation presented in this section.

A probabilistic analysis of risk is intended to estimate the distribution of the probability of losses for a group of exposed assets (e.g., building stock, roads, railways, crops) and population over a given period of time, as a consequence of the occurrence of future events. The proposed methodology is state of the art and is based on probabilistic techniques that consider the uncertainties existing in the different steps required to estimate the risk in the target countries. The risk is characterized by economic and human losses due to simulated earthquakes and floods collected in a stochastically-generated catalogue of events that are statistically consistent with the historical events. For earthquake and flood hazard the stochastic catalogs developed in Tasks 2 and 3 of the project will represent 10,000 years of events. The result from this probabilistic methodology is a key element to underpin regional and national risk financing and insurance applications, as explained at the end of this section.

The proposed methodology evaluates losses that will affect a group of exposed assets during each of the scenarios that collectively describe the hazard, and then probabilistically weighting the results obtained for each scenario by the likelihood that the specific scenario will occur in the year following the analysis. This evaluation of risk requires the following analytical steps (see Figure 17):

1) Hazard assessment (seismic, pluvial and fluvial flood), which, for regional studies such as this one, consists of assembling stochastic catalogs that will represent 10,000 years of all hypothetical earthquakes and floods, with related annual frequency of occurrence, that may occur in the region of interest (see Sections 4.1, 4.2.2 and 4.2.3).
2) Definition of the inventory of exposed assets (e.g., building stock, roads, railways, crops), including replacement cost for the estimation of ground-up losses and population for estimation of casualties. Again, this computation will be carried out for both the 2020 and the 2080 exposure conditions. For the earthquake risk assessment case the seismicity will be considered stationary in time while for the flood risk assessment case we will consider different projections of climate conditions as described in Section 4.2.6.
3) Vulnerability functions of classes of exposed assets.
4) Probabilistic Risk Assessment of economic and human losses, in metrics such as:
   - Annual Average Loss (AAL)
   - Probable Maximum Loss (PML)
   - Exceedance Probability Curves (EPC)
   - Year Loss Tables (YLT)
5) Extraction of hazard and risk footprints and of loss estimates with uncertainty for the five selected earthquake and flood scenarios

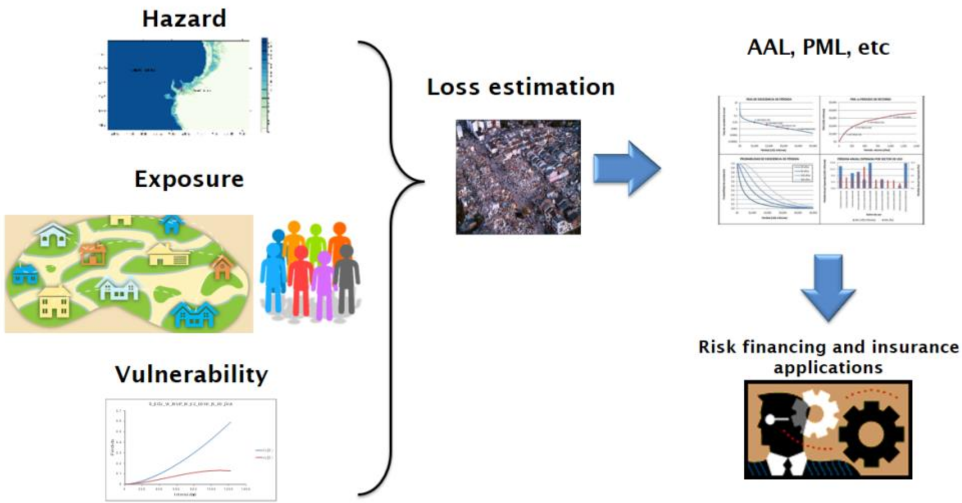

Figure 17. Risk assessment methodology for a specific hazard, the procedure will be applied separately to the two hazards considered in the analysis, earthquake and flood.

The risk of natural hazards is fully described by an Exceedance Probability Curve (EPC), which provides the annual frequencies (or rates) of exceedance of different loss values due to the occurrence of natural events (e.g., earthquakes or floods). The inverse of the annual frequency of exceedance of a given loss is the so-called return period of the loss, namely the average amount of time that one has to wait to observe such a loss or greater.

Other specific estimators of risk, such as the Average Annual Loss (AAL, i.e., the expected value of the annual loss) and the Probable Maximum Loss (PML, i.e., a loss that does not occur frequently and is associated with a specific return period), can be obtained from the information contained in the EPC curve.

This framework's outputs will be summarized in digital thematic maps, showing AAL and selected return period losses aggregated at different geographical Administration Levels (ADM): ADM1, ADM0 and regional levels, for both the 2020 and all 2080 exposure and climate change projections.

Scenario analysis will also be performed. This analysis will allow the estimation of losses (economic and human) given the occurrence of specific events. For example, a historical earthquake or flood that produced significant damage in the past, and for preparedness and mitigation plans it is important to estimate the probable losses according to the current exposed assets. The loss results will be presented both in terms of mean value and confidence intervals.

The risk assessment will be computed using the CAPRA platform (www.ecapra.org) (Figure 18), which is an open-source and free platform for probabilistic and deterministic risk assessment. CAPRA is an on-going initiative that has been developed in different phases with the initial financial support of the World Bank, the Inter-American Development Bank and the UNISDR (Reinoso et al., 2018). ERN International was the key leader in developing the probabilistic risk assessment methodologies for the CAPRA platform; that experience will be valuable for the development of this project.

CAPRA provides different advantages such as: multi-peril assessment, includes the probabilistic methodologies described in this section, allows the use of geographical information (exposure, hazard) and the outputs of the analysis are aligned with the risk metrics required in this project (AAL, PML, etc.) for economic and human losses.

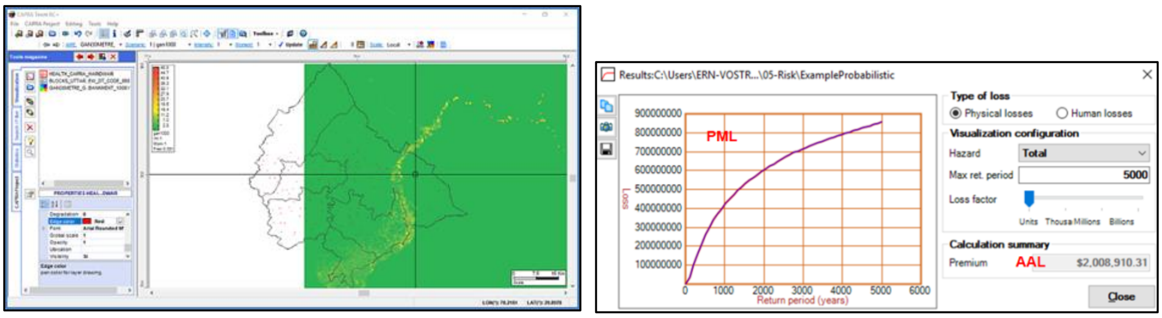

Figure 18. CAPRA interface (left) and results on screen (right)

The risk to crops will be based on GIS layers with information of crop area and estimated yield per crop type, and hazard footprints for specific return periods (for example, 100 and 500 years).

In addition to the probabilistic metrics described, exposure of industrial sites, critical facilities (excluding schools, healthcare) and supply infrastructure will be quantified in terms of number or kilometer length exposed to key thresholds of hazard intensity. This quantification and emergency response costs will be based on GIS layers with information of exposed assets, including replacement values and hazard layers.

Before completing the task, a validation process will be carried out through historical scenario analysis by comparing the model results on an event-by-event basis with reported losses from historical events, obtained from public available information in the literature (project reports, research papers, etc.). A useful representation of this validation is using scatter plots of observed vs. simulated losses; these plots are particularly useful for comparing the observed and simulated losses and assessing eventual systematic biases.

4.5.1 Application of risk results to regional and national risk financing and insurance purposes

A common step of catastrophic risk management undertaken by governments, after they have identified, measured, and mitigated risk, is to transfer or obtain financing from global markets. Internationally placed insurance, multi-lateral contingent loans, public foreign debt and catastrophe bonds, are all examples of instruments available in the global markets that interact with a country's own reserve funds (i.e., earmarked to fund disaster losses) as part of a comprehensive Risk Management Policy[13]. The way governments mix and use those instruments depends mainly on the objectives that each one has in terms of dealing with the social costs, and the budget available to fund its activities.

In fact, the risk management strategy of a country may be focused mainly on the protection of public assets, or, on the other end of the spectrum, on the well-being of specific population vulnerable to natural catastrophes even when these events generate limited economic losses. Under any strategy, it is important to consider the opportunity cost of allocating resources to execute disaster risk management strategies, as well as to have a clear measure of their impact and social benefits. For this reason, it is necessary to adopt a methodology that can socially compare costs and benefits of alternative strategies so that policymakers can act wisely[14].

4.5.1.1 General description of the proposed methodology

The first step is to consider the Exceedance Probability Curve (EPC), that already includes the public assets and goals to protect. The EPC is built, in more formal terms (as described previously in this section) by computing the rate of exceeding certain levels of loss.

The EPCs of the different natural events (earthquake and flood) are used to estimate the benefits and costs of the financial instruments to be considered in each risk management strategy. The specific measures for such costs and benefits are their price and the net losses that each financial instrument generates. The net probable losses after financial instruments recoveries are computed by aggregating ground-up losses for each modelled event (synthetic and historical) into a new EPC. These losses are considered as gross in terms of financial instrument recoveries. To produce net losses, we will generate actuarially consistent scenarios to estimate the recoveries. This cost-benefit analysis can be carried out through the comparison of the current risk scenario without the

[13] We use capital letters to highlight the active role that many governments around the world are taking to explicitly formulate public policies around the financial management of the costs of disasters (natural or man-made) as a permanent function.

[14] Most countries already use a social measure of the cost of public funds (i.e., the social discount rate) for these purposes.

application of any risk transferring strategy with a scenario that includes the risk financing strategy considered. The common metrics used to evaluate the results of the analysis are mainly the annual aggregate loss and a probable maximum loss.

The main analysis will be on financial instruments that protect the public finances on a national level. However, particular analyses of indirect allocation of losses and recoveries can be produced for the different sectors (e.g., residential/commercial/industrial buildings, education, healthcare, or road/rail) to the extent that it makes sense to use some of the chosen financial instruments on a sectorial level.

To produce the cost-benefit analysis for this step, the methodology includes a formal description of the attributes of each risk transfer or financing instrument, including self-funds. For this analysis three different generic instruments will be considered: set-aside fund, contingent debt, and insurance. DRFI assessment requires only the EPC and a set of assumptions related to each financial instrument.

Set-aside fund corresponds to a financial resource that a government allocates to meet the needs that may arise in the event of a catastrophic risk under specific operating rules. Its constitution, traditionally, is generated over several years in which part of the budget for risk management is set-aside, until the accumulated amount has reached the proposed total.

Contingent debt is a financial instrument traditionally contracted between a government and a multilateral of international aid entity of developed countries, the purpose of which is to provide resources to the country in the event of the occurrence of a catastrophic risk, through the figure of debt. Generally, this type of debt is issued with better conditions than those to which the government could ordinarily have access, for example, lower interest rate, longer repayment periods, etc.

Insurance used to transfer the losses arising from the occurrence of a catastrophic event to a third party in exchange for the payment of a premium. Catastrophe bonds also fall under this category. In the issuance of this type of contracts it is established the characteristics of the catastrophic event that will trigger the payment by the insurer, the maximum amount of responsibility by the insurer and the cost or premium.

In each case, we will compute the net losses for each modelled event, as a function of the loss borne by the financial instrument, that is, the benefit of the financial instrument, the lower and upper limit of responsibility for each event in charge of the financial instrument, the aggregate loss in charge of the financial instrument and the accumulated loss in charge of the financial instrument.

Indemnity and parametric financial instruments will be analyzed. All risk financing instruments consider payment triggers that are aligned with the probabilistic model to assess relative performance. In general, indemnity insurance for large scale catastrophic losses has several caveats: scarcity of loss adjusters in the affected country, high underinsurance in the private sector that results in attempts to transfer such losses to the government (moral hazard), dated asset inventories (if any). All these aspects are not included in the modelling, and hence will not be treated endogenously. Rather, a discussion on their implications will be included in the report to help the governments understand the pros and cons of traditional insurance.

From the general analytical framework above, which will be further detailed during the development of the project, costs and benefits' metrics can be analyzed. After all the costs and benefits are computed, policy makers can categorize, prioritize, and execute disaster risk management strategies to achieve the highest social impact in a cost-effective manner.

4.5.2 Modelling outputs

A technical report on the risk assessment (Deliverable D6a) will be completed by the end of week #82, on May 27th, 2022, including the description of the methodology, the outcomes and their validation. In addition to the report, full EP curve (EPC) and event or year loss table per different Administration Levels (ADM1 unit, country and region, for each combination of hazard and asset type analyzed) will be provided in tabular format (Deliverable D6b). Tabulated return period loss estimates and AAL for each combination of hazard and asset type, at ADM1 and ADM0 levels, and for the whole region will be provided in tabular format at least for the following return periods: 5, 10, 25, 50, 100, 250, 500, and 1000 years (Deliverable D6c). Tabulated scenario losses for deterministic analysis and tabulated summary of key industrial sites, critical and supply infrastructure, and expected hazard intensity at selected return periods will be provided in tabular format (Deliverable D6d). GIS-compatible geospatial data layers with metadata, describing estimated loss (AAL and selected return period losses) per ADM1 unit, and identifying the location of key industrial sites, critical and supply infrastructure and expected hazard at those locations will be provided in raster or vector formats (Deliverable D6e).

4.6 Landslide scenario assessment

4.6.1 Methodology

Landslide susceptibility will be assessed during the development of Task 7 by the application of geo-statistical analyses. Through a close collaboration with Tasks 2 and 3, scenarios in compliance with the earthquake and flood hazards will be obtained ensuring homogeneity among the outputs (e.g., the same reference return periods and map scale will be used). The consortium has already developed and tested a variety of methodologies in different geographic settings and at different scales (Casagli and Catani, 2020; Catani et al., 2013, 2005; Di Traglia et al., 2018; Segoni et al., 2018; Tacconi Stefanelli et al., 2020; Trigila et al., 2013). These methodologies can be adjusted to a multi-scale approach in the target countries, depending both on the input data collected on inception and during the data acquisition stages.

4.6.2 Model set-up

To obtain a spatial description of the predisposition to *earthquake-induced* and *rain-triggered* landslides at a regional level a series of landslide susceptibility index maps will be generated by means of the "Random Forest" machine learning algorithm, which is credited as one of the most advanced techniques in this field (Catani et al., 2013). The available DEM resolution (SRTM or AsterGDEM DEMs) is considered optimal, for the Random Forest susceptibility estimation. Input data will include all predisposing factors commonly associated to landslides. The algorithm has an internal procedure of forward selection of parameters that can evaluate a large number of explanatory variables, handling collinearity and selecting with an objective and quantitative criterion only the most important variables to be used to define the susceptibility map. The input parameters will include thematic layers as geology and land cover, DTM-derived morphometric and hydrologic attributes (e.g., steepness, curvature, topographic wetness index, etc.), rainfall regime, road networks, buildings and, in order to study in detail *earthquake-induced* landslides, distance-from-faults and levels of the peak ground acceleration expected with specified return periods. Depending on the thematic accuracy of the landslide dataset to be used for calibration, the susceptibility assessment will be differentiated according to the available landslide characteristics (e.g., rainfall-triggered vs. earthquake-induced; deep seated vs. shallow). In order to train the susceptibility model, existing landslide inventories available from the literature (Behling et al., 2016; Havenith et al., 2015a; Pittore et al., 2018, Pittore et al., 2020) and provided by local partners will be used. A significant contribution in this step will come from the experience and expertise of the local experts. The landslide expected intensity, which influences the vulnerability of the elements at risk, will be modelled with a newly developed and tested methodology, based on a morphometric approach, differentiated according to the landslide typologies. For slow-moving slides, intensity will be initially defined in terms of magnitude (dimensions) with statistical analyses on the frequency of dimensions of existing inventories. For rapid landslides, the intensity will be estimated by means of morphological and geostatistical analyses, to be used as a proxy for the velocity. The assessment of landslide exposure, obtained during the exposure data development phase, will be defined considering, for the present and for different future projections:

i. the number of people living in a certain area
ii. the use and economic value of the buildings
iii. the importance of the infrastructures.

The landslide exposure assessment will be carried out at locations based on their high-risk level, which will be selected in agreement with the local experts in the consortium and with RSTC. At finer scales, in order to simulate the process path and run-out area of rain-triggered and seismically induced landslides (mudflows-debris flows-rock avalanches), the Gravitational Process Path (GPP) model (Wichmann, 2017) will be used. The GPP open-source model works in a SAGA-GIS environment and simulates the movement of a mass point over a raster Digital Terrain Model (DTM) from an initiation site to the deposition area. The method will provide the assessment of the intensity of the modelled phenomena, combining both modelled flow thickness and velocity.

4.6.3 Landslide transport disruption

An intensity-based disruption index will be applied to estimate disruption to transport links due to landslides. The potential disruption-duration will be assessed by combining the potential landslide severity and the infrastructure type/length of the impacted section. In this framework, the UNESCO Chair will collaborate with the consortium local experts and RSTC in order to evaluate different scenarios.

4.6.4 Landslide river damming analysis

The river obstruction from a landslide can have extremely dangerous multiscale consequences, as the dammed river swamps the upstream area with rising water level. Furthermore, landslide dams can be part of a chain process, when landslides trigger dams collapse, falling into the retained water body, or are triggered by outburst floods released by a dam failure. A common methodology used for quantitative analysis in earth sciences is the use of morphometric indexes. They are formed by morphometric parameters characterizing the involved elements (e.g., the landslide, the valley, the river) and can assess landslide dam formation and evolution. In this project an innovative method with proven capability in assessing the dam formation will be adopted, called "Morphological Obstruction Index (MOI) method" (Tacconi Stefanelli et al., 2020). The index expression is the ratio of two of the most important parameters of the landslide and of the valley, the landslide volume and the riverbed width. These can be easily derived from a wide range of digital information of the ground (DTM, optical imagery, even using Google-Earth™) and a landslide database. All these common and widespread tools can be integrated in order to overcome local lacks or limitations. Landslide dams classified using MOI are divided within three domains of evolution:

i. formed
ii. not formed
iii. uncertain evolution

The regions bounds are drawn by two lines, the "non-formation straight line" and the "formation straight line". The valley width does not change significantly over decades within each river stretch and can be considered a static variable. Therefore, the average river width of each river stretch can be measured with a semi-automatic GIS procedure and starting from the equations of the two lines, two threshold landslide volumes Vl' and Vl" (non-formation volume and formation volume) able to block a river can be calculated at each section. Vl' is the minimum volume of formation, below which a landslide does not produce any complete obstruction, and Vl" is the minimum value above which the dam is formed. Using a landslide inventory, with some simplifications is possible to estimate landslide volumes. Landslides with volume bigger than Vl' and Vl" for their river section are identified as potentially prone to block the river in that point. Therefore, a "map of the damming susceptibility" for reactivation of existing landslides can be produced.

4.6.5 Validation of the hazard scenarios

A validation test will be performed through a back analysis of the historical records, leading to the definition of a more accurate landslide location. The susceptibility model will be trained using a random sample of the study area (usually about 10% of the cells in which the study area is subdivided). An independent dataset of the same size will be used for the validation. The performance of the model used will be evaluated by building a receiver operating characteristic (ROC) curve, which is a graphical plot that illustrates the diagnostic ability of a binary classifier system as its discrimination threshold is varied. The performance of the model in terms of area under curve (AUC) will be analyzed using a constant minimum number of samples proportion. As a visual comparison of the result with observations a remote sensing satellite data analysis will be performed by means of using the available datasets (SPOT, Landsat, ASTER, Rapid Eye, Sentinel), checking the spectral signature of new landslides at characteristic locations. The combination of Landslide Susceptibility Maps with satellite data can help to identify unknown phenomena and update the landslide state of activity, leading to a more accurate hazard scenario definition. As a further validation the obtained outcomes will be confronted with global datasets, such as the NASA landslide susceptibility map of 2017 (Stanley and Kirschbaum, 2017), bearing in mind the differences in spatial resolution of the two datasets (30-90 m for the new dataset compared to 1 km for NASA dataset)

4.6.6 Assumptions/Limitations

The definition of a landslide hazard scenario assessment largely depends on the characteristics of the available datasets, including spatial density of observation, accuracy of measurements and resolution of the available thematic layers. The finer possible datasets will be used, upon verification of homogeneity and completeness. A recognition of free available dataset has already been accomplished, and global or regional datasets have been identified with an accuracy that allows for a good result at the regional and local scales. Datasets with high quality but limited spatial coverage will be used in finer scale applications, running again the models (fine-tuned for the downscaled approach) and obtaining an increased accuracy in the results. The proposed methodology is based on models that can be theoretically applied at any scale of analysis: the approach from a regional to a finer scale is determined only by the spatial aggregation of the results, and by the quality and completeness of the available input datasets.

4.6.7 Modelling outputs

Interaction with the local partners will allow to define the input parameters and thematic layers selection, and to assemble them. This is expected to result in a landslide inventory (location, type, geometry and triggering/reactivations dates if available), geology and land cover/use, data set, a local DTM with 30 m spatial resolution and finer resolution in correspondence of the selected case studies; however, also global archives such as SRTM, ASTER GDEM, MERIT will be used, together with information on faults locations, peak ground acceleration, river network, mines/waste dumps/dams locations, glacier dams location, rainfall regime (as accurate as possible in terms of spatial and temporal resolution), road networks and buildings. In particular, the data infrastructures must contain typology, and the year of construction/renovation (if available) (Deliverable D7b, due by Week #61 on 30th December 2021). Through the interaction with Tasks 2 and 3, landslide hazard scenario assessment will provide different spatial-temporal scenarios for different landslide typologies and different triggers (mainly earthquakes and rainfall, while human interference in hillslope dynamics will be considered as a predisposing factor). In particular, the return period of both earthquake and rain data will be analyzed to define the temporal probability of occurrence of landslides triggered by extreme events, and then combined with the landslide susceptibility map in order to identify several spatiotemporal hazard scenarios. The hazard scenario maps products will be raster maps with a base resolution depending on the input data resolution (Deliverable D7c, due by Week #61 on 30th December 2021).

Finally, a technical report (Deliverable D7a, due by Week #61 on 30th December 2021) will provide a description of the landslide scenario assessment methodology with assumption and limitations, inventory of sources, description of hazard assessment outputs and validation.

5 Structure and content of capacity building workshops

Capacity building and knowledge transfer in Central Asia countries is one of the main objectives of the project and will be developed under Task 8. The main activity consists into a series of interim workshops organized in close collaboration with local experts and representatives for the regions. The project, in fact, will build on efforts and results from earlier studies, with the aim of harmonizing the available data at the regional scale of Central Asia. Accordingly, the Interim workshops will provide an opportunity to demonstrate the value of the methods that are applied for large-scale risk assessment, and to show how they complement and advance what was previously done in the region. In this framework, the role of local scientific advisors will be essential in recognizing and supplying relevant information from methodologies previously applied in each country, so as to demonstrate the value of the proposed procedures and to validate their products.

The consortium coordinator for Capacity Building (Antonella Peresan, OGS), together with the local coordinator for Capacity Building (Sergey Tyagunov) and with the contribution of local partners, will organize the workshops. Workshops will be tailored on local communities of scientific/technical experts and practitioners. All the partners will contribute to the development of training material and communication strategies that allow to successfully transfer the knowledge to the local communities. Participation will be possible by invitation and through an on-line application/selection process. A list of potential participants to the capacity building workshops, as defined in the technical proposal, is provided in the Appendix; identification, invitation and final selection of the participants will be done in close collaboration with the World Bank.

The contribution of local partners will be essential, not only for their expertise, but also from a logistic point of view, in order to effectively identify and involve local communities of experts and indicate the best settings and facilities for the workshops. The World Bank will also assist in partial administrative and organizational support (e.g., sharing contact information and connecting with service providers). For this purpose, dedicated meetings will be organised with the World Bank, to discuss the details of the capacity building workshops, including dates, mode and participants list, before each one is conducted.

Besides the Inception and Final Workshops, to be organized by the World Bank, the following Interim Workshops are also planned:

Three regional methodological Workshops on:

- Hazard modelling
- Vulnerability analysis
- Risk modelling

These methodological workshops will introduce international best practice and the latest methodologies and tools implemented in the framework of this Project and will include contributions from qualified local and national experts, providing state-of-the-art description of existing data and applications in their respective countries. Each workshop will comprise a focused discussion in order to identify the main issues and challenges encountered by the participants.

Five country-based workshops on Exposure assessment:
One workshop on Exposure assessment will be organized in each of the involved Countries:

- Kyrgyzstan

- Kazakhstan
- Tajikistan
- Uzbekistan
- Turkmenistan

These five workshops on Exposure assessment, will also account for the country-specific needs and data availability, and will have a significant practical training component (especially for young professionals and university students), involving analysis of selected test/validation cases and hands-on software tutorials.

5.1 Main features common to all Interim Workshops

All interim workshops will include the following main features:

- Involvement of qualified local experts in organization and training activities (lecturing and practical exercises). Their direct and in-depth knowledge of local framework and possible data issues guarantees an adequate interpretation of obtained results and may facilitate knowledge transfer to young local experts.
- Significant participation of young professionals and students from relevant university courses in the capacity building workshops. Since participation will be possible by on-line application/selection process, their involvement will be promoted as follows: a) workshops will be advertised among professors and students from relevant university courses and each professor (or thesis supervisor) will be allowed to submit the application for up to two selected students; b) final selection of participants will be done in close collaboration with the World Bank, giving priority to young professionals/partners and to the best selected students.
- The associated training materials will remain available in the form of open access on-line course. The consortium will upload it to the platform identified by the World Bank, if any, or to existing web platforms managed by the partners.
- On-line courses and materials, including those previously developed by the World Bank (https://olc.worldbank.org/content/understanding-risk - English language), will provide a fundamental background for young professionals and staff in universities and research institutes. Consideration of the on-line courses will be recommended to participants, as preliminary information useful for attending the workshops.
- All workshops will be held in English and/or Russian, with simultaneous or on-site translation between the two languages. The training materials specifically developed for the Workshops (e.g., slides or lecture notes) will also be released in Russian and English.
- All workshops will leave the space for questions and interaction with the participants, in order to collect the feedback of the local communities that will be included in interim reports. Participants will be requested to compile an anonymous questionnaire, including a basic test on the presented topics, so as to evaluate the comprehension level and the quality of the training activities, as well as to gather suggestions on how to improve them. The workshop facilitators will be available in the aftermath of the training activity, in order to answer questions related to the workshop content.

The contribution of local partners will be essential from a logistic point of view, in order to identify the best settings and facilities for the workshops. Following World Bank indications, for all the regional workshops, the venue at Almaty-based CESDRR (Kazakhstan) will be used, as Almaty is more accessible than other regional locations. For the country-based workshops, the capital city is considered, since it should be accessible to all the participants of the workshops.

An overview of the workshops is provided in the next section and the workshops time schedule, venue and organizers, are summarized in Table 7. It is intended that, in view of possible restrictions due to COVID-19 emergency, virtual workshops will be considered as an alternative to in-person workshops, as discussed in Section 5.3.

5.2 Interim workshops overview

5.2.1 T8.3 Interim workshop on Hazard Modelling

Title:	"Hazards modelling in Central Asia"
Directors:	Valerio Poggi (OGS), Gabriele Coccia (RED), William Frodella (UNESCO Chair)
Scientific advisor:	Natalya Silacheva (IS, Kazakhstan)
Local organizers:	Nursarsen Uzbekov (IS, Kazakhstan)
Time:	13 September - 17 September (Two days, within Week 46)
Venue:	Almaty, Kazakhstan.

Scope/description:
The workshop aims at providing the scientific communities of the Central Asian countries with the sufficient knowledge to understand the basic principles of a hazard assessment, with special regard to the main implications and limitations of the method and its relative modelling assumptions. This two-day technical workshop will also benefit from the contribution of local experts, who will deliver focused lectures on the current status of hazard assessment in their respective countries, with examples of key studies and ongoing activities. At the same time, participants will be trained on how to properly handle data with state-of-the-art processing tools, such as the OpenQuake seismic hazard calculation engine. Management and maintenance strategies of the different datasets produced within the project (e.g., fault database) will also be described, in order to provide to current and future potential users with the necessary guidance to integrate and extend the existing products with newly available information and interpretations.

The workshop will be composed by two complementary blocks of activities. In a first part, a theoretical introduction to hazard assessment, where scopes, base assumptions, common approaches and example applications in Europe and Asia will be illustrated through a series of thematic seminars. The second part will consist of hands-on laboratory sessions. In these sessions, more specific and technical issues will be discussed, with the support of tutorials and practical exercises directly from the Central Asia hazard model under development.

The first day of the workshop will be entirely dedicated to earthquake hazard. The second day will be devoted to flood and landslide hazards, with emphasis on floods (grossly, 75% flood and 25% landslide). In both days, theoretical lectures will be delivered in the morning, while the hands-on sessions in the afternoon. In case the workshop will take place on-line, the scheme will be preserved, but activities will be distributed over four half-days, to facilitate the participation of the attendees.

Possible speakers: Valerio Poggi (OGS, Italy), Gabriele Coccia (RED, Italy), William Frodella (UNESCO Chair, Italy). Local Experts Involved: Natalya Silacheva (IS, Kazakhstan), Murat

Kassenov (Kazselezaschita, Kazakhstan), Roman Ibragimov (Earthquake hazard, ISASUZ, Uzbekistan), Kanatbek Abdrakhmatov (Institute of Seismology, ISNASKR, Kyrgyzstan), Zhanar Raimbekova (Department of Meteorology and Hydrology, Al-Farabi Kazakh National University, Almaty, KZ), selected Members of the RSTC

Participation: Participation will be open to scientific/technical experts and practitioners, including research groups, engineers, territorial planners, representative of the main institutions and facility managers from all Central Asian countries. Participation will be possible by invitation and through on-line application. Identification and invitation of the participants will be done in close collaboration with WB and the country representatives.

Expected number of participants: 40 participants from all countries involved (Up to 60 participants, in case of fully on-line workshops)

5.2.2 T8.5 Interim Workshop on Vulnerability Analysis

Title:	"Seismic and flood vulnerability analysis in Central Asia"
Directors:	Mauro Niño (ERN), Gianbattista Bussi (RED)
Scientific advisor:	Baurzhan Adilhan (IS, Kazakhstan)
Local organizer:	Rinat Amirzhanov (IS, Kazakhstan)
Time:	17 January 2022 - 23 January 2022 (Two days, within Week 64)
Venue:	Almaty, Kazakhstan.

Scope/description:
During this 2-day workshop on the approach followed and the interpretation of the outputs of vulnerability modelling, the participants will be introduced to the different types of fragility/vulnerability functions available for the area and their field of applicability. Special attention will be devoted to the understanding of the underlying assumptions that allow choosing specific fragility/vulnerability functions from literature, and how to account for the uncertainties introduced. Practical exercises will be organized in order to allow the participants to construct, adapt or select appropriate fragility/vulnerability curves for specific building typologies or facilities in their area of expertise. Specific discussion will provide feedback to the developed fragility/vulnerability model.

The lectures will cover the following general topics:

- Background and previous work for assessing vulnerability (earthquake and flood) in Central Asia.
- Basic concepts and general issues for assessing vulnerability.
- Development of seismic vulnerability curves.
- Development of flood vulnerability curves.
- Use of the vulnerability assessment within the risk assessment framework.

Possible speakers: Mauro Niño (ERN, Mexico), Gianbattista Bussi (RED, Italy). Local Experts Involved: Baurzhan Adilhan (IS, Kazakhstan), Zukhritdin Ergashev (Vulnerability of Railway Facilities, TSTU), Zhanar Raimbekova (Department of Meteorology and Hydrology, Al-Farabi Kazakh National University, Kazakhstan), selected Members of the RSTC.

Participation: Participation will be open to scientific/technical experts and practitioners, including research groups, engineers, territorial planners, representative of the main institutions and facility managers from all Central Asian countries. Participation will be possible by invitation and through on-line application. Identification and invitation of the participants will be done in close collaboration with WB.

Expected number of participants: 40 participants from all countries involved (Up to 60 participants, in case of fully on-line workshops)

5.2.3 T8.6 Interim Workshop on Risk Modelling

Title:	"Risks modelling in Central Asia: from earthquakes to floods"
Directors:	Paolo Bazzurro (RED), Mario Ordaz (ERN)
Scientific advisor:	Vakhitkhan Ismailov (ISASUZ, Uzbekistan)
Local organizer:	Nursarsen Uzbekov (IS, Kazakhstan)
Time:	27 June -3 July 2022 (Two days, within Week 87)
Venue:	Almaty, Kazakhstan.

Scope/description:

A 2-day workshop on risk modelling will be organized by the consortium during the final phase of the project; it will be strictly connected in time with the Final Workshop to be organized by the World Bank. Participants will be showed the approach followed for risk assessment and loss estimation and will be familiarized with several risk metrics. Examples of loss calculation and risk model calibration/validation will be provided, as well as recommendations on how to use loss estimates in the framework of Disaster Risk Management strategies.

This workshop will benefit from the main findings, data and results gathered at each country's level during Exposure workshops. It will build on theoretical background provided during Hazard and Vulnerability workshops and will provide a general view of the most important aspects of risk assessment from the regional point of view of Central Asia.

The lectures will cover the following general topics during the first day of the workshop:

- Components of risk assessment (hazard, exposure and vulnerability
- What is Probabilistic Risk Assessment?
- Probabilistic and deterministic scenarios
- Common outputs of risk modelling
- Examples of risk results
- Applications of probabilistic risk assessment

The second day of the workshop will consist of hand-on sessions for the use and understanding of the CAPRA platform (www.ecapra.org). CAPRA is a tool and platform for probabilistic and deterministic risk assessment, it is open source and fully supported by ERN International. The hand-on sessions will cover the following topics:

- General overview of the CAPRA platform.
- Sections and components of the CAPRA platform.
- Outputs and results.
- Hand-on session for deterministic risk assessment.
- Hand-on session for probabilistic risk assessment.

The workshop will end with a round table with the participants, where suggestions about how to introduce the project results in the countries standard practices, accounting for local regulations and procedure, will be discussed.

Possible speakers: Paolo Bazzurro (RED, Italy), Mario Ordaz (ERN, Mexico), Stefano Parolai (OGS, Italy). Local Experts Involved: Baurzhan Adilhan (IS, Kazakhstan), Vakhitkhan Ismailov (Seismic Risk Assessment, ISASUZ, Uzbekistan), Zhanar Raimbekova (Department of Meteorology and Hydrology, Al-Farabi Kazakh National University, Kazakhstan), selected Members of the RSTC.

Participation: Participation will be open to scientific/technical experts and practitioners, including research groups, engineers, territorial planners, representative of the main institutions and facility managers from all Central Asian countries. The scientific advisor Stefano Parolai (OGS, Italy) will participate to facilitate the discussion during the round table. Participation will be possible by invitation and through on-line application. Identification and invitation of the participants will be done in close collaboration with WB.

Expected number of participants: 40 participants from all countries involved (Up to 60 participants, in case of fully on-line workshops)

5.2.4 T8.4 Interim Country-based Workshops on Exposure Mapping (five workshops)

The workshops focused on the exposure assessment will be organized in the capital cities of each of the involved target Countries, taking into account the local needs and available data. The workshops will provide a chance to gather missing information and to validate the exposure data layers with locals, promoting their specific knowledge while making the best use of it, within their respective countries. All these 2-days workshops will have a common structure, starting from basic notions and giving an overview of the data sources (e.g., global and regional datasets, remote sensing data) and tools to be used for the exposure assessment (e.g., GIS, inspection forms). Methodological and data harmonization will be promoted as much as possible between the involved Countries.

The WB-developed course (https://olc.worldbank.org/content/understanding-risk) will provide general background information, especially recommended to young professionals/researchers attending the workshops. The exposure development methodologies will be then introduced and the exposure data available for the specific country will be presented. This will create the basis for the hands-on activities: as a rule, each workshop will focus on two perils (earthquakes and floods) and study areas specifically designed to match the country priorities, for which a given set of already-collected data sources (e.g., satellite images) will be provided. Participants will also have the opportunity to bring and work on their own data (if any), so as to contribute to the testing and validation of the presented methods and software. They will be assisted by tutors, who will guide them through the use application of provided tools, as well as to prepare the necessary input data for exposure analysis. Accordingly, participants will potentially contribute to the exposure mapping for the selected areas, producing a set of exposure layers for a total of 10 selected areas.

The exercises will be focused on exposure fundamental topics, including:

- Guidelines for collecting and managing exposure data
- Accessing software and familiarizing with the basic tools
- Accessing online resources
- Replication of the exposure assessment methodology

- Preparation of the necessary input files for the subsequent risk analysis starting from sample data
- Validation of the current datasets based on additional data (e.g., aerial images)

Methodological and data harmonization will be promoted as much as possible between the involved Countries. The project, in fact, aims at large-scale risks assessment, which requires resorting to regional scale, systematically collected data sets (e.g., remote sensing images of assets for exposure analysis). Such data naturally complement high quality and very specific engineering-level building investigations, by interrelating and generalizing them to a wider territory. Accordingly, cross-checking and validation of large-scale satellite data versus the point-like engineering building-by-building inspection provided by local experts, will be one of the most important activities foreseen in the framework of the five country-based Exposure workshops. During the hands-on session, participants will have the possibility to compare and get a deeper insight on both typologies of data, their consistency, differences and limits. This will allow participants to appreciate the value of remote sensing data and will eventually provide the basis for developing a specialized community of local experts, receptive and capable to exploit the different technologies.

These workshops, especially the tutorials and practical exercises, will be tailored on participants, accounting for their scientific/technical expertise and practitioners participating the activities. To properly organize the hands-on session (e.g., define the data to be used and the tutorials' complexity level), prior to the workshops all participants will be requested to compile a questionnaire to be submitted along with the application form. The questionnaire will allow identifying target groups (e.g., students, experts) and their interests and skills; in particular, participants who wish to provide their own data will anticipate that. The specific configuration of the software to be used for hands-on tutorials (for instance by means of pre-configured virtual machine and/or remote access to a shared machine), will depend on the specific risks addressed in each workshop and will be tailored on participants expertise, based on the questionnaire answers gathered a few weeks before the workshop. Therefore, it will be finalized about one week before the specific workshop. Additional training materials (e.g., papers and manuals) will be provided to students and early-career professionals. After the completion of the exercises, there will be a specific time allocated to question and answer and/or review of the results, in order to interact with the participants, receive feedback and estimate the impact of the training.

All partners will contribute to data collection needed for Exposure workshops, as well as to development of training material and communication strategies, in order to successfully transfer the knowledge to the local communities. The local scientific advisors, in particular, will play a key role in identifying and supplying relevant data, information and results from previously applied methodologies in each country; this will provide the fundamental basis to complement and advance what has previously been done in the region, as well as to validate their products. A detailed description of the five country-based exposure workshops, including schedule and possible speakers, is presented below; the workshops time schedule, venue and organizers, are also summarized in Table 7.

5.2.5 T8.4.1 Interim workshop on exposure mapping (earthquakes and floods)

Title:	"Exposure mapping in Kazakhstan: focus on earthquakes and floods"
Directors:	Chiara Scaini (OGS), Ettore Fagà (RED)
Local organizer:	Rinat Amirzhanov (IS, Kazakhstan)
Time:	10-14 May 2021 (Two days, within Week 28)
Venue:	Almaty, Kazakhstan.

Scope/description:
This workshop will be focused on the exposure assessment related with seismic and flood hazards in Kazakhstan. The first part of the workshop will show the exposure assessment methodology. The consortium will describe the theoretical framework for the exposure assessment and will take advantage of useful examples and case-studies to illustrate their specific application to earthquakes and floods. In particular, case studies will be selected amongst the national data available. Past project examples of exposure assessment considering residential buildings, transportation system, critical infrastructures in the city of Almaty (Japan International Cooperation Agency, 2009) will be considered.

Participants will receive a set of data (e.g., satellite images, census data) or will use their own data for testing the methods and software during the exercises. Participants will be assisted by tutors, who will guide them through the use application of provided tools, as well as to prepare the necessary input data for exposure analysis.
Examples of exercises that are planned to be carried out for Kazakhstan are:

- Retrieval of crops distribution, classification of exposed crops and estimation of replacement costs
- Validation and improvement of the available Almaty exposure data set collected in the project "The study on earthquake disaster risk management for Almaty City in the Republic of Kazakhstan" (Japan International Cooperation Agency, JICA 2009), which includes several exposed assets including residential buildings but also data on the transportation system, water supply and other exposed assets.
- Validation and improvement of the available residential buildings' exposure layers. The residential buildings exposure will be validated for selected areas, using as a starting point the layers produced at national scale by the EMCA project, and at urban scale for Almaty by JICA (2009).

Other exercises will be specifically designed considering the responses to the questionnaires (to be gathered a few weeks before the workshop) and the key datasets and areas identified by the consortium while working on the exposure assessment.

Possible speakers: Chiara Scaini (OGS), Ettore Fagà (RED). Local Experts Involved: Baurzhan Adilhan (IS, Kazakhstan), Turekulova Kulanda (Kazakhstan), Amangeldy Ospanov (Kazakhstan), selected Members of the RSTC.

Participation: Participation will be open to scientific/technical experts and practitioners, including research groups, engineers, territorial planners, representative of the main institutions and facility managers from the host Country. All participants (including invited ones) will be requested to fill in an application form, including information about their expertise.

Expected number of participants: 40 participants (Up to 60 participants, in case of fully on-line workshops)

5.2.6 T8.4.2 Interim workshop on exposure mapping (floods and earthquakes)

Title:	"Exposure mapping: floods and earthquakes in Kyrgyzstan "
Directors:	Gabriele Coccia (RED), Carlos Avelar (ERN)
Local organizer:	Kanatbek Abdrakhmatov, Institute of Seismology (ISNASKR, Kyrgyzstan)
Time:	14-18 June 2021 (Two days, within Week 33)
Venue:	Biškek, Kyrgyzstan

Scope/description:
This workshop will be focused on the exposure assessment related with earthquakes and floods hazards in Kyrgyzstan. The first part of the workshop will introduce the exposure assessment methodology. The consortium will describe the theoretical framework behind the exposure assessment and will provide useful examples and case-studies to show the application to the specific topics tackled by this workshop. The explanation will be supported by examples selected among the national data available. In particular, examples of exposure assessment from past projects on the residential buildings (e.g., SENSUM, EMCA) will be used to explain the methodology. Participants will then be given a set of data (e.g., satellite images, census data) or use their own data and test the presented methods and software. Participants will be assisted by tutors, who will guide them through the use application of provided tools, as well as to prepare the necessary input data for exposure analysis.
Examples of exercises that can be deployed for Kyrgyzstan are:

- Retrieval of crops distribution, classification of exposed crops and estimation of replacement costs
- Estimation of the population living in flood-prone areas based on the existing data (e.g., EMCA residential buildings catalogue map), the global and regional population datasets (e.g., WorldPop population grid) and the available census statistics at the best available resolution.
- Validation and improvement of available residential buildings exposure layers (produced during the EMCA project). Participants will learn how to classify specific residential buildings in urban areas (e.g., Biskek, where Google maps images are available) and residential building types in rural areas (based on satellite images).

Other exercises will be designed based on the questionnaire's answers (to be gathered a few weeks before the workshop) and the key datasets and areas identified by the consortium while working on the exposure assessment.

Possible speakers: Gabriele Coccia (RED), Carlos Avelar (ERN), Chiara Scaini (OGS). Local Experts Involved: Kanatbek Abdrakhmatov, Institute of Seismology (ISNASKR, Kyrgyzstan), selected Members of the RSTC.

Participation: Participation will be open to scientific/technical experts and practitioners, including research groups, engineers, territorial planners, representative of the main institutions and facility managers from the host Country. All participants (including invited ones) will be requested to fill in an application form, including information about their expertise.

Expected number of participants: 40 participants (Up to 60 participants, in case of fully on-line workshops)

5.2.7 T8.4.3 Interim workshop on exposure mapping (earthquakes and floods)

Title:	"Exposure mapping: earthquakes and floods in Tajikistan"
Directors:	Alberto Tamaro (OGS), Gianbattista Bussi (RED)
Local organizer:	Zainalobudin Kobuliev (IWPHE NAST)
Time:	19-23 July 2021 (Two days, within Week 38)
Venue:	Dushanbe, Tajikistan.

Scope/description:
The first part of the workshop will be dedicated to the exposure assessment methodology. The consortium will describe the theoretical framework for the exposure assessment and provide useful examples and case-studies to illustrate the application to the specific hazards tackled by this workshop. The explanation will be supported by examples selected among the national data available. In particular, examples of exposure assessment from past projects will be shown to the participants.
Participants will then be given a set of data (e.g., satellite images, census data) or use their own data and test the presented methods and software. Participants will be assisted by tutors, who will guide them through the use application of provided tools, as well as to prepare the necessary input data for exposure analysis.
Examples of exercises that can be deployed for Tajikistan are:

- Retrieval of crops distribution, classification of exposed crops and estimation of replacement costs
- Estimation of the population living in the areas prone to flooding based on the existing data (e.g., EMCA residential buildings catalogue), the global and regional population datasets (e.g., WorldPop population grid) and the available census statistics at the lowest available resolution.
- Validation and improvement of available residential buildings exposure layers (e.g., those produced during the EMCA project). Participants will learn how to identify residential building types in urban and rural areas (based on satellite images or on buildings images, when available).

Other exercises will be designed based on the questionnaire answers (to be gathered a few weeks before the workshop) and the key datasets and areas identified by the consortium while working on the exposure assessment.

Possible speakers: Alberto Tamaro (OGS), Gianbattista Bussi (RED), Chiara Scaini (OGS). Local Experts Involved: Zainalobudin Kobuliev (IWPHE NAST), selected Members of the RSTC.

Participation: Participation will be open to scientific/technical experts and practitioners, including research groups, engineers, territorial planners, representative of the main institutions and facility managers from the host Country. All participants (including invited ones) will be requested to fill in an application form, including information about their expertise.

Expected number of participants: 40 participants (Up to 60 participants, in case of fully on-line workshops)

5.2.8 T8.4.4 Interim workshop on exposure mapping (earthquakes and landslides)

Title:	"Exposure mapping: earthquakes and landslides in Uzbekistan"
Directors:	Chiara Scaini (OGS), Ettore Fagà (RED)
Local organizer:	Vakhitkhan Ismailov (ISASUZ)
Time:	18 - 22 October 2021 (Two days, within Week 51)
Venue:	Tashkent, Uzbekistan

Scope/description:
The workshop will be divided in two parts. During the first one the exposure assessment methodology will be explained. The consortium will describe the theoretical framework for the exposure assessment and provide useful examples and case-studies, selected among the national data available. In particular, examples of exposure assessment from past projects e.g., EMCA project) will be selected and illustrated.
Participants will receive a set of data (e.g., aerial images, census data) or use their own, and will test the methods and software they learned. Participants will be assisted by tutors, who will guide them both through the use application of provided tools, and to the preparation of the necessary input data for exposure analysis.
Examples of exercises that can be deployed for Uzbekistan are:

- Validation and improvement of available residential buildings exposure layers available at national scale (e.g., those produced during the EMCA project). For urban areas, satellite images and other specific information provided by local partners (e.g., information about existing villages along the main railways) will be used to identify and classify rural buildings into the existing typologies, and/or update the classification according to the specific features encountered.
- Exposure assessment for main country infrastructures (e.g., roads, railways) based on available data. In particular, the contributions of local partners and participants will improve the process of identification and validation of railway assets. The partner can also provide relevant information to estimate replacement costs of such assets. This exercise will also supply useful indications that can be used to estimate replacement costs for similar infrastructures in the other Countries of the region.
- Estimation of the population living in the areas prone to earthquakes based on the existing data (e.g., EMCA residential buildings catalogue), the global and regional population datasets (e.g., WorldPop population grid) and the available census statistics at the best available resolution.

Further exercises will be designed based on the questionnaire answers (to be gathered a few weeks before the workshop) and the key datasets and areas identified by the consortium while working on the exposure assessment.

Possible speakers: Chiara Scaini (OGS), Ettore Fagà (RED). Local Experts Involved: Vakhitkhan Ismailov (ISASUZ), Zukhritdin Ergashev (TSTU), Roman Ibragimov (ISASUZ), Gany Bimurzaev (Institute of Hydrogeology and Engineering Geology "HYDROINGEO"), Nodir Tolibov (Scientific Research Hydrometeorological Institute "NIGMI"), Sharofiddin Yodgorov (ISASUZ), selected Members of the RSTC.

Participation: Participation will be open to scientific/technical experts and practitioners, including research groups, engineers, territorial planners, representative of the main institutions and facility managers from the host Country. All participants (including invited ones) will be requested to fill in an application form, including information about their expertise.

Expected number of participants: 40 participants (Up to 60 participants, in case of fully on-line workshops)

5.2.9 T8.4.5 Interim workshop on exposure mapping (earthquakes)

Title:	"Exposure mapping: earthquakes in Turkmenistan"
Directors:	Chiara Scaini (OGS), Carlos Avelar (ERN)
Local organizer:	Japar Karaev (Turkmenistan)
Time:	29 November - 3 December 2021 (Two days, within Week 57)
Venue:	Ashgabat, Turkmenistan

Scope/description:
The first part of the workshop will show the exposure assessment methodology. The consortium will describe the theoretical framework for the exposure assessment and provide useful examples and case-studies, selected among the national data available. In particular, examples of exposure assessment from past projects will be shown (e.g., EMCA for residential buildings). However, there are some restrictions to the use of national data. For this reason, the consortium will mostly use open access data and data on similar assets collected in the other Central Asian countries.

Participants will then be given a set of data (e.g., satellite images, census data) or use their own data and test the presented methods and software. Participants will be assisted by tutors, who will guide them through the use application of provided tools, as well as to prepare the necessary input data for exposure analysis.

Examples of exercises that can be deployed for Turkmenistan are:

- Estimation of the population living in the areas prone to earthquakes based on the existing data (e.g., EMCA residential buildings catalogue), the global and regional population datasets (e.g., WorldPop population grid) and the available census statistics at the lowest available resolution.
- Validation and improvement of available residential buildings exposure layers (produced during the EMCA project)
- Improvement of the definition of typical building typologies and estimation of their replacement costs based on available information supplied by local partners and/or similar information collected from the other Central Asian countries.
- Classification and validation of the main characteristics of relevant infrastructure (e.g., roads and bridges) extracted from an OpenStreetMap layer and from other open access layers.

Further exercises will be tailored on participants expertise, based on the questionnaire answers (to be gathered a few weeks before the workshop), and the key datasets and areas identified by the consortium while working on the exposure assessment. In particular, given the very limited amount of data available in the area, specific activities will be designed depending on information contributed by the participants and based on their level of knowledge of the exposed assets considered.

Possible speakers: Chiara Scaini (OGS), Carlos Avelar (ERN). Local Experts Involved: Local Experts Involved: Sergey Izyumov - head of the laboratory "Modern geodynamics and atmospheric physics" of the Institute of seismology and atmospheric physics of the Academy of Sciences of Turkmenistan. Ahmed Lokkayev - chief project engineer engineering and construction company "Sudur", selected Members of the RSTC.

Participation: Participation will be open to scientific/technical experts and practitioners, including research groups, engineers, territorial planners, representative of the main institutions and facility managers from the host Country. All participants (including invited ones) will be requested to fill in an application form, including information about their expertise.

Expected number of participants: 40 participants (Up to 60 participants, in case of fully on-line workshops)

5.2.10 Interim workshops time schedule

Disclaimer: the time schedule of the Workshops has been chosen according to the plans provided in the Technical Proposal and taking into account the local festivities. In order to account for possible, currently unpredictable events (including continued Covid-19 emergency), which might prevent the regular organization of a workshop, the dates and organization mode (either in-presence or on-line), will be confirmed (in agreement with the World Bank) 8 weeks before the beginning of the Workshop.

Table 7. Workshops time schedule

TASK 8 - Capacity Building and Knowledge Transfer WORKSHOPS LIST		ORGANIZER	TIME	LOCATION	TOPIC	DIRECTORS	LOCAL ORGANIZER
T8.2	Project inception workshop (workshop W1)	World Bank	W11 11/1 2021	Online	Inception Workshop		World Bank
T8.4.1	Interim workshop on Exposure mapping (workshop TW3)	Team - OGS/RED	W28 10/5 - 14/5 2021	Almaty Kazakhstan	"Exposure mapping in Kazakhstan: focus on earthquakes and floods"	Chiara Scaini Ettore Fagà	Rinat Amirzhanov IS- Kazakhstan
T8.4.2	Interim workshop on Exposure mapping (workshop TW4)	Team - RED/ERN	W33 14/6-18/6 2021	Biškek Kyrgyzstan	"Exposure mapping: floods and earthquakes in Kyrgyzstan "	Gabriele Coccia Carlos Avelar	Kanatbek Abdrakhmatov ISNASKR - Kyrgyzstan
T8.4.3	Interim workshop on Exposure mapping (workshop TW5)	Team - OGS/RED	W38 19/7-23/7 2021	Dushanbe Tajikistan	"Exposure mapping: earthquakes and floods in Tajikistan"	Alberto Tamaro Gianbattista Bussi	Zainalobudin Kobuliev IWPHE NAST
T8.3	Interim workshop on Hazard Modelling (workshop TW2)	Team - OGS	W46 13/9-17/9 2021	Almaty Kazakhstan	"Hazards modelling in Central Asia"	Valerio Poggi Gabriele Coccia William Frodella	Nursarsen Uzbekov IS- Kazakhstan

T8.4.4	Interim workshop on Exposure mapping (workshop TW6)	Team – OGS/RED	W51 18/10-22/10 2021	Tashkent Uzbekistan	"Exposure mapping: earthquakes and landslides in Uzbekistan"	Chiara Scaini Ettore Fagà	Vakhitkhan Ismailov: ISASUZ-Uzbekistan
T8.4.5	Interim workshop on Exposure mapping (workshop TW7)	Team - OGS/ERN	W57 29/11-3/12 2021	Ashgabat Turkmenistan	"Exposure mapping: earthquakes in Turkmenistan"	Chiara Scaini Carlos Avelar	Japar Karaev Turkmenistan
T8.5	Interim workshop on Vulnerability Analysis (workshop TW8)	Team - ERN	W64 17/01-23/01 2022	Almaty Kazakhstan	"Seismic and flood vulnerability analysis in Central Asia"	Mauro Niño Gianbattista Bussi	Rinat Amirzhanov IS- Kazakhstan
T8.6	Interim workshop on Risk Modelling (workshop TW9)	Team - RED	W87 27/6-3/7 2022	Almaty Kazakhstan	"Risks modelling in Central Asia: from earthquakes to floods"	Paolo Bazzurro Mario Ordaz	Nursarsen Uzbekov IS- Kazakhstan
T8.7	Final project workshop (workshop W10)	World Bank	W87 27/6-3/7 2022	Almaty Kazakhstan	Final Workshop		World Bank

* Workshops are **ordered chronologically**, not by task (a graphical timeline is shown in Figure 22)

5.3 Delivery of the workshops in case of continued COVID-19 emergency

The recent COVID-19 outbreak severely affected several countries in the world and most of them are currently facing restrictions imposed by the local authorities that reduce the intra- and international mobility. The evolution of the outbreak during the project time span is still very uncertain. The most critical aspect related to the COVID-19 outbreak is the organization of the workshops planned during the project development, since there is the possibility that travels among most countries will be banned or will be subject to restrictions (including quarantine or other prevention measures) during the specific periods of workshops organization.

In view of possible restrictions due to COVID-19 emergency, which are very likely to occur especially during the early interim workshops on exposure (starting in May 2021), virtual workshops will be considered as a primary/valid alternative to in-person workshops. Accordingly, organization of lectures and tutorial sessions will be organised as much as possible on remote basis (e.g., remote handling of basic materials, data or software), so that a possible shift from physical- to virtual-mode attendance will not affect the overall workshops program. However, in case of on-line organization of the activities, we propose a longer duration (i.e., 4 days, half-day only) for the workshops, in order to provide participants sufficient time to practice independently and interact with lecturers about data (especially during Exposure workshops), as well as to account for possible technical difficulties, which might arise (e.g., connection problems).

In case international travels will be actually banned at the moment of the workshop delivery, the consortium will undertake two possible solutions depending on the severity of the ban:

- If travels within the target countries will be allowed while travels from the international countries such as Europe, Mexico and USA will be banned, the local coordinator and the local representatives will take care of conducting the workshops in the target countries, identifying with the assistance of the world Bank a venue that guarantees a stable internet connection for the international partners that will participate remotely;
- If all international travels will be banned, the workshops will be delivered in a fully on-line mode. This will include webinars, group discussions and text chats (for areas with poor internet connection). Please note that on-line courses and related materials will be the expected outputs of the contract. Part of the budget expenses allocated for travels and accommodation will be used to allow the on-line delivery of workshops, such as: the preparation of digital contents (video, manuals, etc.); the possible use of a web platform facilitating remote tutorial activities; acquisition of devices to improve internet connection or the update of software to the latest version compatible with the web tools used during the workshops.

Country-based Exposure Workshops will be open to participants from the hosting country. However, if the workshops will be delivered in a fully on-line mode, a few representatives from each of the partner countries will be allowed to participate in the Exposure Workshops in the neighboring countries.

6 Workplan of activities

6.1 Workplan

Figure 19 depicts the tasks foreseen for the development of the project and their interrelations. The proposed workplan is presented in the Gantt chart in Figure 22, highlighting the duration and phasing of each task and subtask, the delivery date of each deliverable, and the workshop planning. Table 9 lists the documents and datasets that will be delivered as final output. The total proposed project duration for the completion of the project is 21 months.

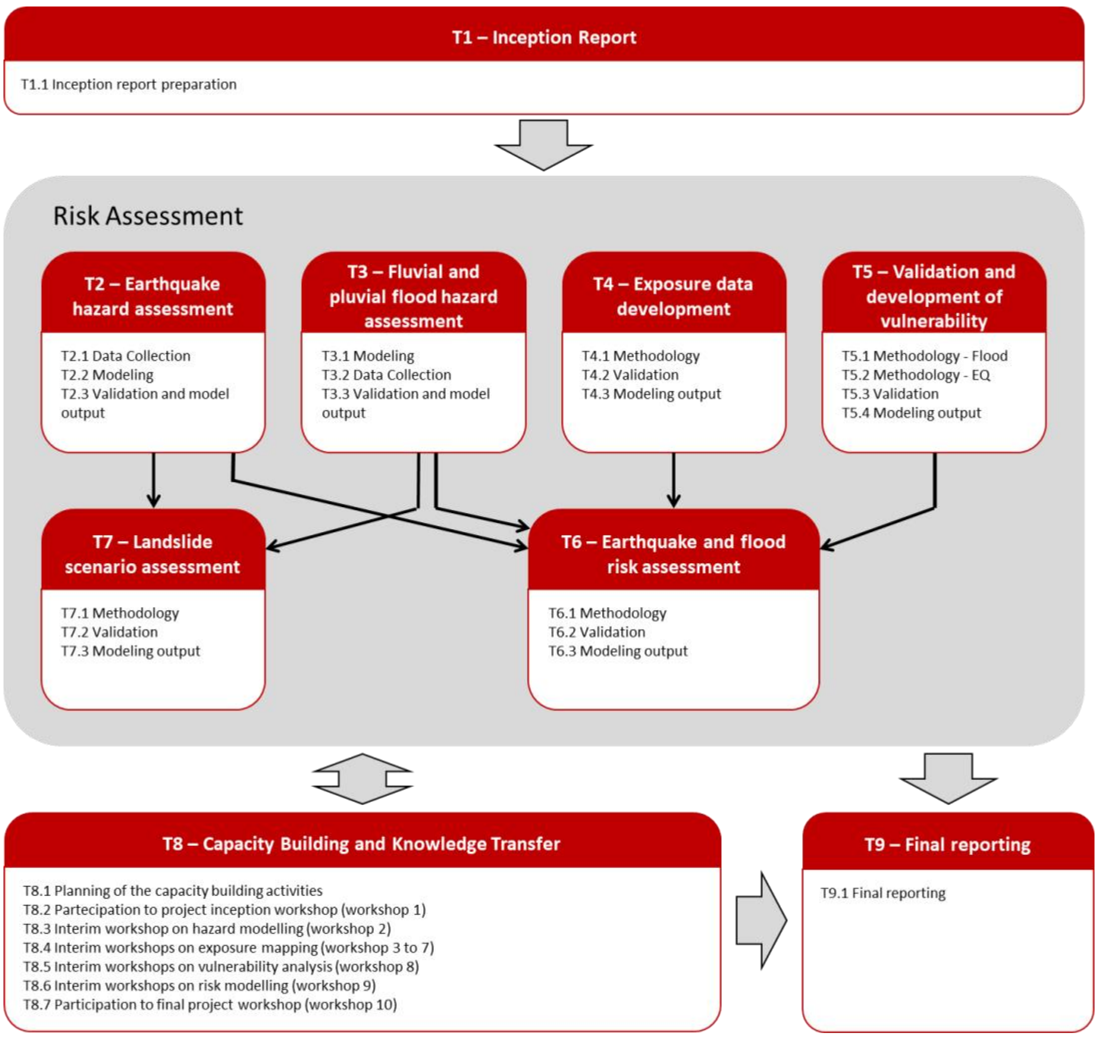

Figure 19. Scheme of project tasks and of their interactions

The proposed work plan is presented in Table 8. For a detailed schedule showing the duration of each activity, please refer to Figure 22. Delivery dates for each deliverable are provided in Table 9 and Figure 22.

Table 8. Work plan of activities

Task 1: Inception Report	
Duration	6 weeks (draft); 12 weeks (final)
Input	-
Activities	1. Background information. 2. Definition of methodology. 3. Proposal of methodology
Deliverables	D1a. Inception Report

Task 2: Earthquake hazard assessment	
Duration	37 weeks (draft deliverables), 41 weeks (final deliverables)
Input	Tasks 1, 8
Activities	1. Modelling. 2. Data Collection. 3. Validation. 4. Model output
Deliverables	D2a. Interim technical report – seismic PSHA
	D2b. Tabulated and geospatial seismic PSHA input data with full metadata
	D2c. Stochastic event sets
	D2d. Geospatial seismic PSHA output layers with full metadata

Task 3: Fluvial and pluvial flood hazard assessment	
Duration	37 weeks (draft deliverables), 41 weeks (final deliverables)
Input	Tasks 1, 8
Activities	1. Modelling. 2. Data Collection. 3. Validation. 4. Model output
Deliverables	D3a. Interim technical report – flood analysis
	D3b. Tabulated and geospatial flood analysis input data with full metadata
	D3c. Stochastic event sets
	D3d. Geospatial flood analysis output layers with full metadata

Task 4: Exposure data development	
Duration	35 weeks (draft d4a) – 37 weeks (draft d4b) - 44 weeks (final deliverables)
Input	Tasks 1, 8
Activities	1. Methods. 2. Validation. 3. Modelling output
Deliverables	D4a. Interim technical report of exposure development
	D4b. Geospatial data layers with full metadata (exposure)

Task 5: Validation and development of physical vulnerability or fragility rel. and casualty rel.	
Duration	37 weeks (draft deliverable) – 44 weeks (final deliverable)
Input	Tasks 1, 8
Activities	1. Methods – Flood. 2. Methods – Earthquake. 3. Validation. 4. Modeling output

Deliverables	D5a. Interim technical report – vulnerability data

Task 6: Earthquake and flood risk assessment	
Duration	30 weeks (draft deliverable) – 36 weeks (final deliverable)
Input	Tasks 1, 2, 3, 4, 5, 8
Activities	1. Methods. 2. Validation. 3. Modeling output
Deliverables	D6a. Interim report – seismic and flood risk assessment
	D6b. EP curves and Event / Year Loss Tables
	D6c. Tabulated return period loss estimates and AAL
	D6d. Tabulated scenario losses
	D6e. Geospatial data layers with full metadata

Task 7: Landslide scenario assessment	
Duration	33 weeks (draft d7a) – 35 weeks (draft d7b) - 44 weeks (final deliverable)
Input	Tasks 1, 2, 3, 8
Activities	1. Methods. 2. Validation. 3. Modeling output
Deliverables	D7a. Interim report – landslide scenario assessment
	D7b. Tabulated and geospatial flood analysis input data with full metadata
	D7c. Landslide scenario analysis output layers with full metadata

Task 8: Capacity Building and Knowledge Transfer	
Duration	87 weeks (workshop and trainings held during the whole project)
Input	Tasks 1, 2, 3, 4, 5, 6, 7
Activities	1. Project inception workshop (workshop 1). 2. Interim workshop 2 (Hazard modelling). 3. Interim workshops 3, 4, 5, 6, 7 (Exposure mapping). 4. Interim workshop 8 (Vulnerability analysis). 5. Final project workshop (workshop 9)
Deliverables	D8a. Project inception workshop (workshop 1) including development of training materials describing the components of this risk assessment
	D8b. Interim workshop 2 (Hazard modelling).
	D8c. Interim workshops 3, 4, 5, 6, 7 (Exposure mapping).
	D8d. Interim workshop 8 (Vulnerability analysis).
	D8e. Interim workshop 9 (Risk modelling).
	D8f. Final project workshop (workshop 10) to be held in the region prior to project conclusion. Includes training materials describing the components of this risk assessment, the application of the risk assessment, and presentation of results and discussion at the final workshop.

Task 9: Final reporting	
Duration	87 weeks (draft deliverable) – 91 weeks (final deliverable)
Input	All tasks
Activities	Final reporting
Deliverables	D9a. Final technical report
	D9b. Final country summaries

Table 9. List of deliverables

ID	Name	Description	Task	Draft week	Final week
D1a	Inception Report	Outcome from the literature review and stock-taking and the inception workshop with refined methodology and workplan	T1.1	W6	W11
D2a	Interim technical report –PSHA	Technical report describing the hazard modelling strategy and the available calibration data, with a focus on the main assumptions and possible limitations and discussion on the reliability, usability and potential limitations of the final results.	T2.1	W37	W41
D2b	Tabulated and geospatial seismic PSHA input data with full metadata	Harmonized regional fault database, background seismicity dataset, historical earthquake catalogue.	T2.3	W37	W41
D2c	Stochastic event sets	Tabulated stochastic event set for each country and the region including all event parameters, and hazard curves for selected urban areas.	T2.3	W37	W41
D2d	Geospatial seismic PSHA output layers with full metadata	Spatial distribution of peak ground acceleration and spectral acceleration for hard rock and local soil conditions and scenario footprints.	T2.3	W37	W41
D3a	Interim technical report – flood analysis	Technical report describing flood hazard assessment methodologies, inventory of data sources, inventory and description of hazard assessment outputs, validation of hazard outputs.	T3.2	W37	W41
D3b	Tabulated and geospatial flood analysis input data with full metadata	Flow gauge data, rainfall gauge data, flow hydrograph data summary of climate reanalysis.	T3.3	W37	W41
D3c	Stochastic event sets	Tabulated stochastic event set including all rainfall and flood event parameters, and hazard curves for selected urban areas.	T3.3	W37	W41

D3d	Geospatial flood analysis output layers with full metadata	Spatial distribution of flood depth for different return periods for fluvial and pluvial flood, for climate conditions at 2020 and 2080, and scenario footprints for selected events.	T3.3	W37	W41
D4a	Interim technical report of exposure development	Technical report describing exposure development methodologies and outputs (including maps); Inventory of input data sources; description and results of validation and description of how the exposure data influences the application or requirements of vulnerability / fragility relationships	T4.2	W52	W61
D4b	Geospatial data layers with full metadata (exposure)	Geospatial data layers with metadata containing distribution and attributes of each exposure asset type.	T4.3	W54	W61
D5a	Interim technical report – vulnerability data	Technical report describing existing structural vulnerability and fragility relationships and casualty estimation relationships and existing gaps in vulnerability information and the development process. Inventory of data sources and validation process; and inventory of all relationships applied in the analysis, for each (sub) category of exposure.	T5.4	W54	W61
D6a	Interim report – seismic and flood risk assessment	Technical report describing seismic and flood risk assessment methodology, validation of loss and exposed value estimates, inventory and description of all risk data outputs.	T6.2	W76	W82
D6b	EP curves and Event / Year Loss Tables	Full EP curve and event or year loss table per ADM1 unit, country and region, for each combination of hazard and asset type analyzed.	T6.3	W76	W82
D6c	Tabulated return period loss estimates and AAL	Tabulated return period loss estimates and AAL for each combination of hazard and asset type, at ADM1 and ADM0 levels, and for the whole region.	T6.3	W76	W82
D6d	Tabulated scenario losses	(1) Tabulated scenario losses resulting from the deterministic analysis, and (2) tabulated summary of hazard intensity at key industrial sites, critical and supply infrastructure for selected return periods	T6.3	W76	W82
D6e	Geospatial data layers with full metadata	GIS-compatible geospatial data layers with metadata, describing estimated loss per ADM1 unit, and identifying the location of key industrial sites, critical and supply infrastructure and expected hazard at those locations.	T6.3	W76	W82
D7a	Interim report – landslide scenario assessment	Technical report with description of landslide scenario assessment methodology with assumption and limitations, inventory of sources, description of hazard assessment outputs (scenario footprints) and validation.	T7.2	W50	W61

D7b	Tabulated and geospatial input data used to develop the scenarios. Tabulated landslide scenario parameters	Tabulated and geospatial input data used to develop the scenarios. Tabulated landslide scenario parameters.	T7.3	W54	W61
D7c	Landslide scenario analysis output layers with full metadata	Scenario footprints (distribution of landslide impact area of run-out) and impacts of scenario on population, buildings and roads.	T7.3	W54	W61
D8a	Project inception workshop (workshop 1)	Project inception including development of training materials describing the components of this risk assessment	T8.2	-	W11
D8b	Interim workshop 2	Interim workshop on hazard modelling	T8.3		W46
D8c	Interim workshops 3, 4, 5, 6, 7	Interim workshops on exposure mapping	T8.4	-	W28 W33 W38 W51 W57
D8d	Interim workshop 8	Interim workshop on vulnerability analysis	T8.5	-	W64
D8e	Interim workshop 9	Interim workshop on risk modelling analysis	T8.6	-	W87
D8f	Final project workshop (workshop 10)	Final project workshop to be held in the region prior to project conclusion. Includes training materials describing the components of this risk assessment, the application of the risk assessment, and presentation of results and discussion at the final workshop.	T8.7	-	W87
D9a	Final technical report	Technical report with background information, contents from Tasks 2-7; documentation of the attendance, discussion and output of each capacity building exercise; presentation of the risk assessment results and recommendations for future risk assessment and data development.	T9.1	W87	W91
D9b	Final country summaries	Country-specific short documents with description of the risk assessment methodology applied and presentation of the results.	T9.1	W87	W91

6.2 Project organization

The project is run by a Consortium of ten (10) partners, of which five (5) local institutes and a group of local key experts, covering all the project countries. This Consortium of international and local partners aims at providing the highest quality services for assessing risk and for strengthening financial resilience and accelerating risk reduction in the project countries. The Consortium is anyway open to integrate also other local expertise, for example during the workshops and training activities, inviting selected local key experts to share their knowledge as invited speakers (as mentioned in Section 5). This will further strengthen both the activities of capacity building and transfer of knowledge of the project, and the quality of the project outcomes.

Figure 20 presents the functional chart of the project showing that the Consortium represents a well-balanced combination of international as well as local expertise due to the involvement of several institutions belonging to the project countries.

Figure 21 schematically shows a more detailed overview of the team composition and the interaction between the partners of the consortium.

The Consortium is coordinated by Project Manager / Team Leader - Paolo Bazzurro (Director of RED), which has more than 30 years of experience in hazard and risk modelling and in the coordination of large-scale international projects. Among many others, he was the Project Leader of the "Seismic Risk Assessment for Kazakhstan" for developing a new loss assessment model and estimating the earthquake induced risk to residential buildings in Kazakhstan.

The Project Manager / Team Leader is supported by two Deputy Team Leaders who are two key experts of the projects. Mario Ordaz (ERN), together with Paolo Bazzurro, was team leader and coordinator of large regional disaster risk reduction initiatives similar to this assignment (e.g., PCRAFI, CAPRA, SPHERA-EQ and TC, XSR and others presented in detail in Section B of the Technical Proposal). Nicola Casagli (OGS) is the founder and president-elect of the International Consortium on Landslides (ICL), and member of the Major Risks National Committee of the Department of Civil Protection of the Italian Government and of the World Centre of Excellence on Landslide Risk Reduction of the International Programme on Landslides. He will work in close collaboration with experts of UNESCO Chair team, scientifically coordinated by Veronica Tofani, for the evaluation of the landslide risk assessment.

Furthermore, all the activities will be coordinated and performed following the scientific feedback of the Project Advisor – Stefano Parolai (OGS), who has been additionally involved in the Consortium after the project approval for further strengthen it, with his strong expertise in hazard and risk assessment in particular in Central Asia. Among several activities, it is worth mentioning that he was the Coordinator of the EMCA (Earthquake Model Central Asia) initiative.

The expertise of AKUA, and in particular of his founder Dario Luna-Pla, in disaster risk management, risk transfer structuring for catastrophe and specialty risks and private equity advisory for investments in the insurance and reinsurance sector will strength the Consortium activities for defining financial strategies for the project countries.

The consortium includes a specific position as Local Coordinator for Capacity Building. Sergey Tyagunov has been appointed for this role because of his close relationship with all the local partners and his more than 30 years of experience in the field of engineering seismology and earthquake engineering, being involved in several international projects such as EMCA, SIBYL (EC ECHO), SAFER (EU FP6), MATRIX (EU FP7) and CASCADE. The Local Coordinator for Capacity Building is the main point-of-contact between the international partners and local partners. Among the latter, five Local Representatives (one per project country) have been appointed for coordinating the activities to be carried out by the teams of experts of each project country. The local institutions that are partners of the Consortium are listed below:

- LLP "Institute of Seismology" of the Science Committee of the Republic of Kazakhstan (IS).
- Institute of Seismology of the Academy of Sciences of Uzbekistan (ISASUz).
- Tashkent State Transport University, which is the legal successor of the Tashkent Institute of Railway Transport Engineers (TashIIT in the proposal) (TSTU).
- Institute of water problems, hydropower and ecology, National Academy of Sciences of Tajikistan (IWPHE).
- Institute of Seismology of the National Academy of Sciences of Kyrgyz Republic (ISNASKR).

The local partners will be involved in all the project activities, as it was presented in the Technical Proposal (Annex 1). On the basis of their expertise, they will supply technical inputs for several project tasks as listed in Figure 20. Furthermore, their contribution will be fundamental to the achievement of the following tasks:

- Data collection for all tasks (especially for hazard and exposure)
- Providing information on flood defenses, reservoirs management, drainage networks
- Selection of historical/realistic scenarios
- Validation (earthquake and flood hazard and residential building typologies)
- Identification of exposed assets and areas of interest
- Involvement of workshop participants (e.g., local communities of experts) and support for identifying the best settings and facilities for the workshops.

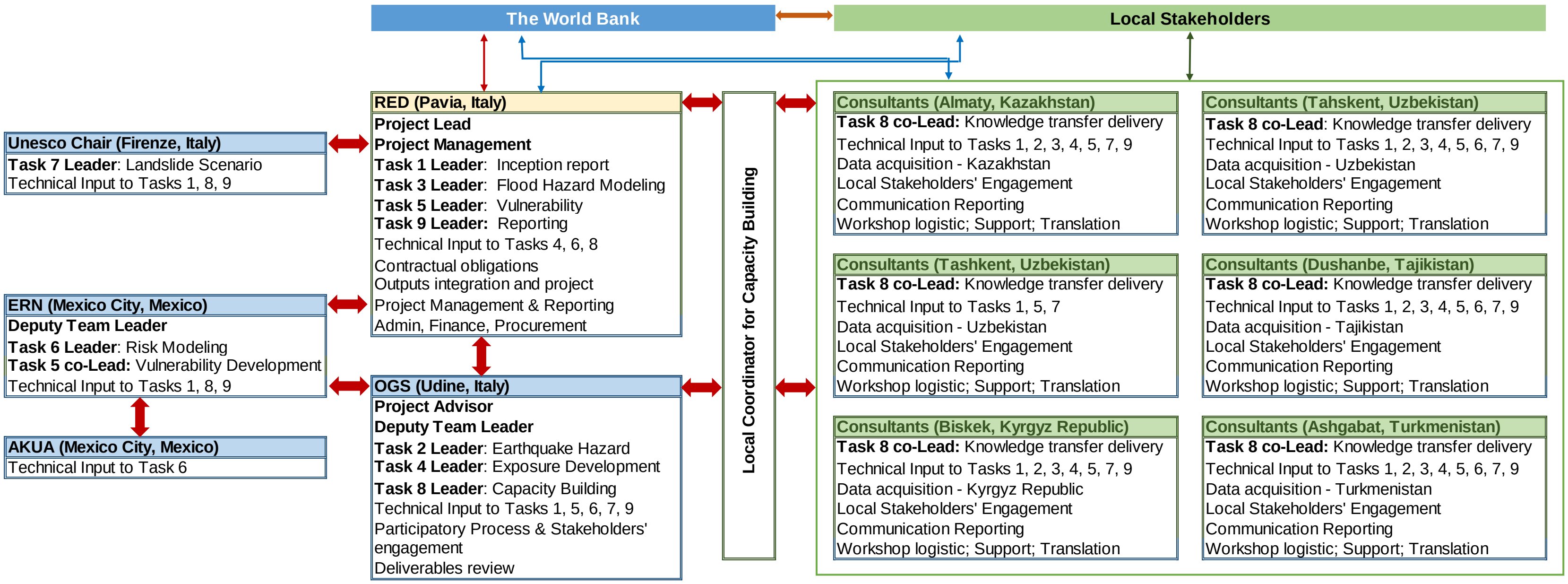

Figure 20. Functional chart of the project

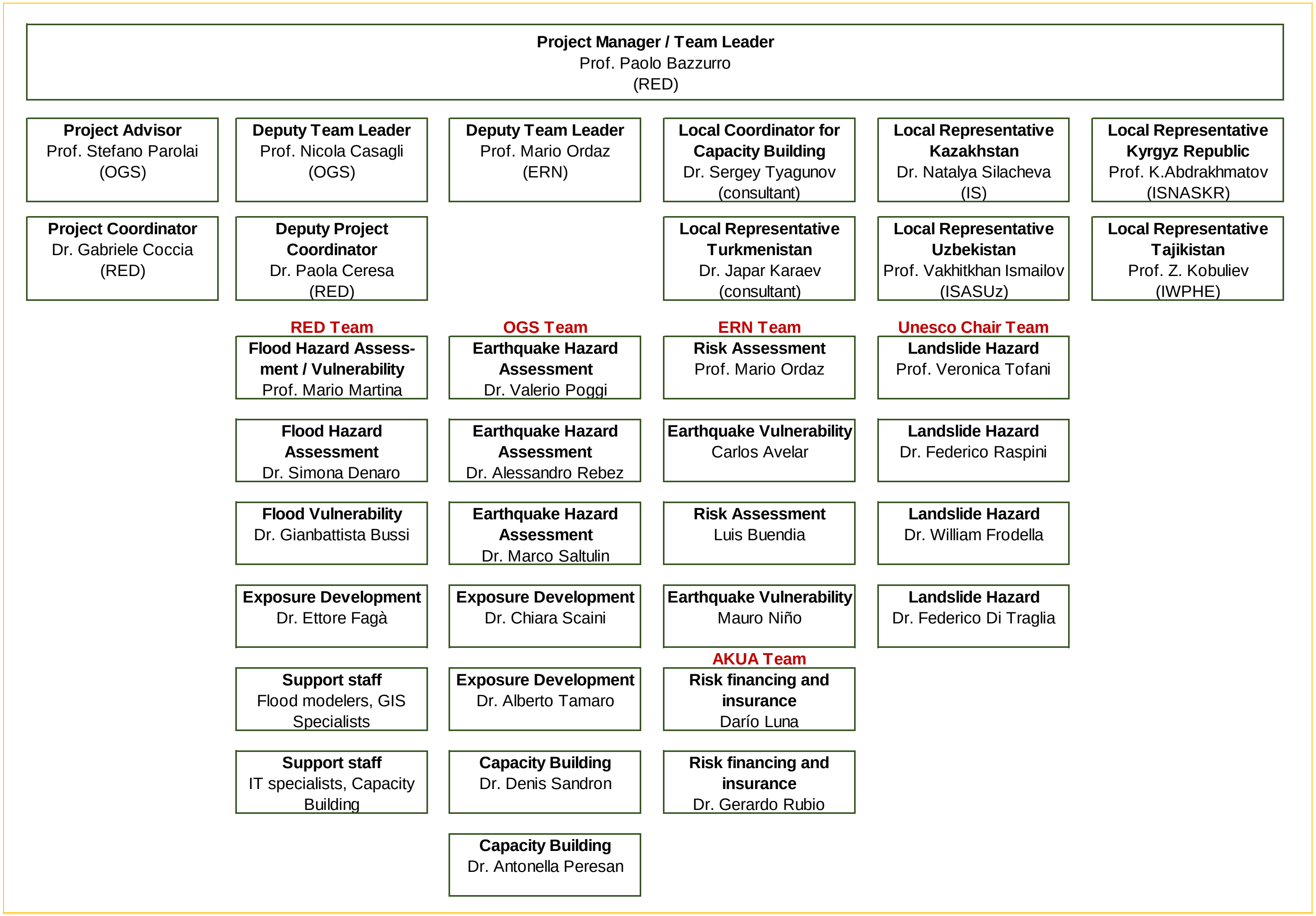

Figure 21. Organizational chart and key experts of the project

6.3 Management and reporting to the World Bank

This task represents an important pillar of the project, as it goes along the entire project and across all the other nine tasks. It keeps all the partners and activities together, assuring that the conducted initiatives will be in agreement with the overall objectives. As such, it consists of management and reporting activities that include:

(1) coordinate and oversee consistency of project activities
(2) secure the overall administrative and financial management of the project
(3) manage contacts with the World Bank
(4) manage the Consortium, keeping the partners working as a whole
(5) monitor quality and timing of project results
(6) establish effective internal and external communication procedures
(7) meet the deadlines and check the correspondence between activities and project aims
(8) draw contingency plan and implement eventually necessary corrective measures.

The project will be coordinated by RED through a Project Managing Committee (PMC) composed by the Project Manager / Team Leader (Chair of the Committee), the Project Coordinator, the Deputy Project Coordinator, the two Deputy Team Leaders, the Local Coordinator for Capacity Building, the Task Leaders (Figure 21).

The Project Manager / Team Leader working closely with the PMC ensures that the project complies with the provisions set out in the Consultancy Services Contract and achieves its objectives. The Project Coordinator and the Deputy Project Coordinator assist in the day-to-day management of the project. Furthermore, the latter will communicate, on behalf of the PMC, the status of the project to the World Bank Task Team Leads via a written summary Project Management Report (PMR) on the first Friday of each month. Furthermore, a monthly project meeting with the World Bank Task Team Leads two working days after the submission of the PMR. However, the precise day of the monthly meeting will be agreed between the World Bank Task Team Leads and the Project Manager / Team Leader during the submission of each PMR.

This task is composed by the following activities:

Overall financial and administrative management. The Project Manager / Team Leader, assisted by the other PMC members, manages the World Bank contributions and distributes funds among partners according to the rules established in the Contract Agreements. The Project Manager / Team Leader takes care of checks and audits requested by the World Bank.

Technical work coordination and monitoring. The Project Manager / Team leader leads the technical kick-off meeting with the Partners as well as he plans, implements and follows up on the periodic meetings with the Partners. The comprehensive Work Plan presented in Table 9 is the output of the kick-off meeting. The PMC meetings are scheduled for months 7, 14 and 20, potentially concurrently with the workshops scheduled on month 7 (TW3), month 14 (TW7) and month 20 (TW9 and W10), respectively. Additional meetings could be organized remotely every month or in person together with the workshops and training session events (Months 8, 9, 11, 12 and 15), as summarized in Table 10. The minutes of the meetings of the PMC will be prepared and delivered to the World

Bank. After the review of the minutes carried out by the World Bank, a coordination meeting with the Bank will be organized to clarify the progress of the project activities, as written in Table 10.

Table 10. Project management meetings

Board	Frequency of meetings	Meeting type	Chair	Notes
World Bank Task Team Leads + Project Manager / Team Leader + Project Coordinator and Deputy Project Coordinator	Every month	Virtual	World Bank Task Team Leads	Each meeting will be scheduled 2 days after the submission of the PMR
PMC	M7, M14, M20	Face-to-face (if feasible) or virtual	Project Manager / Team Leader	Further meetings could be scheduled at M8, M9, M11, M12, M15 in conjunction with the workshops.
World Bank Task Team Leads + Project Manager / Team Leader + Project Coordinator and Deputy Project Coordinator	M7, M14, M20	Virtual	World Bank Task Team Leads	The 6-monthly meetings will be scheduled after the review of the minutes of the PMC meetings by WB Task Team Leads, but not later than 5 working days after the submission of the minutes of the PMC meetings.
Task Leaders meetings	Every 3 months	Preferably virtual	Project Coordinator	
World Bank Task Team Leads + Consortium	When required	Virtual	World Bank Task Team Leads or Project Manager / Team Leader	The Consortium is available for additional meetings to address specific / urgent topics with WB, at the request of WB or Consortium when required.

The PMC has defined strategies of project monitoring and internal reporting. According to the agreements established during the preparation of the proposal and written in the Contract Agreement between the coordinating partner and the partner, each task is assigned to a responsible Partner which is in charge of supervising and reporting to the PMC on all the activities carried out under that task. On the basis of minutes of the meetings of the PMC, the Project Manager / Team Leader and the Partner responsible for each activity will monitor and report achievements and results. Progress results will be measured on the basis of the compliance of produced deliverables and achieved outcomes. The Task Leaders meetings, scheduled every three months (Table 10), will support the monitoring of the progress results.

In the event the PMC, or any of the Partners involved, identifies any delay or non-compliance with the obligations by other partners, ad-hoc strategies will be agreed with the World Bank in order to fully comply with the obligations or to find alternative measures.

The PMC supports the management of the project carried out by the Project Manager / Team Leader. The PMC approves adjustments, if necessary, to the working programme and carries out arbitration actions, according to the World Bank.

The PMC can propose changes in the working programme and gives the standards for the produced documentation, providing that the minimum obligations in terms of technical content and documentation/formats required by the World Bank are complied.

Also, the PMC defines internal and external project communication strategies and procedures. The main person responsible for the communication is the Deputy Project Coordinator. The Consortium internal communication strategy aims at ensuring the appropriate transparency and cooperation among partners as well as the timely generation, collection and storage of project information. The strategy includes three main methods of communication: email exchange, e-meetings (and, whenever feasible, face-to-face meetings), and document sharing on a platform with restricted access. Day-to-day communication will be based on emails. As already mentioned, several meetings will take place over the project implementation (Table 10) to monitor the progress of the project, planning the future activities and develop eventual corrective measures if necessary. Furthermore, a project working space platform has been set up for internal collaboration and documents distribution. After the accurate analysis of possibilities taking into account security, easiness and flexibility of use, as well as cost efficiency, the Project Coordinator has opted for *Nextcloud* (https://nextcloud.com/), that is already in use by RED, ERN and Akua Capital for managing the activities within their collaborative international projects. The File Sharing of PMR/deliverables/other documents to be delivered to WB will be carried out via Nextcloud links.

Quality management. All partners are responsible for the quality assurance of the project. The quality of the project activities and outputs will be monitored by the members of the PMC according to the roles and responsibilities defined in Figure 21. A total of 27 deliverables need to be submitted to the World Bank over the project implementation. A set of guidelines is presented here below to ensure the efficient, timely and high-quality delivery of all deliverables.

a. *Due date and progress monitoring.* The due date of the deliverable is specified in the Work Plan and in Table 9. Progress on deliverables is monitored on monthly basis by the **Project Coordinator** and the **Deputy Project Coordinator** through an Excel-based tool – Deliverable Monitoring file – which is uploaded the Project Platform *Nextcloud*. This file contains the list of all project deliverables with their related details: description, due date, responsible partner(s), identified internal reviewer, status. The status of upcoming and eventually pending deliverables should be monitored by the **Task Leaders** and reported to the **Deputy Project Coordinator**. Any problem or expected delays should be flagged immediately providing explanation, any planned mitigation action and the anticipated completion date.
b. *Deliverable templates and naming.* A template for the deliverables (such as reports, presentations) has been produced and is available on the project platform. If the deliverable is a report, the template already provides the following general structure to be maintained and followed: cover page, revision history, table of contents, introduction, core part, references, annexes (optional).
c. *Deliverable processes: preparation, review and approval.* The **Project Coordinator** will inform the Consortium of the upcoming **deliverable that are due within 3 months** from communication.

The Deliverable Leading partner identified in the proposal and reported in the **Deliverable Monitoring Table** is responsible for the preparation, editing and quality of a deliverable. The partners in charge for each deliverable are reported within the "Deliverable Monitoring" file stored in the project platform.

As agreed with the World Bank during the inception phase, the deliverables (drafts and final versions) will be released in English and in Russian, according to the schedule reported in Table 9.

An internal review process is a key step in the preparation of the deliverable in order to guarantee that the result is up to the appropriate standard. All partners should therefore take the appropriate steps to ensure that this process is completed in time in order to issue the deliverable within the due date.

The PMC identifies as **internal reviewers** for each deliverable both the **Project Manager / Team Leader and the Project Advisor**. The leading partner will share the deliverable final draft with the appointed reviewers once ready, **14 working days** before the due date at latest. Then, the reviewers are in charge of a thorough check of the deliverable, making sure the following **quality criteria** are respected. If the deliverable is a **report**, quality checks will be carried out evaluating if: the content is consistent with the project task; the objectives of the deliverable are clear, smart and in line with project objectives; the content is scientifically correct; appropriate references and citations are provided; English grammar rules are correctly applied, and the text is easy to read and understand; the deliverable follows the formatting rules and templates of the project. If the deliverable will be a **data set**, the Consortium will define ad-hoc quality management criteria. Even if the specifics of these criteria will depend on the types of datasets to be released, the Consortium will assess the accuracy, consistency, completeness, integrity and timeliness of the data sets. Regarding the evaluation of the **accuracy** of the data sets, the proposed methodology will indicate whether data is void of significant errors. A typical metric to measure accuracy is the ratio of data to errors, a metric that tracks the number of known errors (such as a missing, an incomplete or a redundant entry) relatively to the data set. When feasible, the **consistency** of the data sets will be evaluated checking that values are within a reasonable range for the represented variable and data values pulled out from separate data sets are not conflicting with each other. The **completeness** of the data sets will be evaluated and measured by determining whether or not each data entry is a full data entry. Ad-hoc techniques will be set up to check if all available data entry fields are complete and to reduce, when feasible, the number of empty values within a data set. Regarding the **integrity** of the data sets, this step is already carried out in all the validation phases of this Technical Assignment. In terms of **timeliness** of data sets, the activities of the Consortium are planned for releasing first a draft version of each deliverable, followed by its final version to be released after the review of the WB and the RSTC members. The planned schedule of both the activities and the (draft and final) deliverables will allow to evaluate the expected time for the **availability and accessibility** of the data sets, as well as to optimize the moment when the data sets will be readily available for use. This knowledge will support the activities of the World Bank, and in general of the stakeholders, for planning and implementing new data-driven decision-making strategies for Strengthening Financial Resilience and Accelerating Risk Reduction in Central

Asia. Table 11 schematically summarised some of the checks to be implemented for the quality management of data sets.

Table 11. Examples of checks for the quality management of data sets

Accuracy	Consistency	Completeness	Integrity	Timeliness
Data is void of significant error. Ratio of data to errors.	Values within a reasonable range. Data values not conflicting with each other.	Full data entries	Validation phases	Planned schedule of activities and deliverables

Within **4 working days** from receipt, the reviewers should respond via email to both the Task Leader and the Deputy Project Coordinator indicating whether the deliverable is ready for translation in Russian language or revisions are required. In the latter case, comments and precise indications must be provided and the revision process will be repeated until final approval. Once the deliverable has been approved, the Deputy Project Coordinator will send it to the **Local Committee**, composed by a selected group of local partners appointed during the project inception phase according to their own expertise in relation to the different project tasks, **for the Russian translation**. The Local Committee will translate the deliverable within **7 working days**, then the Russian version of the deliverable will be revised by the **Local Coordinator for Capacity Building**, who should also check the consistency of the contents between the English and the Russian versions of the deliverable. Once the Russian version will be approved by the Local Coordinator for Capacity Building, the **PMC** will finalize the bilingual draft and the deliverable will be submitted to the **World Bank**. A copy will be uploaded on the project platform and the Consortium will be informed via email. The main steps of the internal review process for the release of the project deliverables are summarized in Table 12.

As per TOR requirements, the review of all deliverables will be conducted by the World Bank, in accordance with the schedule defined for draft and final deliverables set out in Table 9. The World Bank will coordinate internal review and return written review comments to the Project Manager / Team Leader for response and edits where required. A review meeting may be convened as required. Acceptance of final deliverables will be subject to the review of edits made following the review of draft deliverables.

Table 12. Main steps of the internal review process of the project deliverables

Internal Reviewers:	Project Manager / Team Leader and Project Advisor.
3 months before due date:	Project Coordinator will update the Consortium on the upcoming deliverables.
14 working days before due date:	English draft ready for internal review with quality management checks.
4 working days for internal review:	If positive feedback, deliverable will be sent to Local Committee; otherwise, deliverable sent back to Task Leader or Deliverable Leading Partner for review.
7 working days for Russian translation:	By the Local Committee.
2 working days for the review of bilingual deliverable:	By the Local Coordinator for Capacity Building.
2 working days for the final checks of the deliverable:	By PMC.
Due date:	Deliverable sent to WB for review by Deputy Project Coordinator.

		November 2020				December 2020					January 2021				February 2021				March 2021					April 2021				May 2021				June 2021					July 2021				August 2021			
		M1				M2					M3				M4				M5					M6				M7				M8					M9				M10			
		02/11	09/11	16/11	23/11	30/11	07/12	14/12	21/12	28/12	04/01	11/01	18/01	25/01	01/02	08/02	15/02	22/02	01/03	08/03	15/03	22/03	29/03	05/04	12/04	19/04	26/04	03/05	10/05	17/05	24/05	31/05	07/06	14/06	21/06	28/06	05/07	12/07	19/07	26/07	02/08	09/08	16/08	23/08
Task	Subtask	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
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	draft deliverable	K	Remote consortium kick-off
	WB / stakeholder feedback and revisio	W1	Project Inception Workshop
	final deliverable	TW	Training Workshop
		W10	Final Project Workshop

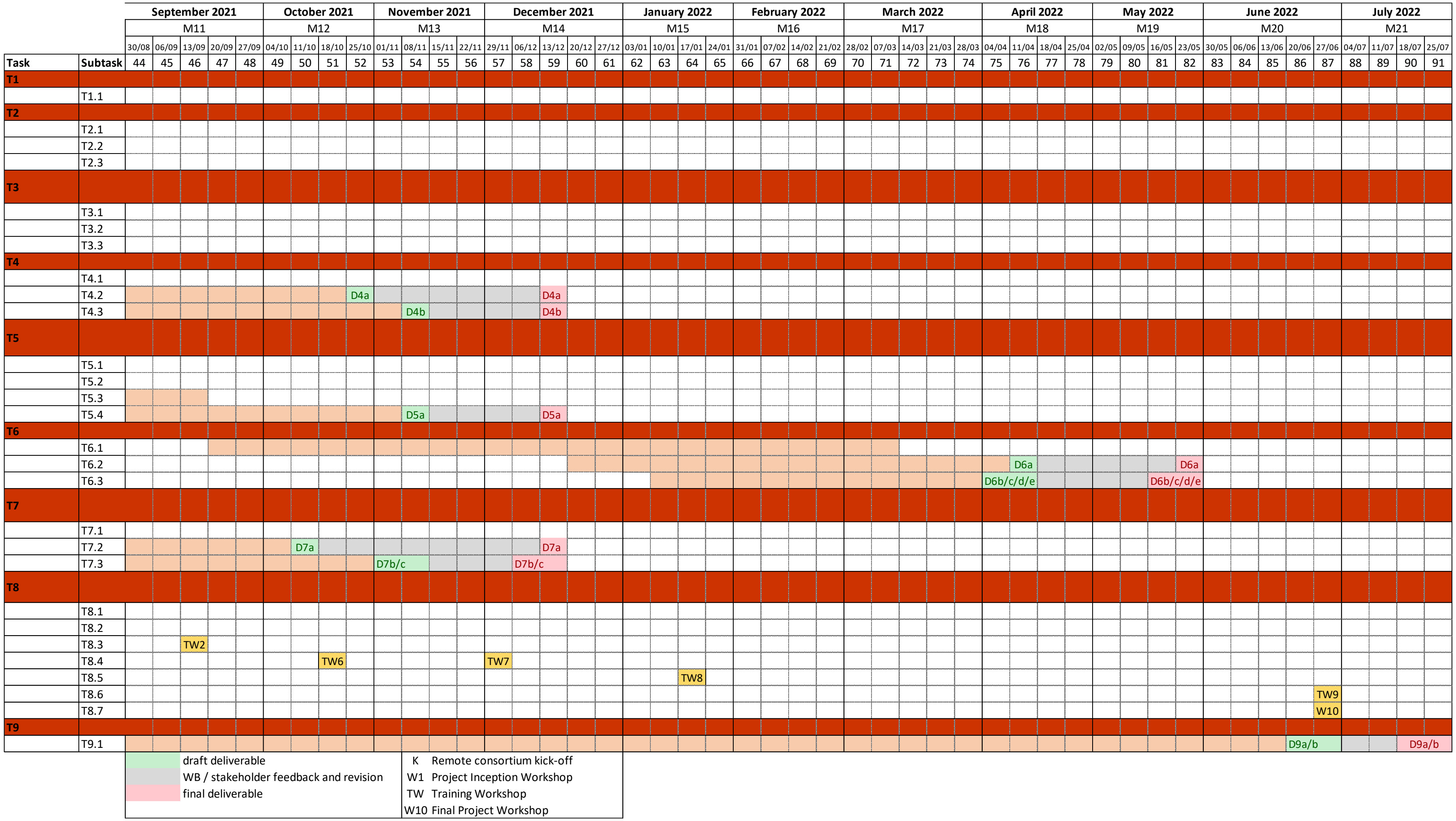

Figure 22. Gantt chart of activities, see Table 1 for tasks definition.

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Appendix A - List of potential participants to the capacity building workshops

Kazakhstan
LLP "Institute of Seismology" of the Science Committee of the Republic of Kazakhstan (IS) *(project partner)* Emergency Ministry CESDRR Kazakhstan National Data Centre KazNIISA Satbayev University Al-Farabi Kazakh National University Kazselezachita - State institution of the Committee on Emergency Situations of the Ministry of Internal Affairs of PK Kokshetau Technical Institute
Kyrgyz Republic
Institute of Seismology of the National Academy of Sciences of Kyrgyz Republic (ISNASKR) *(project partner)* Ministry of Emergency Situations CAIAG (Central-Asian Institute for Applied Geosciences) National Platform of Kyrgyz Republic on Disaster Risk Reduction Scientific and Engineering Center "Geopribor", Institute of Geomechanics and Subsoil Development GISSIIP (State Institute of Earthquake Engineering and Design) KGUSTA (Kyrgyz State University of Construction and Architecture) INTUIT (International University of Innovation Technologies)
Tajikistan
Institute of water problems, hydropower and ecology, National Academy of Sciences of Tajikistan (IWPHE) *(project partner)* Institute of Geology, Earthquake Engineering and Seismology (sub-contractor of IWPHE) Emergency Ministry Technological University of Tajikistan
Turkmenistan
Institute of Seismology and Atmospheric Physics of Academy of sciences of Turkmenistan Centre of Technologies of Academy of sciences of Turkmenistan Research Institute of the Earthquake Resistant Construction of the Ministry for Construction and Architecture Turkmen State Water Research and Design Institute of the Ministry of Agriculture and Water Resources State Commission for Emergency Situations Hyakimlik (Municipality) of the City of Ashgabat State Corporation "Turkmengeology" Research and Design Association "Turkmengosprojekt" Turkmen State Institute of Architecture and Construction
Uzbekistan
Institute of Seismology of the Academy of Sciences of Uzbekistan (ISASUz) *(project partner)* Tashkent State Transport University (TSTU, former TashIIT) (*project partner*) Hydroingeo (Institute for Hydrogeology and Engineering Geology) (*sub-contractor of ISASUz*) State Service for Monitoring of Hazardous Geological Processes (*sub-contractor of ISASUz*) Scientific Research Hydrometeorological Institute "NIGMI" (*sub-contractor of ISASUz*) National Railway Department Institute of Mechanics and Seismic Stability of Structures of the Uzbek Academy of Sciences Institute of Geology and Geophysics of the Uzbek Academy of Sciences Tashkent State Technical University Tashkent Architectural Construction Institute Turin Polytechnic University in Tashkent Emergency Ministry Ministry of Construction

Appendix B - List of acronyms

AAL: Annual Average Loss

ADRC: Asian Disaster Reduction Center

AIT: Asian Institute of Technology

ARC: African Risk Capacity

ASTER: Advanced Spaceborne Thermal Emission and Reflection Radiometer

AUC: Area Under Curve

BCPR: Bureau for Crisis Prevention and Recovery

BMBF: German Federal Ministry of Research and Technology

CAC DRMI: Central Asia and Caucasus Disaster Risk Management Initiative

CAHA-BU: Central Asia Hazard Assessment and Bulletin Unification

CAIAG: Central-Asian Institute for Applied Geosciences

CAPRA: Comprehensive Approach to Probabilistic Risk Assessment

CASC: Central Asia and South Caucasus

CASHA-BU: Central Asia Seismic Hazard Assessment and Bulletin Unification

CASRI: Central Asia Seismic Risk Initiative

CCRIF: the Caribbean Catastrophe Risk Insurance Facility

CESDRR: Center for Emergency Situations and DIsaster Risk Reduction in Almaty

CFSR: Climate Forecast System Reanalysis

CHC: Climate Hazards Center

CHIRPS: Climate Hazards Group InfraRed Precipitation with Station

CMORPH: Climate Prediction Center morphing method

DEM: Digital Elevation Model

DIPECHO: Disaster Preparedness ECHO programme

DRFI: Disaster Risk Financing and Insurance

DRM: Disaster Risk Management

DRR: Disaster Risk Reduction

DTM: Digital Terrain Model

ECHO: European Civil Protection and Humanitarian Aid Operations

ECMWF: European Centre for Medium-Range Weather Forecasts

EMCA: Earthquake Model of Central Asia (project)

EPC: Exceedance Probability Curve

ERIK: Enhancing Resilience in Kyrgyzstan (project)

ERN: Evaluación de Riesgos Naturales

ESA: European Space Agency

FAO: Food and Agriculture Organization

G1WBM: Global 1 arc-second Water Body Map

GCMT: Global Centroid Moment Tensor

GDEM: Global Digital Elevation Model

GDP: Gross Domestic Product

GEM: Global Earthquake Model

GEV: Generalized Extreme Value distribution

GFDRR: Global Facility for Disaster Reduction and Recovery

GFZ: German Research Centre for Geosciences

GIS: Geographic Information System

GISSIIP: State Institute of Earthquake Engineering and Design (Kyrgyzstan)

GLOF: Glacial lakes outburst flood

GLOFAS: Global Flood Awareness System

GMPE: Ground Motion Prediction Equations

GNSS: Global Navigation Satellite System

GPM: Global Precipitation Measurement

GPP: Gravitational Process Path model

GRIP: Global Roads Inventory Project

GSHAP: Global Seismic Hazard Assessment Program

GSWO: Global Surface Water Occurrence from Landsat

HFA: Hyogo Framework for Action

ICL: International Consortium on Landslides

IIASA: International Institute for Applied Systems Analysis

IM: Intensity Measure

IMAC: Information Management and Analytical Centre

IMERG: Integrated Multi-satellitE Retrievals for GPM

INTUIT: International University of Innovation Technologies

IRIS: Incorporated Research Institutions for Seismology

IS: LLP "Institute of Seismology" of the Science Committee of the Republic of Kazakhstan

ISASUZ: Institute of Seismology of the Academy of Science of Uzbekistan

ISC: International Seismological Centre

ISDR: International Strategy for Disaster Reduction

ISNASKR: Institute of Seismology of the Academy of Science of Kyrgyzstan

ISTC: International Science and Technology Center

ITF: International Transport Forum

IWPHE: Institute of water problems, hydropower and ecology, National Academy of Sciences of Tajikistan

JICA: Japan International Cooperation Agency

JMA: Japan Meteorological Agency

JRC: Joint Research Centre

KGUSTA: Kyrgyz State University of Construction and Architecture

KNDC: Kazakh National Data Center

KNMI: Royal Dutch Meteorological Institute

MERIT: Multi-Error-Removed Improved-Terrain DEM

MES: Ministry of Emergency Situations of the Kyrgyz Republic

MOI: Morphological Obstruction Index

MSK: Medvedev-Sponheuer-Karnik

NASA: National Aeronautics and Space Administration

NATO: North Atlantic Treaty Organization

NCEP-DOE: National Centers for Environmental Prediction - Department of Energy

NIGMI: Scientific Research Hydrometeorological Institute (Subcontractor of ISASUZ)

NOAA: National Oceanic and Atmospheric Administration

OGS: Istituto Nazionale di Oceanografia e di Geofisica Sperimentale

OSM: Open Street Map

PCRAFI: Pacific Catastrophe Risk Assessment and Financing Initiative

PGA: Peak Ground Acceleration

PMC: Project Managing Committee

PML: Probable Maximum Loss

PMR: Project Management Report

PSHA: Probabilistic Seismic Hazard Analysis

RED: Risk Engineering + Development

ROC: Receiver Operating Characteristic

RSTC: Regional Scientific and Technical Council

SAR: Synthetic Aperture Radar

SEDAC: Socioeconomic Data and Applications Center (NASA)

SEME: Seismological Experimental and Methodological Expedition

SHA: Seismic Hazard Assessment

SIBYL: SeIsmic monitoring and vulneraBility framework for civiL protection (project)SRES

SRTM: Shuttle Radar Topography Mission

TAPI: Turkmenistan–Afghanistan–Pakistan–India Pipeline

TASHIIT: Tashkent Institute of Railway Transport Engineers

TIPTIMON: Tian Shan-Pamir Monitoring Program

TOR: Term Of Reference

TRMM: Tropical Rainfall Measuring Mission

TSTU: Tashkent State Transport University (former TashIIT)

UHS: Uniform Hazard Spectra

UNDP: United Nations Development Programme

UNDRR: United Nations Office for Disaster Risk Reduction

UNESCAP: United Nations Economic and Social Commission for Asia and the Pacific

UNESCO: United Nations Educational, Scientific and Cultural Organization

UNISDR: United Nations International Strategy for Disaster Reduction

USGS: United States Geological Survey

USSR: Union of Soviet Socialist Republics

WB: World Bank

YLT: Year Loss Table

Appendix C – Glossary

1D/2D hydraulic model: both 1D and 2D models can be used to simulate fluvial flooding events. 1D models are made up of a series of cross sections describing the topography of the river and floodplain, and water levels are calculated using the 1-dimensional form of the governing equations. 2D hydraulic models use a more complex form of the governing equations and consist of a 2D computational mesh/grid, representing the underlying topography by connected cells/elements. 2D modeling have shown to better estimate flows in topographically complex floodplains, where the flow is considered largely 2-dimensional.

Building typology: the term refers to a specific building type, characterized by similarities in their function, shape, construction type, etc. The building stock in a specific area can be classified into several building typologies, defined based on the commonly observed characteristics (e.g., material, age, usage), and associated with a group of buildings that share these characteristics.

Catalogue Completeness: quantification of the threshold level above which the full spatial/temporal earthquake information is captured in the compilation.

Crop Dominance database: dataset that has been assembled based on multiple input data including satellite data and other remote-sensing data, elevation data, crop type data, meteorological data (precipitation, temperature) and statistic data at the country level. The dataset is constituted by 8 crop classes: 3 classes of irrigated crops, 4 classes of rainfed crops, one mixed crop class and two non-cropland classes.

Data harmonization: cross-checking and integration of existing data, available at different scale and for different areas.

Data samples: pre-selected data sets used to demonstrate application of the different components of risk analysis.

Deep seated landslide: landslide with a sliding surface depth ranging from a few to hundreds of meters.

Distributed physically based model: a model that is based on our understanding of the physics of the hydrological processes and use physically based equations to describe these processes.

Distributed Seismicity: representation of all the potential earthquake sources in a region as continuous spatial distribution of epi-/hypocentres within a bounded area.

Earthquake Catalogue: compilation of information of past earthquakes including at least timing, location and size.

Entrapment rate: fraction of the people who is inside a building since they were not able to evacuate it before the occurrence of an earthquake and may have been affected by the non-structural components and contents.

Exposure: the collection of highly valued resources and assets that can be susceptible to a specified hazard. It is estimated by identifying/mapping such assets and their value.

Fatality rate: the number of people who died before being rescued due to the partial or full building collapse.

Flood footprint: are maps showing the area covered by the flood water at a given time during the event.

Fluvial flood: fluvial, or riverine flooding, occurs when excessive rainfall over an extended period of time or heavy snow melt causes a river to exceed its capacity. The damage from a river flood can be widespread as the overflow affects smaller rivers downstream, often causing dams and dikes to break and swamp nearby areas.

Fragility: the probability of value loss of the exposed assets as a function of hazard intensity.

Fragility curve: relates the intensity of the earthquake and the degree of damage in a structure in terms of the cumulative probability of reaching or exceeding a certain performance level.

Frequency: is a measure of how often an event occurs on average during a unit of time (e.g., how many times an earthquake of magnitude five occurs per year).

Gross loss: the aggregate of loss payments without deductions for credits (subrogation, salvage, etc.) or reinsurance during a given period.

Ground Motion Prediction Model (GMPE): empirically calibrated equation used to predict the ground motion intensity level (e.g., PGA, PGV, SA) from an earthquake of given size and distance.

Hands-on tutorials: training activities and practical exercises delivered using specific software or via online applications.

Hazard: the potential damage, harm or adverse health effects on something or someone that can be caused by a destructive physical phenomenon. Hazard is characterized by the combination of likelihood and intensity.

Hazard Curve: curve representing the variation of the probability of exceedance for different ground motion intensity levels.

Hazard map: a map describing the areas exposed to a certain hazard intensity with a given probability.

Hazard scenario: a hazard scenario is a planning tool that helps us understand hazards (e.g., earthquakes and floods) and plan for the future. A successful scenario tells the story of a defined peril and its specific impacts.

Indemnity: in insurance, a sum of money paid as compensation for losses in exchange of a premium (insurance cost).

Knowledge transfer: training activities and practical exercises delivered using specific software or via online applications.

Landslide dam: geomorphologic processes caused by the obstructions of streams/river channels by landslides, which can cause upstream backwater formation, catastrophic downstream flooding, channel instability, changes in the river bed dynamics, and triggering of secondary landslides with a cascading effect.

Landslide hazard scenario: the way a landslide phenomenon can develop and its consequences.

Landslide susceptibility: landslide probability of occurrence.

Logic Tree: approach used in probabilistic analysis to represent the (epistemic) variability of a statistic parameter by accounting for multiple alternative realizations.

Mitigation: disaster mitigation measures are those that eliminate or reduce the impacts and risks of hazards through proactive measures taken before an emergency or disaster occurs.

Moment Magnitude (Mw): measure of the earthquake size based on the quantification of the seismic moment, which is proportional to the average displacement occurring on the fault source and its surface extension.

Net probable loss: the loss that an insurer is expected to pay on an insurance policy, after reinsurance recoveries and salvage. Insurers use various models and data to determine the risk associated with underwriting a policy, which includes estimation of probable losses.

OpenQuake: an open source seismic hazard and risk calculation software developed, maintained and distributed by the Global Earthquake Model (GEM) Foundation.

Overturning collapse: a condition that occurs when a building is literally laid over on its side.

Paleoseismological Data: information about ancient earthquakes usually retrieved from rock and sediment analysis.

Pancake collapse: this type of collapse happens when some or all floors of a building end up lying on top of each other like the layers of a pancake, with the floor contents crushed between them.

Parametric Insurance: a non-traditional insurance product that offers pre-specified payouts based upon a trigger event generally identifyiable thus avoiding the need to provide proof of loss.

Pluvial flood: a pluvial, or surface water flood, is caused when heavy rainfall creates a flood event independent of an overflowing water body.

Poisson Occurrence Model: model used to describe the probability of earthquakes occurring in a fixed time interval as independent realisations of a stochastic process.

Probabilistic: a probabilistic method or model is based on the theory of probability or the fact that randomness plays a role in predicting future events. The opposite is deterministic, which is the opposite of random — it tells us something can be predicted exactly, without the added complication of randomness.

Probabilistic Seismic Hazard Analysis (PSHA): method to study the likelihood of a certain ground motion level being exceeded on a specific site from all earthquakes generated by any known and/or potential earthquake sources in the region.

Reconstruction cost ratio refers to the amount of money required to repair a structure and return it to its original state that it had before a certain event occurred.

Replacement costs: part of the exposure dataset, represent the total cost of replacing the original asset at current market prices. In the context of risk assessment, replacement costs are used in order to quantify the loss produced by a natural or human-made hazard (which is usually a fraction of the total cost). Replacement costs are estimated based on construction costs, content costs and other costs (e.g., operation costs).

Risk: the product of hazard and its effects on the exposed assets (Risk = Hazard x Exposure x Vulnerability).

Sample case study: selected area or object of special interest identified to exemplify specific risk assessment during practical exercises.

Seismic Microzonation: process of dividing a target study region in zones of supposedly homogeneous seismic response under earthquake excitation.

Seismogenic Structure: geological or tectonic structure capable of generating an earthquake, such as a fault or a fault system.

Seismotectonic Environment: a region characterised by uniform geological, morphological and tectonic settings, capable of generating earthquakes of specific type and with peculiar spatial and temporal patterns.

Shallow landslide: landslide with a few meters of the sliding surface depth.

Shared socio-economic pathways (SSPs): scenarios defined in order to assess the future socio-economic development under different conditions (e.g., fossil-fueled development, energy consumption). There are 5 SSPs that correspond to the broad categories of socio-economic development that might happen in the future: SSP1 ("Sustainability"), SSP2 ("Middle of the Road"), SSP3 ("Regional Rivalry"), SSP4 ("Inequality") and SSP5 ("Fossil-fueled Development"). SSPs are usually associated with narratives that describe qualitatively how the socio-economic development happens and evolves in the future (up to 2100) globally or for specific regions/countries.

Stochastic catalogue (flood): a dataset containing a collection of flood footprints caused by flood events, either historical or synthetically generated (but consistent with the historical ones).

Taxonomy (referred to buildings): the term is usually referred to a global classification scheme that allows encoding a number of features with a selected number of fields. The report often speaks of building taxonomies and refer to a classification system aimed at describing the building features. The GEM taxonomy, in particular, has been specifically developed in order to collect buildings features related to their behavior in case of earthquakes.

Topographic wetness index: measure of moisture content in soils from a DEM analysis procedure in a GIS environment.

Uncertainty: refers to situations under which either the outcomes and/or their probabilities of occurrences are unknown to the decision-maker.

Uniform Hazard Spectra: response spectra created by collecting ground motion intensity level with identical exceedance probability computed for different spectral ordinates.

Vs30: average shear-wave velocity computed over the first 30m of the vertical soil profile.

Vulnerability: the percentage value change of the exposed assets for different levels of hazard intensity

Vulnerability curve: the graphic representation that expresses, in a continuously way, the expected damage that a structure may suffer when it is subjected to a seismic event of a certain level.