World Bank

Measuring Seismic Risk in Kyrgyz Republic

Seismic Risk Reduction Strategy

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Seismic Risk Reduction Strategy for the Kyrgyz Republic

Executive Summary

This Seismic Risk Reduction Strategy provides guidance to the Government of the Kyrgyz Republic and other key stakeholders to prioritise a range of risk reduction options that will save lives, reduce damage to critical buildings and infrastructure and reduce the economic losses caused by earthquakes in the Kyrgyz Republic.

Background to Seismic Risk Reduction Strategy for the Kyrgyz Republic

The Kyrgyz Republic is located in a highly seismic region subjected to devastating earthquakes that have caused loss of life, destroyed homes and ruined livelihoods in historical and recent times. Although earthquakes occur less frequently than other natural hazards such as floods and landslides, they cause the largest proportion of disaster related losses across the country (World Bank, 2008). Due to rapid urbanisation and the developing nature of the economy in the Kyrgyz Republic, there is a strong incentive to invest in a national seismic risk reduction strategy as the most effective way to mitigate the potential impact of disaster related shocks and reduce expected losses. Risk reduction programmes have the added benefit of helping to alleviate poverty in more vulnerable groups of society who are often disproportionately affected by disasters. These programmes should not be considered as stand-alone, but instead, integrated into general development programmes in the country.

In order to better understand seismic hazard and risk in the country, the World Bank and the Global Facility for Disaster Reduction and Recovery (GFDRR) have commissioned Ove Arup & Partners International Ltd (Arup), Helmholtz Centre Potsdam German Research Centre for Geosciences (GFZ), the Central Asian Institute of Applied Geosciences (CAIAG) and the Global Earthquake Model Foundation (GEM) to perform the first detailed countrywide quantitative seismic hazard and risk study for the Kyrgyz Republic. This report presents the seismic risk reduction strategy and recommendations for critical building and infrastructure assets based on the seismic hazard and risk study results and cost benefit analyses for selected recommended risk reduction measures (Arup 2017a; Arup 2017b). This strategy is aligned with the Sendai Framework for Disaster Risk Reduction (United Nations, 2015) which has been formally adopted by the government of the Kyrgyz Republic.

The scope of the study was determined by consultation with the Government and other stakeholders and included the following asset portfolios for the country: residential buildings, hospital buildings, fire station buildings, school buildings and transport infrastructure including roads and bridges. In addition, recommendations have been provided for cultural heritage assets. Direct losses including damage to buildings and infrastructure, cost of damage and fatalities were considered in the seismic risk calculations. All economic losses are given in 2015 USD.

People, Buildings and Transport Infrastructure Exposure in the Kyrgyz Republic – What is at Risk?

The Kyrgyz Republic has a total population of approximately 6 million people and Bishkek, the largest city and the capital, has a population of almost 1 million people. Currently approximately only one-third of the population live in urban areas but the major urban areas are experiencing rapid growth and the population in rural areas is declining. The Kyrgyz Republic has a developing economy with a GDP of 6.6 billion USD in 2015 and a per capita GDP of approximately 1,100 USD (World Bank, 2016). Figure 1 below summarizes the estimated numbers of buildings of different usage categories, the estimated value of the buildings in each usage category as well as the estimated length and value of the roads and the number and value of bridges. The combined total value of residential buildings across the country is estimated to be 60 billion USD, hospital buildings total value 9 billion USD, school buildings total value 1.5 billion USD, roads network total value 33 billion USD and bridges 500 million USD. As expected, it can be seen that residential buildings comprise the largest proportion of the buildings in the country both in terms of number of buildings and total economic value of the residential buildings in the country. In addition, it can be seen that hospitals which are more expensive to construct and have valuable equipment and contents make up a high proportion of the overall value of assets for the country, given the relatively small number of buildings. It can also be seen that secondary roads comprise the largest proportion of the road network across the country and that the total number and value of bridges across the country is relatively modest.

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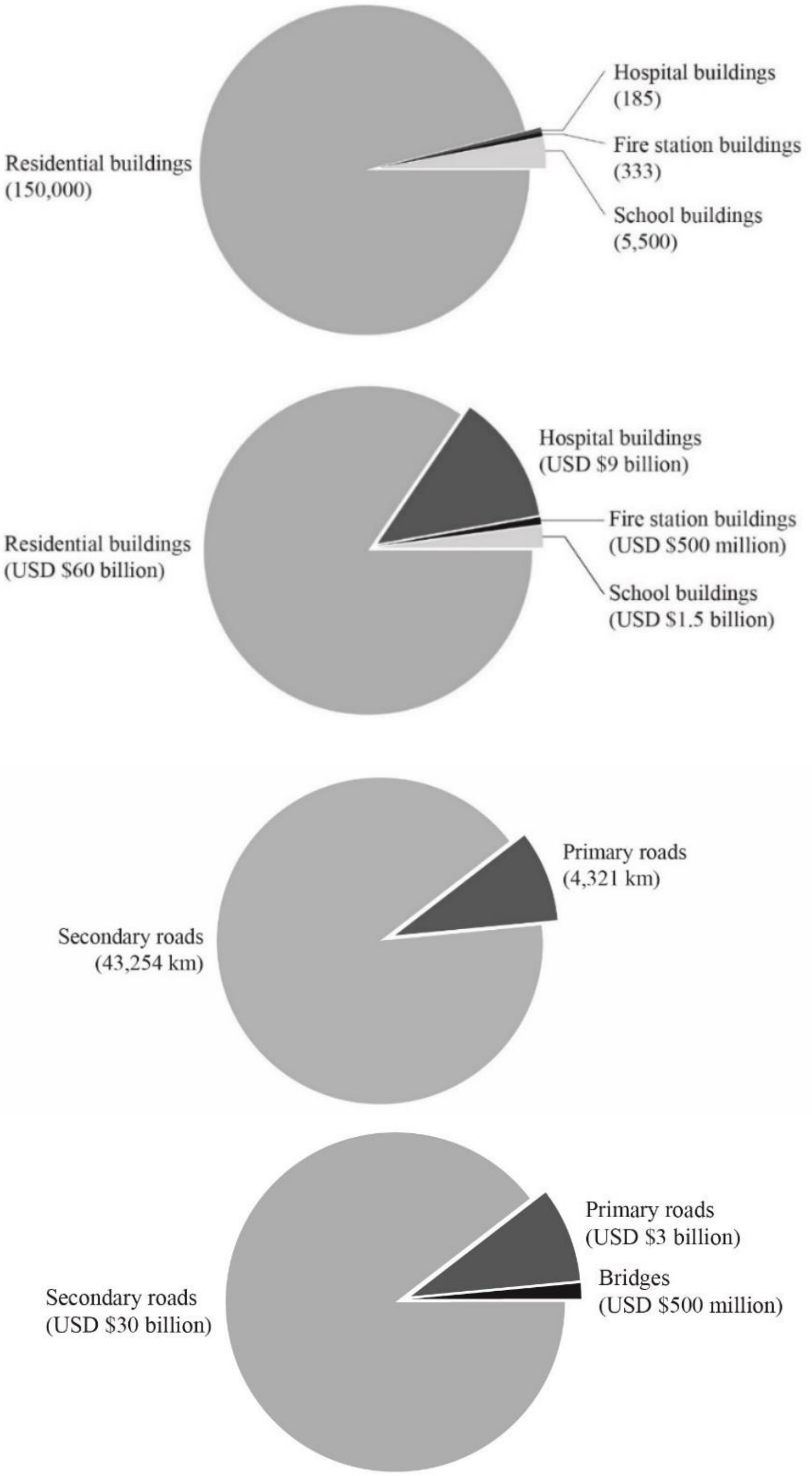

Figure 1: Estimated number and value of buildings and estimated length and value of infrastructure assets (roads and bridges).

Seismic Hazard and Risk in the Kyrgyz Republic

The Kyrgyz Republic is located in a highly seismic region subjected to devastating earthquakes that have caused loss of life, destroyed homes and ruined livelihoods in historical and recent times. As part of this study, seismic hazard and risk calculations were undertaken using two interrelated methods as part of this project:

- Scenario earthquake seismic hazard and risk assessments; and
- Probabilistic time-based seismic hazard and risk assessments.

Scenario earthquake seismic hazard calculations were undertaken for twelve (12) representative scenario earthquake events. These scenarios were selected based on the mapped location of known active geological faults located near to urban centres across the country. The magnitudes used for the scenario earthquake calculations are representative of maximum credible earthquakes that have occurred on these geological faults in historic to recent times. It is emphasised that in the future earthquakes could occur on other geological faults located in other parts of the country. The twelve scenario earthquakes were selected to be representative of the type of earthquake events that could occur.

Probabilistic time-based seismic hazard assessments were also performed and these results indicate the amplitude of earthquake ground shaking that could occur anywhere in the country. Figure 2 below is an example seismic hazard map for the Kyrgyz Republic showing the distribution of ground shaking amplitude across the country in terms of peak horizontal ground acceleration (PGA).

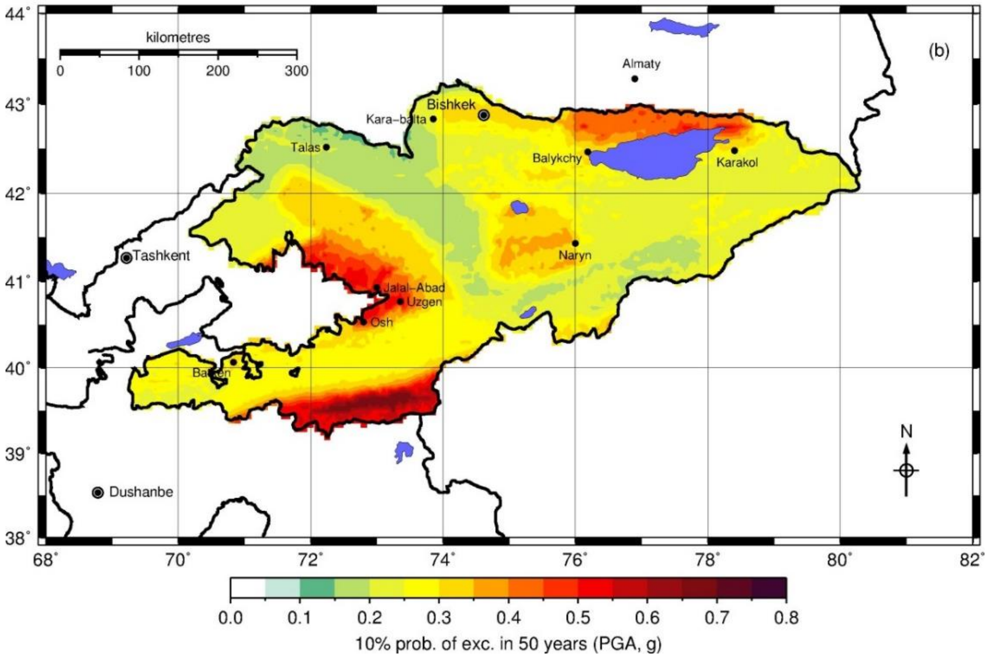

Figure 2 Probabilistic seismic hazard map for the Kyrgyz Republic in terms of peak ground acceleration (PGA) with a 10% probability of being exceeded over 50 years and considering the ground conditions using the USGS shear wave velocity Vs30. (Arup, 2017a).

The potential losses associated with the infrequent but large magnitude (Mw= 6.7 to 8.3) scenario earthquakes that can occur across the country were calculated. The potential losses associated with these scenario earthquake events are expected to be very high: potentially resulting in thousands of fatalities and many billions of USD of damage to buildings and infrastructure.

As an example, the potential casualties and economic losses associated with one of the scenario earthquake events, the magnitude Mw = 7.5 Ferghana Valley event, are presented in Figure 3 below. Full seismic hazard and risk results for all twelve scenario earthquakes are described in the associated Seismic Risk Assessment Report (Arup, 2017b). The Ferghana Valley scenario earthquake is one of the most severe for the country and predominantly affects the region near the cities of Jalah-Abad, Osh and Uzgen. Expected fatalities are high: over 5,500 in residential buildings, over 7,500 in school buildings as well as over 150 direct casualties in hospital and fire station buildings. Expected monetary losses are also very high: over 6 billion USD losses to residential buildings and damage to schools, hospitals and other buildings valued at hundreds of millions of USD, damage to transport infrastructure estimated to be 275 million USD for roads and 12 million USD for bridges. The potential fatalities, amount of damage to buildings and infrastructure and the economic impact associated with a similar earthquake scenario on the Issyk-Ata geological fault occurring near to the city of Bishkek are also expected to be of similar severity.

The scenario earthquake risk calculations reveal subtle but important details to inform the development of risk reduction strategy recommendations. For example, it can be seen that the number of potential fatalities associated with damage to school buildings in the Ferghana Valley earthquake scenario is unusually high. This is interpreted to be associated with the high concentration of school buildings that are constructed from adobe in the southwest of the country and these adobe buildings are highly vulnerable to damage in earthquakes and therefore potentially cause large numbers of casualties to the school building occupants – i.e. children and teachers.

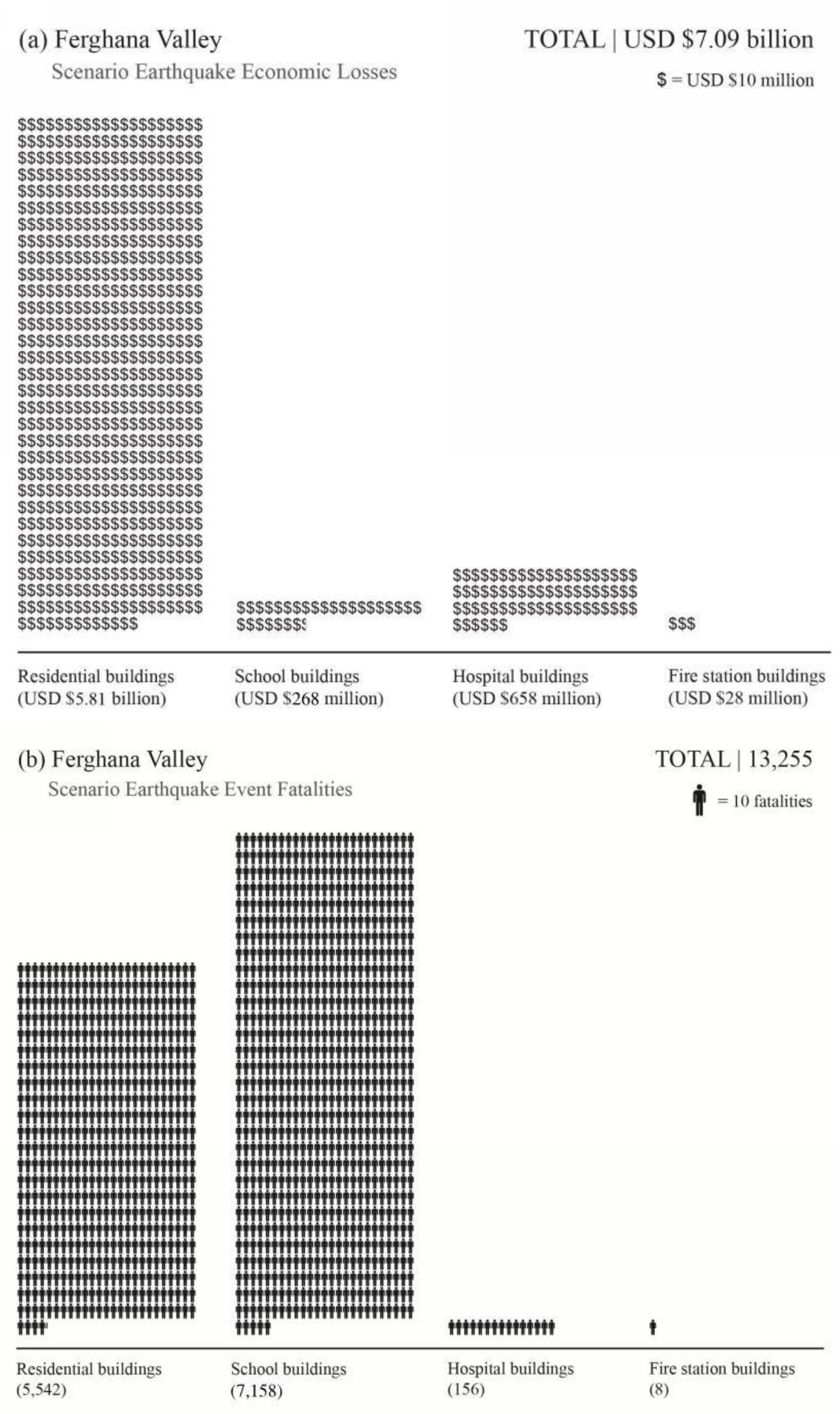

Figure 3: Expected economic losses (a) and fatalities (b) for the Ferghana Valley scenario earthquake with magnitude M=7.5.

Probabilistic risk calculations were also undertaken as part of this study. The probabilistic time-based risk results show that the Kyrgyz Republic is exposed to a severe level of seismic risk, with expected annual economic losses associated with direct damage to buildings exceeding 280 million USD annually – i.e. over 4% of GDP - and expected annual fatalities of up several hundred. The expected annual economic losses are reported because they provide an estimate of what might occur each year on average and this is useful information for financial planning or insurance purposes.

In addition to the consideration of the expected annual losses, it is important to also consider the potential losses with lower probabilities of occurring – i.e. the losses associated with rarer earthquake events that occur with return periods of 50, 475 or even 2475 years. In accordance with international good practice, seismic loss curves and maps have been produced which show the potential seismic losses that could occur over a full range of probabilities. For example, for residential buildings across the country, potential economic losses of up to 6.4 billion USD (almost 100% of GDP) and fatalities up to 4,400 people are calculated to have a 10% probability of being exceeded over a period of 50 years (i.e. to occur with a return period of 475 years) (Figure 4). This scale of expected losses – both economic and the number of fatalities – emphasises the urgency for stakeholders to plan and implement seismic risk reduction strategy actions in the Kyrgyz Republic.

It can be seen for the probabilistic time-based seismic risk results that the highest amount of economic losses is expected for residential buildings and the second highest for hospital buildings. In terms of expected fatalities, the highest number are expected to occupants of residential buildings but the second highest are expected for occupants of school buildings. The high concentration of risk associated with school buildings and the occupants is alarming and requires attention. It is important to note that although expected fatalities associated with damage to hospitals buildings are relatively low, only direct fatalities associated with primary damage to the buildings are considered in this project. This does not include secondary fatalities related to hospitals and fire stations whose functionality becomes compromised and patients cannot be treated adequately or if emergency personnel are not able to respond after a damaging earthquake event.

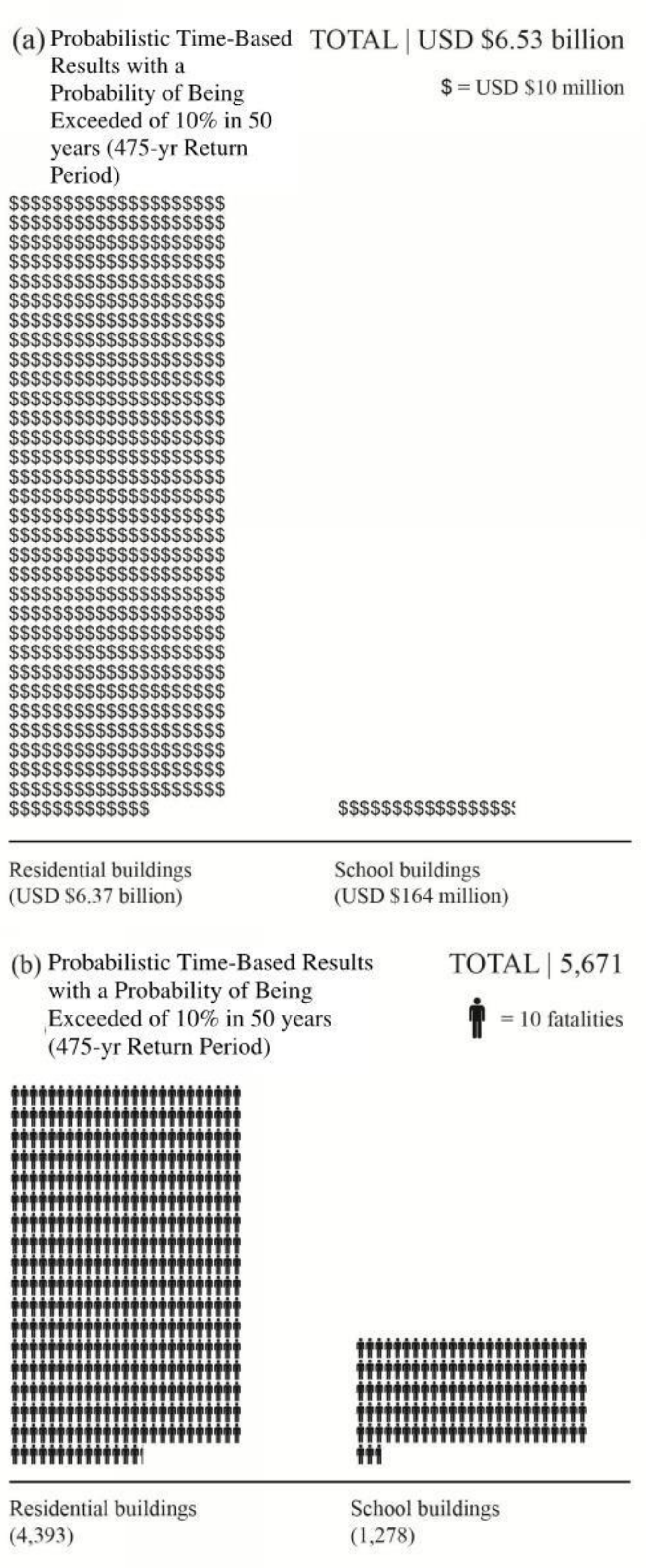

Figure 4: Expected economic losses (a) and expected fatalities (b) with a probability of being exceeded of 10% in 50 years (475-yr return period) (probabilistic time-based results).

In addition to highlighting the high level of seismic hazard and risk in the country overall, this study found that the seismic risk is not evenly distributed across the country. In terms of fatalities, the risk is highest around Osh and Jalah-Abad, followed by Bishkek and its surrounding urban areas. Seismic risk, in terms of economic losses, is highest in Bishkek and surrounding urban areas (see Figure 5). These geographic variations in the level of risk are important in terms of developing prioritization for investment by geographic region and rayon.

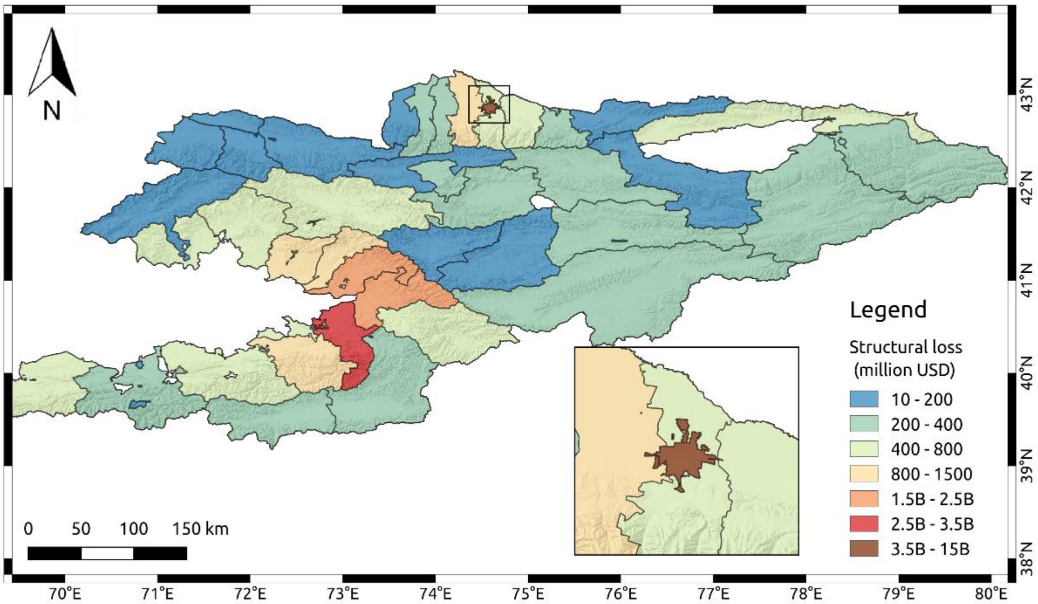

Figure 5 Mean economic loss map for residential buildings (return period of 475 years), aggregated at the rayon level.

Key Seismic Risk Reduction Strategy Recommendations for the Kyrgyz Republic

The following section highlights key seismic risk reduction strategy recommendations from this study and is organized in accordance with the Sendai Framework priorities. These are drawn from the proposed strategy in Section 3 and the detailed recommendations (by area and sector), timelines and proposed investment budgets provided in Section 4 of this report. Section 5 gives guidance on seismic assessment and retrofit. Section 6 provides a summary of the results for the cost benefit analyses carried out to evaluate the specific retrofit options for the building asset categories. Section 7 provides seismic risk reduction recommendations tailored specifically for the consideration of key stakeholders.

Priority 1 – Understanding Seismic Risk

This study has provided a systematic quantitative countrywide seismic hazard and risk study for the Kyrgyz Republic:

- **Wide dissemination and communication of the results of this study** has been undertaken to stakeholders. Further dissemination and communication should be undertaken to wider stakeholders and the general public to raise awareness of seismic hazard and risk in the country.

- **The understanding of seismic hazard in the country can be improved** through further study of active faulting, extending the existing countrywide network of strong ground motion recording instruments and further study of seismic site effects in urban areas[1].
- **The understanding of exposure and vulnerability of critical assets in the country can be improved** through surveys of existing buildings and infrastructure as well as post-earthquake damage and loss surveys.
- **This study has produced a useful set of seismic risk results for critical assets to inform recommendations for the seismic risk reduction strategy**. However, risk management is a continuous process and building upon the findings of this project and using future updated hazard, exposure and vulnerability data, more detailed seismic risk assessments can be performed for critical assets. **These risk assessments can then inform more detailed sectoral risk reduction plans.**

Priority 2 – Strengthening Disaster Risk Governance

A robust framework for disaster risk management in government and law as well as having adequate capacity and capability (in terms of funding, program management and technical expertise) in government and supporting institutions is essential to successfully execute risk reduction programmes. There is already a good foundation for DRM policy as well as strong engagement of government stakeholders and international organisations in implementation of DRM policy in the country. The following are key recommendations to further improve disaster risk governance in the Kyrgyz Republic:

- Approve the 'Law on Seismic Safety' to provide a **legally mandate framework for seismic risk reduction**.
- **Finalize the draft '2016-2030 Strategy for the Emergency Protection of the Kyrgyz Republic'** taking into consideration the seismic risk results and seismic risk reduction strategy recommendations of this study.
- **Increased funding for seismic risk reduction programmes** in the country based on the goals of the finalized strategy. A summary of proposed investment budgets for seismic risk reduction strategy recommendations is included below.
- Provide capacity and capability in the relevant government bodies and institutions to ensure **seismic hazard and risk information is used to inform land use planning including aspects related to emergency response**.
- Assign roles and responsibilities and funding to support **openly accessible data on seismic hazard, exposure and risk**.

[1] We understand the a real-time strong motion network is currently in operation, consisting of about 20 stations distributed across the territory of the Kyrgyz Republic (Parolai et al, 2017).

- **Improve capacity and capabilities of the checking authorities** for design and construction in general and also specifically target improvements related to seismic design for new construction and seismic retrofits.

Priority 3 – Investing in Risk Reduction for Improved Seismic Resilience

The following are key recommendations to improve seismic resilience in the Kyrgyz Republic, particularly for critical assets:

- **Plan and implement seismic risk reduction programmes** with prioritized actions for critical assets. These should be a combination of physical interventions (replacements and retrofits of assets) and soft measures (policies, community engagement and incentives). Specific recommendations are provided in this report for each asset portfolio, including retrofit measures for representative building types.

  This study has provided useful evidence to support the case for improving seismic resilience of critical assets to reduce future losses in the Kyrgyz Republic. For example, the cost benefit analysis for retrofitting selected schools with the highest losses showed that **an investment of 60 million USD would result in a 24% reduction of fatalities for students and teachers in the country**.

- **Produce guidance and carry out training for design professionals** on the seismic provisions of the Kyrgyz building codes to improve understanding of the building codes and regulations. **This report provides guidance on seismic assessment and retrofitting** which can be used as a starting point as well as training materials developed in the course of this project for the numerous communication workshops with stakeholders.
- **Update the seismic codes and improve code provisions** related to seismic design and retrofit of buildings and infrastructure. **The country-wide seismic hazard map produced as part of this study can be used as an input to an updated code hazard map.** Other specific recommendations for code updates are provided in this report.
- **Improved and up-to-date land use plans** which incorporate seismic risk information.

Priority 4 – Enhancing Preparedness for Earthquake Disasters

The following are key recommendations to enhance preparedness for earthquake disasters in the Kyrgyz Republic:

- **The results of this study should be used to inform updated emergency plans in all sectors.** Specific recommendations for each sector are provided but **cross-sectoral coordination is strongly encouraged** as well as **community engagement** to communicate emergency plans.
- The results of this study should be used **to identify gaps in emergency response capacity** in the country.

- The government and relevant stakeholders (the World Bank, the State Insurance Organization) should explore disaster risk financing options as well as measures to strengthen the insurance industry.

  The results of this study can be used to understand the magnitude of expected losses from damaging earthquake events.

Proposed Budgets for Seismic Risk Reduction by Asset Category

Proposed budgets for seismic risk reduction (physical interventions only) for the period of 2017-2021

Asset Category	Proposed Budgets
Residential buildings	Not provided.
School buildings	60 million USD
Hospital buildings	75 to 100 million USD
Fire station and emergency response buildings	10 million USD
Transport infrastructure - roads	Not provided.
Transport infrastructure - bridges	50 million USD
Cultural heritage assets	10 million USD

Conclusion

In addition to the **urgency** to take action to reduce seismic risk, the recommendations communicated in this report should give the Government of the Kyrgyz Republic and other stakeholders a sense of **ownership** for their management of the seismic risk. With help from the government **to clarify roles and responsibilities** and **allocate funding**, it is now time for the stakeholders to use these results and recommendation to form specific plans and to implement those plans. To effectively do so, stakeholders need to **collaborate across sectors, departments and institutions**. **Information should be open and shared** in government managed databases.

The Kyrgyz Republic is not alone in being exposed to high seismic risk. Many other countries face similar challenges. **Engagement and collaboration with the international community and even greater sharing of solutions** should be encouraged and increased. The World Bank and the GFDRR continue to show their commitment to support the Kyrgyz Republic in achieving their development goals and to recognize that disaster risk reduction is a key component of sustainable development.

1 Introduction

1.1 General

The geography, tectonic regime and topography of Central Asia make it highly prone to natural hazards such as earthquakes, landslides, floods, windstorms and drought. The Kyrgyz Republic is known to be a region of particularly high seismic hazard (Arup, 2017a). Earthquakes of magnitude $M_w \geq 5$ occur on the order of once per month in the study area, and potentially devastating earthquakes of magnitude $M_w \geq 7$ occur with return periods of several decades.

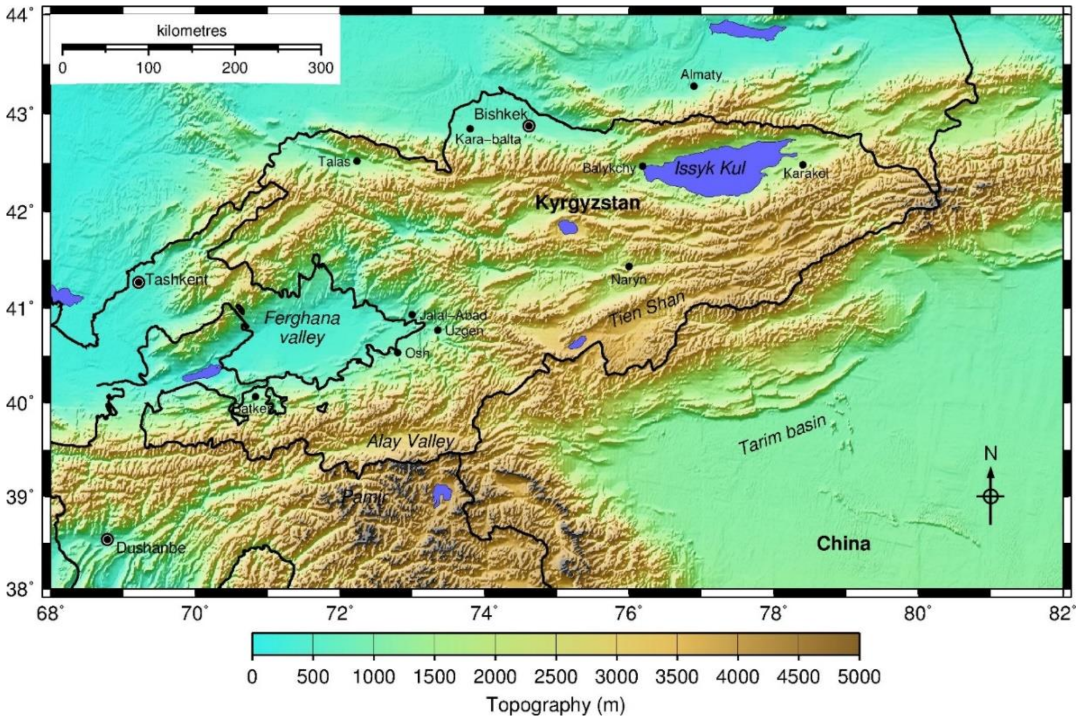

Figure 6: Study area of this project, showing the locations of major population centres and geographical features.

There has been significant progress towards understanding and quantifying natural hazards in the Kyrgyz Republic. The Ministry of Emergency Situations (MoES) of the Government of the Kyrgyz Republic collects data on natural hazards across the country and publishes annual reports summarising the location, characteristics and losses associated with natural hazard events. As part of this effort, the MoES, along with other organisations, maintain a GeoNode database of natural hazard and risk geospatial information, located at the MoES and at the Central Asian Institute of Applied Geosciences (CAIAG) in Bishkek.

To better understand seismic risk in the Kyrgyz Republic, the World Bank and the Global Facility for Disaster Reduction and Recovery (GFDRR) has initiated a project to measure the level of seismic risk across the country, to systematically study the potential fiscal impacts and to develop a robust seismic risk management strategy. The World Bank has appointed a team comprising Ove Arup & Partners

International Ltd (Arup), Helmholtz Centre Potsdam German Research Centre for Geosciences (GFZ), the Central Asian Institute of Applied Geosciences (CAIAG) and the Global Earthquake Model Foundation (GEM) to undertake the study "Measuring Seismic Risk in the Kyrgyz Republic" under Contract 7173664.

The scope of work for the project is divided into five main components:

- Component 1: Development of Input Datasets for Probabilistic Seismic Hazard Assessment;
- Component 2: Development of Exposure Datasets and Vulnerability Functions for Seismic Risk Assessment;
- Component 3: Probabilistic and Scenario-based Seismic Hazard and Risk Analysis;
- Component 4: Macro-level Seismic Risk Reduction Strategy;
- Component 5: Communication and Transmission of Datasets, Analysis, and Results and Final Report.

1.2 This Report

This report presents the seismic risk reduction strategy for the territory of the Kyrgyz Republic based on the results of the seismic risk assessment (Component 3) including ten examples of risk reduction measures and the results of the cost benefit analysis for the specific measures. The report concludes with key recommendations for seismic risk reduction specifically tailored for stakeholders. The activities reported are in reference to Component 4: Macro-level Seismic Risk Reduction Strategy:

- Activity 41 "Risk Reduction Measures for Buildings and Transport Infrastructure".
- Activity 42 "Up to Ten Examples of Risk Reduction Options".
- Activity 43 "Cost benefit Analyses for Risk Reduction Options".
- Activity 44 "Development of a Risk-Reduction Investment Strategy".

This report is divided into the following sections:

Section 1 provides an introduction to this report;

Section 2 provides background information on the Kyrgyz Republic relevant to the risk reduction strategy, including a high level summary of the seismic hazard and risk results from the Component 3 probabilistic and scenario based seismic hazard and risk assessment;

Section 3 provides a summary of existing policy related to disaster risk management in the Kyrgyz Republic, names key stakeholders and gives recommendations for wider seismic risk reduction strategy for the Kyrgyz Republic;

Section 4 provides risk reduction recommendations related to the general DRM policy, the construction and regulatory environment and understanding seismic risk in the Kyrgyz Republic. In addition, this section includes specific risk reduction recommendations for each asset portfolio: schools, hospitals, fire stations, residential buildings, transport infrastructure (roads and bridges) and cultural heritage assets. For the building portfolios, seismic retrofit options for representative construction types are given.

Section 5 gives guidance on seismic assessment and retrofit. Further supplementary guidance in more technical detail is provided in Appendix B;

Section 6 provides a summary of the results for the cost benefit analyses carried out to evaluate the specific retrofit options for schools, hospitals, fire stations and residential buildings. Cost benefit analysis was not carried out for transport infrastructure due to lack of data provided for the asset portfolio; and

Section 7 provides seismic risk reduction recommendations tailored specifically for the consideration of key stakeholders.

Supporting material for this report is provided in a series of appendices:

- Appendix A provides additional guidance on selected retrofit measures specified for the asset portfolio retrofits;
- Appendix B provides more detailed technical discussion to support the seismic assessment and retrofit guidance in Section 5;
- Appendix C gives the methodology for the cost benefit analyses;
- Appendix D gives cost assumptions for the seismic retrofit measures;
- Appendix E provides a description of the structural typologies assumed for the Kyrgyz Republic for this study;
- Appendix F summarizes past disaster risk management activities in the Kyrgyz Republic;
- Appendix G provides descriptions for key stakeholders;
- Appendix H provides a high level review of disaster risk finance and insurance options for the Kyrgyz Republic; and
- Appendix I provides guidance on recommended types of construction that perform better in earthquakes for new construction in the Kyrgyz Republic.

1.3 Associated Reports

This report for Component 4 should be read in conjunction with the following two key reports prepared as part of this project:

- Seismic Hazard Assessment Report (Arup, 2017a); and
- Seismic Risk Assessment Report (Arup, 2017b).

1.4 Limitations of this Report

The recommendations in this report are based on the results of the seismic risk assessment, on information provided by the stakeholders and on desktop literature review. For the different asset categories, the quality of the information provided varied considerably, which has led to different levels of uncertainty in the risk results and cost benefit analyses. Engineering judgement, statistical data treatment and the input of local experts were used to overcome the above limitations in building and infrastructure information for the current project.

Table 1 Quality of input information for each asset category for the seismic risk assessment

Asset Category	**Inputs provided to this study**			**Level of uncertainty**
	Building Locations	**Physical Characteristics**	**Cost Data**	
Hospital buildings	Yes	No, but limited field survey data was gathered by the project team. Visual surveys only.	No, costs assumptions were calibrated against local cost data available based on usage type using international cost data.	High
Fire station buildings	Yes	No, but limited field survey data was gathered by the project team. Visual surveys only.	No, cost assumptions were calibrated against local cost data available based on usage type using international cost data.	High
School buildings	Yes	Yes, from the UNICEF database. Visual surveys only.	Yes	Moderate
Residential buildings	No, but exposure mapping techniques were used and calibrated against field survey data gathered by the project team.	No, but state of the art exposure mapping techniques were used and calibrated against field survey data gathered by the project team. Visual surveys only.	Yes, from desktop review.	Moderate
Transport infrastructure (roads and bridges)	No, publically available open source data was used.	No, publically available open source data was used.	Yes, for roads from desktop review. Cost assumptions for bridges were based on international sources.	High

The risk reduction recommendations highlight the level of uncertainty associated with different areas and specify where more detailed study is recommended. For example, recommendations for prioritization are given based on geography at rayon level and by construction type. A more detailed prioritization for each asset category would require more detailed seismic risk assessment and related cost benefit analyses.

Approximate budgets have been proposed to fund risk reduction measures for each asset category over the next four years. These proposed budgets are intended to be comparable to the level of funding proposed for investing in safer schools by the Government of the Kyrgyz Republic in the 'Draft 2016-2030 Strategy for the Emergency Protection of the Kyrgyz Republic'. These budgets should be considered in the wider context of funding priorities for the government.

Nevertheless, it is important to emphasize that this study has provided a meaningful set of risk results to inform a seismic risk reduction strategy for the country. This strategy includes specific risk reduction recommendations with timescales and priorities as well as estimated investment required to support the risk reduction programmes for each asset category.

2 Country Background and Context

2.1 Introduction

This section presents relevant background on the geography, demographics, economy and government structure of the Kyrgyz Republic for the seismic risk reduction strategy and recommendations. In addition, a high level summary of natural disaster statistics for the country is presented along with key seismic hazard and risk results from Component 3 of this study (Arup, 2017a; Arup, 2017b).

2.2 Geography

The Kyrgyz Republic is a landlocked country located in the eastern part of Central Asia. The country is bordered by China to the east, Uzbekistan to the south-west, Kazakhstan to the north and Tajikistan to the south. The Kyrgyz Republic has an area of around 199,900 km^2 (UNECE, 2010) (refer to Figure 6). Over three quarters of the terrain is covered by the Tien Shan and the Pamir mountain ranges (CAREC, 2008). As most of the terrain is mountainous, the Kyrgyz Republic has little arable land (around 7% of the total land area); this is mostly located in the Ferghana Valley in the south-west and the Chu and Talas valleys along the northern border. The mountainous terrain is the result of the active tectonic and mountain building processes that are ongoing in the Central Asian region.

2.3 Population and Demographics

The Kyrgyz Republic has a total population of 5.9 million and projected population growth is expected to remain low in the coming years (1% per year (World Bank, 2015). Bishkek, the largest city and the capital, has a population of almost 1 million followed by the second largest city, Osh, which has a population of approximately 500,000. The average population density in the country is 30 people per km^2. Around one-third of the population lives in urban areas. Since the transition from Soviet rule, small to medium size cities have experienced low growth or a decline in population, whereas Bishkek and Osh are experiencing rapid growth (World Bank, 2016). This has led to a concentration of population in the north of the country in and around Bishkek and in the southwest in and around Osh and Jalah-Abad. This study has shown that these are also regions of relatively high seismic hazard (Arup, 2017a).

2.4 Economy

The Kyrgyz Republic had a GDP of approximately 6.6 billion USD in 2015 and a per capita GDP of approximately 1,100 USD (World Bank, 2016a).

In the Soviet period, incentives and subsidies encouraged regional specialization in agriculture as well as industries which processed materials supplied by other parts of the Soviet Union. The economy was severely affected by independence in

1991 as trade and industry were heavily dependent on imports from and exports to the former Soviet Union. A rapid transition to a market economy led to improved economic performance by 1996 (UNECE, 2010). The economy continues to be strongly influenced by Russia's economic performance as well the economic performance and trade levels of neighbouring countries with larger economies, such as Kazakhstan and China.

In 2014, the total revenue and grants for the Government budget was 34.7% of GDP and total expenditures were 38.8% of GDP. Public debt grew to 53% of GDP in 2014 (World Bank, 2015; Economist Intelligence Unit, 2015). Current government spending is concentrated on public investments in energy, agricultural and transport infrastructure and communications; these projects are often co-financed by donors such as the World Bank and the Asian Development Bank. The modest size and developing nature of the economy makes the Kyrgyz Republic more vulnerable to shocks such as natural disasters as well as making long-term recovery more challenging.

2.5 Governance

The government administration is organized in a five tiered hierarchical system as follows (World Bank, 2016):

- The national level;
- Seven oblasts (state or province) plus Bishkek and Osh which have national level status;
- 40 rayons (districts) plus 11 cities with rayon level status;
- 459 ayil oskhmota (primary territorial level); and
- The settlement level.

As the Kyrgyz Republic transitioned away from a system with centralized control based on the Soviet system, local government has gained more influence and responsibilities. That said, agencies at local government level still often rely on transfers of funds from central government (World Bank, 2016a). This also impacts the level of funding at a local level for disaster risk reduction and community engagement.

2.6 Natural Hazards Profile

The geography, tectonic regime and topography of the Kyrgyz Republic make it highly prone to natural hazards such as earthquakes, landslides, floods, windstorms, glacial lake bursts and drought. Due to the mountainous terrain, most of the country is subject to significant landslide hazard. Mudflows and floods occur frequently and cause significant damage. Floods are most often caused by heavy rains, snow and glacier melt, and/or a combination of these factors. The breaching of natural dams that restrain natural lakes cause the most severe and damaging flash flooding. In addition, the Kyrgyz Republic has five locations with old mine tailings and waste rock dumps containing radioactive materials which can be susceptible to seepage of radionuclides particularly when effected by flooding or landslides (Pusch, 2004). Figure 7 shows the distribution of disasters during the period of 1988 to 2007 affecting the Kyrgyz Republic. It can be seen for natural disasters in the county that 27% of reported disasters were caused by landslides, 18% by earthquakes, 9% by floods and 5% by avalanche. Other types of disaster such as epidemics, industrial accidents and transport accidents make up the remaining 41%.

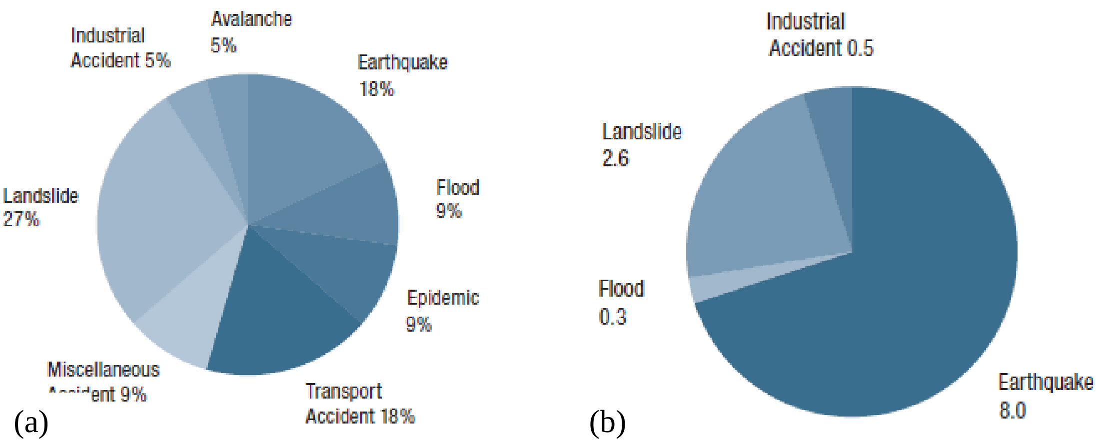

Figure 7: Percentage distribution of reported disasters (a) and average annual losses (million USD) (b) for selected disasters in the Kyrgyz Republic for the period of 1988-2007 (World Bank, International Strategy for Disaster Reduction and CAREC, 2008).

It can be seen that although earthquakes make up only 18% of disasters in the country, they result in the largest proportion of economic losses (73%) from disasters. This highlights the importance of this countrywide seismic hazard and risk assessment and the related recommendations for seismic risk reduction. These natural disaster statistics also indicate that earthquake risk should not be considered in isolation, as the occurance of other natural hazards across the country contribute significantly to damage to buildings and infrastructure, potential loss of life, numbers of people impacted and overall economic losses.

2.7 Seismic Hazard Context (This Study)

The entire country is subjected to a high level of seismic hazard. Earthquakes of magnitude $M_w \geq 5$ occur on the order of once per month in the study area, and potentially devastating earthquakes of magnitude $M_w \geq 7$ occur with return periods of several decades. Table 2 below lists recent significant earthquakes in the Kyrgyz Republic and the consequences of each event.

Table 2 Recent significant earthquakes in the Kyrgyz Republic (UNECE, 2010)

Date	**Location**	**Magnitude, Mw**	**Consequences**
15 May 1992	Burgandi-Nookat region	6.6	4 killed, 50,000 people affected, losses of 31 million USD
9 January 1997	Ak-Tala district	7.0	1,230 people affected, losses of 2 million USD

Date	Location	Magnitude, Mw	Consequences
19 August 1997	Jalal-Abad region	7.3	54 killed, 86,000 affected, losses of 130million USD
26 December 2006	Isakeevo-Kochkorka region	5.8	12,050 people affected
5 October 2008	Alai and Chonalai districts, village of Nura	6.6	In the village of Nura: 74 killed, 850 people affected, losses of 8 to 10 million USD

Figure 8 presents the uniform probabilistic seismic hazard map from this study for the Kyrgyz Republic based on historic seismicity and area sources.

The level of seismic hazard varies widely within the country. The highest hazard areas are in the Ferghana Valley near Osh and Jalah-Abad, the north shore of Lake Issyk-Kul near the border with Kazakhstan and to the south along the Alai mountain range near the border with Tajikistan. The hazard is moderate in much of the rest of the country.

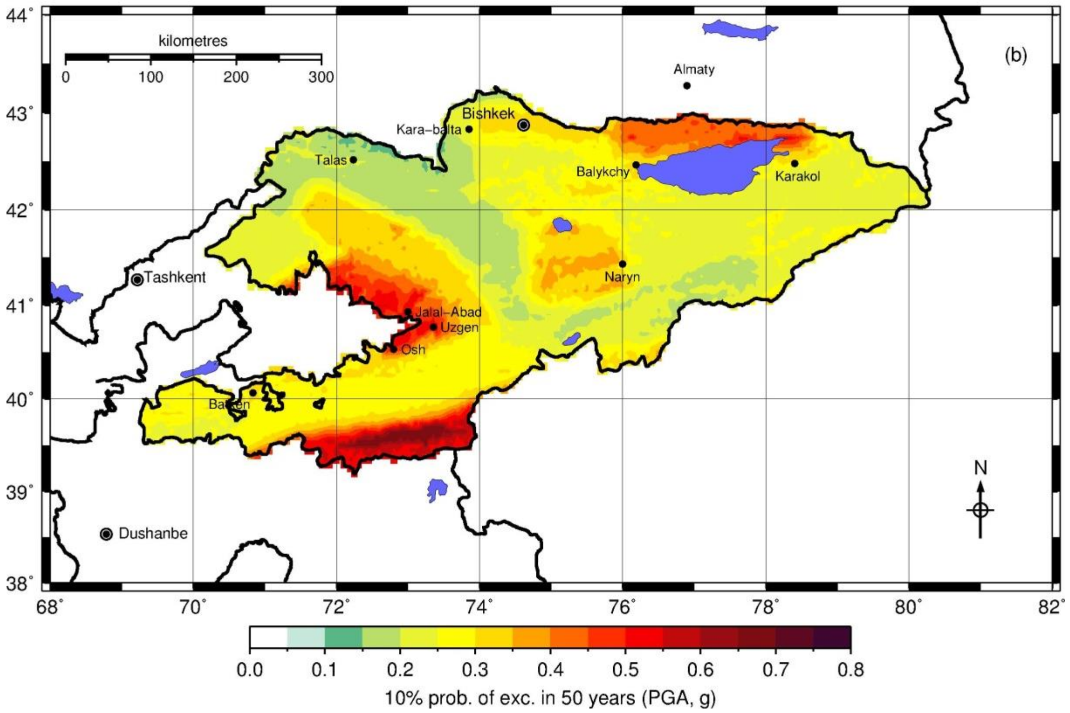

Figure 8: Uniform hazard maps in terms of PGA for the Kyrgyz Republic (mean hazard map) for USGS V_{s30} site conditions for a probability of exceedance of 10% over 50 years (Arup, 2017a).

In addition to the uniform seismic hazard map, seismic hazard associated with 12 scenario earthquakes was assessed. These scenarios were selected based on their proximity to urban areas in the country. Hazard results for the two scenarios with the most significant losses are presented below. Figure 9 presents results for the Issyk-Ata fault scenario, with magnitude M_w 7.3, which most affects Bishkek and surrounding urban areas. Figure presents results for the Ferghana Valley fault scenario, with magnitude M_w 7.5, which most affects the towns of Osh, Jalah-Abad and Uzgen.

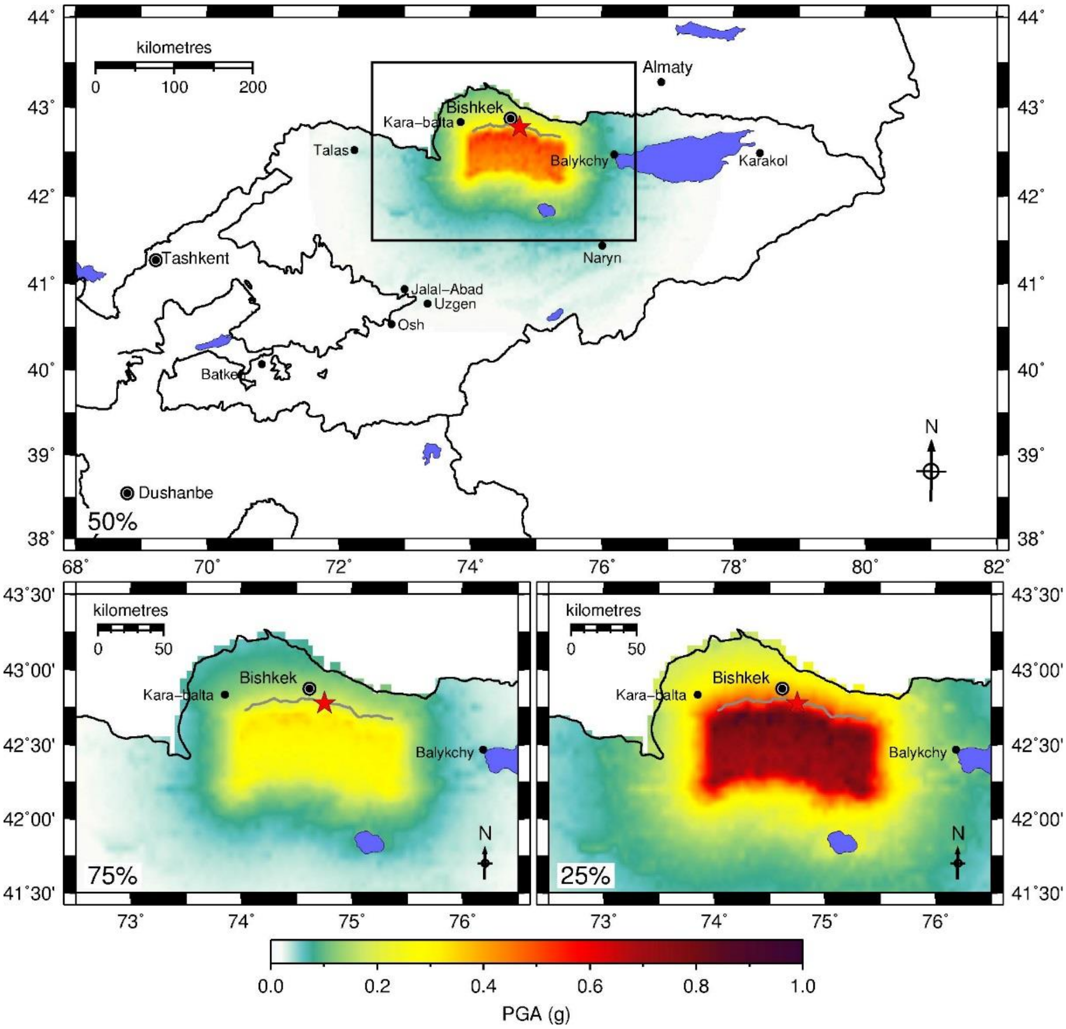

Figure 9: Scenario earthquake PGA values (percentiles) for the Issyk-Ata fault scenario: (a) 50th, (b) 25^{th} and (c) 75^{th} percentile results are presented. The red star marks the epicentre. These calculations are for USGS Vs30 site conditions (Arup, 2017a).

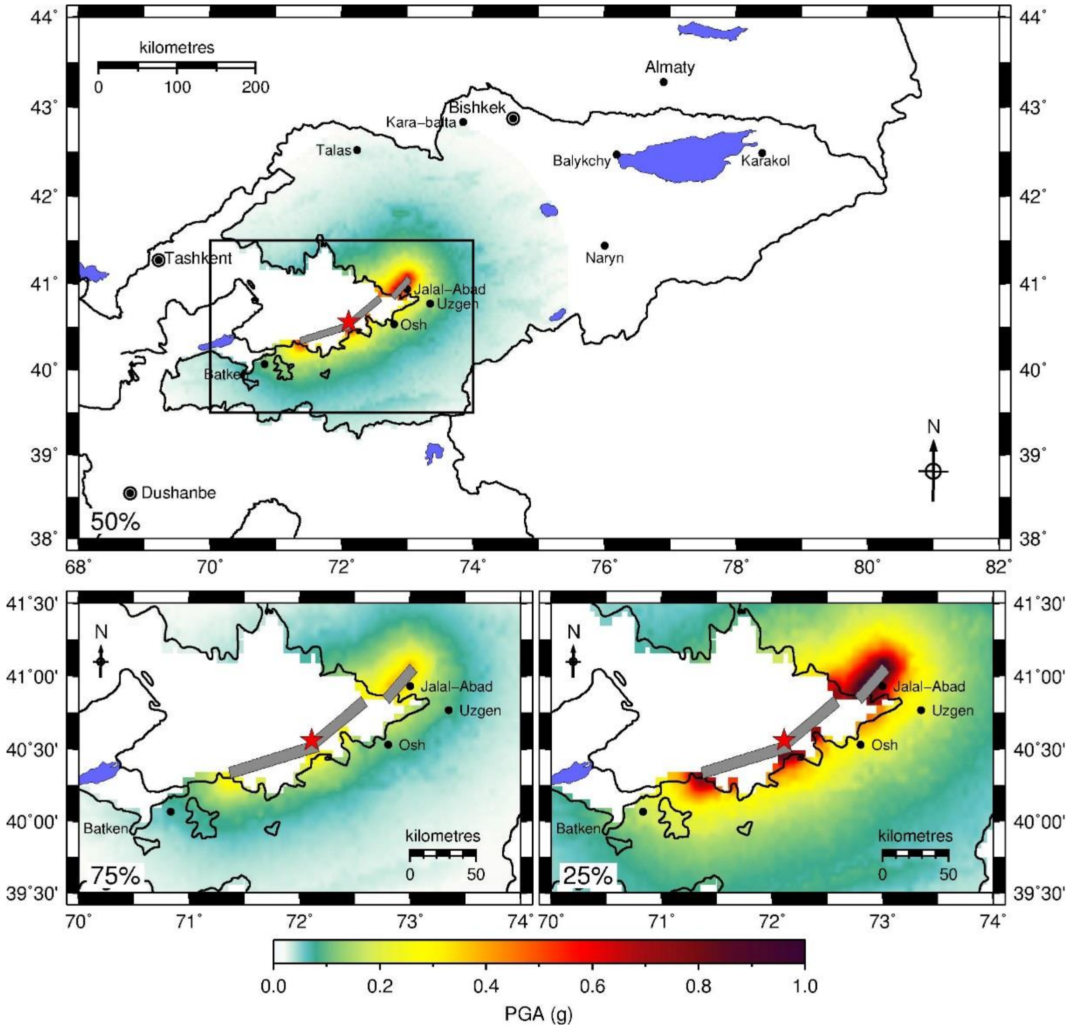

Figure 10: Scenario earthquake PGA values (percentiles) for the Ferghana Valley faults scenario: (a) 50th, (b) 25th and (c) 75th percentile results are presented. The red star marks the epicentre. These calculations are for USGS Vs30 site conditions (Arup, 2017a).

It can be seen that severe levels of earthquake ground shaking is expected for both these scenarios in areas with significant population. Refer to the Component 3 seismic hazard report for more details and full scenario hazard results (Arup, 2017a).

2.8 Seismic Risk Context (This Study)

This section presents a high level summary of the earthquake-based risk results from the Component 3 seismic risk assessment report (Arup 2017b).

Selected results in this section include the following:

- A summary of the range of mean risk results for the 12 scenario earthquake events across all portfolios (Table 4); and
- A summary of risk results for the probabilistic time-based risk assessment (except for the infrastructure portfolios) are provided in terms of a range of mean expected annual losses (EAL) (Table 5).

Direct losses only were considered in the scope of this study. The reported economic losses are in 2015 USD.

Figure 11 and Table 3 show the locations of the earthquake scenario events and closest urban population centres. It should be noted that expected losses from the scenarios could extend to the wider region in the vicinity of each scenario and affect additional urban areas not listed in this table.

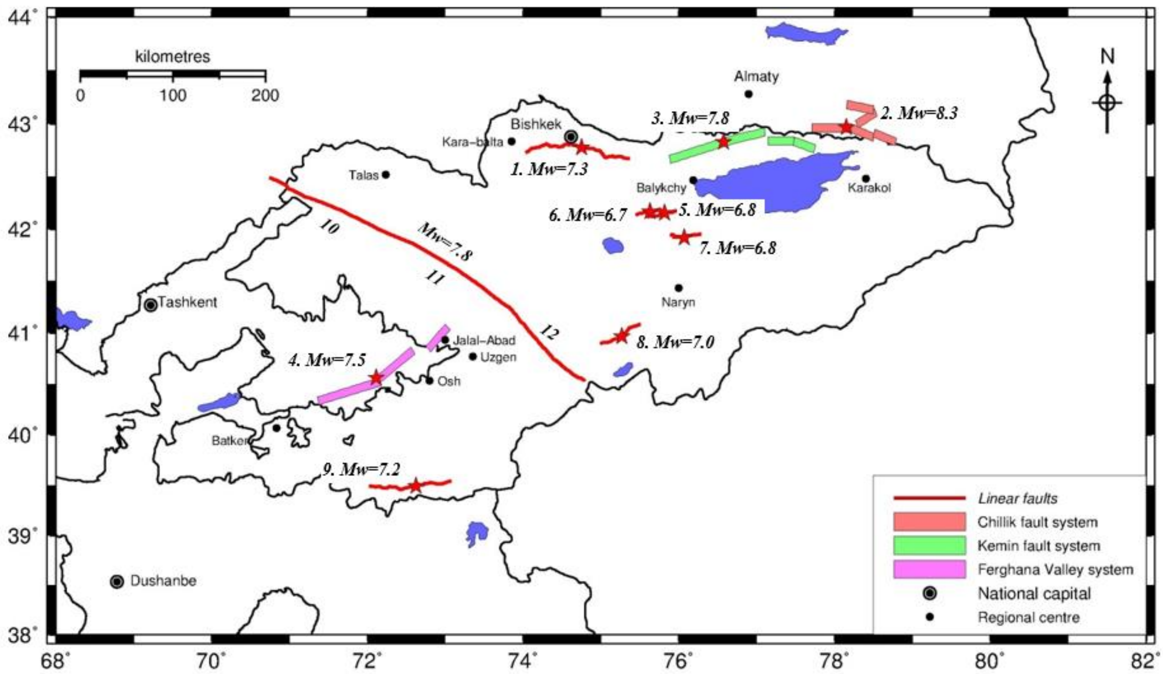

Figure 11 Fault distribution and locations of the scenario events for each fault system.

Table 3 List of scenarios events and closest urban centres

No.	Scenario	Magnitude, M_w	Nearby Urban Centres
1.	Issyk Ata	7.3	Bishkek
2.	Chilik	8.3	Ak-Bulak, Tup, Balykchy, Karakol
3.	Kemin	7.8	Kemin, Balykchy, Karakol, Chopon Ata
4.	Ferghana Valley	7.5	Jalah-Abad, Osh, Uzgen
5.	South Kochkor	6.8	Kochkor, Balykchy
6.	Akchop Hills	6.7	Kochkor, Balykchy
7.	Telek Karakhudzhur	6.8	Kochkor, Balykchy
8.	Oinik Djar	7.0	At-Bashy, Naryn
9.	Alai Pamir	7.2	none
10.	Talas Ferghana West	7.8	Talas, Toktogul
11.	Talas Ferghana Central	7.8	Talas, Toktogul, Birdick, Kazarman
12.	Talas Ferghana East	7.8	Toktogul, Birdick, Kazarman

Table 4 Range of scenario results for each asset portfolio (mean results)

Asset Portfolio	Economic Losses			Fatalities
	USD	% Total Portfolio Value	% GDP	
Hospital Buildings	22 million to 1.93 billion	n/a	0.33% to 29%	2 to 385
School Buildings	13 to 387 million	0.9% to 26%	0.20% to 5.9%	164 to 11,400
Fire Station Buildings	1.6 to 43 million	n/a	0.02% to 0.65%	1 to 11
Residential Buildings[2]	138 million to 11 billion	0.23% to 19%	2.1% to 167%	200 to 10,300
Transport Infrastructure - Roads	60 million to 1.0 billion	0.2% to 3.0%	0.9% to 15%	n/a
Transport Infrastructure - Bridges	2.4 to 22 million	0.5% to 4.4%	0.04% to 0.33%	n/a

The losses associated with infrequently occurring but large magnitude (Mw= 6.7 to 8.3) scenario earthquakes across the country that could occur are expected to be very large: potentially in the order of many billions of USD and thousands of casualities (refer to Table 4).

Table 5 Probabilistic time-based results, Expected Annual Losses (EAL) (mean results)

Asset Portfolio	Economic Losses (EAL)			Fatalities (EAL)
	USD	% Total Portfolio Value	% GDP	
Hospital Buildings	27 to 55 million	n/a	0.41% to 0.84%	3 to 6
School Buildings	6.5 to 11.4 million	0.43% to 0.76%	0.10% to 0.17%	32 to 54
Fire Station Buildings	1.2 to 2.4 million	n/a	0.02% to 0.04%	1 to 2
Residential Buildings[3]	121 to 265 million	0.21% to 0.45%	1.8% to 4.0%	96 to 200
Transport Infrastructure - Roads	Not provided	Not provided	Not provided	Not provided
Transport Infrastructure - Bridges	Not provided	Not provided	Not provided	Not provided

[2] For the R2 residential exposure model results. Refer to the Component 3 Risk Report (Arup, 2017b).

[3] For the range of results from the R1 and R2 residential exposure models.

The probabilistic time-based risk results show that the Kyrgyz Republic 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 (refer to Table 5).

In addition to highlighting **the high level of seismic risk in the country overall,** this study found that **the risk was generally highest around Osh and Jalah-Abad, followed by Bishkek and its surrounding urban areas.** Due to the amount and type of building stock in Bishkek, this study found that the highest economic losses for residential buildings, hospitals and fire station buildings are concentrated in Bishkek (Figure 12).

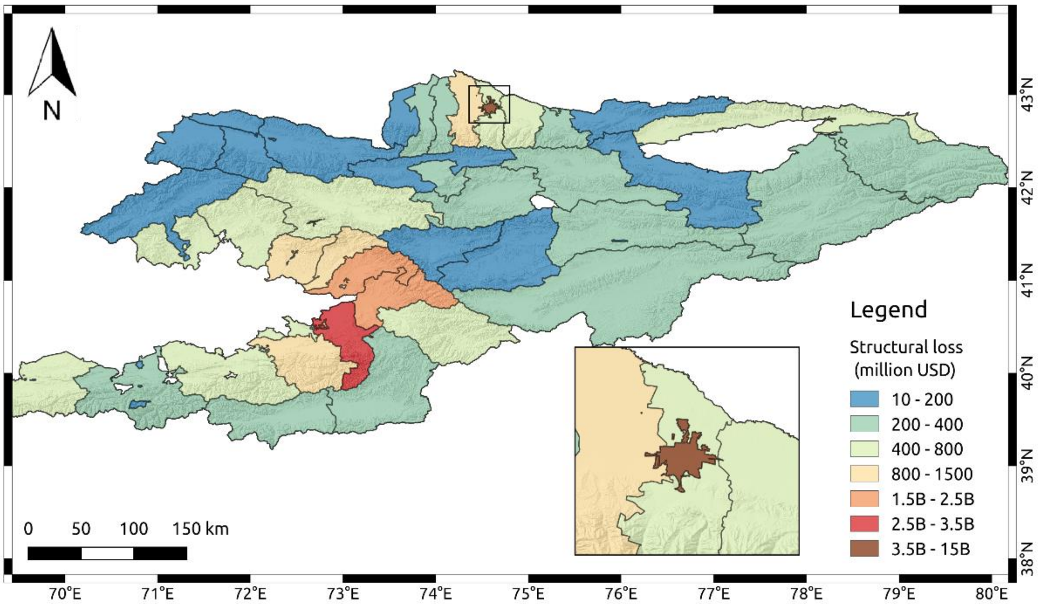

Figure 12 Mean economic loss map for residential buildings (return period of 500 years), aggregated at the rayon level. USGS definition of V_{S30}. Exposure model R2.

From the seismic risk assessment results, structural typologies (construction types) with the highest losses (economic and human) were: adobe buildings, unreinforced masonry buildings, reinforced/confined masonry buildings, flat slab pre-cast buildings and reinforced concrete frame buildings with masonry infill. For residential buildings, pre-cast panel buildings, concrete moment frame buildings and concrete shearwall also contributed significantly to economic losses. Refer to Appendix E for descriptions of the structural typologies.

This level of risk highlights the importance of developing a country-wide seismic risk reduction strategy and investing in seismic risk reduction measures, particularly for higher importance assets such as hospitals, schools, fire stations and critical transport infrastructure.

The next section will present recommendations for the strategy based on the results of this study.

3 Seismic Risk Reduction Strategy - Overview

3.1 Introduction

There is already an awareness of the severe risks in the Kyrgyz Republic posed by earthquakes, and there have been ongoing efforts by the government and other stakeholders to reduce the risk. This section summarizes existing policy in the Kyrgyz Republic relating to Disaster Risk Management (DRM) and proposes a seismic risk reduction strategy for the country based on the results of this study.

More detailed risk reduction recommendations are given in Section 4 of this report and in Section 7, the recommendations are framed for key stakeholders. In Section 5, high level guidance on seismic assessment and retrofit is given. In Section 6, the results of the cost benefit analyses are presented.

3.2 Existing Strategy, Policies and Programmes Related to Disaster Risk Management

Disaster Risk Management (DRM) is defined as the systematic process of using administrative decisions, organizations, operational skills, and capacities to implement policies, strategies, and coping capacities of a society to reduce the impacts of disasters. Supporting this, the purpose of Disaster Risk Reduction (DRR) actions are to minimize disaster vulnerability by avoiding (prevention) or limiting (mitigation and preparedness) the adverse effects of hazards within the broad context of sustainable development (UNISDR, 2009).

The government of the Kyrgyz Republic has recognized the importance of adopting DRM and DRR strategies to address the risks in the county from natural and man-made disasters. There are a number of policies and laws which incorporate DRM and DRR into national policy, including the 'National Strategy for Sustainable Development for the Kyrgyz Republic for the period of 2013 to 2017' and the 'Draft 2016-2030 Strategy of the Emergencies Protection of the Kyrgyz Republic'. The recommendations in this report for seismic risk reduction are aligned with current policy. In addition, consideration has been given to past and ongoing programmes in disaster risk reduction in the country and ongoing coordination with neighbouring countries and NGOs.

Past key legislation and activities relating to DRM and DRR in the Kyrgyz Republic include:

- Development of laws and regulations in Civil Protection;
- Database on natural hazards in the Kyrgyz Republic;
- Uniform Warning and Control System (2014) and National Integrated Population Notification and Warning System (OKSION);
- Unified Emergency Dispatch Service – 112;
- National Platform of Disaster Risks Reduction; and

- National Program of Repair and Reconstruction of School and Pre-School Buildings for the period of 2014 to 2020.

Appendix F contains a more detailed summary of past DRM and DRR activities.

3.3 Key Stakeholders

Key stakeholders related to seismic risk reduction and their abbreviated names used in this report are listed in Table 6 below:

Table 6 Stakeholders related to DRR in the Kyrgyz Republic

Stakeholders
National Government of the Kyrgyz Republic (National Government)
Steering Committee for Seismic Risk Reduction in Kyrgyz (Steering Committee)
Ministry of Education and Science (MoE)
Ministry of Health (MoH)
Ministry of Emergency Situations (MoES)
Construction/Building (GOSSTROY)
Ministry of Finance (MoF)
State Insurance Organization (SIO)
Ministry of Transport and Communications (MoT)
Ministry of Economics (MoEc)
Institute of Seismology (IS)
The National Statistical Committee (NSC)
State Institute of Seismic Construction and Engineering Projects (SISCEP)
National Institute of Strategic Research (NISR)
Central-Asian Institute for Applied Geosciences (CAIAG)
World Bank (WB)

Refer to Appendix G for descriptions of the function and role of the stakeholders.

3.4 Seismic Risk Reduction Strategy – Goals and Priorities

The seismic risk reduction strategy for the Kyrgyz Republic is presented in this section. The recommendations are framed according to the priorities and objectives of the Sendai Framework for Disaster Risk Reduction (United Nations, 2015) which was formally adopted in the recent 'Draft 2016-2030 Strategy for the Emergency Protection of the Kyrgyz Republic'(National Government, 2016).

The Sendai Framework is a 15-year, voluntary, non-binding agreement which recognizes that the State has the primary role to reduce disaster risk but that responsibility should be shared with other stakeholders including local government and the private sector. Its main aim is the substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries (UNISDR, 2009).

The proposed goals of the Sendai Framework are to:

- Reduce **loss of life** (Goal 1);
- **Reduce the number of people** affected by seismic events/disasters (Goal 2);
- **Reduce the damage to physical assets** and related disruption through improved seismic resilience (Goal 3);
- **Improve regional and international cooperation** in seismic risk reduction (Goal 4); and
- **Improve communication of seismic risk** to the population through awareness campaigns, disaster preparedness training and early warning systems (Goal 5).

The broader DRR priorities (tailored for the reduction of seismic risk) of the framework are:

- **Understanding seismic risk** (Priority 1);
- **Strengthening disaster risk governance** for earthquake related disasters at the local, regional and national level (Priority 2);
- **Investing in seismic risk reduction measures** for improved seismic resilience (Priority 3); and
- **Enhancing disaster risk preparedness** for earthquake risk including promoting risk awareness, emergency preparedness training and promoting 'Building Back Better' (Priority 4).

3.5 Seismic Risk Reduction Strategy – Objectives, Actions and Key Stakeholders

Table 7 below provides an overview of seismic risk reduction strategy recommendations for the Kyrgyz Republic. Seventeen (17) areas for improvement are provided aligned with the four Sendai Framework priorities. Table 7 also summarizes the related objectives, priority actions and outputs for each area as well as indicating key stakeholders. In addition, the table identifies if the recommended action is already included in the 'Draft 2016-2030 Strategy for the Emergency Protection of the Kyrgyz Republic'(National Government of the Kyrgyz Republic, 2016) and where additional information is provided in this report.

Table 7 Seismic Risk Reduction Strategy for the Kyrgyz Republic

Priority 1 – Understanding Seismic Risk							
No.	**Area for Improvement**	**Objectives**	**Actions**	**Outputs/Outcomes**	**Key Stakeholders (Lead Stakeholder(s) in bold)**	**Included in the Kyrgyz Republic Draft 2016-2030 Strategy?**	**Detailed Recommendations (This Report)**
1	**Improved knowledge of seismic hazard** in the Kyrgyz Republic.	To better understand and characterize active tectonic faults in the country.	Further investigation and study of active tectonic faults across the country. Fund courses on seismology and engineering seismology at university level.	Geological fault maps and associated geological fault characterisation reports.	**National Government** (for funding and assignment of roles)**,** CAIAG	**Possibly,** Item 21.2 refers to modernization of an observation network of seismic hazards.	*Section 4.3*
		To better understand the characteristics of strong ground shaking from earthquakes in the country.	Support the existing countywide network of strong ground motion recording instruments. Collect and openly share ground motion data.	Strong motion recording network and strong motion record database.	**National Government** (for funding and assignment of roles)**,** CAIAG	**No**	
		To better understand seismic site effects, particularly for more densely populated areas of the country.	Perform shear-wave velocity and geotechnical investigations in urban areas (as already undertaken by CAIAG in urban centres around the country).	Microzonation maps for urban areas (Bishkek, Osh and other prioritised urban areas).	National Government (for funding and assignment of roles), **Local Government**, Technical Specialists (in-county and international)	**No**	
2	**Improved knowledge of exposure and vulnerability for critical assets** in the Kyrgyz Republic to inform updated seismic risk assessments.	To gather selected data collection on exposure and vulnerability (site assessments) for priority assets in the country (hospitals, emergency response facilities, schools and critical infrastructure including roads and bridges). As a secondary priority, data should also be gathered for selected types of older, high occupancy residential buildings.	Perform detailed site surveys and seismic assessments for priority assets. Establish a national database for survey data and reports. Communicate findings with key stakeholders.	Detailed survey data and reports to be available in an accessible national database in geospatial format managed by an appointed government agency.	National Government, Local Government, **GOSSTROY** MoES, MoE, MoH, MoT World Bank, Technical Specialists (in-county and international)	**Yes** for residential housing in seismic intensity zones 8 & 9, see Item 2.2. **Not included for other asset categories** specifically but Item 2.3 calls for seismic risk assessment for large settlements.	*Section 4.6* (hospitals). *Section 4.7* (emergency response facilities) *Section 4.4* (schools) *Section 4.9* (roads and bridges) *Section 4.8* (residential buildings)
		To gather and share post-earthquake damage and loss data for physical assets. To gather and share post-earthquake site effect data (landslide, liquefaction, fault rupture etc.).	Form an in-country organization to carry out multi-disciplinary post-earthquake data collection missions. This should include investigation of: performance of physical assets, geological and seismographic data, evaluation of disaster management and socio-economic effects. Communicate findings with key stakeholders including the insurance industry.	Field investigation reports and related data. A database where geospatial data (survey data and reports) are stored.	**National Government** (for funding and assignment of roles), MoES, **Technical Specialists (in-county and international),** GOSSTROY, Insurance.	**No**	*Section 4.3*

Priority 1 – Understanding Seismic Risk							
No.	**Area for Improvement**	**Objectives**	**Actions**	**Outputs/Outcomes**	**Key Stakeholders (Lead Stakeholder(s) in bold)**	**Included in the Kyrgyz Republic Draft 2016-2030 Strategy?**	**Detailed Recommendations (This Report)**
3	Improved program and planning for systematic updating of **earthquake damage and loss estimation for critical assets** in the country to inform decision makers and other stakeholders.	To perform updated seismic risk assessments for priority assets (hospitals, emergency response facilities, schools and critical infrastructure, cultural heritage assets). The risk assessment for residential buildings can be updated to incorporate any findings from the additional survey data on the performance of specific residential building typologies.	Commission and execute a series of more detailed seismic risk assessments for critical asset portfolios that will inform the ongoing DRR strategy. Communicate findings with key stakeholders including the insurance industry.	Reports and digital data should be uploaded to the Kyrgyz GeoNode.	National Government, Insurance MoES, MoE, MoH, MoT World Bank, **Technical Specialists (in-county and international)**	**Possibly**, Item 2.3 calls for seismic risk assessment for large settlements but asset categories are not specified. Item 2.6 is for assessment of risks caused by hazardous production facilities.	*Section 4.6* (hospitals). *Section 4.7* (emergency response facilities) *Section 4.4* (schools) *Section 4.9* (roads and bridges) *Section 4.8* (residential buildings) *Section 4.10* (cultural heritage)
4	**Improved education of and communication to citizenry about seismic risk.**	To increase awareness of seismic risk. To inform public officials and other decision makers. To promote competency of professionals.	Continue public awareness campaigns through national media.	Radio, television broadcasts. Written materials.	National Government, **MoES**.	**No**	
			Implementation of earthquake disaster awareness in schools.	Schools curriculum for teachers and students on seismic risk.	National Government, Local Government, **MoE**, MoES.	**Yes**, Item 4.1.	*Section 4.5* (schools)
			Education of government and municipal officials through training and written materials.	Training materials and guidance documents for government and municipal officials.	National Government, Local Government, **MoES**.	**Yes**, Item 4.2.	
			Education of engineers and architects.	Continued Professional Development (CPD) courses for engineers and architects. University curriculum on seismic hazard and risk, including design requirements.	**GOSSTROY**, MoES, Kyrgyz Republic Universities.	**No**	*Section 4.4*
			Education of communities in earthquake awareness. Consideration should be given for gender and age factors, cultural differences as well as more vulnerable groups.	Community engagement to empower community groups and local leaders.	**Local Government**, MoES, Communities.	**Yes**, Item 4.3.	

Priority 2 – Strengthening Disaster Risk Governance							
No.	**Area for Improvement**	**Objectives**	**Actions**	**Outputs/Outcomes**	**Key Stakeholders (Lead Stakeholder(s) in bold)**	**Included in the Kyrgyz Republic Draft 2016-2030 Strategy?**	**Detailed Recommendations (This Report)**
5	**A legally mandated and more robust framework for DRM**.	To strengthen the DRM framework and policy in the Kyrgyz Republic, including aspects which address seismic risk.	To finalize and approve the draft 'Law on Seismic Safety' to provide a legal basis for the National Programme for Seismic Safety. To finalize the current draft '2016-2030 Strategy for the Emergency Protection of the Kyrgyz Republic'. To establish consistent DRM terminology among stakeholders and in laws related to DRM and DRR.	A finalised and adopted DRM strategy. Investment plans to carry out DRM actions. Strategy for obtaining funds to carry out DRM (from National Government, local government and NGOs).	**National Government**, MoES World Bank.	**Yes**	*Section 4.2*
6	**Improved, up-to-date land use plans for local authorities**, particularly for urban areas which also incorporate seismic hazard and risk considerations as well as emergency response needs.	Overall, to reduce the risk from earthquake hazards for new and existing development. Specifically: To ensure the regulatory framework requires the development and adoption of up-to-date land use plans.	Enact new laws which require urban areas to have up-to-date land use plans.	Legal framework to require up-to-date Master plans and Detailed plans for urban areas.	**National Government**, Local Government, World Bank	**Yes**, Item 11.2	*Section 4.4*
		To ensure land use plans take into account up-to-date information on seismic hazard and risk.	Provide funding and added capacity to those who carry out land use planning to access, understand and incorporate seismic hazard and risk considerations into land use planning documents. This should involve the ability to access relevant databases which contain hazard and risk data (GeoNode and others).	Hiring of additional staff in Local Government, MoES and other government agencies involved in producing land use planning. Training programmes for existing staff involved in land use planning in seismic hazard and risk.	National Government, **Local Government**, Design Institute, World Bank, Technical Specialists	**No**	
		To enforce the law which requires land use planning authorities to take into account emergency response needs.	Provide funding and added capacity within MoES and local authorities for emergency response planning input into land use planning.		**Local Government,** MoES, World Bank	**No**	

Priority 2 – Strengthening Disaster Risk Governance							
No.	**Area for Improvement**	**Objectives**	**Actions**	**Outputs/Outcomes**	**Key Stakeholders (Lead Stakeholder(s) in bold)**	**Included in the Kyrgyz Republic Draft 2016-2030 Strategy?**	**Detailed Recommendations (This Report)**
7	**Improved capacity and capability of design and checking authorities** related to ensuring the seismic safety for new construction and seismic retrofits.	To improve the quality of reviews ahead of design approvals and construction permits. To ensure consistent construction monitoring To ensure consistent enforcement of regulatory documents.	Ensure the permitting process is simple and transparent. Introduce information communications technology (ICT) for building control procedures. Increase capacity and remuneration of officials involved in design approvals and construction monitoring. Ensure fees are consistent with the cost of regulatory services. Ensure penalties are enforced for lack of compliance. Increase inspection requirements for construction, particularly residential construction. Involve seismic engineers in approvals process for construction licences. Introduce more stringent requirements for obtaining an engineering professional license.	Updated regulatory requirements and processes. Added capacity for officials involved in the regulatory process. Revised requirements for obtaining engineering professional licences.	Local Government, **GOSSTROY**	**No**	*Section 4.4*
8	**Improved regional and international collaboration** in the area of seismic engineering and risk reduction.	To promote international collaboration and exchange of knowledge in the area of seismic engineering and risk reduction.	Create (or further develop) academic exchanges at university level. Strengthen international collaboration in the field of seismic engineering among professionals. Also Refer to Priority 1, No. 2, establishing mechanisms to collect post-earthquake survey data.	Established exchange programmes with targets that are monitored. Incentives can be provided to participating institutions such as research or teaching grants. Government scholarships to foreign universities (which include conditions such as returning to the Kyrgyz Republic for a certain number of years after completion of degree). Hosting of international conferences related to seismic engineering and/or DRR.	National Government, **Universities**, Technical Specialists (in-county and international)	**Yes**, Item 18.1 (not specific to seismic risk).	
9	**Improved and maintained centrally managed and accessible data on seismic hazard, exposure and risk.**	To create county-wide databases for seismic hazard and risk data including location and characteristics of physical assets and expected damage and losses.	Roles and responsibilities to be assigned for the maintenance of databases and sharing of information among government agencies and other stakeholders.	Establishment of openly accessible databases, potentially via the Kyrgyz Republic GeoNode.	**National Government** and other appointed stakeholders, Technical Specialists (in-county and international)	**Possibly,** Item 1.1 involves data collection and processing for monitoring and forecasting emergencies**.** Not specific to seismic hazard and risk and does not include physical damage and loss data.	*Section 4.6* (hospitals). *Section 4.7* (emergency response facilities) *Section 4.4* (schools) *Section 4.9* (roads and bridges) *Section 4.8* (residential buildings)

Priority 3 – Investing in Risk Reduction for Improved Seismic Resilience							
No.	**Area for Improvement**	**Objectives**	**Actions**	**Outputs/Outcomes**	**Key Stakeholders (Lead Stakeholder(s) in bold)**	**Included in the Kyrgyz Republic Draft 2016-2030 Strategy?**	**Detailed Recommendations (This Report)**
10	**Improved land use plans taking into consideration hazard and risk information**.	To reduce the risk from earthquake hazards for new and existing development.	Review and update land use plans based on the results of this study. Add capacity and capability to local authorities and others who carry out land use planning (the Design Institute) so they can access and use hazard and risk data from the Kyrgyz GeoNode and other sources.	Hazard and risk maps and data are integrated into land use planning and regulations. Efforts should prioritize large urban centres (Bishkek, Osh) and other more highly populated areas.	National Government, **Local Government,** Design Institute, Technical Specialists	**No**	*Section 4.4*
			Educate government officials in planning and engineering professionals on selection of safer sites for critical/higher importance buildings and infrastructure.	Guidelines for site selection for critical buildings (schools, hospitals, emergency response facilities) and infrastructure.	Local Government, Design Institute, **Technical Specialists**, MoES.	**No**	
11	**Improved understanding** among engineers, architects and developers **about correctly applying the Kyrgyz Republic seismic code provisions** and guidance for seismic assessment and retrofit.	To train engineering professionals and architects in seismic engineering code provisions. To train engineering and architectural university students in seismic engineering code provisions.	Develop and deliver Continuing Professional Development courses on the current seismic code and on good practice seismic design principles and detailing. Include curriculum on seismic design and the use of the codes at Kyrgyz Universities for architectural and engineering degrees.	Training materials for CPD. University courses in seismic design and application of Kyrgyz Republic seismic codes.	**GOSSTROY**, Technical Specialists (in-country and international), Universities	**No**	*Section 4.4*
		To build capability for engineering professionals to perform seismic assessments and retrofits for common usage and construction types in the country.	Develop practical, locally appropriate guidance on seismic retrofit of buildings and infrastructure (schools, hospitals, fire stations, residential, roads and bridges).	Guidelines in seismic assessment and retrofit. Specific guidance is recommended for different asset portfolios (schools[4], hospitals, emergency response facilities, transport infrastructure). Guidance for retrofit of common types of single-family residences.	GOSSTROY, **Technical Specialists (in-country and international),** Local Government, World Bank MoE (schools), MoH (hospitals), MoES (emergency response facilities), MoT (bridges)	**No**	*Section 4.4*
12	**Improved codes and standards and guidance related to seismic design, assessment and retrofit.**	To update seismic codes. To improve the provisions for seismic design and retrofit of buildings and infrastructure.	Recommendations related to updates for the seismic code include: For new design, prohibition of certain structural systems known to perform poorly in earthquakes for critical/high importance buildings and infrastructure. Updated seismic design maps for seismic hazard criteria. New provisions for non-structural mitigations. Update Norms and/or guidelines on seismic assessment of buildings and infrastructure.	Revised Norms. Guidance materials relating to the Norms.	National Government, **GOSSTROY,** Technical Specialists (in-country and international) MoE (schools), MoH (hospitals), MoES (emergency response facilities), MoT (bridges)	**No**	*Section 4.4* *Section 4.6* (hospitals) *Section 4.7* (emergency response facilities) *Section 4.4* (schools) *Section 4.9* (roads and bridges) *Section 4.8* (residential buildings)

[4] We understand from consultation with stakeholders that as part of the World Bank Safer School Program in the Kyrgyz Republic, guidance for schools retrofitting is currently in development.

Priority 3 – Investing in Risk Reduction for Improved Seismic Resilience							
No.	**Area for Improvement**	**Objectives**	**Actions**	**Outputs/Outcomes**	**Key Stakeholders (Lead Stakeholder(s) in bold)**	**Included in the Kyrgyz Republic Draft 2016-2030 Strategy?**	**Detailed Recommendations (This Report)**
			Update Norms related to seismic retrofit of buildings and infrastructure.				
13	**Improved seismic performance of buildings and infrastructure to reduce economic losses and loss of life from damaging earthquakes.**	Based on updated seismic risk assessments for priority assets in the country, develop and implement updated DRR plans for critical assets (hospitals, schools, emergency response facilities, critical infrastructure, cultural heritage). Facilitate and incentivize economically feasible seismic retrofit/upgrading of physical assets in both the public and private sectors.	Targeted upgrading and replacement of critical assets. Plans for continuity of critical services (health, communications, financial services, etc.) should be in place. For hospitals, schools, emergency response facilities (including fire stations) and critical infrastructure (including bridges), prioritized upgrading, replacement and seismic retrofitting of hospitals. Special considerations are required for reducing risk to cultural heritage assets. Cost benefit analyses can be performed to evaluate options.	Costing of new construction (replacement) and for seismic retrofit options. Cost benefit analyses to inform decision making and prioritization. Finalized investment plans for each sector/type of critical asset. Identifying funding to carry out investment plans. Implementation of risk reduction plans for each sector/type of critical asset. Monitoring and feedback from implementation phase to inform ongoing risk reduction programmes.	**National Government (for investment planning), GOSSTROY (for implementation)** World Bank, other NGOs MoES, MoE, MoH, MoT	**Yes,** Item 16.6 for schools, also Item 2.3 for large settlements (no specific asset types specified). Specific programmes for **hospitals, emergency response facilities** are critical infrastructure are recommended.	*Section 4.6* (hospitals). *Section 4.7* (emergency response facilities) *Section 4.4* (schools) *Section 4.9* (roads and bridges) *Section 4.8* (residential buildings) *Section 4.10* (cultural heritage)
			Provide incentives for owners of multi-family occupancy residential buildings to repair and retrofit. Provide incentives for owners to retrofit their houses.	Low interest government loans and/or matching funding for multi-family occupancy housing. Tax credits for retrofitting of single family houses.	National Government, **Local Government,** GOSSTROY**,** MoF	**No**	*Section 4.8* (residential buildings)
14	**Improved prevention of contamination of water supplies and exposure to radionuclides** from tailings and waste dumps in the event of an earthquake-triggered landslide.	Conduct risk mitigation actions for high-priority tailings and storage areas for radioactive wastes located in earthquake and landslide risk areas.	Refer to Item 10.2 in Draft 2016-2030 Strategy.	Refer to Item 10.2 in Draft 2016-2030 Strategy.	**National Government**, MoES, Technical Specialists	**Yes,** Item 10.2 (not specifically for seismic risk)	Not provided as excluded from the scope of this study.

Priority 4 – Enhancing Preparedness for Earthquake Disasters							
No.	**Area for Improvement**	**Objectives**	**Actions**	**Outputs/Outcomes**	**Key Stakeholders (Lead Stakeholder(s) in bold)**	**Included in the Kyrgyz Republic Draft 2016-2030 Strategy?**	**Detailed Recommendations (This Report)**
15	**Improved understanding and implementation of actions for earthquake preparedness**.	To improve emergency preparedness in different key sectors (education, health, critical infrastructure, cultural heritage) and at different scales (National, regional, city-level and communities).	In general, the results of this study should be used to inform emergency response and preparedness planning at a national and local level. Cross sectoral collaboration and sharing of information is essential for robust planning.	Updated national, regional and city level emergency plans.	**MoES**, National Government, Local Government, MoH, MoE, MoT, Communities	**No.**	
			For hospitals, MoES to coordinate which hospitals are more critical for emergency response and expected number of causalities for earthquake scenarios. Countywide emergency preparedness planning and training for hospital staff including communication and coordination post-disaster and maintaining emergency medical supplies. Provision of mobile emergency medical facilities to allow adequately resourced emergency medical response for remote regions or where access to permanent medical facilities is not available.	Sharing of emergency response plans among stakeholders. Hospital emergency response plans and training materials for hospital staff.	MoES, **MoH**, Local Government	**No**, but *Item 7.2* may be related. *Item 20.2* relates to provisions for mobile hospitals.	*Section 4.6* (hospitals)
			For emergency response facilities (including fire stations), MoES to coordinate which emergency responses facilities are more critical for emergency response Countywide emergency preparedness planning and training for emergency response staff including communication and coordination post-disaster and maintaining emergency supplies. Countrywide programme for community first responders.	Sharing of emergency response plans among stakeholders. National, regional and local emergency response plans and training materials for first responders related to seismic risks. Countrywide coverage for emergency response plans and resource (permanent and voluntary), including rural and remote areas.	**MoES**, Local Government, Communities	**Possibly** *Item 7.3* relates to voluntary firefighting.	*Section 4.7* (emergency response facilities)
			For schools, MoES to coordination with MoE and municipalities on which schools they plan to use for emergency response. Countywide emergency preparedness training for teachers and students.	Sharing of emergency response plans among stakeholders. Training materials for teachers and students.	MoES, **MoE,** Local Government		*Section 4.4* (schools)

Priority 4 – Enhancing Preparedness for Earthquake Disasters							
No.	**Area for Improvement**	**Objectives**	**Actions**	**Outputs/Outcomes**	**Key Stakeholders (Lead Stakeholder(s) in bold)**	**Included in the Kyrgyz Republic Draft 2016-2030 Strategy?**	**Detailed Recommendations (This Report)**
15	**Improved understanding and implementation of actions for earthquake preparedness**.	To improve emergency preparedness in different key sectors (education, health, critical infrastructure, cultural heritage) and at different scales (National, regional, city-level and communities).	For critical infrastructure, information on critical roads and bridges (and other critical infrastructure) should be considered for emergency response plans.	Updated emergency response plans (for evacuation, rescue access).	National Government, **MoES**, MoT, Local Government	**No**	*Section 4.9* (roads and bridges)
			For continuity of housing post-disaster, improved plans for housing displaced individuals and families post-disaster.	To plan for assistance to individuals including temporary housing post-disaster consider: Tele-registration programme Temporary financial assistance (cash transfers or vouchers) Disaster assistance centres	**MoES**, Local Government	**No**	*Section 4.8* (residential buildings)
			For cultural heritage assets, emergency preparedness planning and training should include evacuation plans, plans for security post-earthquake and plans to prevent fire.	Emergency response plans and training materials for cultural heritage assets.	**Managers of cultural heritage sites**, MoES, Technical Specialists.	**No**	*Section 4.10* (cultural heritage)
16	**Improved responsiveness and comprehensive systems for emergency response.**	Assess emergency response capability in country or through wider international assistance (shelter, food, search and rescue). Improved early warning systems. Improved and country-wide communications network for emergency response.	Using the results of this study, assess gaps in emergency response infrastructure (i.e. fire stations) and first responders across the country. Scale-up programmes for training of community first responders in areas without designated emergency response personnel.	Updated investment plan for improving capacity for emergency response including capacity building in communities. Implementation of the plan.	National Government, Local Government, **MoES,** Communities	**Possibly** *Item 5.1* establishes a Civil Protection Training and Research Center. *Item 7.2* relates to emergency medical services. *Item 7.3* relates to volunteer fire fighting formations.	*Section 4.7* (emergency response facilities)

Priority 4 – Enhancing Preparedness for Earthquake Disasters							
No.	**Area for Improvement**	**Objectives**	**Actions**	**Outputs/Outcomes**	**Key Stakeholders (Lead Stakeholder(s) in bold)**	**Included in the Kyrgyz Republic Draft 2016-2030 Strategy?**	**Detailed Recommendations (This Report)**
17	**Improved economic resources to address post-disaster funding and recovery.**	To understand the funding gap for potential losses from earthquake disasters. To identify potential sources of funds that can be allocated post-disaster. To strengthen government regulation of the insurance market to ensure financial stability and growth of capitalisation and incentivize take up of disaster risk insurance. To spread insurance risk regionally/globally. To increase robustness and penetration in insurance market to respond to earthquake losses.	Gather and share seismic risk assessment loss data to understand funding gap and ensure fair pricing of insurance. The National Government should consider viability of exte-ante funding arrangement, insurance pools, traditional insurance and re-insurance. Consider mandating earthquake insurance for building owners. Train and retain more insurance professionals in the Kyrgyz Republic. Update laws and regulations relating to insurance. Standardize insurance coverage with respect to natural disasters. Raise public awareness about the benefits of private insurance coverage for natural disaster events.	Engagement with international, regional and local insurance stakeholders to share seismic loss data to inform updated catastrophe models for the country and region. A disaster risk financing plan for the National Government. This could include in the longer term, public and private insurance partnerships (countrywide and regional/global). Training for insurance professionals related to policies for disaster related insurance.	**National Government**, MoF, **Insurance**, Technical specialists.	**No,** Some measures to strengthen the insurance industry are included in the 'National Strategy of Sustainable Development of the Kyrgyz Republic for the period of 2013 – 2017' Note that *Item 3.1* related to standardized report for damage and loss data.	*Section 7.2* (Recommendations for National Government) and *Section 7.10* (Recommendations for Insurance sector) *Appendix H* (Further recommendations on Disaster Risk Financing and Insurance)

4 Seismic Risk Reduction Strategy – Detailed Recommendations

4.1 Introduction

In this section, seismic risk reduction recommendations for the Kyrgyz Republic are presented in more detail.

First, general recommendations for risk reduction are given related to DRM policy, understanding seismic risk and the construction and regulatory environment in the Kyrgyz Republic.

Next, risk reduction recommendations for schools, hospitals, fire stations and residential buildings are given including specific seismic retrofit measures for representative building types for each asset category (Refer to Table 8). Appendix A provides more detailed guidance on the selected retrofit measures.

Finally, risk reduction recommendations for transport infrastructure (roads and bridges) are given, with selected examples of critical roads and bridges identified from the scenario risk assessment results. Due to the lack of data provided for transport infrastructure as input to this study, specific recommendations for physical interventions for roads and bridges were not developed.

In addition, this section contains risk reduction recommendations for cultural heritage assets in the Kyrgyz Republic.

Table 8 Summary of proposed seismic retrofit options

Asset Type	No	Description of Seismic Retrofit Options
Schools buildings	S1	Proposed seismic retrofit for 3 storey unreinforced masonry bearing wall school building in a region of moderate to high seismic hazard. Life Safety performance objective.[5]
	S2	Proposed seismic retrofit for 2 storey adobe (mud brick) bearing wall school building in a region of moderate seismic hazard. Limited Life Safety performance objective.
	S3	Proposed seismic retrofit for a 2 storey cast-in-place concrete frame school with unreinforced masonry infill walls in a region of moderate to high seismic hazard. Life Safety performance objective.
Hospital buildings	H1	Proposed seismic retrofit for 4 storey unreinforced masonry bearing wall hospital building in region of moderate to high seismic hazard. Life Safety performance objective.
	H2	Proposed seismic retrofit for 4 storey unreinforced masonry bearing wall hospital building in region of moderate to high seismic hazard. Immediate Occupancy performance objective.
Fire Station buildings	F1	Proposed seismic retrofit for 1 storey unreinforced masonry bearing wall fire station in region of moderate to high seismic hazard. Life Safety performance objective.

[5] Refer to Section 5 and Appendix B for guidance on seismic performance objectives.

Asset Type	No	Description of Seismic Retrofit Options
Residential buildings	R1	Proposed seismic retrofit for 6 storey reinforced masonry residential apartment building in region of moderate to high seismic hazard. Life Safety performance objective.
	R2	Proposed seismic retrofit for 5 storey pre-cast panel residential with monolithic joints apartment building in region of moderate to high seismic hazard. Life Safety performance objective.

4.2 Recommendations Related to the DRM Framework in the Kyrgyz Republic

The following actions are recommended to strengthen the DRM legal and policy framework in the Kyrgyz Republic.

Recommendations	Key stakeholders	Estimated timeframe	Indicative budget	Sendai priority areas
Recommendation 1: Approve the Law on Seismic Safety. Establish consistent DRM terminology in laws related to DRM.	National Government	3 to 6 months	Not provided	2
Recommendation 2: Finalize the DRM strategy for the country.	National Government, World Bank	3 to 6 months	Not provided	1, 2, 3, 4
Recommendation 3: Increase funding for disaster risk reduction, especially related to increased seismic resilience for existing and new assets.	National Government, World Bank, other NGOs	1 to 10 years	Not provided	1, 2, 3, 4
Recommendation 4: Increase community engagement activities as part of disaster risk reduction.	All stakeholders, Communities	1 to 10 years	Not provided	1, 2, 3, 4

4.2.1 DRM Recommendations

The proposed Law on Seismic Safety should be approved by the government. This will provide a legal basis for the current National Programme on Seismic Safety (ICF Consulting Services, 2016b).

Consistent DRM terminology should be established (for hazard, exposure, vulnerability and risk) and the definitions should be included in the preamble to laws relating to DRM in the Kyrgyz Republic; and

The updated DRM Strategy for the Kyrgyz Republic should be finalized which is currently in draft (National Government of the Kyrgyz Republic, 2016). We understand that World Bank will be engaged in a future project to support this. **It is recommended that the results of this study inform the finalised DRM strategy.**

Funding should be increased for seismic risk reduction ahead of a disaster as most funding is currently directed towards post-disaster response (emergency preparedness and relief). Government funds should prioritize seismic risk reduction investments for **critical (lifeline) infrastructure, hospitals, schools, emergency response facilities (including fire stations) and other public buildings.** This should include risk reduction for existing assets as well as investment and regulations to ensure new construction is safer; and

In additional to close collaboration between the current stakeholders (government, private sector and technical specialist organizations), greater emphasis should be put on **engagement with civil society (communities)** in planning, communicating and implementing DRM policy in the Kyrgyz Republic. Recommendations are given in this report for specific areas where community engagement would be beneficial.

4.3 Recommendations Related to Understanding Seismic Risk in the Kyrgyz Republic

This study has produced the first country specific seismic risk assessment for the Kyrgyz Republic but the study has limitations and the understanding of seismic risk (hazard, vulnerability and exposure) can always be improved upon.

Table 9 Priority recommendations related to understanding seismic risk in the Kyrgyz Republic

Recommendations	Key stakeholders	Estimated timeframe	Indicative budget	Sendai priority areas
Recommendation 1: Establish a plan for management of seismic risk data for different sectors. This should including funding and roles and responsibilities.	National Government, GOSSTROY, Insurance	6 to 12 months	Not provided	1, 3
Recommendation 2: Establish a mechanism for post-earthquake damage and loss data collection.	National Government, Technical Specialists	3 to 6 months	Not provided	1
Recommendation 3: Extend the existing countrywide ground motion recording network.	National Government, CAIAG, Institute of Seismology	2 to 10 years	Not provided	1
Recommendation 4: Perform further investigation of active faults in the country.	Technical Specialists	2 to 10 years	Not provided	1
Recommendation 5: Investigate site response effects, particularly in urban areas. This could result in updated microzonation maps in the code.	City governments, GOSSTROY, CAIAG, Institute of Seismology	2 to 10 years	Not provided	1

4.3.1 Seismic Hazard

It is recommended that the seismic hazard model from this study should be used as a basis for future seismic hazard and risk studies. To reduce the uncertainty in the magnitude, frequency and distribution of earthquake ground shaking for the seismic hazard assessment, the following recommendations should be actioned in order of priority:

- **The existing country-wide earthquake ground motion recording network** should be extended to allow the collection of country-specific ground shaking records and calibration of ground motion prediction equations.[6] A government department should be assigned to manage earthquake strong ground motion records.[7]

- Further investigation and the study of the **characterization of active geological faults** across the country should be carried out[8]; and
- **Seismic site response effects** should be investigated in all urban areas so that microzonation maps can be produced.[9] This will require systematically undertaking shear-wave velocity and geotechnical investigations.

4.3.2 Exposure and Vulnerability

It is recommended that the exposure model, structural typologies and assigned fragilities for the risk model in this study should be used as a basis for future risk studies. The limitations of this study generally relate to the lack of accurate information available for the engineering characteristics of the buildings and infrastructure assets. Engineering judgement, statistical data treatment and the input of local experts were used to overcome the above limitations in building and infrastructure information. This exercise has enabled a meaningful set of risk results to be developed that is suitable to inform the development and prioritization of risk management actions at the rayon level. In order to increase confidence in the level of vulnerability of the building stock and implement future building-specific actions and prioritization, selected detailed building-by-building assessments should be performed for the asset portfolios, focusing on:

- Construction material, structural system, total area, number of floors and year of construction;
- Inventory of non-structural components (e.g. medical equipment, in the case of hospitals);
- Accurate investigation of the occupancy of each building;
- Understanding of ground conditions; and

[6] We understand that a country-wide earthquake ground motion monitoring network is planned by GFZ with the collaboration of CAIAG (project Advanced Remote Sensing – Ground Truth Demo and Test Facilities [ACROSS]). Collaboration is ongoing with the Ministry of Emergency Situations in order to exploit this infrastructure for the implementation of early warning and rapid response systems. The long-term sustainability of this infrastructure is dependent on commitmemtn from the Government of the Kyrgyz Republic towards the maintenance and operation of the system.

[7] We understand that the Seismological Institute compiles seismological information and that CAIAG has a network of strong ground motion acceleration instruments. However we are unsure if any government agency is responsible for recording and managing earthquake strong ground motion acceleration records.
We also understand that the World Bank is currently supporting the Central Asia Hydromet Modernization Project (CAHMP). It might be beneficial to consider undertaking the expansion of the country-wide earthquake ground motion recording network as part of CAHMP.

[8] There is good in-country capability to carry out the assessment of geological faults.

[9] We understand that seismic site response investigations have been undertaken by CAIAG and GFZ in selected urban areas.

- Understanding of the broader range of geohazards that might be encountered in addition to the seismic ground shaking hazard.

Similar data should be collected for bridges.[10]

Given they provide critical services, and the current lack of available data, particular attention should be given to **hospitals, fire stations and other emergency response facilities** (Refer to Sections 4.6 and 4.7).

Open source tools and methodologies are available to collect and compile the required information. This information should be held in **building and infrastructure databases** for the entire country and a government department should be assigned to manage this data. Metrics should be established for defining losses in terms of casualities and economic losses. It is recommended that the exposure and vulnerability components for the risk assessments are systematically updated over time.

4.3.3 Learning from Earthquakes

Appropriate mechanisms shall be put in place in order to allow for the **assessment of building and infrastructure damage and losses after earthquake events** by post-earthquake damage surveys. This should include investigation of: performance of physical assets, geological and seismographic data, evaluation of disaster management and socio-economic effects. Such data can potentially be used to calibrate exposure data, fragility functions, as well as fatality and injury rates for different building types and usages. This data will also be useful for the insurance sector to calibrate their pricing and ensure adequate capitalization overall for future seismic risk.

4.4 Recommendations Related to the Construction and Regulatory Environment

This section presents risk reduction recommendations related to the construction and regulatory environment in the Kyrgyz Republic. Specifically, land use planning regulations, building regulations and how effectively regulations are implemented have been considered.

Table 10 Priority recommendations related to the construction and regulatory environment

Recommendations	**Key stakeholders**	**Estimated timeframe**	**Indicative budget**	**Sendai priority areas**
<u>Recommendation 1:</u> Review and update land use plans based on the results of this study.	Local Government, MoES	3 to 6 months	Not provided	2

[10] We understand from stakeholder consultation that approximately 800 bridge assessments have been carried out by the Ministry of Transport (MoT) but no data related to these assessments was provided as part of this study.

Recommendations	**Key stakeholders**	**Estimated timeframe**	**Indicative budget**	**Sendai priority areas**
Recommendation 2: Strengthen legal framework (requirement for land use plans, input from MoES) for land use planning and increase funding. Added capacity in land use planning officials is needed for risk information to be incorporated into plans.	Local Government, MoES	1 to 2 years	Not provided	2
Recommendation 3: Roll out countrywide training in using seismic design standards for professionals.	GOSSTROY, Universities	1 to 2 years	Not provided	2, 3
Recommendation 4: Develop guidance for seismic assessment and retrofitting tailored to each sector.	GOSSTROY, Universities, World Bank	6 to 12 months	Not provided	2, 3
Recommendation 5: Update seismic Norms based on the recommendations of this study. For example, construction types to prohibit for higher importance assets and non-structural mitigations Norm.	National Government, GOSSTROY, Universities	1 to 4 years	Not provided	2
Recommendation 6: Implement measures to improve compliance with regulatory requirements for construction. Refer to Section 4.4.2.	Local Government, GOSSTROY	1 to 2 years	Not provided	2

4.4.1 Land Use Planning

There are four different levels of documents developed for land use management and urban development in the Kyrgyz Republic:

- **Master Plans** (city wide and for large infrastructure projects):
- **Detailed Plans** with accompanying normative acts (based on master plans but with more detailed guidelines on land use, density, function, etc.); and
- At a more detailed scale, **Site Plans** and **Detailed Architectural and Engineering Drawings** for individual buildings.

Most master plans and detailed plans are prepared by the State Design Institute for Architecture and Urban Planning. This Design Institute is largely self-financing and so often uses resources from consultants attached to universities or other specialist institutes. Site plans and detailed drawings are typically prepared by private consultants and developers (ICF Consulting Services, 2016b).

Specific recommendations for reducing seismic risk related to the land use planning regulatory system in order of priority are:

1. **Review and update land use plans based on the results of this study**, particularly relating to the updated information on seismic hazard**.**
2. **Legally require local authorities to develop up-to-date Master Plans and Detailed Plans which are periodically updated at specified intervals.** There is no current legal requirement for this and as a result many smaller settlements do not have them or existing plans are not up-to-date (up to 30 or 40 years old). This will require increased funding for local government authorities to commission the plans.
3. It is recommended that **funding and capacity should be increased in the Design Institute** so it can deliver these plans to a higher standard and take advantage of the current knowledge relating to hazards and risks from natural disasters, including seismic risk. For example, the Design Institute currently does not have the skills and capacity to access the Kyrgyz Geonode which contains up-to-date hazard and risk data. Hence, risk information is often descriptive and not communicated in map form (ICF Consulting Services, 2016b);
    - It is recommended that current data from the Geonode and other knowledge from expert institutions is used in the Master Plans and Detailed Plans and incorporated into maps. Ideally a nationwide database would exist that combines land use planning information with hazard and risk data; and
    - If up-to-date seismic design hazard maps are subsequently developed building upon the results of this study for the country (using PGA or spectral acceleration rather than MSK intensity), it is recommended that these maps be incorporated into considerations for land use planning and building regulatory requirements (i.e. specific hazard zones should link to specific code requirements including structural design requirements).
4. **Master Plans and Detailed Plans should incorporate wider planning considerations for risk reduction and disaster planning**. These include avoiding development on higher risk sites as well as incorporating urban planning requirements for post-emergency response including adequate open spaces, access routes and pre-identified community buildings for emergency supplies/first aid/emergency response coordination.

    Closer coordination with the Ministry of Emergency Situations (MoES) is recommended, particularly related to urban planning requirements for emergency response. The legal requirement for the MoES to be consulted in all land distribution decisions (in the Civil Protection Law 2009) also needs to be observed and enforced. In order to do so, the MoES may need to employ additional specialist staff.
5. **Communicate to the public the rationale for land use management related to seismic hazard and risk**. This is important if recommendations for building retrofit and relocation for specific areas are made with relation to hazard and risk information.

There can be **problems with enforcement** of land use planning requirements and conditions of permit in the Kyrgyz Republic (ICF Consulting Services, 2016b).

4.4.2 Building Regulations

Building codes (Norms) and regulations in the Kyrgyz Republic were under the former Soviet Norms until independence from the USSR in 1991. After independence a number of the former Soviet Norms were updated but were still largely based on Soviet standards. In terms of seismic code development, the standards before 1951 (before PSP 101-51 Regulations of Buildings in Seismic Regions) would be considered 'pre-code' (i.e. no seismic provisions). Significant updates were made to the code in terms of seismic provisions in 1991 (SNiP 11-A 12-81* Buildings in Seismic Regions: Design Codes) and in 2009 (KR 20-02:2009 Aseismic Construction: Codes of Design).[11]

Recommendations related to building regulations in order of priority and timeframe are:

- There is a need **to increase awareness among engineers, architects and developers about seismic safety and regulatory provisions.** It is recommended that training be developed in the form of: (a) Continued Professional Development (CPD) for building professionals and government officials in related specialities; and (b) courses as part of engineering and architectural degrees at Kyrgyz Universities. In addition, there is some confusion among stakeholders and building professionals whether the building codes (Norms) are compulsory (ICF Consulting Services, 2016b). It is recommended that the status of the codes be clarified by the relevant authorities.

  There is also a need **to raise awareness among the general public about seismic safety** provisions so pressure is applied by owners to ensure compliance.

- **Guidelines for seismic assessment and retrofit should be developed for the Kyrgyz Republic** that are compatible with the current Norms.[12] Section 5 and Appendix B provide high level guidance on seismic assessment and retrofit. Appendix A provides guidance on retrofit measures proposed for the buildings in each asset category.

- In the longer term**, the 2009 seismic code should be reviewed and updated.** It is recommended that code updates include prohibiting more vulnerable construction types for higher importance buildings, updated seismic hazard

[11] A review of the history and provisions of the codes in the Kyrgyz Republic can be found in 'Disaster Risk Management, Urban Planning and Housing Construction in the Kyrgyz Republic, Draft' (ICF Consulting Services, 2016b).
[12] A guideline was developed by UNICEF Kyrgyzstan for retrofitting of schools (Pandey, post-2013).

design criteria and hazard maps, and new requirements for the safe anchorage and design of non-structural components[13].

Further research jointly with the private sector should be carried out into seismic design (including retrofit design) and performance of common Kyrgyz construction types, to inform future code updates. Also refer to Section 4.3.3, on learning from in-country post-earthquake damage surveys.

Recommendations related to improved enforcement of construction regulations in the Kyrgyz Republic are:

- Ensure the **permitting process is simple and transparent** and that a conflict resolution and appeals process exists;
- Introduce Information and Communication Technology **(ICT) for building control procedures** to increase efficiency and transparency;
- Increase the **capacity and remuneration of officials** involved in approvals and inspection for planning and construction. One way capacity can be increased is by involving the private sector in design and planning approvals;
- **Ensure fees are consistent with the cost of regulatory services**;
- **Follow through on penalties for lack of compliance**. It should be noted that very harsh penalties may be counterproductive and can encourage avoidance of the regulatory system entirely;
- **Require more inspections for property types and at key stages**: before pouring foundations, at the beginning of constructing the superstructure, during the superstructure construction and at project commissioning;
- **Seismic expert engineers should be engaged in the process of issuing construction licences**; and
- **Increase requirements for professional engineering licences**. For example, require a number of years of supervised experience signed off by a licensed engineer required to obtain professional engineering licence.

These recommendations are consistent with advice given in reports by other organizations including the World Bank and ICF Consulting Services (World Bank, 2016b; ICF Consulting Services, 2016b).

4.5 Seismic Risk Reduction Recommendations for School Buildings

This section presents a summary of priority seismic risk reduction recommendations for school buildings (Table 11). These recommendations apply to pre-school facilities, primary and secondary school buildings and university buildings. A summary of seismic risk results for school buildings is presented followed by a more detailed discussion of the risk reduction recommendations for school buildings. These include recommendations for new and existing schools, emergency preparedness measures and specific retrofit measures. In addition,

[13] US Standards such as IBC 2015 and CBSC 2013 could be used as a basis for updated Norms to address seismic safety of non-structural components.

recommendations are given for geographic prioritization by rayon for carrying out seismic risk reduction measures for school buildings.

Table 11 Summary of priority recommendations for seismic risk reduction for schools

Recommendations	Key stakeholders	Estimated timeframe	Indicative budget	Sendai priority areas
Recommendation 1: Implement a countrywide programme of **emergency planning and preparedness training** for teachers and children. The results of this study should inform emergency response plans.	MoE, MoES, Local Government	6 to 12 months	Not provided	4
Recommendation 2: Enhance knowledge of the **infrastructure baseline** for school in the county by performing selected seismic assessments and update of the schools database.	MoE, GOSSTROY, National Government	3 to 6 months	Not provided	1
Recommendation 3a: Based on an updated exposure model for schools, perform an updated **quantitative seismic risk assessment** for school buildings.	World Bank, MoE	6 months	Not provided	1
Recommendation 3b: Based on the results of the risk assessment, perform **cost benefit analyses to inform a more detailed investment plan and prioritization** for school risk reduction to inform Recommendation 4.	World Bank, MoE			3
Recommendation 4: Perform **prioritized seismic retrofits and replacements for schools.** Consideration should be given to ongoing requirement for investment to maintain school infrastructure (new and existing).	MoE, GOSSTROY	1 to 4 years*	60 million USD	3
Recommendation 5: **Review and update existing model school designs.**	MoE, GOSSTROY	3 to 6 months	Not provided	3
Recommendation 6: Increase requirements for **design approvals and construction monitoring** for schools.	MoE, GOSSTROY, Local Government	1 to 2 years	Not provided	2
Recommendation 6:	GOSSTROY, MoE	1 to 2 years	Not provided	3

Recommendations	Key stakeholders	Estimated timeframe	Indicative budget	Sendai priority areas
Update codes and standards related to new school construction.				
* Note that the schools risk reduction programme is likely to carry on for a much longer period. The timeframe of four years is given for proposed budget.				

Refer to 4.5.3 for recommendations for preliminary prioritization for schools risk reduction activities by rayon based on the high level cost benefit analyses performed in this study.

4.5.1 Summary of Seismic Risk Results for School Buildings

The school building portfolio used for this study for the Kyrgyz Republic contains approximately 5,500 buildings with an estimated total portfolio value of 1.5 billion USD. The total average occupancy for school buildings (teachers and students) is around 1 million people.

4.5.1.1 Scenario Earthquake Risk Results

The earthquake scenario risk results for hospital buildings are summarised in Table 12.

Table 12 Scenario earthquake risk results for school buildings

Scenario	Magnitude, Mw	School Buildings	
		Economic Losses (mean), in million USD	Fatalities (mean)
Akchop Hills	6.7	47	1080
Alai Pamir	7.2	32	466
Chilik	8.3	39	586
Ferghana Valley	7.5	275	7549
Issyk Ata	7.3	181	3757
Kemin	7.8	73	1184
Oinik Djar	7.0	21	403
South Kochkor	6.8	32	650
Talas Ferghana Central	7.8	109	1498
Talas Ferghana East	7.8	97	1368
Talas Ferghana West	7.8	86	1441
Telek Karakhudzhur	6.8	24	370

Refer to Figure 11 in Section 2.7 for locations of scenario events in this study and closest urban centres.

The results for the scenario earthquake events indicate that very large monetary losses, large number of collapsed buildings and a large number of fatalities can be expected. The estimated monetary losses are in the range of 13 to 387 million USD but could be significantly higher (up to 555 million USD). Fatalities are estimated to be in the range of 164 to 11,400 but could be significantly higher (up to 19,000).

4.5.1.2 Time-based Seismic Risk Results

The average annual economic losses associated with earthquake damage to school buildings are estimated to be in the range of 6.5 to 11.4 million USD but could be higher (up to 13 million USD). The average annual fatalities of school occupants are estimated to be in the range of 32 to 54 fatalities but could be higher (up to 63).[14]

The building types that are expected to contribute the most to the estimated monetary losses and human fatalities in school buildings are adobe (ADO), unreinforced masonry (URM2) and reinforced concrete frame buildings with masonry infill walls (RC3). Adobe buildings present the highest contribution to the estimated fatalities, followed by RC3 and URM2 building types. In the case of monetary losses, ADO, RC3 and URM2 have similar contributions.[15]

Economic losses for school buildings are concentrated in Bishkek and rayons near Osh and Jalah-Abad in the south-east of the country (the rayons of Kara-Suisky, Suzaksky, Uzgensky, Bazar-Korgonsky and Nookensky). Human losses are concentrated in the same rayons near Osh and Jalah-Abad in the south-east and for more rare events, in Bishkek.

4.5.2 Recommendations for Risk Reduction for School Buildings

4.5.2.1 Risk Reduction for Existing School Buildings

Significant progress has already been made in establishing baseline data for schools in the Kyrgyz Republic through previous school assessment programmes carried out by government in partnership with NGOs (e.g. UNICEF, the Aga Khan Foundation). This study identified where additional survey data should be selectively gathered to supplement the existing assessment data including:

- In the UNICEF school buildings database, survey data is not distinguished for individual school buildings. Survey data should be organized to identify characteristics of individual buildings and include a school site plan with each building labelled with a unique identifier. This may require additional surveying or input from school authorities to clarify which data are associated with which building;
- More detailed assessments of selected schools representative of common school construction typologies should be undertaken to identify structural systems and non-structural components. This should include opening up

[14] Results presented are the range of mean expected annual losses for all combinations of soil type assumptions and ground motion prediction equations. The upper bound presented are the 95th percentile results. Refer to the Component 3 risk assessment report (Arup, 2017b).
[15] Refer to Appendix E for descriptions and photos of the Kyrgyz Republic structural typologies.

works and materials testing. Ideally, these would take a multi-hazard approach to determine vulnerability to various hazards (seismic, landslide, flooding, etc.); and

- Additional surveys should be conducted for new schools that have been constructed since the past assessment programmes were completed.

This survey data should be kept in a **national level database** maintained by a designated government department which is easily accessible to all relevant stakeholders in the school risk reduction programme (National Government, GOSSTROY, Ministry of Education and others).

Based on the updated school survey data, an **updated quantitative seismic risk assessment of schools** should be performed to further refine **the prioritization strategy for schools** proposed by this study.

In carrying out detailed retrofits to selected schools, the retrofit programme should consider **incremental retrofit** as an option (Refer to Section 5.6). Retrofit work can also be **coordinated with other planned rehabilitation work**. Refer to Section 5.6 for considerations for implementing seismic retrofitting programmes. In addition, the following recommendations apply:

- **Develop retrofit guidance for schools.** There is a current project to do so funded by the UNDP. The project outputs should be reviewed and updated to take into account the results, recommendations and guidance of this study; and
- **Evaluate designs for current seismic retrofits** being carried out in the Kyrgyz Republic and any **cost data** available for retrofit.

4.5.2.2 Risk Reduction for New School Buildings

For the construction of new schools, the following risk reduction recommendations apply:

- **Norms and/or Ministry of Education model school programmes should prohibit certain structural systems** in the code for new schools. The prohibited systems should include adobe (ADO), pre-cast flat slab systems (RCPC3) and unreinforced masonry (URM) that have been shown to perform poorly in earthquakes. Appendix I gives recommendations for construction types which have been shown to perform better in earthquakes for new school buildings. These include:
    - Cast-in-place concrete moment frame buildings, cast-in-place concrete shearwall buildings and dual system buildings (a combination of shearwall and moment frame) for large scale school buildings; and
    - Reinforced hollow block masonry buildings and timber frame with nailed plywood shearwall buildings for smaller scale schools of 4 storeys or less. In rural or remote areas, timber brace frame schools may be one of the best performing options using local construction skills and materials.
- **The current code should be reviewed and updated to consider functional requirements** for schools. The code is based on former Soviet codes and may be too prescriptive in terms of layouts allowed, etc.;

- **Evaluate model school designs** in terms of cost of construction, their appropriateness for local construction techniques and materials, their compliance with current code and their seismic performance;
- **Increase requirements for design approvals and construction monitoring** for new schools and school retrofitting activities; and
- **Target higher than Life Safety performance** for new schools to provide an added margin of safety for protecting the lives of school children as well as to ensure continuity of education after an event.[16]
- It is recommended that budgets are identified (either at local or national level) for the maintenance of school buildings over the course of their design life.

In general, the current capacity in schools and the new demand (or reduction in demand) for school facilities as well as any government plans for development of facilities in this sector should be evaluated. These **planning considerations should be integrated into the school risk reduction programme** decision-making process.

It is important that seismic design requirements are enforced for new construction. Improved land use plans and enforcement can also ensure that development for new school buildings avoids higher risk sites. Refer to Section 4.4.1.

4.5.2.3 Emergency Response and Preparedness for School Buildings

Key risk reduction recommendations related to **emergency response and preparedness** for students and teachers include:

- **The Ministry of Emergency Services** should coordinate and communicate with local governments about **which schools they plan to use for emergency response or temporary accommodation post-disaster**. There is an incentive to prioritize retrofits for these schools and have higher seismic performance objectives for the design of these retrofits;
- **Countrywide emergency preparedness training** for teachers and staff should be implemented for the whole country. This can build on previous programmes and materials (UNDP, 2008); and
- **Egress routes** in schools should be clearly marked and **hazardous non-structural components that may fall and impede egress or injure people evacuating from a school building should be mitigated**.

4.5.3 Specific Retrofit Measures for School Buildings

On the basis of the seismic risk results obtained in the present study, retrofits should focus on the following school building types with the highest economic losses and fatalities:

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[16] The code currently requires an importance factor of 1.2 to increase seismic design loads for schools which increases the seismic design loads by 20% (Table 5.4 of SNIP KR 20-02:2009).

- **Adobe** (ADO);
- **Reinforced concrete buildings with masonry infill walls** (RC3); and
- And **unreinforced masonry** (URM).

Retrofit options have been developed for the following types:

- **Retrofit S-1** is for an unreinforced masonry school and consists of adding new concrete walls, improving the diaphragm capacity of pre-cast floors, additional tying to improve load path and non-structural element mitigations. The Life Safety performance objective is targeted.[17]
- **Retrofit S-2** is for an adobe school and consists of strengthening walls, adding buttresses to walls, tying to improve load path and bracing the timber roof as well as non-structural element mitigations. The Limited Life Safety performance objective is targeted.
- **Retrofit S-3** is for a cast-in-place reinforced concrete frame school with masonry infill walls and consists of adding new concrete walls, jacketing columns, improving the diaphragm capacity of pre-cast concrete floors, additional tying to improve load path and non-structural element mitigations. The Life Safety performance objective is targeted.

Each retrofit option is presented in more detail for a representative building selected from the exposure dataset. A photograph, plan view, description of the building and list of key deficiencies and proposed mitigations are given for each retrofit example. More detailed guidance for each mitigation measure is provided in Appendix B of this report.

[17] Refer to Section 5.4.4 and Appendix B, Table B-2 for definitions of seismic performance objectives.

School Name: Toktogul HS No. 1 **Retrofit S-1**
Address: 15 Chernotkach Street, Toktogul City
GIS Coordinates: 41.86925, 72.94587
Approximate Gross Area: 4482 m^2


Building elevation 1


Building elevation 2

Site Description
The building is located on flat terrain, and there is an open access area to the building on all sides of the school property.

Building Description
The school building consists of 2 and 3 storey blocks. The structural system is loadbearing unreinforced masonry walls (for both gravity and lateral loads). The wall thickness is assumed to be 510 mm for exterior walls and 380 mm for interior walls. The floors are precast (reinforced concrete) and the foundations are continuous reinforced concrete strip footings. The roof is constructed with pitched timber rafters and asbestos roof sheeting above precast floor slabs

Hazard Level
Moderate to High

Seismic Performance Objective
Life Safety (no code importance factor)

Context
Semi-urban

Building Layout
H-shaped plan; consists of 3 rectangular-shaped building blocks separated by construction joints. Plan dimensions vary. Two longer blocks have approximate dimensions 70 m x 13 m (length x width) and a connector block is approximately 30 m x 13 m.

Key Deficiencies		**Proposed Retrofit Measures (Retrofit ID)**
GLOBAL	Lack of global strength Plan irregularity (U-shaped) Vertical irregularity (discontinuous internal masonry walls)	Add new reinforced concrete walls (GL-1) Locally strength diaphragms (DIA – 1) Remove discontinuous walls and replace with lightweight partitions (NS – 3)
LOAD PATH & DETAILING	Inadequate connection between diaphragms and walls to transfer lateral loads	Improve connection between pre-cast floor and unreinforced masonry walls (LP-1)
DIAPHRAGMS	Inadequate diaphragm to transfer lateral loads – precast slabs lack topping slab	Add new reinforced topping slab (DIA- 1)
FOUNDATIONS	Foundations may require strengthening locally	Local strengthening of strip foundations by adding width/depth (F-1)
NON-STRUCTURAL	Out-of-plane failure of internal unreinforced masonry walls Tall, narrow contents (shelves) may overturn Lighting is unrestrained	Either replace with lightweight partitions (NS-3) or add angles at wall headers and vertical steel posts to restrain out of plane failure (NS-4). Anchor tall, narrow contents (shelves) (NS-5) Anchor/brace lighting (NS-6)

Retrofit S-2

School Name: 60 years anniversary of Great Victory High school No2
Address: Kara-Balta c., Kommunisticheskaya No3
GIS Coordinates: 42.8192 73.8405
Approximate Gross Area: 1320 m^2

Building elevation

Building in plan (Google Earth)

Site Description
The building is located on flat terrain, and there is an open access area to the building on all sides of the school property.

Building Description
The school building consists of a 2 storey block. The structural system is loadbearing low strength clay/mud brick walls (for both gravity and lateral loads). The wall thickness is assumed to be 300 mm for exterior walls. The foundations are reinforced concrete continuous footings. The floors are timber joists and planks. The roof is constructed with pitched timber rafters and asbestos roof sheeting.

Hazard Level
Moderate

Seismic Performance Objective
Limited Life Safety (no code importance factor)

Context
Semi-urban

Building Layout
Long and narrow, rectangular in plan; the building has approximate dimensions of 60m x 11m (length x width).

Key Deficiencies		**Proposed Retrofit Measures (Retrofit ID)**
GLOBAL	Lack of global strength and stiffness – potential in and out-of-plane failure of walls Plan irregularity due to long, narrow shape	Add reinforced mesh to walls to strengthen them and prevent damage to walls to pose a threat to Life Safety (falling bricks) (GL-3) Add buttress elements to provide out-of-plane restraint to wall panels (LP-2)
LOAD PATH & DETAILING	Inadequate connection between roof and walls to transfer lateral loads Lack of tying at wall intersections Lack of tying of walls to foundations.	Add masonry anchors to tie walls to floors (LP-1).
DIAPHRAGMS	Inadequate roof diaphragm (lack of bracing)	Add steel or timber bracing to roof diaphragm.
FOUNDATIONS	Foundations may require strengthening locally	Local strengthening of strip foundations by capping with reinforced concrete (F-1)
NON-STRUCTURAL	Fit-out is assumed to be minimal	Anchor tall, narrow contents (shelves) (NS-5) Anchor/brace lighting (NS-6)

Retrofit S-3

School Name: S. Aitiev High School no. 38
Address: Kyzyl-Tuu Village, Dzhalal-Adad Province, Aksy Rayon
GIS Coordinates: 41.68417, 72.01837
Approximate Gross Area: 450 m^2 (Block B)

Building elevation 1

Plan view from Google Earth with arrow to Block B

Site Description
The building is located on flat terrain, and there is an open access area to the building on two sides of the school property.

Building Description
The school building consists of a 2 storey block connected to adjacent 2 storey buildings constructed in 1990. The structural system is a cast-in-place reinforced concrete frame with infill brick walls. The wall thickness is assumed to be 380 mm for exterior walls and 120 mm for interior walls. The floors are precast (reinforced concrete) and the foundations are continuous reinforced concrete strip footings. The roof is constructed with pitched timber rafters and asbestos roof sheeting.

Hazard Level
Moderate to High

Seismic Performance Objective
Life Safety (no code importance factor)

Context
Rural

Building Layout
Rectangular and compact in plan; Plan dimensions have approximate dimensions 32 m x 14 m (length x width).

Key Deficiencies		**Proposed Retrofit Measures (Retrofit ID)**
GLOBAL	Lack of global strength / ductility Lack of global stiffness in long direction Short column effect caused by infill masonry walls Pounding with adjacent buildings	Add new reinforced concrete walls (GL-1) or Strengthen walls (typically unreinforced masonry or mud masonry) with reinforced concrete overlay (GL-3) Locally strengthen columns with jacketing (short column effect) (DET-1)
LOAD PATH & DETAILING	Inadequate connection between diaphragms and walls to transfer lateral loads	Improve connection between pre-cast floor and unreinforced masonry walls (LP-1)
DIAPHRAGMS	Inadequate diaphragm to transfer lateral loads – precast slabs lack topping slab	Add new reinforced topping slab (DIA- 1) Add steel bracing to timber roof
FOUNDATIONS	Foundations may require strengthening locally	Local strengthening of strip foundations by adding width/depth (F-1)

NON-STRUCTURAL	Out-of-plane failure of internal unreinforced masonry walls Tall, narrow contents (shelves) may overturn Lighting is unrestrained	Either replace with lightweight partitions (NS-3) or add angles at wall headers and vertical steel posts to restrain out of plane failure (NS-4). Anchor tall, narrow contents (shelves) (NS-5) Anchor/brace lighting (NS-6)

4.5.4 Preliminary Prioritization for Schools Risk Reduction by Rayon

Cost benefit analysis (CBA) was performed for the three retrofits presented in Section 4.5.3 to inform a rayon level prioritization strategy for the schools. Refer to Section 6.3 for CBA results for schools and Appendix C for the CBA methodology. Based the results of the cost benefit analysis in terms of reduction of fatalities and return on investment, Table 13 presents the country's rayons grouped by priority for school retrofits:

Table 13 Prioritization of School Retrofits by Rayon

Priority Level	Rayons
1	Nookensky, Suzaksky, Bazar-Korgonsky, Uzgensky, Kara-Suisky
2	Kara-Kuljinsky, Aravansky, Askyisky, Ala-Buka, Chon-Alaisky
3	Bishkek (4 rayons)
4	Alaisky, Issyk-Kulsky, Nookatsky, Kadamjaisky, Ak-Talinsky, Tyupsky

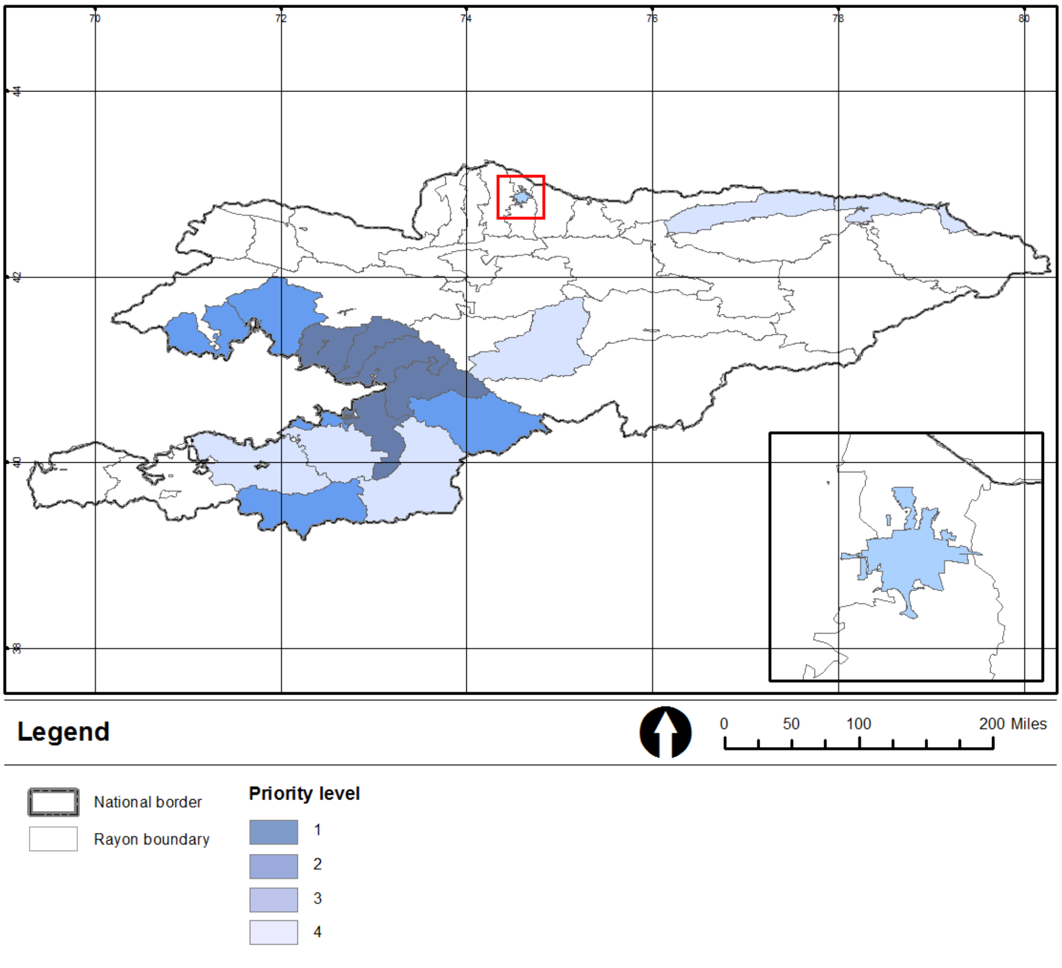

Figure 13 Priority rayons for school retrofitting

4.6 Seismic Risk Reduction Recommendations for Hospital Buildings

This section presents a summary of priority seismic risk reduction recommendations for hospitals and healthcare facilities (Table 14). A summary of seismic risk results for hospital buildings is presented followed by a more detailed discussion of the risk reduction recommendations for hospital buildings. These include recommendations for new and existing hospitals, emergency preparedness measures and specific retrofit measures. In addition, recommendations are given for geographic prioritization by rayon for carrying out seismic risk reduction measures for hospital buildings.

Table 14 Summary of priority recommendations for seismic risk reduction for hospital buildings

Recommendations	Key stakeholders	Estimated timeframe	Indicative budget	Sendai priority areas
Recommendation 1: Implement a countrywide programme of **emergency planning and preparedness training** for hospital operations and staff.	MoH, MoES	6 to 12 months	Not provided	4
Recommendation 2: Implement a countrywide programme of **mitigations for non-structural components and contents** in hospitals and healthcare facilities.[18]	MoH, GOSSTROY	6 to 18 months	Not provided	3
Recommendation 3a: Establish an **infrastructure baseline** for hospitals and healthcare facilities in the county. This will involve a programme of seismic assessments and creation of a national level database.	MoH, GOSSTROY, National Government	6 to 12 months	Not provided	1
Recommendation 3b: Perform an updated **quantitative seismic risk assessment** for hospitals and healthcare facilities.	World Bank, MoH	6 months	Not provided	1
Recommendation 3c: Based on the risk assessment, perform **cost benefit analyses to inform a more detailed investment plan and prioritization** for hospital risk reduction to inform Recommendation 4.	World Bank, MoH			3

[18] We understand that some non-structural mitigations may have already been implemented for selected hospitals in the Kyrgyz Republic (HA KR, 2012).

Recommendations	Key stakeholders	Estimated timeframe	Indicative budget	Sendai priority areas
<u>Recommendation 4:</u> Perform **prioritized seismic retrofits and replacements for hospitals.** Consideration should be given to ongoing requirement for investment to maintain health infrastructure (new and existing).	MoH, GOSSTROY	1 to 4 years*	75 to 100 million USD	3
<u>Recommendation 5:</u> **Update codes and standards** related to new hospital construction and mitigations for hospital contents.	GOSSTROY, MoH	1 to 2 years	Not provided	3
* Note that the hospital risk reduction programme is likely to carry on for a much longer period. The timeframe of four years is given for proposed budget.				

4.6.1 Summary of Seismic Risk Results for Hospital Buildings

The healthcare building portfolio used for this study for the Kyrgyz Republic contains approximately 185 buildings. Hospital building locations were provided by the MoES. It should be emphasized that the potential performance of hospital buildings is very uncertain because of the limited information available on their engineering characteristics.

4.6.1.1 Earthquake Scenario Risk Results

The earthquake scenario risk results for hospital buildings are summarised in Table 15.

Table 15 Scenario earthquake risk results for hospital buildings

Scenario	Magnitude, Mw	Hospital Buildings	
		Economic Losses (mean), in million USD	Fatalities (mean)
Akchop Hills	6.7	434	82
Alai Pamir	7.2	55	6
Chilik	8.3	273	42
Ferghana Valley	7.5	658	156
Issyk Ata	7.3	1304	190
Kemin	7.8	629	88
Oinik Djar	7.0	166	29
South Kochkor	6.8	243	61
Talas Ferghana Central	7.8	691	105
Talas Ferghana East	7.8	573	85
Talas Ferghana West	7.8	578	81

Scenario	Magnitude, Mw	Hospital Buildings	
		Economic Losses (mean), in million USD	Fatalities (mean)
Telek Karakhudzhur	6.8	183	28

Refer to Figure 11 in Section 2.7 for locations of scenario events in this study and closest urban centres.

The results for the range of scenario events indicate the very large potential economic losses and potential fatalities associated with hospital buildings. The estimated economic losses (mean) are in the range of 22 million to 1.93 billion USD but could be significantly higher (up to 5.7 billion USD). The potential fatalities (mean) are estimated to be in the range of 2 to 385 depending on the scenario earthquake location but could be significantly higher (up to 900). However, these results indicate that many hospital buildings may potentially be too badly damaged to be operational following a large earthquake.

4.6.1.2 Time Based Seismic Risk Results

The average annual economic losses associated with earthquake damage to hospital buildings are estimated to be in the range of 27 to 55 million USD but could be significantly higher (up to 200 million USD). The average annual casualties are estimated to be in the range of 3 to 6 fatalities but could be significantly higher (up to 22).[19]

It should be noted that the fatality results do not include potential secondary fatalities if hospitals are not able to function after a damaging earthquake event and patients do not receive proper treatment.

4.6.2 Risk Reduction Recommendations for Hospital Buildings

4.6.2.1 Risk Reduction for Existing Hospital Buildings

The first priority for hospitals is **to create a complete inventory of existing hospitals** and healthcare facilities to increase confidence in the level of vulnerability of the hospital building stock and implement future building-specific actions and prioritization for risk reduction. This should include facilities such as dormitory buildings for hospital staff. To do this, **detailed building-by-building seismic structural assessments should be performed[20]**, focusing on:

- Construction material, structural system, total area, number of floors and year of construction;

[19] Results presented are the range of mean expected annual losses for all combinations of soil type assumptions and ground motion prediction equations and the upper bound presented are the 95th percentile results. Refer to the Component 3 risk assessment report (Arup, 2017b).
[20] We understand that selected hospital assessments have been performed in the past but no hospital assessment data was shared as input to this study.

- The impact on of potential earthquake damage on operability for critical hospitals. This will involve an inventory of non-structural components (e.g. hazardous non-structural partitions, medical equipment, tall narrow furniture, etc.) and critical services (utilities, back-up sources of power, etc.);
- Accurate investigation of the occupancy of each building in terms of staff and patients;
- Understanding of ground conditions; and
- Understanding of the broader range of geohazards that might be encountered in addition to the seismic ground shaking hazard at the site.

Seismic assessments for existing hospitals in areas of **higher seismic hazard** should be prioritized based on the results of this study.

This survey data should be kept in a **national level database** maintained by a designated government department which is easily accessible to all relevant stakeholders in the hospital risk reduction programme (National Government, GOSSTROY, Ministry of Health and others).

In order to prioritize resources, it may be advantageous for **this survey programme to consist of two phases**: rapid visual surveys[21] for the portfolio followed by more detailed assessments for higher priority buildings (either based on their risk level and/or level of criticality).

The hospital survey programme and resulting data will inform two key actions in the risk reduction programme for existing hospitals:

- Firstly, upon completion of the contents survey, a **programme of non-structural mitigations for building contents for hospitals** should be initiated immediately. This typically involves anchorage of medical equipment, lab equipment, tall and narrow furniture and securing the storage of hazardous materials so that these items are not damaged during moderate levels of earthquake shaking. This is a relatively **low cost programme which will realize immediate benefits** to improve the continued operation of healthcare facilities after earthquakes.[22, 23]
- Secondly, based on the hospital assessment data (locations, occupancy, structural typologies and related fragility and vulnerability functions), an updated exposure model can be developed for hospitals in the country. Combining the updated exposure with the hazard (this study), then **an updated quantitative seismic risk assessment of hospital buildings should be performed** to estimate potential losses (economic and human) and levels of damage.

[21] These could be similar to FEMA P-154 surveys (FEMA, 2015). Also refer to Appendix B for further guidance.

[22] In addition to international codes and standards such as the US International Building Code, useful guides have been produced on non-structural mitigations for hospitals including ‘Reducing Earthquake Risk in Hospitals from Equipment, Contents, Architectural Elements and Building Utility Systems’, GeoHazards International, 2009.

[23] Through stakeholder consultation, we understand a similar programme of non-structural mitigations may have been performed for selected hospitals in the country.

The updated seismic risk assessment can inform the development of the **longer term seismic risk reduction strategy and prioritization for hospitals** in the Kyrgyz Republic. This strategy should **establish target performance levels** for health care facilities depending on their criticality. Refer to Section 5 for further guidance. **A detailed prioritization strategy considering retrofit options** (and/or change of occupancy or replacement if certain buildings are uneconomic to retrofit) should be set based on cost benefit analyses.

It is also important to understand the current capacity in hospitals and the new demand (or reduction in demand) for health facilities as well as any government plans for development of facilities in this sector so these **planning considerations can be integrated into the hospital risk reduction programme** decision-making process.

In carrying out detailed retrofits to selected hospitals, the retrofit programme should consider **incremental retrofit** as an option. Incremental retrofit is where retrofitting activities are planned in stages over a longer time frame and often coordinated with other remedial works or renovations. Retrofit work should also be **coordinated with other planned rehabilitation work**. Refer to Section 5.6 for considerations for implementing seismic retrofitting programmes.

4.6.2.2 Risk Reduction for New Hospital Buildings

For the construction of new hospitals, the following risk reduction recommendations apply:

- It is recommended that **the codes/Norms prohibit certain structural systems** for new hospitals and health facilities such as pre-cast flat slab systems (RCPC3), adobe (ADO)[24] and unreinforced masonry (URM) that have been shown to perform poorly in earthquakes. Appendix I gives recommendations for construction types which have been shown to perform better in earthquakes for new hospitals. These include:
    - Cast-in-place concrete moment frame buildings, cast-in-place concrete shearwall buildings and dual system buildings (a combination of shearwall and moment frame) for large scale hospital buildings; and
    - Reinforced hollow block masonry buildings and timber frame with nailed plywood shearwall buildings for smaller scale health facilities of 4 storeys or less.
- It is recommended that **Immediate Occupancy or Operational performance objective is targeted for new hospitals** as they ideally should remain operable or partially operable after an earthquake event. To meet this performance objective, special protective systems such as seismic isolation may be required.

[24] Although hospitals are unlikely to be constructed in adobe, we understand from stakeholder consultation that smaller scale health facilities are often constructed in adobe.

- It is recommended that budgets are identified (either at local or national level) for the maintenance of hospitals and health facility buildings over the course of their design life.

It is important that seismic design requirements are enforced for new construction. Improved land use plans and enforcement can also ensure that development of new healthcare facilities avoids higher risk sites. Refer to Section 4.4.1.

4.6.3 Emergency Response and Preparedness for Hospital Buildings

Key risk reduction recommendations related to **emergency response and preparedness** for hospitals include:

- There should be close coordination between the Ministry of Health (MoH), hospital operators and the Ministry of Emergency Situations (MoES) so hospitals are informed about **which facilities are more critical for emergency response and what the expected influxes of patients and casualtie**s are for different disaster scenarios;
- **Hospitals should maintain back-up supplies** of food, water and critical medical supplies to be ready to respond in a post-earthquake situation;
- **Emergency preparedness training** should be given to hospital staff and plans should be in place for communication to coordinate response after an event (e.g. earthquake drills, phone-trees for critical staff, etc.). Plans for how to best continue operation with limited services should be made ahead of time and communicated to hospital staff; and
- **Egress routes in hospitals** should be clearly marked and hazardous non-structural components that may impede egress if damaged should be anchored as a priority in advance of an earthquake event.

4.6.4 Specific Retrofit Measures for Hospital Buildings

No data was provided on the construction types for specific hospital buildings in the Kyrgyz Republic as part of this study. Coordinates for hospital building locations were provided by the Ministry of Emergency Situations (MoES). A limited number of rapid visual surveys of hospital buildings were performed by the project team and the proposed retrofit options for hospitals are based on a representative building from the fieldwork surveys.

Two retrofit options are given: one for the Life Safety performance objective (**Retrofit H-1**) and one for Immediate Occupancy performance objective[25] (**Retrofit H-2**). It is assumed that this hospital is located in a region of high seismicity.

As this hospital is constructed of unreinforced masonry, it lacks strength and ductility to safely resist earthquake loading. For **Retrofit H-1** where Life Safety performance is targeted, retrofit measures concentrate on strengthening walls and

[25] Refer to Section 5.4.4 and Appendix B, Table B-2 for definitions of seismic performance objectives.

tying details to ensure good load paths for the seismic loads. In additional to the structural mitigations, it is recommended that equipment, tall narrow contents (such as cabinets and shelves), services and other non-structural components be anchored to prevent damage and risk to life in an earthquake. It is likely that in a design level earthquake, the **Retrofit H-1** retrofitted hospital would sustain significant structural and non-structural damage and not remain operational after a design level earthquake. **Retrofit H-2** is a seismic isolation retrofit solution to meet a higher performance objective which means the hospital is more likely to remain operational[26] after a design level event. Seismic isolation concentrates the displacement of the building at the layer of isolation which limits damage to the superstructure. Anchorage of non-structural elements and equipment may still be required in some cases but design accelerations are substantially lower for a seismically isolated building.

Each retrofit option is presented in more detail for a representative building selected from the exposure dataset. A photograph, plan view, description of the building and list of key deficiencies and proposed mitigations are given for each retrofit example. More detailed guidance for each mitigation measure is provided in Appendix B of this report.

[26] In order to achieve a fully operational performance objective, provisions for continuity of power supply, water supply and medical supplies etc. after an earthquake would need to be made in addition to minimizing structural and non-structural damage.

Retrofit H-1

Hospital Name: District Hospital, Tokmok
Address: Tokmok city, 140 Gagarina Street
GIS Coordinates: 42.8425 75.3122
Approximate Gross Area: 2560 m^2


Building elevation

Building plan (Google Earth)

Site Description
The building is located on flat terrain, and there is an open access area to the building on all sides of the property.

Building Description
The hospital building consists of a 4 storey block. The structural system is loadbearing unreinforced masonry walls (for both gravity and lateral loads). The wall thickness is assumed to be 510 mm for exterior walls and 380 mm for interior walls. The floors are cast-in-place (reinforced concrete) and the foundations are continuous reinforced concrete strip footings. The roof is constructed with pitched steel rafters and asbestos roof sheeting above cast-in-place concrete floor slabs.

Hazard Level
High

Seismic Performance Objective
Life Safety (no code importance factor)

Context
Urban

Building Layout
Rectangular and relatively compact in plan. Plan dimensions are approximately 16m x 40m.

Key Deficiencies		**Proposed Retrofit Measures (Retrofit ID)**
GLOBAL	Lack of global strength Vertical irregularity (discontinuous internal masonry walls)	Add new reinforced concrete walls (GL-1) Remove discontinuous walls and replace with lightweight partitions (NS – 3) – see non-structural
LOAD PATH & DETAILING	See Non-Structural for measures related to connection of infill masonry walls to floors.	
DIAPHRAGMS	None	
FOUNDATIONS	Foundations may require strengthening locally	Local strengthening of strip foundations by adding width/depth (F-1)
NON-STRUCTURAL	Out-of-plane failure of internal unreinforced masonry walls Unanchored equipment and services Tall, narrow contents (shelves) may overturn Lighting, services are unrestrained	Anchor tall, narrow contents (shelves) (NS-5) Either replace with lightweight partitions (NS-3) or add angles at wall headers and vertical steel posts to restrain out of plane failure (NS-4). Anchor equipment and services (NS-7) Anchor/brace lighting (NS-6)

Retrofit H-2

Hospital Name: District Hospital, Tokmok
Address: Tokmok city, 140 Gagarina Street
GIS Coordinates: 42.8425 75.3122
Approximate Gross Area: 2560 m^2


Building elevation

Building plan (Google Earth)

Site Description
The building is located on flat terrain, and there is an open access area to the building on all sides of the property.

Building Description
The hospital building consists of a 4 storey block. The structural system is loadbearing unreinforced masonry walls (for both gravity and lateral loads). The wall thickness is assumed to be 510 mm for exterior walls and 380 mm for interior walls. The floors are cast-in-place (reinforced concrete) and the foundations are continuous reinforced concrete strip footings. The roof is constructed with pitched steel rafters and asbestos roof sheeting above precast floor slabs.

Hazard Level
High

Seismic Performance Objective
Immediate Occupancy (with code importance factor)

Context
Urban

Building Layout
Rectangular and relatively compact in plan. Plan dimensions are approximately 16m x 40m.

Key Deficiencies		**Proposed Retrofit Measures (Retrofit ID)**
GLOBAL	Lack of global strength Vertical irregularity (discontinuous internal masonry walls)	Base Isolation (RD-1) Remove discontinuous walls and replace with lightweight partitions (NS – 3) – see Non-Structural
LOAD PATH & DETAILING	Detailing of load path above and below level of isolation	Detailing of services/lifts/stairs if they cross the isolation zone
DIAPHRAGMS	Diaphragm is inadequate about the level of isolation	Strengthen diaphragm (DIA- 1) and additional chord members may be required.
FOUNDATIONS	Foundations may require strengthening locally	Local strengthening of strip foundations by adding width/depth (F-1)
NON-STRUCTURAL	Out-of-plane failure of internal unreinforced masonry walls Unanchored equipment Tall, narrow contents (shelves) may overturn Lighting, services are unrestrained	Either replace with lightweight partitions (NS-3) or add angles at wall headers and vertical steel posts to restrain out of plane failure (NS-4). Anchor equipment and services (NS-7) Anchor tall, narrow contents (shelves) (NS-5) Anchor/brace lighting (NS-6) Detailing of services/stairs/lifts crossing the isolation level.

4.6.5 Preliminary Prioritization by Rayon for Hospital Risk Reduction

In the absence of more detailed seismic risk assessment results for hospitals, a preliminary geographic prioritization by highest numbers of potential casualities expected for from earthquake damage to residential buildings can be used for priority actions such as hospital assessments and non-structural mitigations. Refer to Figure 14 in Section 4.8.

4.7 Seismic Risk Reduction Recommendations for Fire Station Buildings

This section presents a summary of priority seismic risk reduction recommendations for fire station buildings (Table 16). A summary of seismic risk results for fire station buildings is presented followed by a more detailed discussion of the risk reduction recommendations for fire station buildings. These include recommendations for new and existing fire stations and other emergency response facilities, emergency preparedness measures and specific retrofit measures. In addition, recommendations are given for geographic prioritization by rayon for carrying out seismic risk reduction measures for fire station buildings.

Table 16 Summary of priority recommendations for seismic risk reduction for fire station buildings

Recommendations	**Key stakeholders**	**Estimated timeframe**	**Indicative budget**	**Sendai priority areas**
Recommendation 1: Implement a countrywide programme of **emergency planning and preparedness training** for emergency personnel. The results of this study should inform emergency planning.	MoES, Local Government	6 to 12 months	Not provided	4
Recommendation 2: Using the results of this study and knowledge of current capacity in different regions, **identify gaps in emergency response facilities and personnel**. In rural and remote areas, community members can be trained as first responders.	MoES, National Government, Local Government, Communities	6 to 18 months	Not provided	4
Recommendation 3: Implement a countrywide programme of **mitigations for non-structural components and contents** in emergency response facilities.	MoES, GOSSTROY	6 to 18 months	Not provided	3

Recommendations	Key stakeholders	Estimated timeframe	Indicative budget	Sendai priority areas
Recommendation 4a: Establish an **infrastructure baseline** for fire stations and emergency facilities in the county. This will involve a programme of seismic assessments and creation of a national level database.	MoES, GOSSTROY, National Government	6 to 12 months	Not provided	1
Recommendation 4b: Perform an updated **quantitative seismic risk assessment** for fire stations and emergency response facilities.	World Bank, MoES	6 months	Not provided	1
Recommendation 4c: Based on the risk assessment, perform **cost benefit analyses to inform a more detailed investment plan and prioritization** for emergency facility risk reduction to inform Recommendation 5.	World Bank, MoES		Not provided	3
Recommendation 5: Perform **prioritized seismic retrofits and replacements for fire stations and emergency response facilities.** Consideration should be given to ongoing requirement for investment to maintain emergency response facilities (new and existing).	MoES, GOSSTROY	1 to 4 years*	10 million USD	3
Recommendation 6: **Update codes and standards** related to new emergency response facility construction and mitigations for building contents.	GOSSTROY, MoES	1 to 2 years	Not provided	3

* Note that the emergency response facility risk reduction programme is likely to carry on for a much longer period. The timeframe of four years is given for proposed budget.

4.7.1 Summary of Seismic Risk Results for Fire Station Buildings

The fire station building portfolio used for this study for the Kyrgyz Republic contains approximately 333 buildings. No detailed information on the engineering characteristics of these buildings was available, and (on the basis of site survey observations) it was assumed that all fire stations are of the unreinforced masonry typology (URM1)[27].

4.7.1.1 Earthquake Scenario Risk Results

The earthquake scenario risk results for fire station buildings are summarised in Table 17.

Table 17 Scenario earthquake risk results for fire station buildings

Scenario	Magnitude, Mw	Fire Station Buildings	
		Economic Losses (mean), in million USD	Fatalities (mean)
Akchop Hills	6.7	12	3
Alai Pamir	7.2	4	1
Chilik	8.3	9	2
Ferghana Valley	7.5	28	8
Issyk Ata	7.3	31	6
Kemin	7.8	21	4
Oinik Djar	7.0	4	1
South Kochkor	6.8	5	1
Talas Ferghana Central	7.8	21	3
Talas Ferghana East	7.8	18	3
Talas Ferghana West	7.8	18	3
Telek Karakhudzhur	6.8	5	1

Refer to Figure 11 in Section 2.7 for locations of scenario events in this study.

The results indicate large losses to fire station buildings in the order at 1.6 to 43 million USD but could be significantly higher (up to 112 million USD). A relatively small number of occupants is expected in fire station buildings, so the overall fatalities are low, in the order of 1 to 11 fatalities but could be higher (up to 14). However, these results indicate that fire station buildings may not be operational following large earthquakes and fire station staff may be among the casualties. Therefore, fire stations and their staff may not be available to respond following a large earthquake event.

4.7.1.2 Time Based Seismic Risk Results

The average annual economic losses associated with earthquake damage to fire station buildings are estimated to be in the range of 1.2 to 2.4 million USD but could be significantly higher (up to 8 million USD).[28] The average annual

[27] Refer to Appendix E for descriptions and photos of the Kyrgyz Republic structural typologies.
[28] Results presented are the range of mean expected annual losses for all combinations of soil type assumptions and ground motion prediction equations and the upper bound presented are the 95th percentile results. Refer to the Component 3 risk assessment report (Arup, 2017b).

fatalities are estimated to be in the range of 1 to 2 fatalities per year. These results are very uncertain due to the limited engineering information available for fire station buildings.

It should be noted that the fatality results do not include potential additional fatalities if emergency response personnel are not able to respond to rescue operations and firefighting activities after a damaging earthquake event.

4.7.2 Recommendations for Seismic Risk Reduction for Fire Station Buildings

4.7.2.1 Seismic Risk Reduction for Existing Fire Station Buildings

The first priority for fire stations and emergency response facilities is **to create a complete inventory of existing buildings** to increase confidence in the level of vulnerability of the building stock and implement future building-specific actions and prioritization for risk reduction. To do this, **detailed building-by-building seismic structural assessments should be performed**, focusing on:

- Construction material, structural system, total area, number of floors and year of construction;
- The impact on operability for critical emergency response facilities should also be assessed. This will involve an inventory of non-structural components (e.g. hazardous non-structural partitions, equipment, tall narrow furniture, etc.) and critical services (utilities, back-up sources of power, etc.);
- Accurate investigation of the occupancy of each building;
- Understanding of ground conditions; and
- Understanding of the broader range of geohazards that might be encountered in addition to the seismic ground shaking hazard at the site.

This updated fire station building survey data should be kept in a **national level database** maintained by a designated government department which is easily accessible to all relevant stakeholders (National Government, GOSSTROY, Ministry of Emergency Situations and others).

In order to prioritize resources, it may be advantageous for **this survey programme to consist of two phases**: rapid visual surveys[29] for the portfolio followed by more detailed assessments for higher priority buildings (based on their risk level and level of criticality).

The emergency response facility survey programme and resulting data will inform two key actions in the risk reduction programme for existing fire stations:

Firstly, based on the contents survey data, a **programme of building contents mitigation for fire stations and emergency response facilities can be initiated**

[29] These could be similar to FEMA P-154 surveys (FEMA, 2015). Also refer to Appendix B for further guidance.

relatively quickly as a priority. This typically involves anchorage of key equipment, tall and narrow furniture and securing the storage of hazardous materials.[30]

Secondly, based on the emergency response facility assessment data (locations, occupancy, structural typologies and related fragility and vulnerability functions), an updated exposure model can be developed for fire stations and other response facilities in the country. Combining the updated exposure with the hazard (this study), then an updated **quantitative seismic risk assessment should be performed** to estimate potential losses (economic and human) and levels of building damage.

This updated risk assessment can inform the development of the **longer term seismic risk reduction strategy and prioritization for emergency response facilities** in the Kyrgyz Republic. This strategy should **establish target performance levels** for these facilities depending on their criticality. Higher than Life Safety performance is recommended for these facilities so they are more likely to remain operational after an earthquake. Refer to Section 5 for further guidance. **A detailed prioritization strategy considering retrofit options** (and/or change of occupancy or replacement if certain buildings are uneconomic to retrofit) should be set based on cost benefit analyses.

In addition, it is also important to understand any gaps in geographic coverage in emergency response faculties based on consultation with the Ministry of Emergency Situations and local governments so these **planning considerations can be integrated into the emergency response facility risk reduction programme** decision-making process. The results of this study should be used to update emergency plans.

In carrying out detailed retrofits to selected fire stations and other facilities, the retrofit programme should consider **incremental retrofit** as an option. Retrofit work can also be **coordinated with other planned rehabilitation work**. Refer to Section 5.6 for considerations for seismic retrofitting programmes.

4.7.2.2 Risk Reduction for New Fire Stations

For the construction of new fire stations and emergency response facilities, the following seismic risk reduction recommendations apply:

- It is recommended that the code prohibit certain structural systems for new fire stations and emergency response facilities such as adobe (ADO), pre-cast flat slab systems (RCPC3) and unreinforced masonry (URM) that have been shown to perform poorly in earthquakes.
- Appendix I gives recommendations for construction types which have been shown to perform better in earthquakes for new fire station and emergency response facility buildings. These include: cast-in-place concrete moment frame buildings, cast-in-place concrete shearwall buildings, dual system

buildings (a combination of shearwall and moment frame) and reinforced hollow block masonry buildings.

- It is recommended that higher than Life Safety performance is targeted as fire stations should remain operable after an earthquake event. For more critical emergency facilities (command and control centres, for example), the operational performance objective is recommended.
- It is recommended that budgets are identified (either at local or national level) for the maintenance of fire station and other emergency service buildings over the course of their design life.

It is important that seismic design requirements are enforced for new construction. Improved land use plans and enforcement can also ensure that development of new emergency response facilities avoids higher risk sites. Refer to Section 4.4.1.

4.7.2.3 Emergency Response and Preparedness for Fire Station Buildings

Key risk reduction recommendations related to **emergency response and preparedness** for fire stations and emergency response facilities include:

- The results of this study should be used to inform updated emergency plans.
- There should be close coordination between the local government and the Ministry of Emergency Situations (MoES) to understand which facilities are more critical for emergency response and plan for mobilization and response for different disaster scenarios;
- Fire stations should have back-up supplies of food, water and critical medical and emergency supplies to be ready to respond in a post-earthquake situation; and
- In rural or remote areas which lack full-time emergency response personnel, community members should be trained in emergency response. Lessons learned can be applied from past community first responder training programmes carried out by UNDP in the Kyrgyz Republic.

4.7.3 Specific Retrofit Measures for Fire Station Buildings

No data was provided on the construction types for specific fire stations in the Kyrgyz Republic as part of this study. Coordinates for fire station locations were provided by the Ministry of Emergency Situations (MoES). A limited number of rapid surveys of fire stations was performed by the project team and this proposed retrofit of a fire station building is based on one of the buildings from the fieldwork surveys.

The Life Safety performance objective[31] is targeted as it is likely to be uneconomic to aim for higher performance for retrofitting unreinforced masonry

[31] Refer to Section 5.4.4 and Appendix B, Table B-2 for definitions of seismic performance objectives.

buildings. It is assumed that this fire station is located in a region of moderate to high seismicity.

As this fire station is constructed of unreinforced masonry, it lacks strength and ductility to safely resist earthquake loading. Retrofit measures concentrate on strengthening walls, bracing the timber roof diaphragm and tying details to ensure good load paths for the seismic loads. In additional to the structural mitigations, it is recommended that equipment, tall narrow contents, services and other components be anchored to prevent damage and risk to life in the event of an earthquake. Refer to next page for details of **Retrofit F-1**.

This retrofit option is presented in more detail for a representative fire station building selected from the exposure dataset. A photograph, plan view, description of the building and list of key deficiencies and proposed mitigations are given for the retrofit example. More detailed guidance for each mitigation measure is provided in Appendix B of this report.

Fire Station Name: Sokuluk Fire Station
Address: Romanovka, Shopokov
GIS Coordinates: 42.86583 74.3325
Approximate Gross Area: unknown

Retrofit F-1

Building elevation 1

Building Elevation 2

Site Description
The building is located on flat terrain.

Building Description
The 1 storey building consists of a garage for the fire trucks with an accommodation building adjacent to it. The structural system is loadbearing unreinforced masonry walls (for both gravity and lateral loads). The wall thickness is assumed to be 300 mm. The foundations are continuous reinforced concrete strip footings. The roof is constructed with pitched timber rafters and corrugated steel roof sheeting.

Hazard Level
Moderate to High

Seismic Performance Objective
Life Safety (no code importance factor)

Context
Urban

Building Layout
Rectangular and compact plan. Dimensions are approximately 30 m x 14 m.

Key Deficiencies		**Proposed Retrofit Measures (Retrofit ID)**
GLOBAL	Lack of global strength and ductility- unreinforced masonry and large openings in one direction	Strengthen masonry walls with reinforced concrete overlay in long direction (GL-3) Add reinforced concrete frame in short direction (GL-2)
LOAD PATH & DETAILING	Inadequate connection between roof diaphragms and walls to transfer lateral loads	Improve connection between timber roof and unreinforced masonry walls (LP-1)
DIAPHRAGMS	Inadequate diaphragm to transfer lateral loads – timber roof is unbraced	Add steel bracing to timber roof
FOUNDATIONS	Foundations may require strengthening locally	Local strengthening of strip foundations by adding width/depth (F-1)
NON-STRUCTURAL	Tall, narrow contents (shelves) may overturn Lighting, equipment and services are unrestrained	Anchor tall, narrow contents (shelves) (NS-5) Anchor/brace lighting (NS-6) Anchor/brace equipment and services (NS-7)

4.7.4 Preliminary Prioritization by Rayon for Fire Station Buildings Risk Reduction

In the absence of more detailed seismic risk assessment results for fire stations and other emergency response facilities, a preliminary geographic prioritization by highest numbers of potential fatalities expected for from earthquake damage to residential buildings can be used for priority actions such as fire station assessments and non-structural mitigations. Refer to Figure 14 in Section 4.8.

4.8 Seismic Risk Reduction Recommendations for Residential Buildings

This section presents a summary of priority seismic risk reduction recommendations for residential buildings (Table 18). A summary of seismic risk results for residential buildings is presented followed by a more detailed discussion of the risk reduction recommendations for residential buildings. These include recommendations for multiple occupancy and single family residential buildings (both new and existing), emergency preparedness measures and specific retrofit measures. In addition, recommendations are given for geographic prioritization by rayon for carrying out seismic risk reduction measures for residential buildings.

Table 18 Summary of priority recommendations for seismic risk reduction for residential buildings

Recommendations	**Key stakeholders**	**Estimated timeframe**	**Indicative budget**	**Sendai priority areas**
Recommendation 1: For multi-occupancy housing, **prioritized assessments of higher vulnerability buildings in higher risk areas** should be carried out to identify funding priorities for retrofit and repair. It is recommended that **pre-cast flat slab types are gradually demolished and replaced** with better performing construction types.	Local Government, homeowners, GOSSTROY	1 to 10 years	Not provided*	1, 3
Recommendation 2: **Incentives and policies should be developed to encourage retrofit of housing** which could involve tax credits, low interest loans or matching funding.	Local Government, homeowners, GOSSTROY	1 to 2 years	Not provided	2
Recommendation 3: **Plans should be developed for housing and support to individuals post-disaster.** The results of this study should be used to inform emergency planning. This could also include add-ons to existing social protection programmes, communication infrastructure in place for information to transferred to the public, disaster assistance centres, vouchers for temporary relief.	National Government, Local Government, MoES	6 to 18 months	Not provided	4

Recommendations	Key stakeholders	Estimated timeframe	Indicative budget	Sendai priority areas
* It may be better to direct more resources for residential building risk reduction on governance and policy related actions such as increased requirements for construction monitoring, incentives for compliance and retrofit rather than focus predominately on state-funded assessments and retrofits for residential buildings. Government funded assessments and retrofits should focus on the residential buildings subjected to the highest seismic risk (high occupancy RCPC 3 types in high hazard areas, for example).				

4.8.1 Summary of Seismic Risk Results for Residential Buildings

The residential building portfolio used for this study for the Kyrgyz Republic contains approximately 150,000 buildings with an estimated total portfolio value of 55 to 60 billion USD. The total average occupancy for residential buildings is around 5.5 to 6 million people.

4.8.1.1 Earthquake Scenario Risk Results

The earthquake scenario risk results for hospital buildings are summarised in Table 19.

Table 19 Scenario earthquake risk results for residential buildings

Scenario	Magnitude, Mw	Residential Buildings (R2 Exposure model)		
		Economic Losses (mean), in million USD	Fatalities (mean)	No. Collapses (mean)
Akchop Hills	6.7	1623	1335	5100
Alai Pamir	7.2	506	782	3000
Chilik	8.3	805	1246	4300
Ferghana Valley	7.5	6131	5542	17400
Issyk Ata	7.3	7329	4749	18800
Kemin	7.8	1940	1717	8600
Oinik Djar	7.0	348	619	1600
South Kochkor	6.8	466	558	3400
Talas Ferghana Central	7.8	2416	3017	8500
Talas Ferghana East	7.8	2118	2637	7600
Talas Ferghana West	7.8	2002	2284	7300
Telek Karakhudzhur	6.8	333	382	2600

The estimated economic losses from the scenario events are in the range of 138 million to 11 billion USD but could be significantly higher (up to 16 billion USD). Fatalities are estimated to be in the range of 200 to 10,300 but could be significantly higher (up to 19,000) (Table 19). The number of collapsed residential buildings expected for the scenarios ranges from 1,600 to 19,000 (mean aggregated results).

4.8.1.2 Refer to Figure 11 in Section 2.7 for locations of scenario earthquake events in this study.Time-based Seismic Risk Results

The expected annual economic losses associated with earthquake damage to residential buildings are estimated to be in the range of 121 to 265 million USD but could be higher (up to 293 million USD). The average annual fatalities are estimated to be in the range of 96 to 200 fatalities but could be higher (up to 227).[32]

The building types that are expected to contribute the most to economic losses in residential buildings are flat slab pre-cast concrete (RCPC3), reinforced concrete frame with infill masonry walls (RC3), and unreinforced masonry (URM). For more rare events, pre-cast panel buildings (RCPC1) and concrete moment frame (RC1) and concrete shear wall buildings (RC4) are also expected to contribute significantly to economic losses. The most fatalities are expected to be associated with damage and potential collapse of unreinforced masonry (URM), reinforced concrete frame with infill masonry walls (RC3) and adobe (ADO).

The potential economic losses for residential buildings are identified to be concentrated in Bishkek and also near Osh and Jalah-Abad in the south-east of the country (the rayons Kara-Suisky, Uzgensky, Suzaksky and Nookatsky). Potential human losses are identified to be concentrated in the south-east of the country (the rayons Uzgensky, Suzaksky, Kara-Suisky, Bazar Korgonsky and Nookatsky) and the Chon-Alaisky rayon as well as Bishkek and surrounding rayons.

4.8.2 Recommendations for Risk Reduction for Residential Buildings

Reducing seismic risk to residential buildings is challenging. This is for two main reasons: the large size of the residential building portfolio and that there is typically less control of the regulation and construction of housing than in other sectors (such as education or healthcare). The following risk reduction recommendations are aimed at two broad housing categories: multi-occupancy housing and single-family occupancy housing. This is to address specific risks and provide tailored recommendation for each category. For example, it is much more complex to coordinate, implement and finance the retrofit of a multi-owner apartment building than a single family residence.

4.8.2.1 Multi-family Occupancy Housing

A complete inventory of multi-storey apartment buildings should be established for the country. Selected building-by-building surveys should then be performed which collect the following data: location, number of floors, construction type, condition of the building, ground conditions and any geohazards impacting the site. Particular focus should be given to assessing the condition of precast panel

[32] Results presented are the range of mean expected annual losses for all combinations of soil type assumptions and ground motion prediction equations. The upper bound results presented are the 95th percentile results. Refer to the Component 3 risk assessment report (Arup, 2017b).

multi-storey apartment buildings with welded joints as poor construction or lack of maintenance of this type of building can increase its vulnerability. Buildings in higher risk geographies (region near Osh, Jalah-Abad and Bishkek) should be prioritized based on the results of this study.

This survey data should be kept in a **national level database** maintained by a designated government department which is easily accessible to all relevant stakeholders (National Government, GOSSTROY, Ministry of Emergency Situations and others).

For existing multi-occupancy apartment buildings, the following additional recommendations apply:

- It is recommended that the government implement a programme of demolishing and replacing multi-storey apartment buildings in areas of moderate to high seismic hazard when residential buildings are constructed of pre-cast flat slab type (RCPC3) as these have been shown to result in very high levels of fatalities if they collapse in earthquakes and are likely to be uneconomic to retrofit;
- It is recommended the government develop policies to encourage and facilitate maintenance and seismic retrofit of apartment buildings with multiple owners. This could involve low interest loans, supplemental funding from local government and tax credits;

For the construction of new multi-storey apartment buildings, the following risk reduction recommendations apply:

- It is recommended that the code prohibit certain structural systems such as pre-cast flat slab systems and unreinforced masonry that have been shown to perform poorly in earthquakes. Appendix I gives recommendations for construction types which have been shown to perform better in earthquakes for new residential buildings. These include:
    - Cast-in-place concrete moment frame buildings, cast-in-place concrete shearwall buildings and dual system buildings (a combination of shearwall and moment frame) for multi-storey apartment buildings. If well-constructed and maintained, pre-cast panel buildings have been shown to perform well but we understand that these are not commonly constructed since Soviet times; and
    - Reinforced hollow block masonry buildings and timber frame with nailed plywood shearwall buildings for apartment buildings of four storeys or less.

4.8.2.2 Single-family Occupancy Housing

For existing single-family occupancy housing, the following recommendations apply:

- Many single family residential buildings are pre-code or non-engineered. Building regulation approvals are not required for residential buildings with less than 300m^2 in floor area (IFC Consulting Services, 2016b). It is recommended that inspections requirements are increased for smaller residential buildings. Refer to Section 4.4;

- Seismic retrofit guidance should be developed for common single-family housing types for engineers, owners and contractors;
- Incentives such as tax credits should be provided for private owners to seismically retrofit their houses; and
- Private individuals should be encouraged to purchase earthquake insurance. Refer to Section 7.11 and Appendix H.

For the construction of new single family residential buildings, it is recommended that higher performing construction types are used including reinforced hollow block masonry and timber construction with nailed plywood shear walls. Refer to Appendix I for more details.

It is important that seismic design requirements are enforced for new construction. Improved land use plans and enforcement can also ensure that development for new residential buildings avoids higher risk sites. Refer to Section 4.4.1.

4.8.2.3 Emergency Response and Preparedness for Residential Buildings

The results of this study (for example, expected number of building collapses for the scenarios or time based results) should be used to plan for the number of casualties and for the number of individuals that will be displaced by significant earthquakes.

Post-disaster, the following policies should be considered to reduce risk to private individuals and provide continuity of housing (Comerio, 1998):

- Planning and communication infrastructure should be established for a tele-registration programme for individuals affected by disasters;
- Temporary financial support should be provided to those in areas with highest ground shaking immediately;
- Setting up disaster assistance centres which can transition to earthquake service centres to provide support to individuals post-disaster;
- Financial support vouchers for the relief phase for renters to use for temporary housing; and
- Post-disaster planning for the most vulnerable sectors of the society including the elderly, orphans and the physically or mentally disabled should be specifically defined.

If social protection programmes are already in place for vulnerable groups, government should consider integrating mechanism for emergency response and relief into these existing programmes.

4.8.3 Specific Retrofit Measures for Residential Buildings

Based on the seismic risk results, retrofits should focus on the following building types with the highest economic losses and fatalities: unreinforced masonry (URM1), concrete frame with masonry infill walls (RC3) and precast buildings (RCPC1 and RCPC3).

The following seismic retrofit measures have been proposed for residential buildings:

- **Retrofits R-1** is for an reinforced masonry (RM1) multi-storey apartment building with some cast-in-place concrete frame elements and consists of adding new concrete walls, improving the diaphragm capacity of pre-cast floors, additional tying to improve load path and non-structural element mitigations. The Life Safety performance objective is targeted.[33]

  Retrofit measure R-1 has been applied to two difference typologies (RM1 and RC3)[34] in the cost benefit analyses to capture the uncertainty about construction of buildings designated 'reinforced masonry' in the Kyrgyz building. Refer to Section 6 and Appendix C.

- **Retrofit R-2** is for a pre-cast panel multi-storey apartment building (RCPC1 type). These buildings have been shown to perform well in the region in past earthquakes if well-constructed originally and have been well maintained over their lifetime. These measures are mostly to implement repair of the panel connections if they are shown to be of poor quality or deteriorated (WHE, 2002). The Life Safety performance objective is targeted.

A retrofit option has not been developed for flat slab pre-cast buildings (RCPC3) as it was judged that retrofitting these buildings for a Life Safety performance objective would like be very costly and disruptive. Instead, it is recommended that buildings of this type be demolished and replaced over time.

As retrofit measures for unreinforced masonry (URM), concrete frame with infill (RC3) and adobe residential buildings (ADO) are anticipated to be similar to retrofit options presented for and fire stations, these have not been developed in detail for residential buildings or cost benefit analysis. But, as stated previously, losses are anticipated to be high for these vulnerable residential building types, and it is recommended owners are informed that they should be prioritized for retrofit, particularly for higher occupancy buildings.

Each retrofit option is presented in more detail for a representative building selected from the exposure dataset. A photograph, plan view, description of the building and list of key deficiencies and proposed mitigations are given for each retrofit example. More detailed guidance for each mitigation measure is provided in Appendix B of this report.

[33] Refer to Section 5.4.4 and Appendix B, Table B-2 for definitions of seismic performance objectives.

[34] We believe the behaviour of this typology may fall somewhere in between RM1 (bearing wall reinforced masonry) and RC3 (cast-in-place concrete frame with unreinforced infill wall) as information from local sources suggests these buildings are likely to have a cast-in-place concrete frame with partially reinforced infill masonry walls.

Retrofit R-1

Residence Name: n/a
Address: 23 Abay Kechesy, Kara Balta
GIS Coordinates: 42.80611, 73.8522
Approximate Gross Area: 4900 m^2

Building elevation (© Arup, 2015)

Building plan (Google Earth)

Site Description
The building is located on flat terrain, and there is an open access area to the building on all sides of the property.

Building Description
The residential building consists of a 6 storey block with one level of partial basement. The structural system is a combination of partially reinforced/confined masonry walls (for both gravity and lateral loads) and some cast-in-place concrete frame elements. The wall thickness is assumed to be 510 mm for exterior walls and 380 mm for interior walls. The floors are pre-cast concrete and the foundations are continuous reinforced concrete strip footings.

Hazard Level
Low Moderate but **assumed Moderate to High**

Seismic Performance Objective
Life Safety

Context
Urban

Building Layout
Rectangular and but slender in plan length to width ratio. Plan dimensions are approximately 14m x 50m.

Key Deficiencies		**Proposed Retrofit Measures (Retrofit ID)**
GLOBAL	Lack of global strength Plan Irregularity – slender in plan Vertical irregularity (discontinuous internal masonry walls)	Add new reinforced concrete walls (GL-1) or Strengthen existing masonry walls (GL-3) Remove discontinuous walls and replace with lightweight partitions (NS – 3)
LOAD PATH & DETAILING	Inadequate connection between diaphragms and walls to transfer lateral loads	Improve connection between pre-cast floor and unreinforced masonry walls (LP-1)
DIAPHRAGMS	Inadequate diaphragm to transfer lateral loads – precast slabs lack topping slab	Add new reinforced topping slab (DIA- 1)
FOUNDATIONS	Foundations may require strengthening locally	Local strengthening of strip foundations by adding width/depth (F-1)
NON-STRUCTURAL	Out-of-plane failure of internal unreinforced masonry walls Tall, narrow contents (shelves) may overturn Lighting, services are unrestrained	Either replace with lightweight partitions (NS-3) or add angles at wall headers and vertical steel posts to restrain out of plane failure (NS-4). Anchor tall, narrow contents (shelves) (NS-5) Anchor/brace lighting (NS-6)

Retrofit R-2

Residence Name: n/a
Address: exact address unknown, Kara Balta
GIS Coordinates: 42.8053, 73.8533
Approximate Gross Area: 3816 m^2


Building elevation (© Arup, 2015)

Building plan (Google Earth)

Site Description
The building is located on flat terrain, and there is an open access area to the building on all sides of the property.

Building Description
The residential building consists of a 5 storey block with one level of partial basement. The structural system is large panel walls with cast-in-place concrete connections between panels. The floors are pre-cast concrete and the foundations are continuous reinforced concrete strip footings.

Hazard Level
Low Moderate but **assumed Moderate to High**

Seismic Performance Objective
Life Safety

Context
Urban

Building Layout
Rectangular and but slender in plan length to width ratio. Plan dimensions are approximately 11m x 53m.

Key Deficiencies		**Proposed Retrofit Measures (Retrofit ID)**
GLOBAL	Plan Irregularity – slender in plan	
LOAD PATH & DETAILING	Potential deterioration in panel joints (wall panels to wall panels and wall panels to floors) due to lack of maintenance. Potential issues with quality of construction of panel joints.	Repair/rehabilitate connection between pre-cast floor and pre-cast panels.
DIAPHRAGMS	None	None
FOUNDATIONS	None	None
NON-STRUCTURAL	Out-of-plane failure of internal unreinforced masonry walls Tall, narrow contents (shelves) may overturn Lighting, services are unrestrained	Either replace with lightweight partitions (NS-3) or add angles at wall headers and vertical steel posts to restrain out of plane failure (NS-4). Anchor tall, narrow contents (shelves) (NS-5) Anchor/brace lighting (NS-6)

4.8.4 Prioritization by Rayon for Risk Reduction for Residential Buildings

It is recommended that seismic risk reduction investment and activities for residential buildings be concentrated where the highest number of casualties and levels of damage (and associated cost of damage) are expected (the rayons of Chon-Alaisky, Kara-Suisky, Uzgensky, Suzaksky, Bishkek, Bazar-Korgonsky, Nookensky, and Tyupsky). Refer to Figure 14 below.

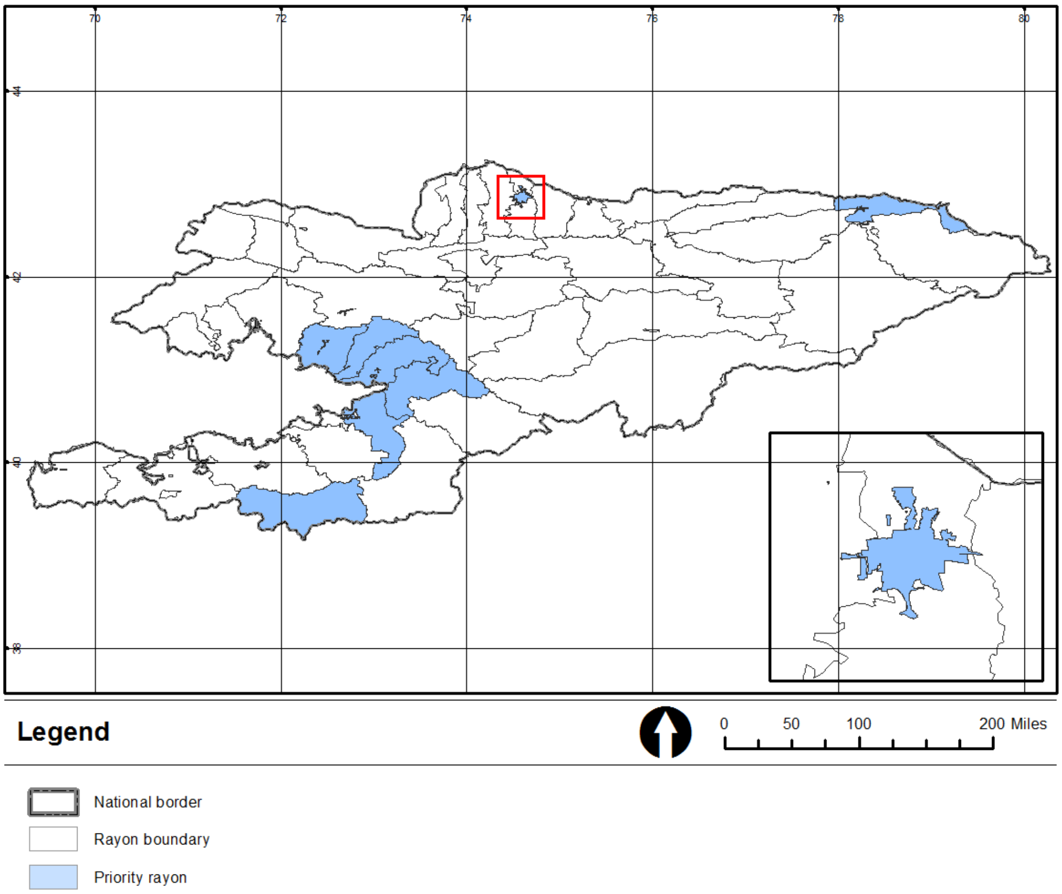

Figure 14 Prioritization by rayon for residential risk reduction

4.9 Seismic Risk Reduction Recommendations for Transport Infrastructure (Roads and Bridges)

This section presents seismic risk reduction recommendations for transport infrastructure (roads and bridges) (Table 20). As no information was provided on the structural characteristics of the bridges portfolio, no specific retrofit measures were developed or cost benefit analyses performed for bridges as part of this study.

Table 20 Summary of priority recommendations for transport infrastructure (roads and bridges) seismic risk reduction

Recommendations	**Key stakeholders**	**Estimated timeframe**	**Indicative budget**	**Sendai priority areas**
Recommendation 1: Use the results of this study to **inform emergency response planning and initial prioritization of critical bridges** for assessment and upgrading.	MoT, MoES, National Government	3 to 6 months	Not provided	3, 4
Recommendation 2a: **Establish a countrywide database of roads and bridges.**	MoT, GOSSTROY, National Government	3 to 6 months	Not provided	1
Recommendation 2b: **Perform selected assessments** for critical bridges.	MoT, GOSSTROY	6 to 12 months	Not provided	1
Recommendation 2c: Perform an **updated seismic risk assessment for transport infrastructure and cost benefit analyses** for bridge retrofits and replacements.	MoT, World Bank, Technical Specialists	3 to 6 months	Not provided	1, 3
Recommendation 3: Based on the results of Recommendation 2c, **perform prioritized upgrades (retrofits or replacements) for critical bridges.**	MoT, GOSSTROY	1 to 4 years	50 million USD	3

4.9.1 Summary of Seismic Risk Results for Transport Infrastructure (Roads and Bridges)

The country-wide road network included in this study was designated as primary roads (around 1000 link segments with a total length of 4,320 km) and secondary roads (around 51,000 link segments with a total length of 43,250 km). The bridges portfolio for the country included around 1450 bridges.

Earthquake Scenario Risk Results

The earthquake scenario risk results for infrastructure (roads and bridges) are summarised in Table 21.

Table 21 Scenario earthquake risk results for transport infrastructure (roads and bridges)

Scenario	Magnitude, Mw	Economic Losses (mean), in million USD	
		Roads	Bridges
Akchop Hills	6.7	235	9
Alai Pamir	7.2	100	3
Chilik	8.3	335	3
Ferghana Valley	7.5	775	12
Issyk Ata	7.3	962	21
Kemin	7.8	567	9
Oinik Djar	7.0	117	3
South Kochkor	6.8	105	4
Talas Ferghana Central	7.8	517	7
Talas Ferghana East	7.8	431	7
Talas Ferghana West	7.8	413	5
Telek Karakhudzhur	6.8	69	3

Refer to Figure 11 in Section 2.7 for locations of scenario events in this study.

The expected economic losses to bridges from the scenario events are in the order of 3 to 27 million USD for the range of earthquake scenarios but could be up to two to three times higher than the upper bound mean value (Table 21). The expected economic losses to roads from the scenario events is much higher and is in the range of 60 million to 1 billion USD but could be up to two to three times higher than the upper bound mean value. These results indicate that many roads and bridges are expected to be damaged in the event of large earthquakes and consequently may impact the emergency response efforts.Seismic Risk Reduction Measures for Transport Infrastructure (Roads and Bridges)

The following recommendations apply for transport infrastructure (roads and bridges):

- Use the results of this risk study to inform emergency response planning;
- Establish a countrywide database of roads and bridges to be maintained by a designed government department;
- Identify critical bridges and perform detailed structural assessments of their condition (location, construction materials, structural system and condition). Identify critical roads based on economic impact of disruption/evacuation and emergency response needs. The results from the scenario events can be used

to inform the initial prioritization for bridge assessment. A network analysis may be used as a method to identify critical roads and bridges[35];

- Based on an updated risk assessment, develop a seismic risk management strategy for roads and bridges to inform prioritized retrofits and replacements of bridges and where new roads or road upgrades are required; and
- Identify funding and responsible stakeholders to support and action risk reduction for roads and bridges.

Other types of critical infrastructure, such as airports, power supply, water supply, sanitation, telecom, were outside the scope of this study. It is recommended that the assessment of seismic risk should be extended to all critical national infrastructure.

4.9.2 High-level Recommendations for Critical Roads and Bridges from Scenario Earthquake Risk Results

For each earthquake scenario, the amount of losses which reflects the level of damage expected for roads and bridges are shown. In addition, areas of primary road are highlighted on key routes between populated areas and in urban areas where bridges may be more critical and higher priority for assessment. In addition, selected examples for secondary roads where expected damage may cut off access to remote communities are also highlighted for the earthquake scenarios.

It should be noted that the scenario earthquake results for roads and bridges have a high level of uncertainty as:

- Simplified assumptions were made to evaluate earthquake related permanent ground deformation due to lack of specific detailed geotechnical data; and
- No information was provided about the physical characteristics of the bridges in the country. Broad structural categories were assigned based on open-source data (OpenStreetMap) available for the bridges in the Kyrgyz Republic.

4.9.2.1 Akchop Hills Fault Earthquake Scenario

The Akchop Hills Fault earthquake scenario risk results and areas of higher risk primary road based on these scenario results are shown in Figure 15. This scenario earthquake event affects the primary road route through the city of Tokmak which leads from Bishkek to the west and to Balykchy to the east. Heavy damage to roads and bridges is expected in the city of Tokmak and nearby urban areas to the south. It is recommended that bridges along the high risk primary roads highlighted be prioritized for assessment and upgrading (if required). If significant damage is expected for secondary roads which lack alternate routes, they may also be designated as higher priority for assessment and upgrading of bridges (for example, to the south of Chon-Jar).

[35] We understand from consultation with the stakeholders that selected bridge assessments and bridge upgrades have been performed by the Ministry of Transport in the country but no information was provided on these assessments or method of prioritization as part of this study.

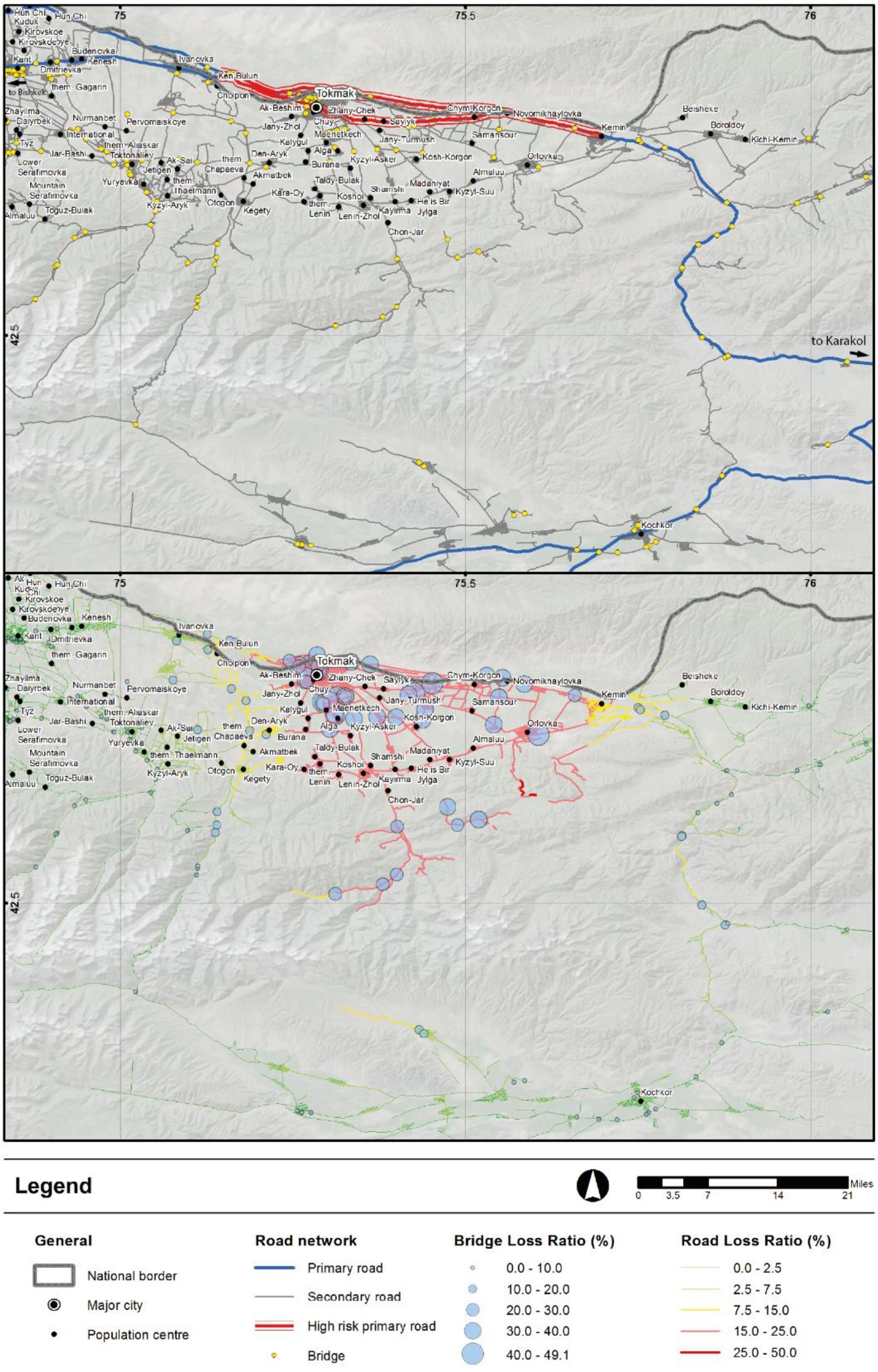

Figure 15: Loss ratios for roads and bridges and higher risk primary road for the Akchop Hills Fault earthquake scenario.

4.9.2.2 Alai Pamir Fault Earthquake Scenario

The Alai Pamir Fault earthquake scenario risk results and areas of damage to more critical primary roads and bridges based on these scenario results are shown in Figure 16. This earthquake scenario event affects a primary road that provides the major trade route from Tajikistan to the south through the Kyrgyz Republic and into China to the east which forms part of the historic ‘Silk Road’. Although this area is sparsely populated, due the economic and regional importance of this route, bridges along this section of higher risk primary road should be prioritized for assessment and upgrading (if required). Damage to this isolated section of road and the damage to bridges could hamper efforts for emergency response from Osh (or potentially from Tajikistan and China, regionally).

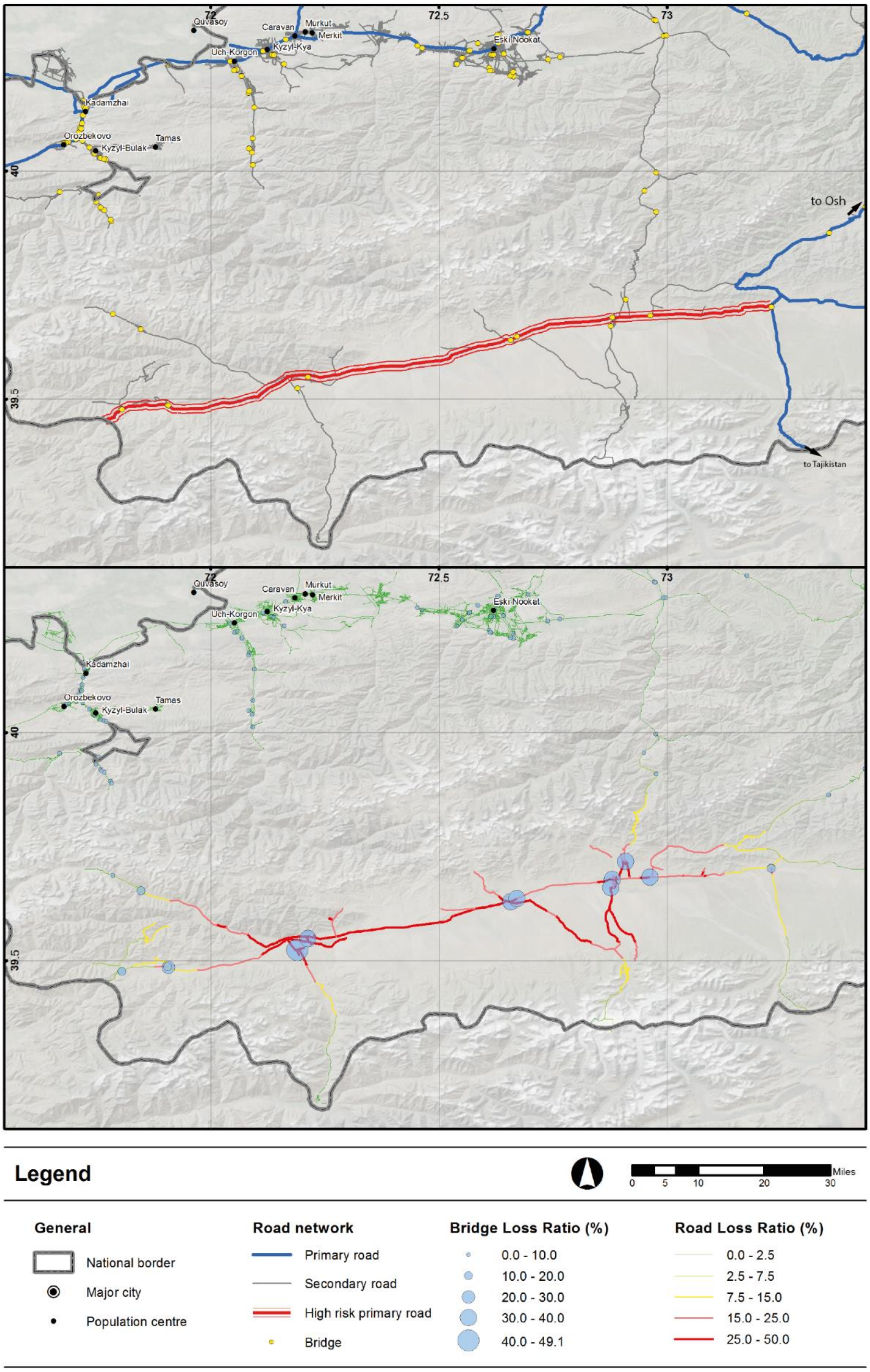

Figure 16 Loss ratios for roads and bridges and higher risk primary road for the Alai Pamir Fault earthquake scenario

4.9.2.3 Chilik Fault Earthquake Scenario

The Chilik Fault earthquake scenario risk results and areas of damage to more critical primary roads and bridges based on these scenario results are shown in Figure 17. This scenario earthquake affects the primary road route from Bishkek to Almaty in Kazakhstan to the north east and Karakol to the south. Heavy damage to roads and bridges is expected particularly in and around the cities of Ak-Bulak and Tup to the north of Karakol. It is recommended that bridges along the high risk primary roads highlighted be prioritized for assessment and upgrading (if required). It should be noted that heavy damage to roads and bridges in this region may cut off access to remote villages. Emergency plans should be put in place to restore access and provide emergency supplies.

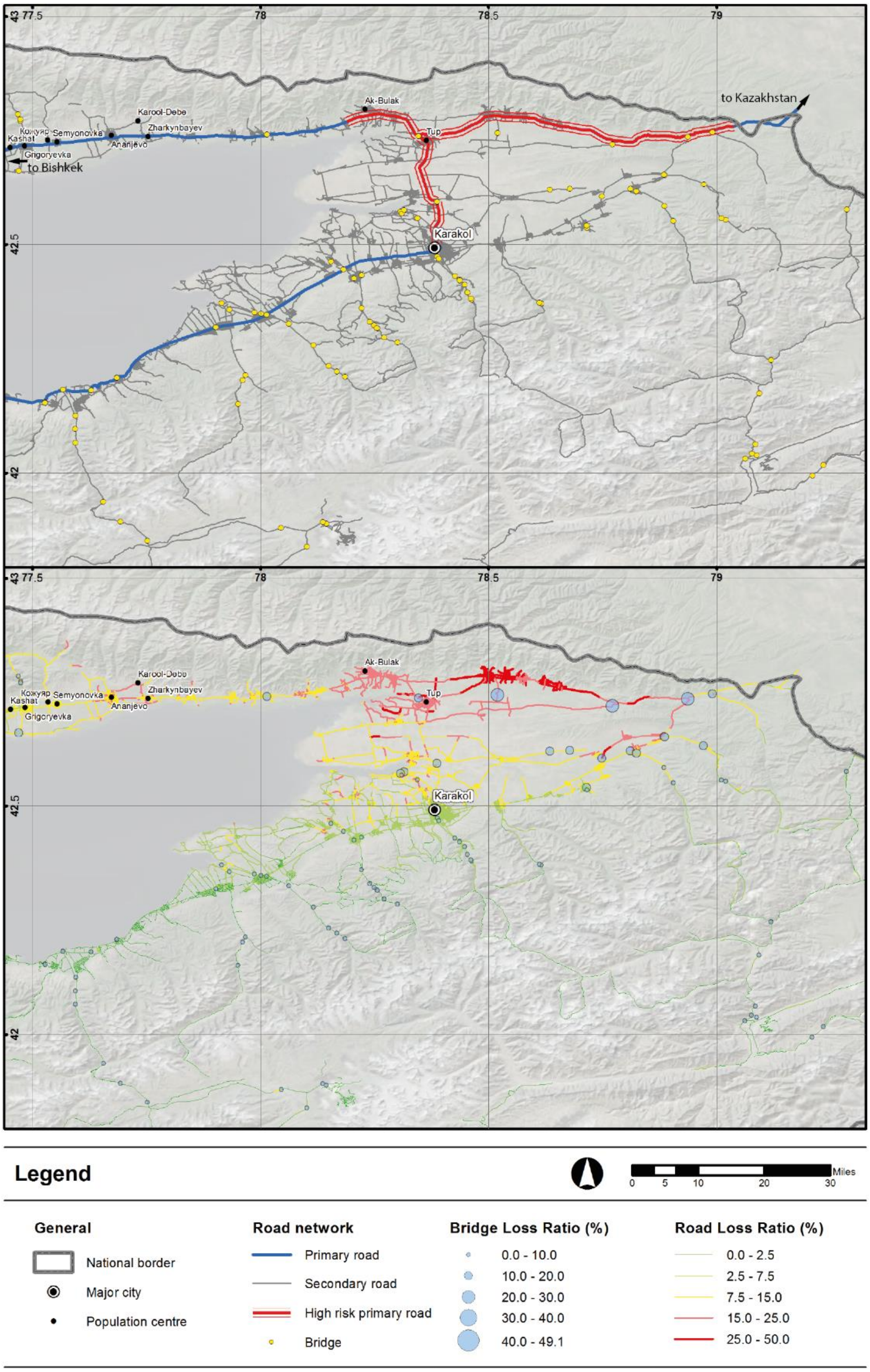

Figure 17 Loss ratios for roads and bridges and higher risk primary road for the Chilik Fault earthquake scenario

4.9.2.4 Ferghana Valley Fault Earthquake Scenario

The Ferghana Valley Fault earthquake scenario risk results and areas of more critical primary roads and bridges based on these scenario results are shown in Figure 18. This earthquake scenario event most heavily affects the cities of Jalah-Abad and Bazar-Korgon with severe damage expected to roads and bridges in the vicinity of these urban areas. Significant damage is also expected to the south west of Osh near the border of Tajikistan near the villages of Tepe-Korgon and Nayna. It is recommended that bridges along the high risk primary roads highlighted be prioritized for assessment and upgrading (if required).

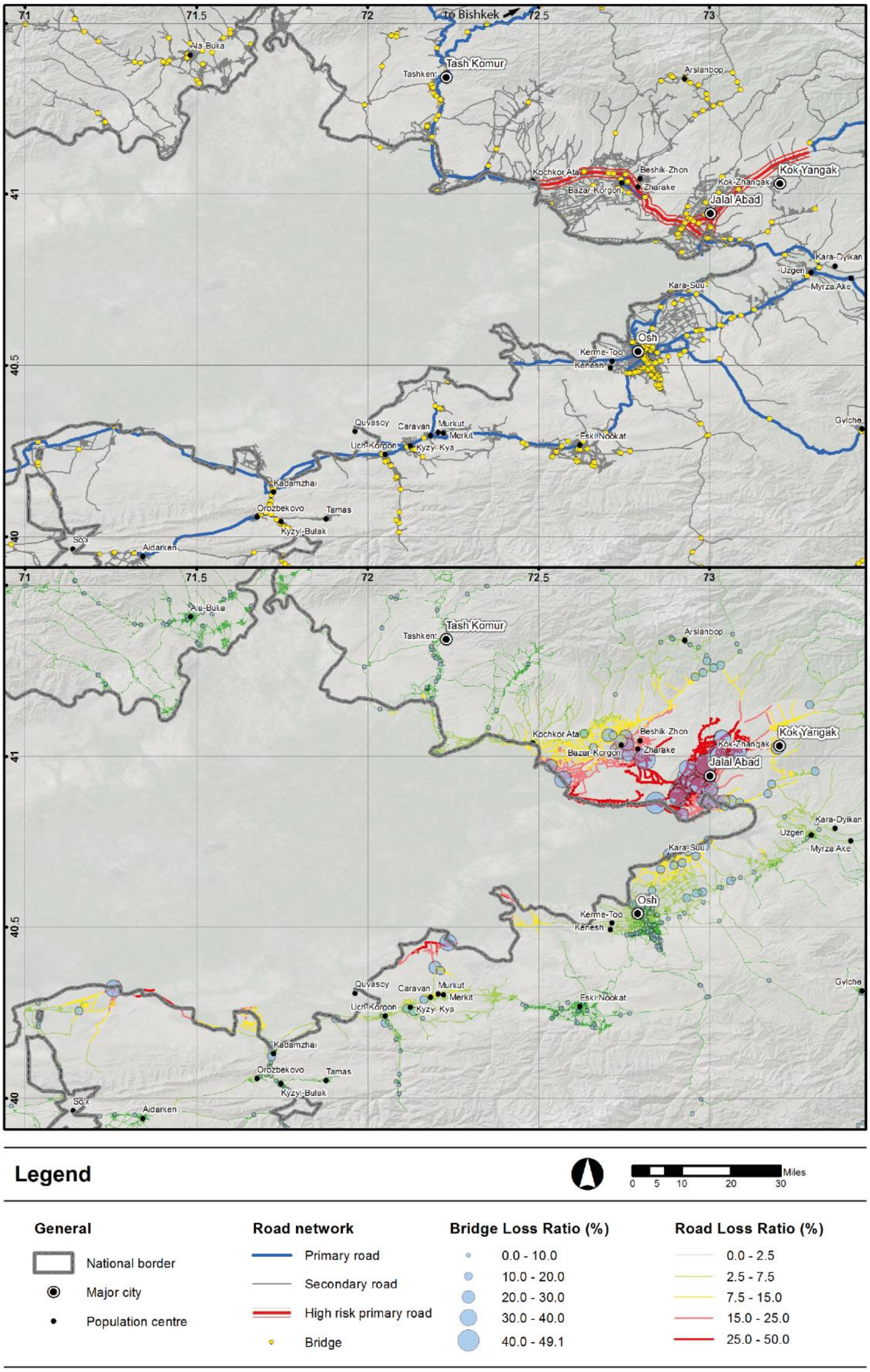

Figure 18 Loss ratios for roads and bridges and higher risk primary road for the Ferghana Valley Fault earthquake scenario

4.9.2.5 Issyk Ata Fault Earthquake Scenario

The Issyk Ata Fault earthquake scenario risk results and areas of more critical primary roads and bridges based on these scenario results are shown in Figure 19. For this earthquake scenario event, the worst damage to roads and bridges is concentrated south of Bishkek but damage can still be expected in Bishkek and the surrounding area. It is recommended that bridges along the high risk primary roads in central Bishkek be prioritized for assessment and upgrading (if required).

It should also be noted that heavy damage is expected for many secondary roads leading into the mountains south of Bishkek which may cut off access to settlements in this region following a major earthquake. Emergency plans should be in place to restore access (potentially strategically stored equipment and supplies) as well as emergency supplies (food, medical supplies) for these settlements for periods where they may be inaccessible. Based on a more detailed evaluation of access and populations in this region, it may be advisable to assess and upgrade selected bridges that are identified as more critical.

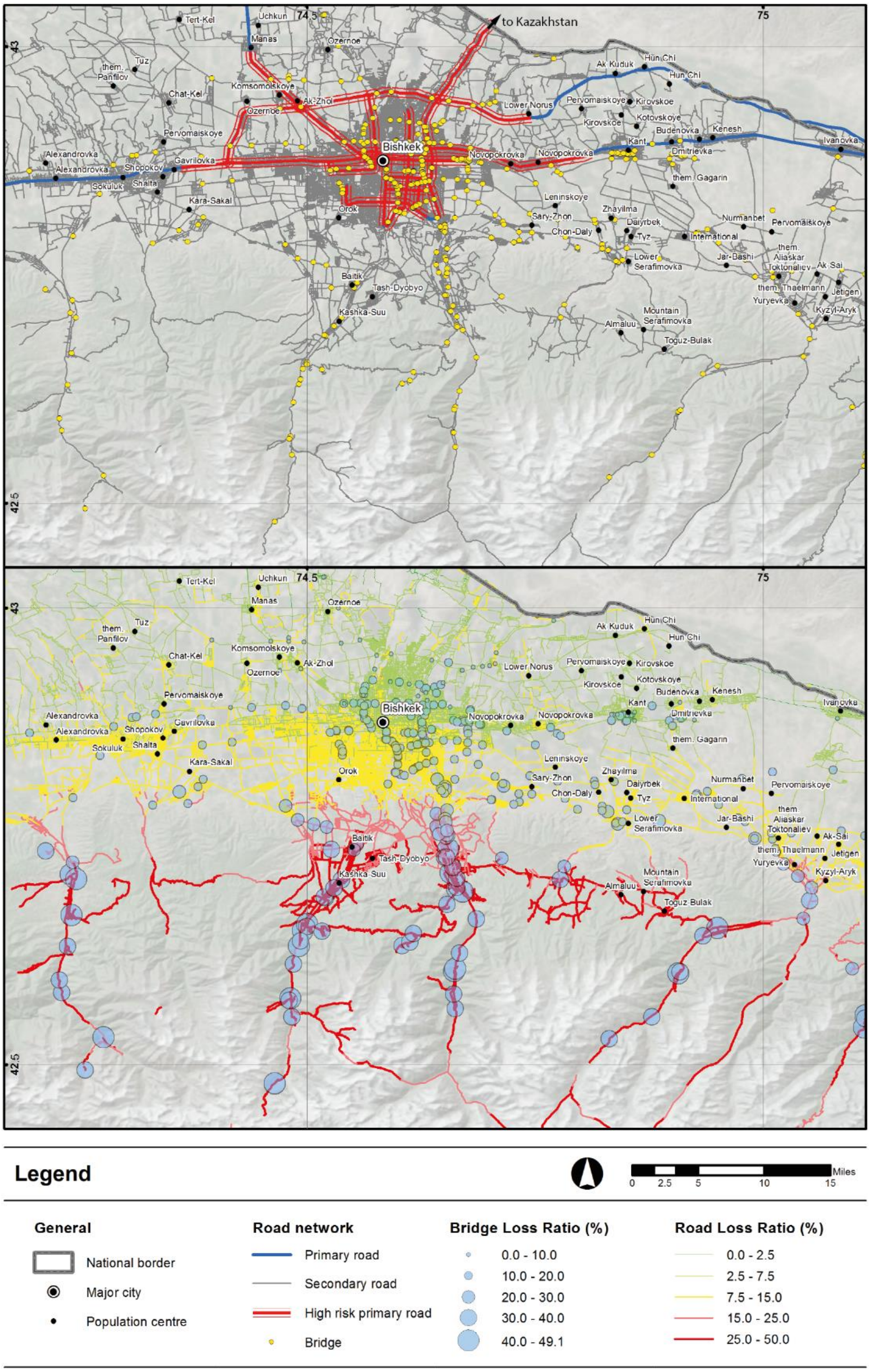

Figure 19 Loss ratios for roads and bridges and higher risk primary road for the Issyk Ata Fault earthquake scenario

4.9.2.6 Kemin Fault System Earthquake Scenario

The Kemin Fault System earthquake scenario risk results and areas of more critical primary roads and bridges based on these scenario results are shown in Figure 20. This earthquake scenario event affects the region to the south east of the town of Kemin and the north west of the town of Balykchy and the north shore of Lake Issyk Kul (the towns of Cholpon Ata, Grigorievka and Ananyevo). Significant damage is expected for roads and bridges in these areas. It is recommended that bridges along the high risk primary roads highlighted from Kemin to Balykchy and to the east of Cholpon Ata be prioritized for assessment and upgrading (if required).

This earthquake scenario may have particular impact on the tourist industry. Emergency management plans should be put in place to take into consideration the potential for increased population in the region during the tourist season.

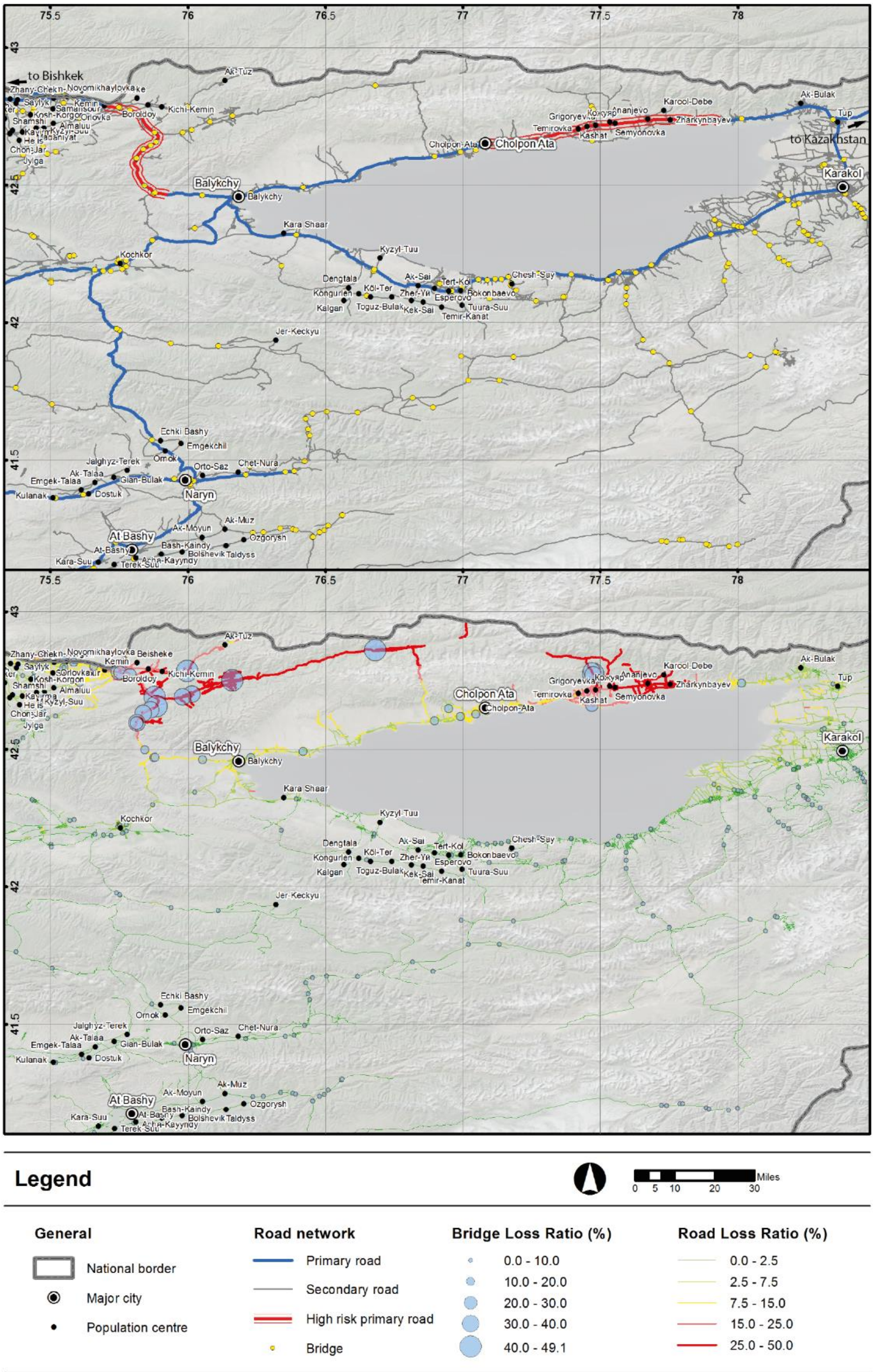

Figure 20 Loss ratios for roads and bridges and higher risk primary road for the Kemin Fault System earthquake scenario

4.9.2.7 Oinik Djar Fault Earthquake Scenario

The Oinik Djar Fault earthquake scenario risk results and areas of more critical primary roads and bridges based on these scenario results are shown in Figure 21.

This scenario event affects the route from the town of Kazarman to Naryn to the east and to the town of Baetovo to the south. From the input data available, few bridges are located along these routes. Although these areas are sparsely populated, emergency plans should be place to restore access for these key regional routes as these roads could be damaged and/or be blocked by landslides for this scenario. Any bridges along the higher risk primary road should be prioritized for assessment and upgrading (if required).

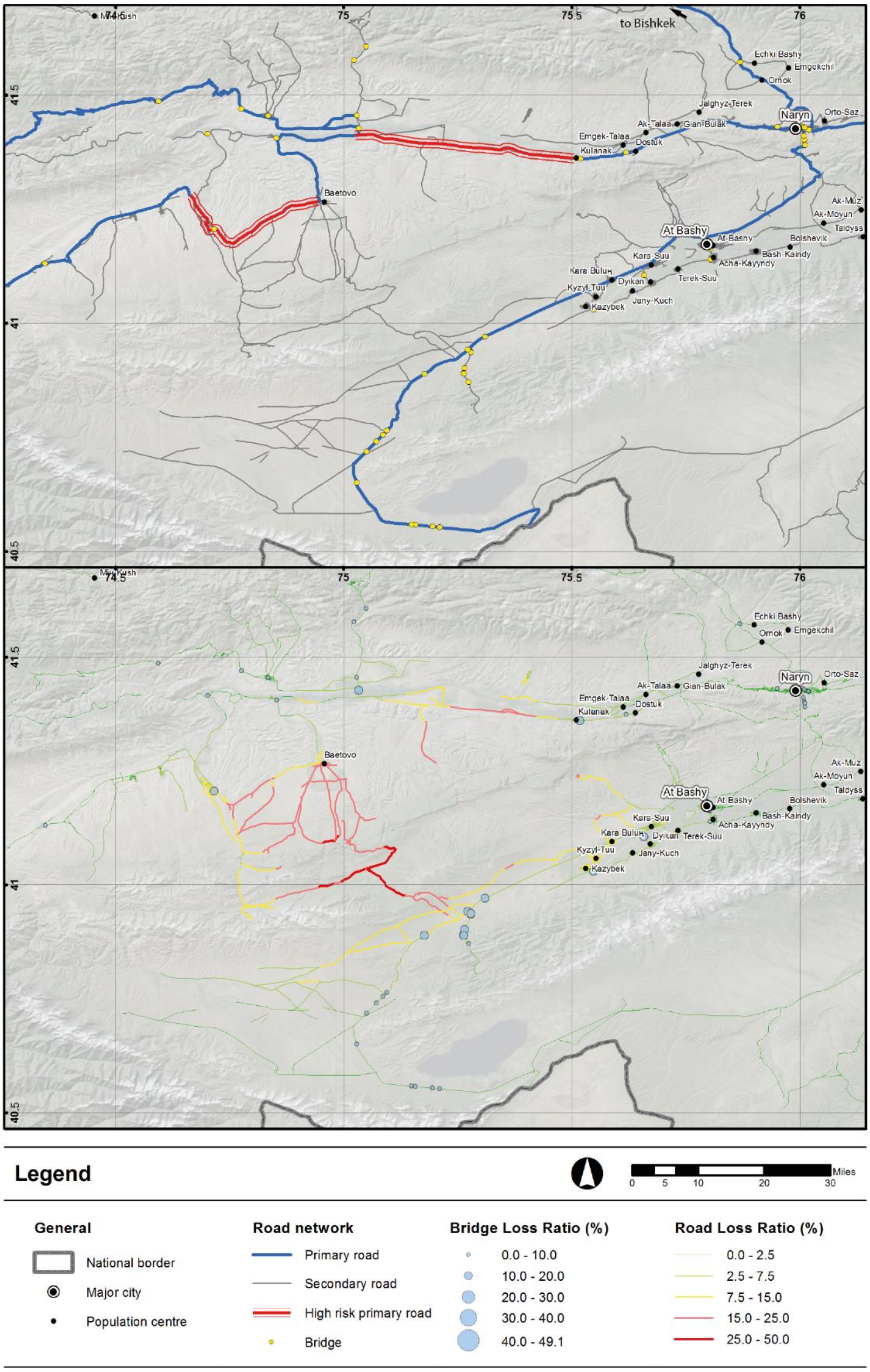

Figure 21 Loss ratios for roads and bridges and higher risk primary road for the Oinik Djar Fault earthquake scenario

4.9.2.8 South Kochkor Fault Earthquake Scenario

The South Kochkor Fault earthquake scenario risk results and areas of more critical primary roads and bridges based on these scenario results are shown in Figure 22. This earthquake scenario event affects the town of Kochkor and the route to the town of Cholpon to the west, the town of Balykchy to the north east and Naryn to the south. Damage is expected for roads and bridges in Kochkor and surrounding areas. It is recommended that bridges along the high risk primary roads highlighted be prioritized for assessment and upgrading (if required).

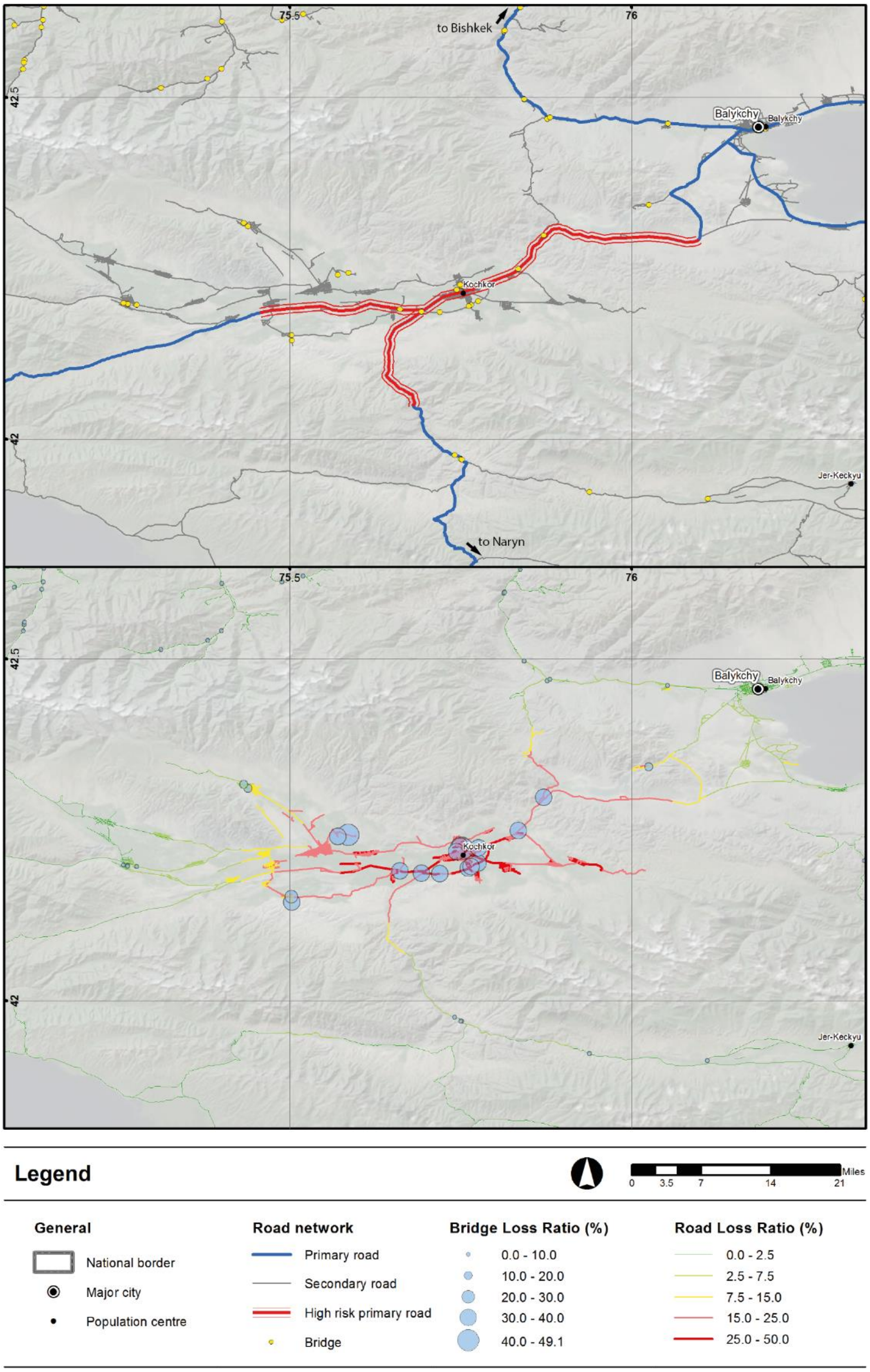

Figure 22 Loss ratios for roads and bridges and higher risk primary road for the South Kochkor Fault earthquake scenario

4.9.2.9 Talas Ferghana Central Fault Earthquake Scenario

The Talas Ferghana Central Fault earthquake scenario risk results and areas of more critical primary roads and bridges based on these scenario results are shown in Figure 23.

This earthquake scenario event affects the city of Toktogul, the towns of Birdick and Kazarman and the route between Tash Komur and Talas and the route between Jalah-Abad and Kazarman. Damage is expected to the roads and bridges in Toktogul and Birdick. It is recommended that bridges along the high risk primary roads highlighted be prioritized for assessment and upgrading (if required). It should be noted that the damage is expected for both main primary routes that connect two major urban centres in the country (Bishkek and Jalah-Abad) which may hamper centralized emergency response efforts.

4.9.2.10 Talas Ferghana East Fault Earthquake Scenario

The Talas Ferghana East Fault earthquake scenario risk results and areas of more critical primary roads and bridges based on these scenario results are shown in Figure 24. This scenario event has similar expected damage as for the Talas Ferghana Central fault scenario (refer to recommendations above).

4.9.2.11 Talas Ferghana West Fault Earthquake Scenario

The Talas Ferghana West Fault earthquake scenario risk results and areas of more critical primary roads and bridges based on these scenario results are shown in Figure 25. This scenario earthquake event affects the city of Toktogul and the route between Tash Komur and Talas. Damage is expected to the roads and bridges in and around the town of Toktogul. It is recommended that bridges along the high risk primary roads highlighted be prioritized for assessment and upgrading (if required).

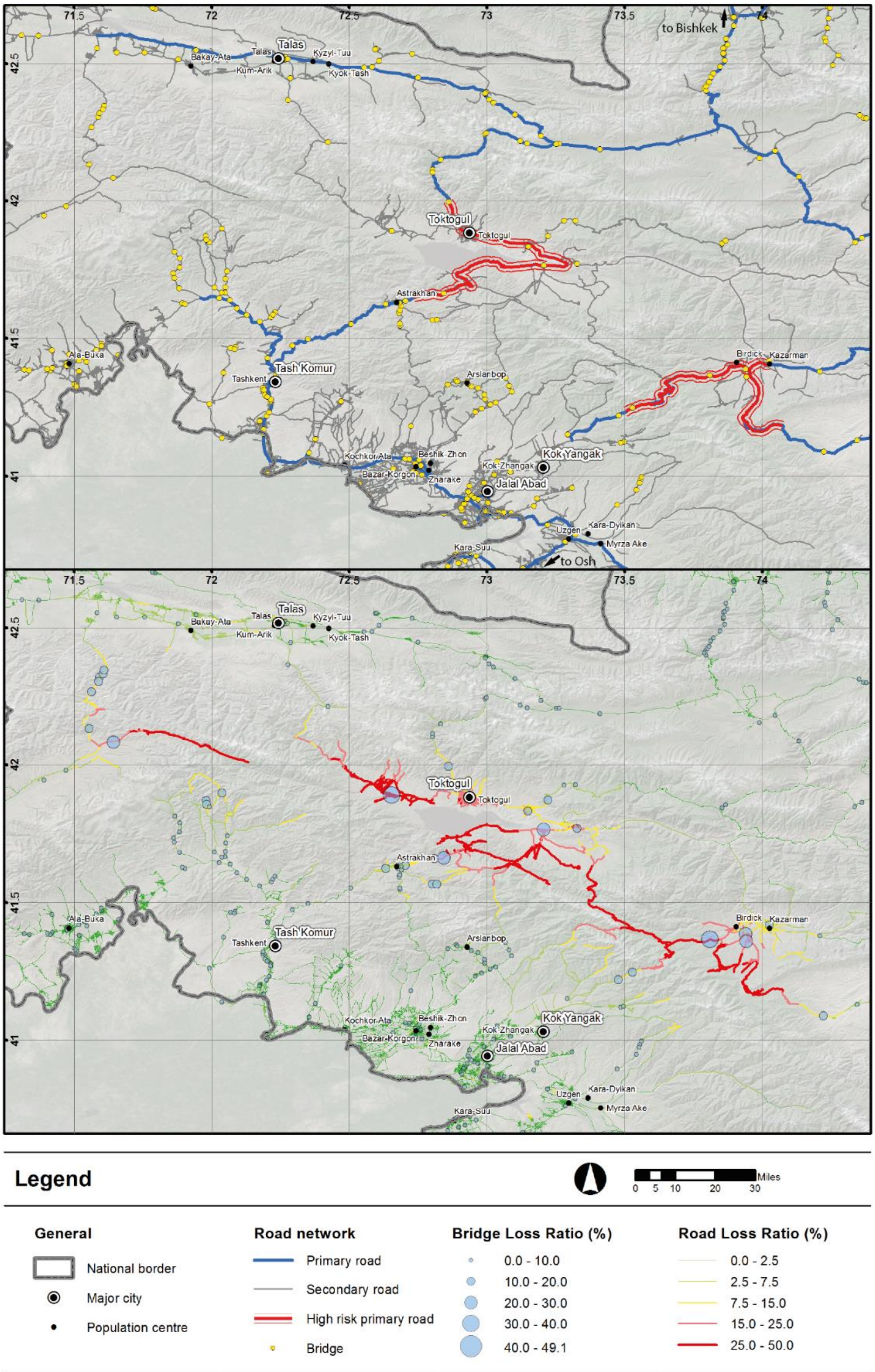

Figure 23 Loss ratios for roads and bridges and higher risk primary road for the Talas Ferghana Central Fault earthquake scenario

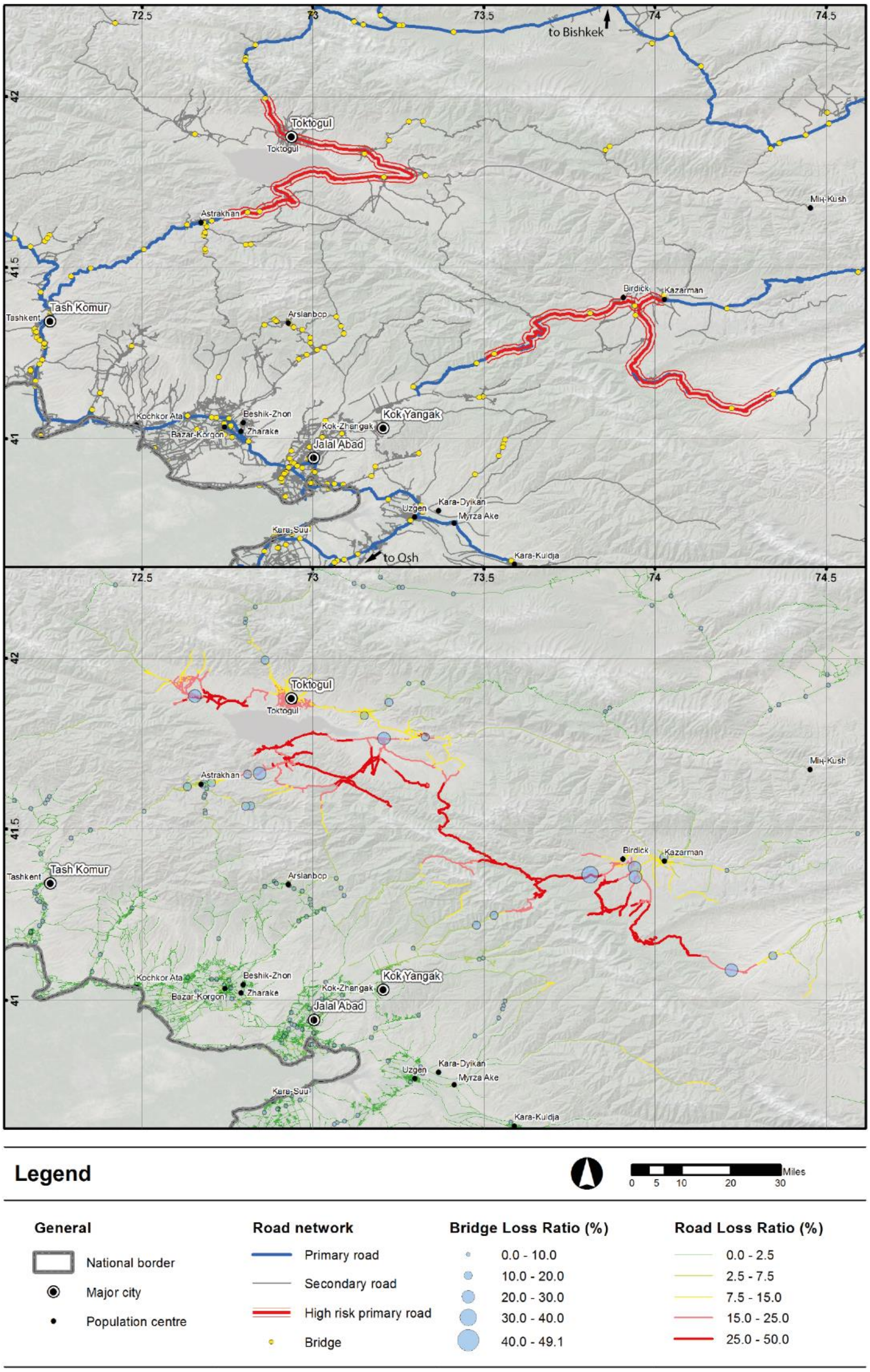

Figure 24 Loss ratios for roads and bridges and higher risk primary road for the Talas Ferghana East Fault earthquake scenario

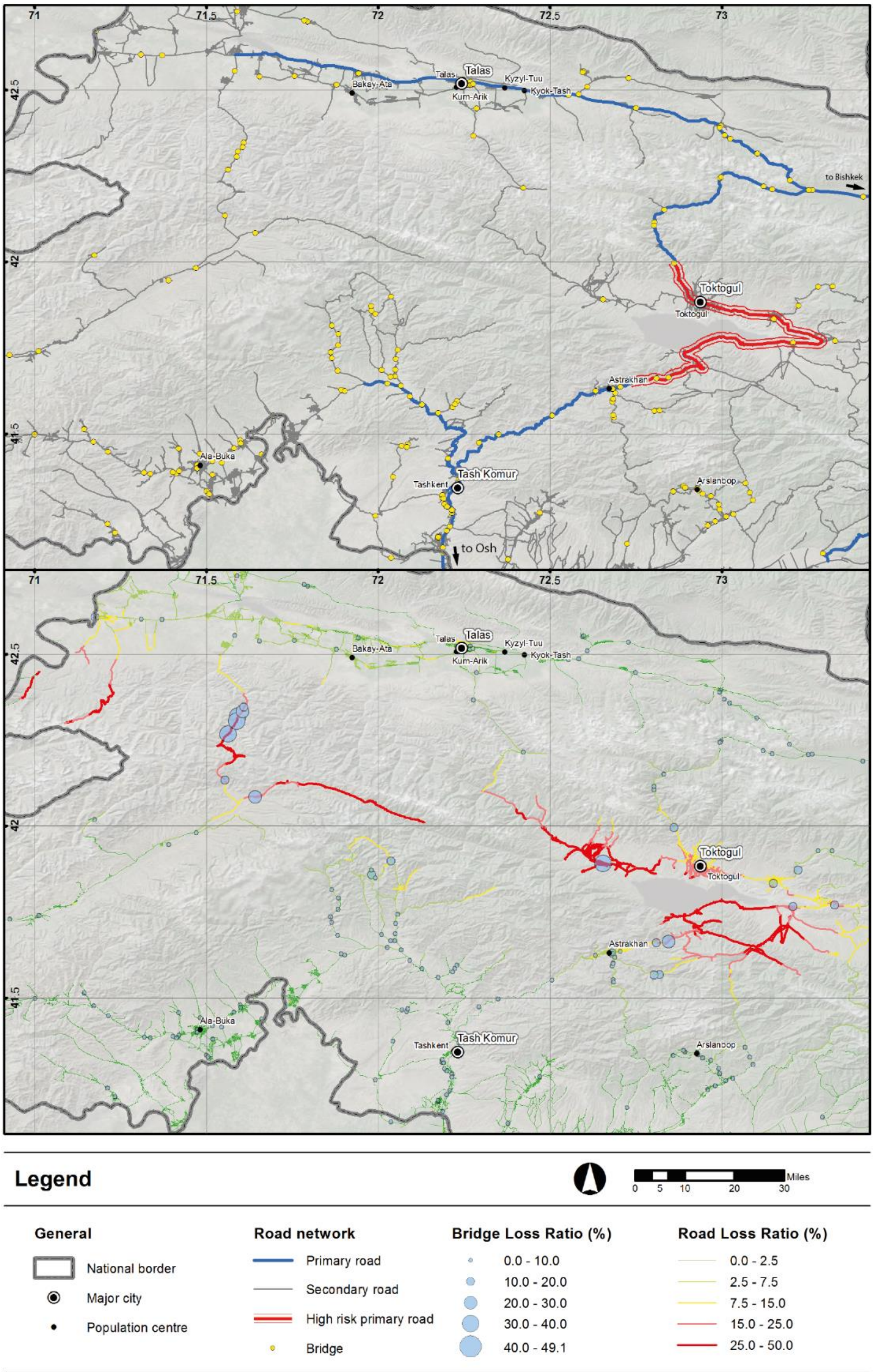

Figure 25 Loss ratios for roads and bridges and higher risk primary road for the Talas Ferghana West Fault earthquake scenario

4.9.2.12 Telek Karakhudzhur Fault Earthquake Scenario

The Telek Karakhudzhur Fault earthquake scenario risk results and areas of more critical primary roads and bridges based on these scenario results are shown in Figure 26. This scenario earthquake event does not result in a large amount of damage to roads and bridges as it occur away from urban areas. It does affect the route from Kockkor to Balykchy where some moderate damage may occur. From the input data available for this study, few bridges are located along this route. Any bridges along the higher risk primary road should be prioritized for assessment and upgrading (if required).

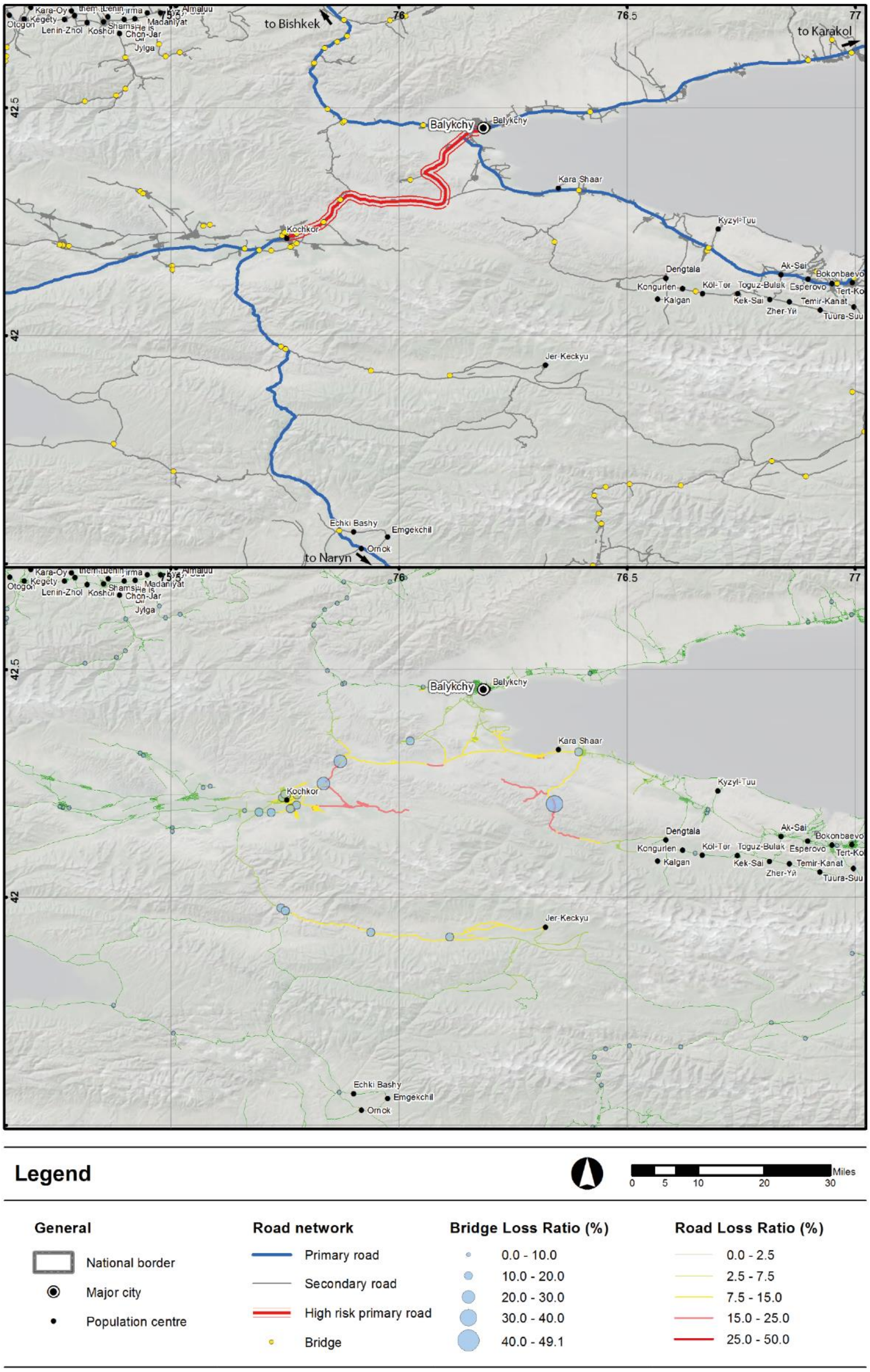

Figure 26 Loss ratios for roads and bridges and higher risk primary road for the Telek Karakhudzhur Fault earthquake scenario

4.10 Risk Reduction Recommendations for Cultural Heritage Assets

This section provides a discussion of general considerations and high level recommendations for seismic risk reduction measures related to cultural heritage in the Kyrgyz Republic. Although assessing seismic risk to cultural heritage assets was outside the scope of this study, it is important to highlight that the government and relevant stakeholders should integrate considerations for cultural heritage assets into the overall risk reduction strategy going forwards. Cultural heritage assets are defined as ruins, historic monuments, historic buildings and archaeological sites as well as historic landscapes (an area showing surface expression of underlying historic land uses, rural or urban). Museums also typically house objects of heritage value. Cultural heritage assets can be an expression of present or former cultures and can be of any age or time period or reflect several time periods. Some examples of cultural heritage for the Kyrgyz Republic are given in Figure 27 below.[36]

Figure 27 Examples of Cultural Heritage in the Kyrgyz Republic: (a) Burana Tower (also known as Gobalik), Sodgia, Chuy Oblast, (b) Buddha statue found near Krasnaya Rechka, near Bishkek, (c) Statue of Zhusup Balasagyn in front of the National University, Bishkek and (d) Koshoy Korgon, a ruined fortress located at At-Bashy District with an on-site museum.

[36] As part of this study, inventory information on cultural heritage assets was requested from local institutions but none was provided.

Protecting and preserving cultural heritage is a priority for the Kyrgyz Republic and this has been formalized into law with the Decree 'About protection and use of historical and cultural heritage' (Last edition from 13 November 2014) which was first ratified by the General Court of Jogorku Kenesh of the Kyrgyz Republic on June 29, 1999. There are many reasons to protect cultural heritage: in addition to the community value they hold, they also often attract economic investment such as from tourism and the production of arts and crafts. It has been recognized by the international community that cultural heritage assets are often particularly at risk from natural disasters and effects of climate change, including earthquakes (UNISDR, 2013 and UNSECO, 2010).

However, no specific seismic risk calculations were undertaken for the cultural heritage assets in this study. The following high level recommendations are proposed for reducing risk to cultural heritage assets in the Kyrgyz Republic:

- In general, relevant stakeholders (national and local governments, heritage experts and institutions, communities) should work together to inform and action the risk reduction strategy. Raising awareness of the seismic risk to cultural heritage assets is a key part of the initial engagement and mobilization of stakeholders.
- Firstly, a country-wide inventory of cultural heritage assets should be established and catalogued in a central and freely accessible digital database. This inventory can be ranked by value or importance. For example: **Very High**/International Status such as World Heritage Sites, **High**/National Status such as assets protected by government laws or listed buildings, **Moderate**/Regional, **Low**/District or Local and **Negligible**.
- Then, these assets can be assessed for the level of seismic risk and associated losses (economic value, cost of disruption, loss of livelihoods). This should be part of a multi-risk assessment that includes other natural hazards and effects of climate change. The asset inventory should be mapped against these hazards to determine overall risk level for the individual assets.
- Risk management and risk reduction measures can then be formulated and prioritized using cost benefit analysis. Social as well as economic costs should be considered when evaluating the risk reduction strategy. Traditional methods of repair and retrofit are generally preferable. Special consideration must be taken to determine when the advantages of a proposed measure to improve the resilience of a heritage asset are worth any risk of destroying the historic fabric of the asset (for a historic building, for example). In some cases, seismic isolation of objects and buildings is appropriate. Some examples of physical measures such as anchoring objects are given in Figure 28 below.

  An initial budget of 10 million USD is recommended for seismic risk reduction for cultural heritage assets over the next four years.
- In terms of operation of sites and on-going monitoring, damage assessments to assets from earthquakes should be integrated into the overall asset management and monitoring programmes. Unlike typical structures, these types of assets can be vulnerable to damage over time from smaller, more

frequent earthquakes in addition to damage from more rare, larger earthquake events.

- To prepare for post-earthquake response, plans should be in place to reduce the likelihood of fire post-earthquake (attention to utilities shut off/connections, back-up water supply, firefighting response plans), safe evacuation of occupants in the event of an earthquake and security of sites post-earthquake to limit damage to sites and looting of artefacts.
- Residual risk will always remain and insurance and other disaster risk financing arrangements should be considered for the long term preservation of cultural heritage assets, similar to other types of asset portfolios in the country. Refer to Appendix H for further information.

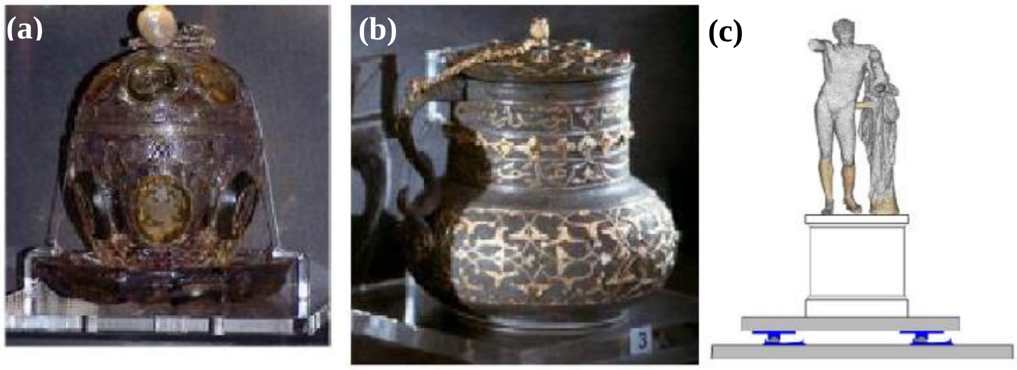

Figure 28 Physical mitigations for museum objects: (a) and (b) use of special mounts and monofilaments to anchor objects at the Topkapi Palace Museum's Treasury Section, Turkey (Erdik, 2010), (c) seismic isolation of the Hermes Statue in the Museum of Ancient Olympia, Greece (www.baulab-domos.gr).

5 Seismic Risk Reduction Strategy for the Kyrgyz Republic - Guidance on Seismic Assessment and Retrofit

5.1 Introduction

In addition to the wider seismic risk reduction strategy and recommendations, a key focus of this study was to develop seismic retrofit measures for the building asset portfolios. To complement those recommendations presented in Section 4, this section of the report provides high level guidance for carrying out seismic assessment and retrofit. More detailed guidance and supporting material can be found in Appendix B.

Seismic retrofitting measures are modifications to existing structures to improve their resistance to earthquake ground motion and related effects such as soil failure. For practical reasons, seismic retrofitting is often combined with other rehabilitation measures (e.g. maintenance and refurbishment), repairs to address deterioration and sometimes with wider modifications and upgrades (for improved functionality and/or energy efficiency).

Improving seismic performance is important in order to protect life and property, to lengthen the lifetime of assets, to reduce post-earthquake disruption to people's livelihoods and businesses, and to minimize relocation and temporary shelter needs after a major earthquake event. For critical facilities, such as emergency response centres, fire stations, hospitals and schools, improvements to seismic performance through retrofit and rehabilitation can ensure that these critical services are more likely to continue to function in the aftermath of a damaging earthquake.

The intent of this section is to provide guidance to government stakeholders as well as civil engineers and other building professionals who will be involved in further developing and implementing seismic retrofit in the Kyrgyz Republic.

This section includes the following:

- A wider framework for implementation of seismic retrofits (Section 5.2);
- High level guidance on types of seismic assessment and regulatory requirements for seismic assessment and retrofit (Section 5.3);
- Key considerations for developing, evaluating and implementing seismic retrofit solutions for individual assets (Sections 5.4 and 5.5); and
- Key considerations for planning and implementation of larger scale retrofit programmes (Section 5.6).

5.2 Framework for Seismic Retrofit

The overall approach to reduce seismic risk through retrofit measures for buildings and infrastructure is as follows:

1. Define the problem with studies to identify the scale and geographic distribution of the seismic risk.
2. Establish performance objectives/design requirements for buildings and infrastructure assets.
3. Develop retrofit options to reduce the seismic risk.
4. Cost benefit analyses can be performed at this stage to help evaluate options. The results of this cost benefit evaluation may determine that it is uneconomic to retrofit a particular asset and replacement should be considered as an alternative.
5. Adopt an approach and implementation strategy. This should include a plan for how design and construction quality will be monitored and enforced.
6. Identify funding and resources to implement the strategy.

This process can be applied for a single asset or for a wider programme of retrofits. Also refer to Section 5.6 for considerations for implementing seismic retrofit programmes and Figure B-1 in Appendix B for more details on the framework for seismic retrofitting.

5.3 Seismic Assessments: Types and Procedures

In order to determine potential mitigation measures to reduce risk, a seismic assessment[37] is required to understand the likely performance of the building or structure in an earthquake. There are different aims for different types of seismic assessments. For example, assessments may be performed to determine:

- If an asset is **safe to occupy** in the **short term** after an earthquake event (**post-disaster)**;
- If the **current risk is acceptable** for the asset or group of assets ahead of possible mitigations to reduce seismic risk in **long term (pre or post-disaster)**;
- **Rapid assessments** may be performed for a portfolio of buildings to **prioritize risk and funding** either for investment planning and/or for a later phase of **detailed assessments** to inform specific building retrofits **(pre or post-disaster)**.

The aims, context and limitations of different types of seismic assessments need to be clearly communicated to those stakeholders impacted by the risk or involved in decision making. These stakeholders could range from asset managers, building occupants, wider government authorities and the general public depending on the scope of the risk assessment or risk reduction programme. This guidance will focus on seismic assessments that inform longer term risk reduction measures, including seismic retrofits and retrofit programmes.

[37] This report defines seismic assessment as an assessment of a physical asset (structural, non-structural and site context). This is different from a site specific seismic hazard assessment which only evaluates seismic hazards relating to a site (ground shaking, etc.) and not the performance of the physical asset or structure.

Although much of a seismic assessment focusses on the **structural** behaviour, the behaviour of **non-structural** components must also be considered as well as **geotechnical** aspects (site ground conditions) and other **site related hazards**. More specifically, seismic assessments evaluate the following aspects to assess the level of seismic risk:

1. The level of seismic hazard at the site including characteristics of the site ground conditions (i.e. geotechnical aspects);
2. The wider site characteristics which may influence the exposure of the asset to hazards such as landslide, soil liquefaction, etc.;
3. The inherent vulnerability of the asset based on its original design, age, as-built construction and construction quality;
4. The impact on the seismic performance of subsequent structural and non-structural modifications during the lifetime of the asset;
5. Increased vulnerability from any damage and deterioration to the asset;
6. The influence of neighbouring structures (e.g. damage from pounding of adjacent structures, damage from vulnerable structures nearby);
7. The safety of egress routes for evacuation of occupants after an earthquake; and
8. The consequences of failure (e.g. how important or essential is the building).

5.3.1 Assessment Procedures

The approach for the seismic assessment of existing buildings is different to the approach for the design of new buildings. Assessing an existing building against a new building standard is often impractical, as it can challenging to bring older buildings up to meet the requirements of new building codes. Many countries have developed standards specifically aimed at assessment and retrofit of existing buildings.

A seismic assessment can be simple or detailed. Depending on the client's or project's needs, the scope could range from a quick visual survey carried out in a few hours to a detailed evaluation involving structural analysis with a programme of weeks or months. Typically, a phased approach is taken, beginning with a desktop study phase, then a physical site survey to identify deficiencies and unknowns, followed by engineering assessment checks and reporting to communicate the findings of the assessment. If a detailed assessment is required, selected opening up works and materials testing may be necessary to reduce uncertainty about the as-built condition. Geotechnical investigations may also be performed to provide data on the site soil conditions.[38] Once the seismic

[38] Most commonly, a Life Safety performance objective is targeted for the assessment procedure for the new code design level earthquake or a reduced code design level earthquake. Refer to Section 5 for definitions of performance objectives. If it is likely that a higher level of performance is required for a critical facility, it may be advantageous to assess structural and non-structural components and services for performance above Life Safety from the start. For example, back-up

deficiencies of an asset have been determined through the assessment process, retrofit options can be developed and evaluated.

5.3.2 Assessment and Retrofit Standards

More specific guidance on seismic assessment is available in international codes and standards as well as in Kyrgyz Republic standards. A desktop literature review of Kyrgyz Norms found two standards relating to the seismic assessment of buildings, SNiP 22-01-98 KR "Estimation of seismic stability of existing buildings" and KR 31-01-2001 "Redesigning the premises of existing residential buildings". Refer to Appendix B, Section B1.5 for selected international standards and guidance on assessment and retrofit and details about the Kyrgyz assessment standards.

The Kyrgyz standards for assessment and modifications to existing buildings state that buildings must be assessed against compliance with current Kyrgyz standards for new construction. In other words, no relaxed performance requirements for assessment or retrofit of existing buildings are given or permitted.

For higher importance/critical facilities, this requirement would mean that critical buildings must be retrofitted to meet a higher performance level than for typical buildings designed to the code.[39] Depending on the condition and original design of the existing facility, engineering retrofit solutions that meet these requirements may be uneconomic to implement.

5.4 Seismic Retrofitting: Design and Construction Considerations

This section will provide an overview of the design and decision making approach for seismic retrofitting including weighing wider alternatives (demolition, reconstruction, relocation or structural retrofit), selecting retrofit measures, key retrofit design criteria, design and analysis methods and considerations for evaluating options. In addition, constructability considerations and recommended quality assurance measures are described including design approvals and construction monitoring.

It has already been mentioned that the approach for upgrading and retrofitting buildings is fundamentally different than for design for new construction (refer to Section 5.3). It is also important to note that each building considered for retrofit is unique and will present its own set of problems. This includes engineering design criteria, architectural considerations, occupancy and economic factors.

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power systems or post-earthquake functioning of key equipment may need to be assessed for a hospital or emergency operations centre.

[39] For example, SNIP KR 20-02:2009 "Earthquake Engineering Design Standards" for new construction specifies that emergency facilities, hospitals needed for emergency response and fire stations be designed for an importance factor of 1.5 and schools, other healthcare facilities and elderly care facilities be designed for an importance factor of 1.2. These importance factors increase the seismic design loading by 50 and 20% respectively.

Thus, retrofits should be considered building-by-building and a holistic approach to retrofit strategy is preferable. This ideally includes a multi-hazard approach (considering other hazards in addition to seismic relevant for the site) to risk reduction from retrofit mitigations.

Although this section is focussed on building retrofits, some of the general considerations can also be applied to seismic retrofits of bridges.

5.4.1 Qualifications to Undertake Seismic Assessment and Retrofit Designs

Seismic assessments and retrofit designs are best carried out by experienced seismic structural engineers. They require considerable knowledge of common forms of local construction and their performance in earthquakes, as informed professional judgement is required. They also often require input from seismic geotechnical engineers for foundation evaluation and design and/or to provide recommendations to mitigate site related hazards.

5.4.2 Demolish, Reconstruct, Relocate or Retrofit?

Before taking the decision to begin the retrofit process, wider options may be considered for an asset or group of assets such as:

- Sell the asset (or terminate the lease) and relocate to a more resilient property;
- Demolish without reconstructing on the site;
- Demolish and reconstruct on the same site;
- Demolish and construct a temporary building or buildings until a permanent building can be constructed on the site;
- Demolish and relocate to a different site;
- Enact a change of usage and/or occupancy levels; or
- Some combination of the above.

Some examples of situations that may lead to these decisions are given below:

- A site may be determined to be too hazardous (for example, subject to high risk of landslide or flooding) where the risks are not considered feasible to mitigate. This may be especially true for a higher importance building such as a school or hospital. It may be preferable to demolish and rebuild on a better site. That said, due to geography and land availability, less hazardous sites may not be available in some cases;
- The capacity is not required for a particular building function or building within a facility, leading to the decision to stop using the building or change its function (and in some cases, demolish it). If the building in question has very high vulnerability, the high costs associated with upgrading combined with it being surplus to requirements can drive this decision. For example, this may be the case for a school where the decision is taken to either demolish certain buildings or downgrade their usage (i.e. no longer use them as classrooms or reduce their occupancy levels).

This same approach could also apply to a piece of a building, for example demolishing a wing or demolishing a floor to reduce loading for a building overall.

Once retrofit options have been developed and cost benefit analysis is performed, these initial decisions may need to be revisited to take into account the cost benefit analysis results. This reflects the iterative process often involved in decision-making around seismic upgrading and retrofits.

5.4.3 Constructability Considerations

Proposed retrofit designs should be appropriate in terms of local context, material quality and availability, as well as skills capability and capacity in the local construction industry. For example, in rural or remote areas, it may be costly or impractical to import materials and locally availably materials may be preferred. Construction skills capacity may be limited to common types of construction in these areas. For example, in the Kyrgyz Republic, adobe, timber and mud brick construction dominate in remote or rural areas whereas cast-in-place reinforced concrete or pre-cast concrete construction are more commonly used in urban areas.

Certain retrofit technologies, such as the use of fibre reinforced polymers (FRP) that are used in international practice may be difficult to implement in the Kyrgyz Republic. Until a local industry is developed, these techniques would require import of all materials and training for both designers and the local construction industry. It would also require international suppliers to send staff to the Kyrgyz to supervise, certify and approve their application of FRP during construction.

5.4.4 Seismic Retrofit Design Criteria

Ahead of developing retrofit options, the seismic performance objectives for the asset should be considered. Selecting the performance objective depends on the **level of criticality or importance** of a structure which relates to its function, occupancy level and/or the social perception of the consequences of failure and risk to life. Critical or higher importance facilities are sometimes referred to as ‘essential facilities’. Table 22 presents examples of higher importance facilities.

Table 22 Examples of higher importance/critical facilities

Category	Types of higher importance/critical facilities
Emergency services	Emergency operations centres Hospitals/critical health care facilities Fire stations
Facilities with hazardous contents	Facilities with nuclear materials Facilities with explosive contents, hazardous chemicals
Higher consequence facilities	Schools Facilities with high occupancy Lifeline infrastructure (bridges, communications, ports, airports) Business critical facilities

The **seismic performance objective** is directly related to seismic performance level (the extent of damage and level of risk to occupants that would be acceptable to be sustained by the asset) for a specified design level earthquake. Building performance in an earthquake is a combination of the performance of the structural and non-structural components. There are four main target performance levels commonly used for seismic design and rehabilitation: **collapse prevention, life safety, immediate occupancy** and **operational** which are described below.

Figure 29 below gives a pictorial representation of the expected damage states for a typical building for each performance level, while Table 23 gives detailed descriptions of these performance levels.

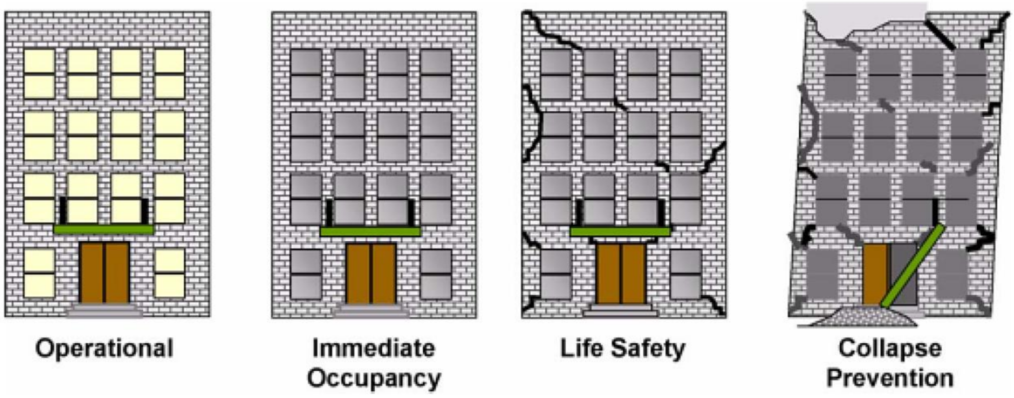

Figure 29 Expected post-earthquake damage states for seismic performance levels (after R. Hamburger)

Table 23 Seismic Performance Levels (from ASCE 41-13)

Seismic Performance Level	Definition
Collapse Prevention	Damage is severe and the building is on the verge of collapse. There is some risk to life and injury for building occupants. Some exits may be blocked. It is likely that the building will be uneconomic to repair.
Life Safety	Occupants are protected from life-threatening damage due to structural collapse or failure of non-structural components in a design level earthquake. Damage may be significant but the building has some margin against collapse. It is possible to repair the building but it may be uneconomic. Repairs are recommended before re-occupancy. Typically, codes for new construction have this level as a minimum requirement for seismic design for a design level earthquake.
Immediate Occupancy	The building or structure has sustained minor damage and is safe to occupy/continue use immediately after the earthquake. It may not be fully operational due to damaged non-structural contents and/or equipment and lack of services (water, power). The building is likely to be economic to repair.
Operational	Damage is very light and all systems important to normal operation are functional. Power and other essential utilities may be from back-up sources. The building is very likely economic to repair, if any repairs are required.

More detailed descriptions of seismic performance levels using engineering terminology are also given in Appendix B, Table B-2.

New building codes (including the Kyrgyz Republic seismic code) typically assign an 'Importance Factor' for more critical or higher importance buildings to crudely mandate higher than minimum code level performance without explicit performance based design checks. This factor increases the seismic design loads that are applied to the structure as compared to a non-essential building. These importance factors often range from 1.1 to 1.5 (i.e. increasing the design loads by 10 to 50%).

Several factors influence choosing building performance objectives:

- the safety afforded building occupants during and after the event (i.e. what is the risk of loss of life or injury to building occupants for a design level earthquake);
- the cost and feasibility of restoring the building to the condition it was in before the earthquake;
- the length of time the building is removed from service to effect repairs; and
- the economic, architectural, or cultural impacts on the larger community from any damage to the building or ultimate loss of the building itself.

Typical existing buildings are often retrofitted to have little damage from more frequent, moderate earthquakes but more serious damage and economic losses from a more severe, infrequent earthquake (i.e. Life Safety performance for the design level earthquake). Where it is not economically feasible to achieve this, a limited rehabilitation objective can be set (i.e. less than Life Safety performance but above Collapse Prevention for the design level earthquake). In many countries, such as the USA and New Zealand, it is acceptable for the limited performance objective to target between 50 to 75% of the level required for new design for typical buildings such as residential and office buildings. Higher importance facilities ideally will meet enhanced performance objectives such as Immediate Occupancy or Operational performance due to their critical nature or cultural value.

Next, the other seismic design criteria should be defined such as the level of hazard and design options to address building vulnerabilities. A summary of the components of seismic risk and common causes of vulnerabilities is given below. More detailed definitions and examples are given in Appendix B, Section B1.3.

Earthquake risk is a function of three interacting components: hazard, exposure and vulnerability. **Hazard** describes the likelihood of exceeding a certain level of seismic shaking or other earthquake related effect at a specific location over a period of time, **exposure** refers to those elements (population, buildings, and infrastructure) which are exposed to earthquakes and are subject to losses, while **vulnerability** defines the susceptibility of a population or structure to damage from earthquakes. All three components have to be assessed in order to understand seismic risk and select appropriate retrofit solutions to address the risk.

Seismic hazard quantifies how much ground shaking can be expected at a given location due to earthquake activity over a specified period of time. It should be emphasized that this does not refer to the shaking arising from an individual earthquake, but considers all plausible events within the region of interest for a specific site. Levels of seismic hazard from ground shaking are often quantified as peak ground acceleration (PGA), Spectral Acceleration (Sa) or macroseismic intensity. Refer to Appendix B Section B1.3 for further definitions. Primary earthquake hazards include ground shaking, landslides, rock falls, avalanche, soil liquefaction and fault rupture. In addition, secondary hazards can be triggered by an event such as tsunami, seiche, flooding or fire. Refer to Appendix B, Section B1.2 for descriptions of each hazard. The majority of damage to structures and risk to people is caused by the ground shaking itself.

The **vulnerability** of buildings and infrastructure assets to earthquakes is influenced by the quality of the design, the construction quality, any pre-existing damage or deterioration sustained as well as any building modifications carried out during the lifetime of the structure. Refer to Appendix B Section B1.4 for common types of seismic vulnerabilities for buildings, roads and bridges.

The **design** should consider the expected earthquake effects and a desired target performance objective. Key factors include the overall **form** of the building or structure, the type of structural and non-structural **detailing**, the level of **redundancy** and a **complete load path** in the structure. As it can often be uneconomic to design physical assets to resist earthquakes without them sustaining any structural damage, seismic engineers often aim to control the damage to the structure and **avoid sudden, brittle failures** of critical elements which could lead to collapse and loss of life.

The regulatory environment and local construction skills capacity influences the **quality of construction.** Poor quality materials and inadequate construction monitoring can contribute to increased vulnerability.

Finally, significant **modifications** to a structure during its design life, including extensions and additional storeys, may compromise the original design and increase its vulnerability in earthquakes. Similarly, **deterioration** in the condition from corrosion, settlement or cracking can also increase vulnerability.

Bridges are often particularly affected by ground shaking and ground failure in an earthquake, while roads are mostly affected by ground failure. For descriptions of hazards that result in ground failure (permanent ground deformation) such as landslides, fault rupture and soil liquefaction, refer to Appendix B, Section B1.2.

5.4.5 Evaluating and Developing Retrofit Options

Once an assessment has identified the vulnerabilities (often referred to as deficiencies) that require mitigation in the retrofit solution and seismic performance objectives have been set, the retrofit options can be assessed using structural analysis. Seismic analysis methods need to be selected to evaluate the retrofit design options. Refer to Appendix B, Section B1.6 for a description of common methods.

In addition to purely structural design considerations, other aspects influence the selection of an optimum retrofit solution such as architectural and functional needs, complexity of implementation in construction and cost benefit of carrying out the retrofit.

The impact of the proposed retrofit on the architectural aspects of the building is a key consideration. For example, adding new steel bracing may block openings or present an undesirable aesthetic appearance in a building façade. Alternatively, implementing retrofit measures may require removal and replacement of non-structural elements and architectural finishes which can significantly influence the overall retrofit cost. For historic buildings and buildings of special cultural value, the cost of disruption to the historic fabric must be weighed against the potential benefit of the retrofit in terms of improved performance. Restoration of the historic fabric may also be especially costly. Refer to Section 4.10 for a discussion of risk reduction for cultural heritage assets.

The complexity of the retrofit solution, the materials and the construction technologies should be appropriate for the local capabilities. If this is not the case, what gets built in practice may not conform with the design intent and ignoring local capabilities may also result in poor construction quality. If outside experts or specialist imported materials are needed for the implementation of the retrofit, this could increase the construction programme and costs.

In order to compare retrofit options, a qualitative or quantitative cost benefit analysis can be performed. This typically examines the level of cost and disruption for the level of achieved performance. Indirect costs from business interruption or having to relocate residents to temporary housing can be considered as part the cost benefit analysis. Often, the cost of the retrofit will be compared to the cost of a replacement building. If the cost of the retrofit exceeds 40 to 60% of the new construction cost, it is usually deemed uneconomic.

5.4.6 Detailed Design and Approvals

Once the decision to retrofit has been taken and initial options evaluated, detailed design can be carried out for the chosen option ahead of construction. In some cases, further surveying is required ahead of this stage to determine the structural, architectural and/or services as-built conditions. Then, based on the detailed design, construction documents can be prepared. These typically include civil engineering drawings (site plan, etc.), architectural and structural plans and details, services drawings and details (electrical, mechanical, plumbing, fire protection), and architectural and engineering specifications. A quality assurance plan should also be included to specify quality control measures on site during construction. The construction documents are used to tender the design ahead of selecting a contractor.

During the detail design phase and ahead of putting the design to tender for construction, is it a common requirement that construction documents must be submitted to a local or government authority for approval ahead of construction.

5.5 Construction Monitoring, Quality Control and Assurance

Quality control and assurance during construction through proper construction monitoring is the most critical part of any retrofit project. The importance of construction quality on building performance in general and the likelihood of encountering unforeseen conditions in retrofit construction in particular warrant special attention to construction monitoring and quality assurance.

It is the responsibility of the design engineer to monitor the construction work and ensure the quality assurance plan is being properly implemented. It is also the engineer's responsibility to carry out any design changes that are required to respond to issues that arise during construction. These changes must be also brought to the notice of the checking authority and approval shall be obtained before proceeding with the construction work.

The design engineer is also typically responsible for performing periodic structural observation of the retrofit work. These structural observations are performed at significant stages of construction, and shall include visual observation of the work for substantial conformance with the construction documents and confirmation of conditions assumed during design. Structural observation shall be performed in addition to any special inspection and testing that is otherwise required for the work.

Any lessons learned from implementing a retrofit design in construction should be noted and used to inform future seismic retrofit projects or programmes.

5.6 Considerations for Implementation of Retrofit Programmes

This section presents a high level summary of considerations for planning and implementing seismic retrofit programmes from a policy perspective. For more specific recommendations for retrofitting that apply to each type of asset and to specific stakeholders as part of the risk reduction measures, refer Sections 4 and Section 7 of this report. The intent of this discussion is to share the wider socioeconomic and political context for such programmes and describe common approaches for retrofitting programmes.

In order to gain political and public support to reduce seismic risk, understanding the level of awareness of the risk among politicians, government officials and the general public is essential. Retrofitting activities often require significant funding and disruption so it is important to convince the stakeholders and affected members of the public that reducing seismic risk is worthwhile. Earthquakes with severe consequences (loss of life, economic losses) occur relatively infrequently and this can pose a challenge; especially when earthquake risk is compared to other, more frequent and visible risks that are competing priorities for funding and attention.

The level of acceptable seismic risk should also be weighed up fairly with other risks, especially when resources are limited. For example, after a disaster, the priority may be to return displaced people to shelter that provides for their basic needs (i.e. protection from an approaching winter) but this shelter (which could include damaged housing) may not be optimal from a longer term seismic safety point of view. Alternatively, government officials may need to make the choice to keep using certain existing school buildings which do not meet code seismic performance levels to gain the benefit of more educational capacity and provision for a population. Ideally, retrofitting programmes can provide integrated solutions to address the range of risks that affect assets (a multi-hazard and risk approach) but such an approach can be complex to coordinate and implement.

When designing a seismic retrofit programme, a robust strategy with focussed priorities need to be formulated. This strategy must be evaluated carefully to ensure it provides the most benefit for the investment. This benefit is not just measured in terms of increased seismic performance and associated reduction in economic losses or loss of life, but also in terms of feasibility and effort required to practically implement the retrofitting within a particular societal, political and regulatory context. Development of locally appropriate retrofit guidance is also important. Although each building will require a unique retrofit solution, this guidance can identify solutions and mitigations for common building typologies. Related to this, retrofitting programmes can provide opportunities to identify and build local capacity and capability in new technologies or construction techniques. Funding sources must be identified from government, outside agencies or individual building and business owners. In some cases, incremental retrofits (retrofitting measures that are carried out in stages over a longer timescale) can add flexibility and allow funds to be raised over time.

It should also be kept in mind that often the most vulnerable people in society (e.g. the young and the elderly) will usually experience the largest “indirect costs” such as dislocation and loss of income from disruption caused by seismic retrofitting programmes. Those affected should be identified and impacts explored through community engagement. Seismic upgrading of housing can be particularly disruptive for multi-family occupancy buildings. For example, rents can increase after a building has been upgraded, causing problems for less affluent renters.

Retrofit programmes require investment. Timescales can range from between five and 25 years for implementing a programme for a group of assets.

There are two main approaches to seismic retrofitting programmes: mandatory and voluntary. Mandatory programmes are where governments identify high risk buildings, set priorities and timelines for action and set guidelines for performance levels for the upgrading. They require consensus about these priorities, criteria, timelines and cost among decision makers before they are approved and may result in push-back from constituencies that are affected by them. Without buy-in from the general public and a high level of awareness of seismic risk, mandatory programmes are difficult to enact and implement. Where government has more control and regulatory power (for example in the educational or health sectors), mandatory seismic upgrades for prioritized buildings have a better chance of success. Communities are also generally supportive of improving school safety to protect the lives of their children. The success of purely voluntary seismic upgrading programmes is dependent on the design and construction industry having experience in seismic retrofitting and building owners and users understanding the risk and the benefits of investing in improved seismic performance for their buildings. If this awareness, experience and correct regulatory requirements and enforcements are in place, voluntary seismic upgrading has the advantage of avoiding government coercion, legal conflicts and major community impacts.

In between a fully mandatory and a voluntary programme, another approach is to provide incentives to building owners to encourage seismic retrofitting and risk reduction. Some examples of this are: negotiating approvals for planning applications for modifying existing buildings where the applicant is encouraged to include seismic upgrading in the design or giving a tax break and some funding to landlords who upgrade their apartment buildings.

Historic buildings or buildings with cultural significance require special consideration when they are retrofitted. Often, the goals of seismic retrofitting should be balanced against the loss of the historic fabric of the building that might result from interventions. Also, refer to Section 4.10 for related recommendations and considerations for cultural heritage assets.

Finally, in order for a programme's success to be measured and feedback to improve existing programmes, a robust strategy to monitor programme outcomes should be put into place.

6 Cost Benefit Analyses Results

6.1 Introduction

Cost benefit analysis (CBA) is a useful tool to evaluate, in economic terms, the outcomes of each proposed component of the seismic risk reduction strategy. This approach allows an objective assessment of each of the risk reduction measures for seismic retrofit proposed in Section 4 in terms of their inherent advantages and disadvantages, by comparing the respective costs and benefits. Cost corresponds to the value of initial investment necessary for the implementation of a given seismic risk reduction measure, and benefit stands for the achieved reduction of economic and/or human losses as a result of the implementation of the proposed retrofit measure calculated over a specific time-span (e.g. 50 years). Benefits are expressed in monetary terms (e.g. total economic losses avoided in a period of 50 years) in order to be directly comparable with the associated costs, using a benefit-cost ratio (BCR). The benefit-cost ratio (BCR) is the ratio of the benefits to the costs:

BCR = present net value of benefits/present net value of costs

If the benefits outweigh the costs (i.e. the BCR >1), then the investment is considered worthwhile. However, when dealing with social and human risk, CBA can be more challenging to apply, as it requires a value to be attributed to human life or other intangible social impacts. In this study, CBA analysis is used specifically to determine the economic benefits of different retrofit solutions, and associated BCRs.

In addition, the reduction in human fatalities expected to be achieved through the implementation of the proposed retrofit measures is estimated using a probabilistic risk assessment framework and methodology that is presented in Appendix C.

6.2 Cost Benefit Analysis Methodology

Appendix C provides a detailed description of the applied CBA framework and the methodology used to compute the estimated reduction in fatalities. Appendix D presents the seismic retrofit costs assumptions specific to the Kyrgyz Republic for the proposed retrofit options. A discount rate of 5% was assumed to account for the future value of money over the 50 year period for the cost benefit analyses. For the cost assumptions, 2015 USD were assumed.

In order to reflect the uncertainty associated with the ground motion and soil condition models presented above, upper and lower bound benefit-cost ratios (BCRs) are presented from all the GMPE/VS30 combinations. For simplicity, only mean fatality results are presented for the GMPE/Vs30 combinations.

In this work, the economic benefits are determined in terms of the reduction of direct structural and non-structural losses only. Business interruption and other secondary economic impacts were excluded from the project terms of reference. However, direct losses to contents and indirect losses due to interruption of functionality may have a significant impact on the results of cost benefit analyses, especially for hospitals and fire stations, where the indirect losses may be of the same order of magnitude. The results presented in this report for this type of critical infrastructure may be complemented in the future to account for this issue. Detailed recommendations are presented in Section 7.

6.3 Cost Benefit Analysis Results for School Buildings Retrofit Measures

Cost benefit analyses results are presented for the schools retrofit options S1 (for an unreinforced masonry school, URM), S2 (for an adobe school, ADO) and for S3 (for a concrete frame with masonry infill school, RC3). Refer to Section 4.5.3 for more detailed descriptions of the proposed school retrofit measures. Retrofit options were selected for types of school buildings which have the highest losses in the country both in terms of economic losses and fatalities. Schools of these typologies make up approximately one third of the school buildings portfolio overall.

Cost benefit analysis results are summarized in Table 24 below and discussed in more detail in this section.

Table 24 Summary of cost benefit analyses results for schools

Asset class	Retrofit options	Cost to retrofit, mean value (these typologies only)	Number of avoided fatalities (over 50 years)	% avoided fatalities (entire schools portfolio)
Schools	S1, S2, S3*	215 million USD	740	33%
	S1, S2, S3**	60 million USD	535	24%

* Assuming that retrofits S1, S2 and S3 are applied to all school buildings of these types in the country.

** Assuming that retrofits S1, S2 and S3 are applied selectively based on highest BCR with a limiting budget of 60 million USD.

Figure 30 illustrates the mean BCRs for the combination of retrofit options S1, S2 and S3, using a discount rate of 5% for a period of 50 years.

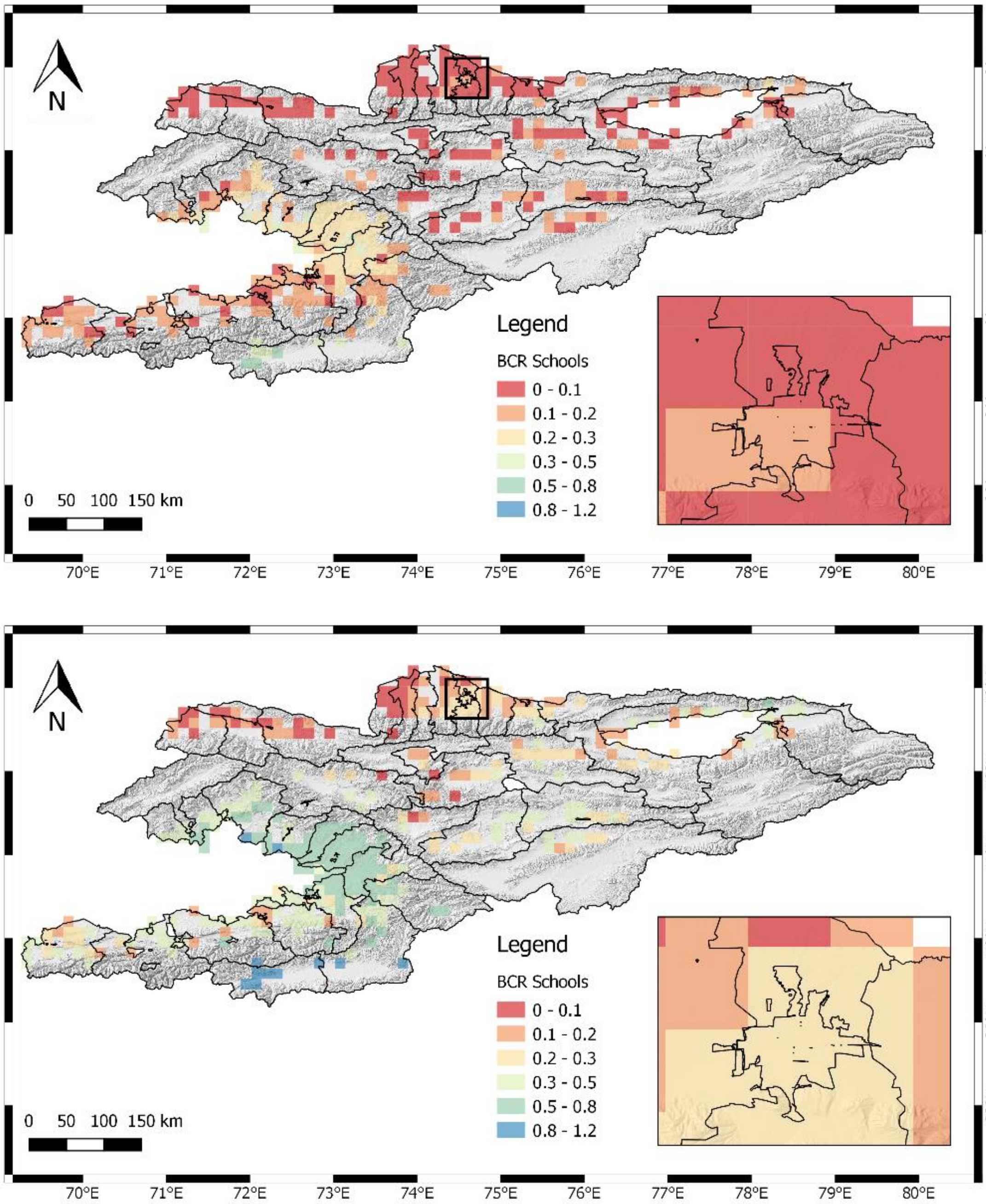

Figure 30 Spatial distribution of BCR for the combination of school retrofit options S1, S2 and S3, using a discount rate of 5% (T = 50 years). Upper plot shows the lower bound (5% percentile), lower plot shows the upper bound (95% percentile)

The total cost of retrofitting all schools buildings of these types in the country would be approximately 215 million USD. Based on these results we can identify the areas where higher (economic) benefit can be achieved for the same cost, in order to inform how retrofit investments can be prioritized. The rayons surrounding the Ferghana Valley near Osh and Jalal-Abad, and the southernmost part of the country near the Alai Mountains are the regions where retrofit investments are expected to return the highest benefit, with a loss reduction of up to 1.5 USD for each USD invested in the Alaisky region.

The reduction in human fatalities one would achieve through the implementation of the combination of retrofit options S1, S2 and S3 across the country is illustrated in Figure 31. Mean values are obtained from the results of all the nine combinations of the ground motion prediction equations (GMPEs) and definition of ground conditions based on shear wave velocity (Vs30) to account for the uncertainty in seismic hazard and therefore seismic risk.

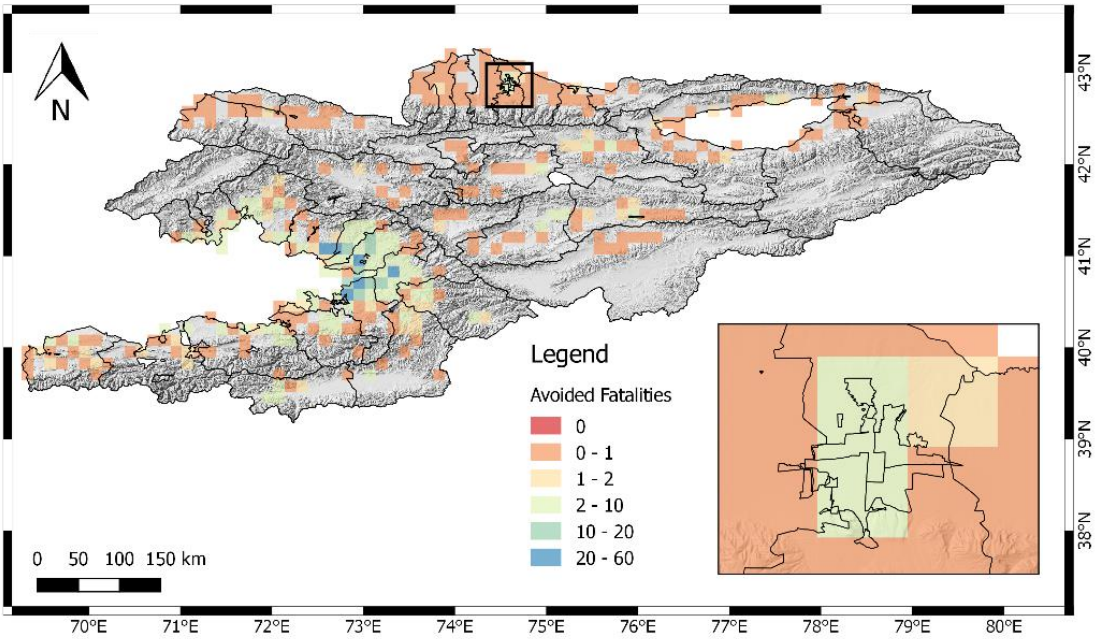

Figure 31 Spatial distribution of mean avoided fatalities for the combination of school retrofit options S1, S2 and S3 (T = 50 years).

The highest benefits in terms of avoided fatalities are expected in the Bishkek and Ferghana Valley regions. The reduction of fatalities in the Ferghana Valley area is clearly driven by the retrofit of adobe and reinforced concrete buildings (retrofit options S2 and S3). In Bishkek, where reinforced concrete buildings are predominant, the highest benefit is achieved for retrofit option S3.

Based on these results, the impact of seismic retrofit was also estimated at the rayon level, considering two alternative retrofit approaches:

- The combination of retrofit options S1, S2 and S3, implemented in all the school buildings of the corresponding vulnerability type (for a total retrofit cost of 215 million USD); and
- The prioritization of retrofit options S1 to S3 based on the BCR of each building, for a limited investment value. In this approach, the maximum possible number of buildings was selected to be retrofitted, considering a maximum total cost of 60 million USD. In this case, buildings with higher BCR were prioritized, irrespective of their building type.

The first option aims to achieve the highest possible reduction of fatalities, irrespective of the associated costs; and the objective of the second alternative is to maximize the ratio between benefits and the assumed total cost. The selected value of 60 million USD was assumed based on the budget for the Safer Schools

Programme as part of the 'Draft 2016-2030 Strategy for the Emergency Protection of the Kyrgyz Republic' (National Government of the Kyrgyz Republic, 2016).

As demonstrated in Figure 32 to Figure 35, as would be expected, the second option (total investment of 60 million USD) has a lower impact on the reduction of fatalities, when compared with the reduction achieved when retrofitting all the buildings (total cost of 215 million USD). The first leads to a total expected reduction of 740 fatalities over a period of 50 years or 33% of overall fatalities for all schools in the country expected over a 50 year period; whereas the latter results in a reduction of only 535 fatalities in the same time frame or 24% of overall fatalities for all schools in the country expected over a 50 year period.

Prioritizing the buildings with higher BCR leads to rayon-level BCRs that are higher than those obtained when retrofitting all the buildings. Therefore, given the limited resources available in virtually all risk reduction exercises, it is the decision-maker's responsibility to define the appropriate balance between targeting the reduction of economic and/or human losses.

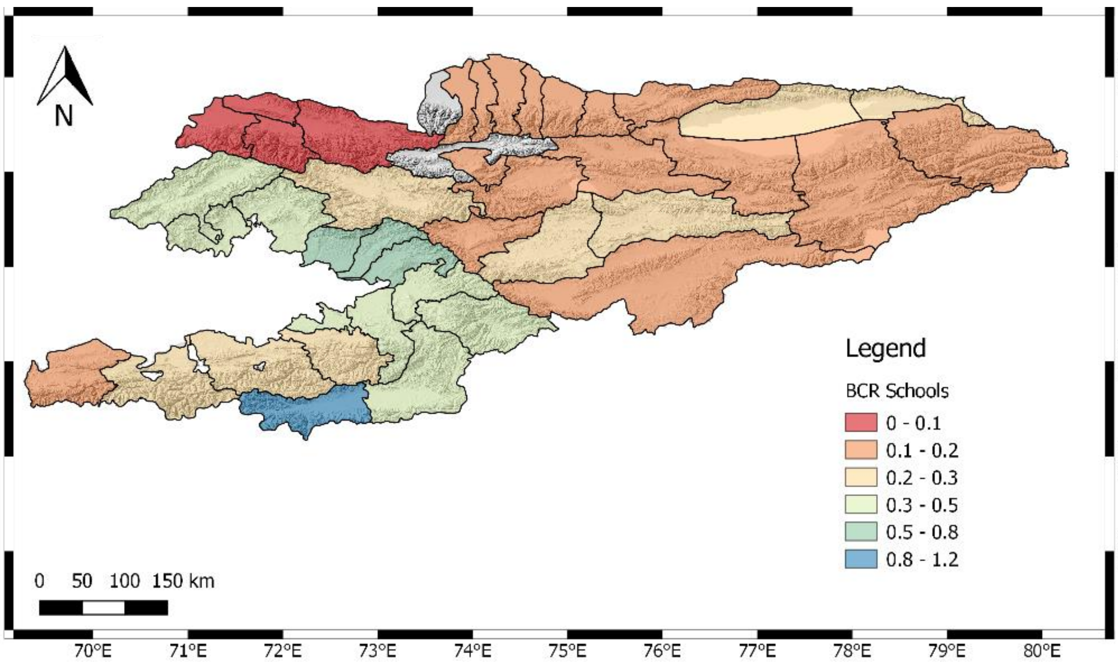

Figure 32 Rayon-level spatial distribution of upper bound BCR values for the combination of school retrofit options S1, S2 and S3 for the whole country that achieves the highest reduction in fatalities, using a discount rate of 5% (T = 50 years).

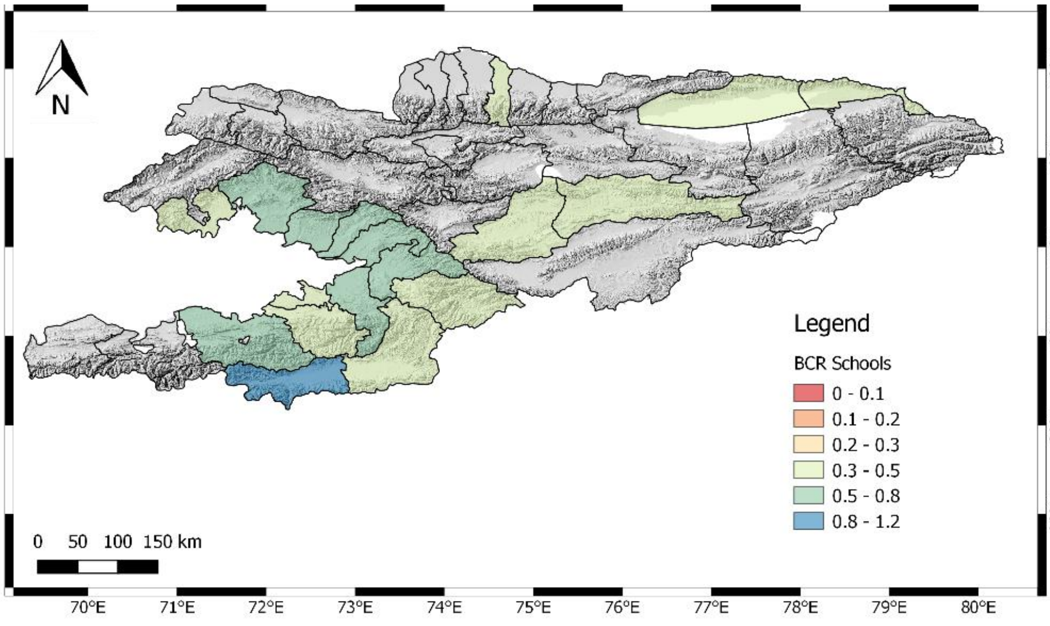

Figure 33 Rayon-level spatial distribution of upper bound BCR values, for the combination of school retrofit options S1, S2 and S3 for selected schools in priority rayons that maximizes economic benefits, using a discount rate of 5% (T = 50 years).

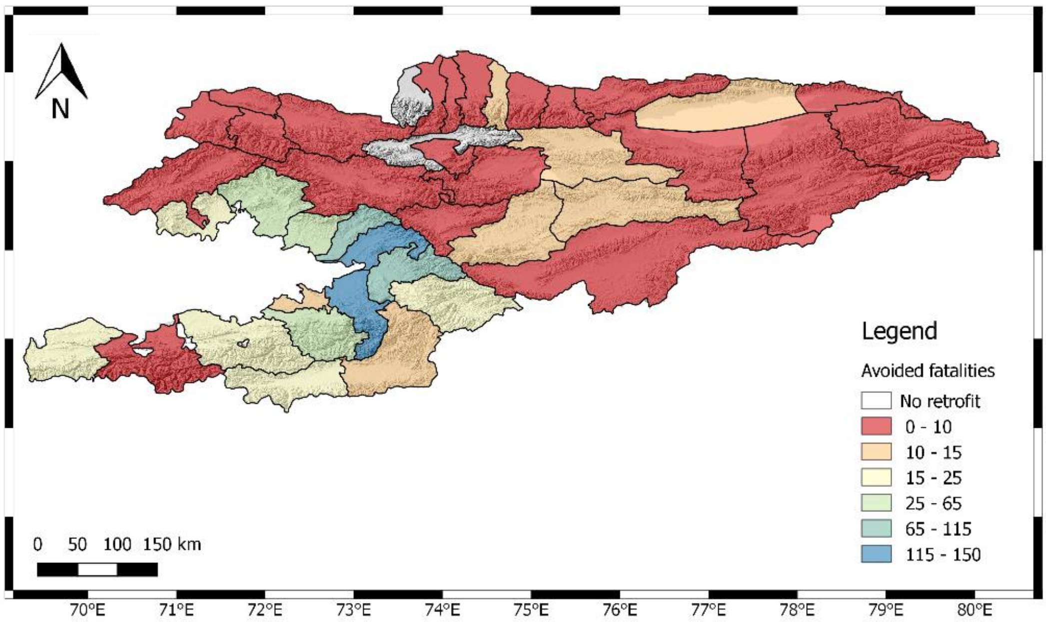

Figure 34 Rayon-level spatial distribution of avoided fatalities, for the combination of school retrofit options S1, S2 and S3 for the whole country that achieves the highest fatality reduction (T = 50 years).

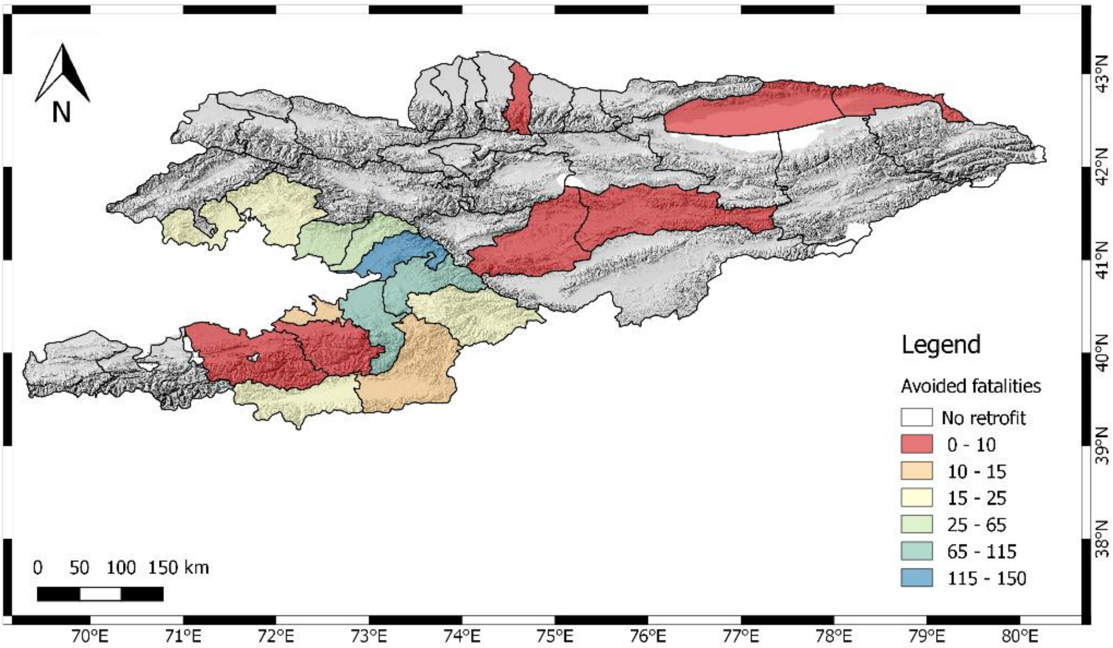

Figure 35 Rayon-level spatial distribution of avoided fatalities, for the combination of school retrofit options S1, S2 and S3 for selected schools in priority rayons that maximizes the economic benefits (T=50 years).

The cost benefit analysis has shown that although it is difficult to justify school retrofits based solely on direct economic benefit over this 50 year time period, investment in retrofit has significant benefit in terms of avoided fatalities for students and teachers in the event of future damaging earthquakes that are expected. The cost benefit analysis results also inform a prioritization of school buildings retrofit by rayon. Refer to Table 25 and Figure 36 below.

Table 25 Prioritization of School Retrofits by Rayon

Priority Level	Rayons
1	Nookensky, Suzaksky, Bazar-Korgonsky, Uzgensky, Kara-Suisky
2	Kara-Kuljinsky, Aravansky, Askyisky, Ala-Buka, Chon-Alaisky
3	Bishkek (4 rayons)
4	Alaisky, Issyk-Kulsky, Nookatsky, Kadamjaisky, Ak-Talinsky, Tyupsky

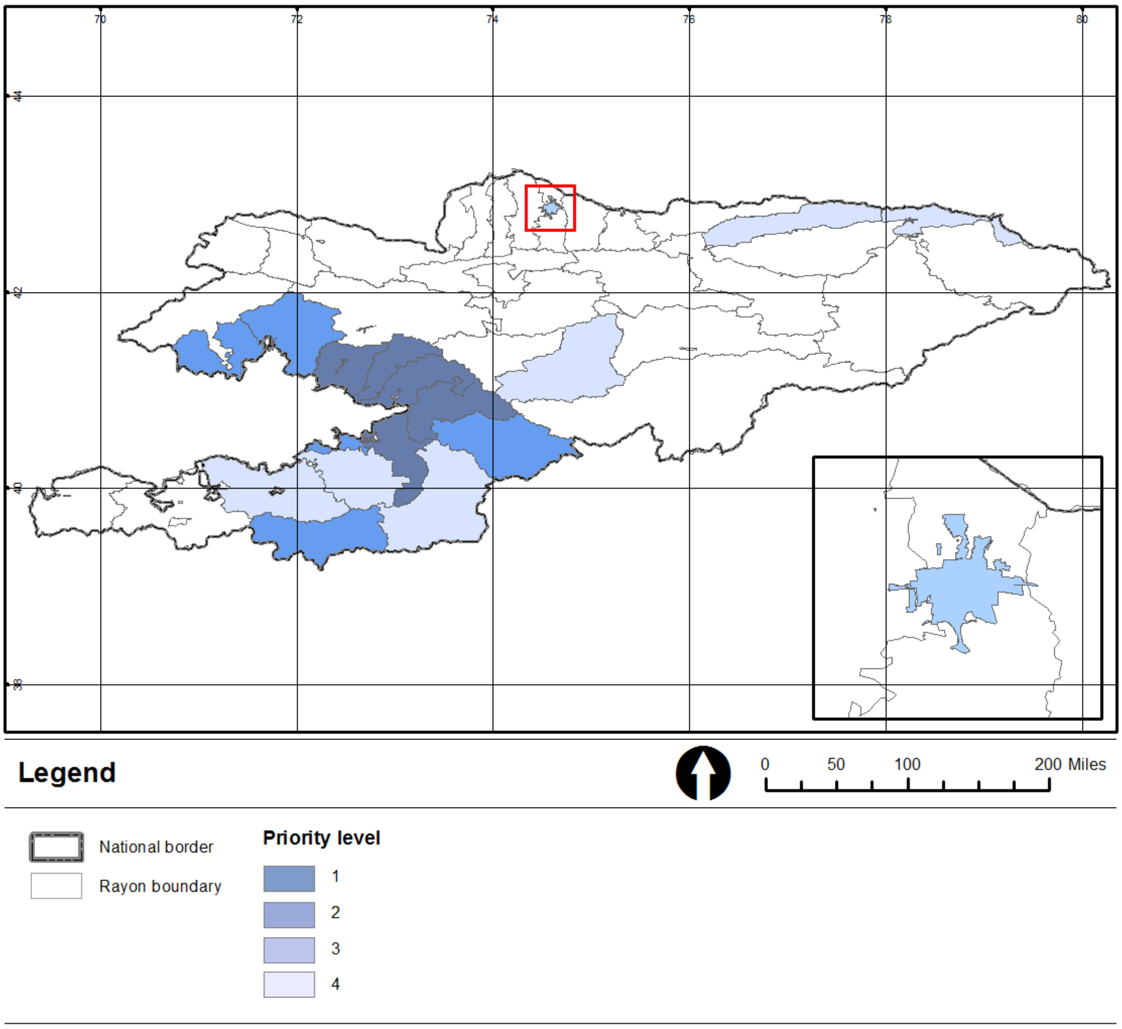

Figure 36 Priority rayons for school retrofitting

6.4 Cost Benefit Analysis Results for Residential Buildings Retrofit Measures

In the risk assessment stage of this project (Arup, 2017b) it was identified that the distinction between reinforced masonry residential buildings and reinforced concrete structures with unreinforced masonry infill walls in the Kyrgyz Republic is highly dependent on subjective judgement in the absence of detailed survey data or construction drawings. These building types share several common attributes, including construction materials, which makes them extremely difficult to differentiate without prior knowledge of construction details (for example, design drawings and/or opening up works). However, despite the similarities, their seismic vulnerability may be significantly different.

In order to account for this source of uncertainty, two alternative residential building exposure models were considered in this work:

- Residential exposure model 1 (Arup, 2017b): buildings initially classified as reinforced or confined masonry were considered as such; and

- Residential exposure model 2 (Arup, 2017b): buildings initially classified as reinforced or confined masonry were assumed as reinforced concrete structures with masonry infill walls.

The retrofit option R1 presented in Table 8 is applied to reinforced or confined masonry buildings only. In order to take both residential exposure models into account, the retrofit option R1 is divided into two alternatives:

- Retrofit option R1 applied to all the reinforced/confined masonry buildings in the exposure model 1 (referred to as option R1.1); and
- Retrofit option R1 applied to all buildings initially classified as reinforced/confined masonry, assuming these are in fact reinforced concrete structures with masonry infill walls (referred to as option R1.2).

Note that cost benefit analyses were not performed for repair of monolithic panel pre-cast apartment buildings (R2) as this option was to restore the building to its original condition rather than to perform a seismic retrofit.

Results are summarized in Table 26 below as well discussed in more detail in this section.

Table 26: Summary of cost benefit analyses results for residential buildings.

Asset class	Retrofit options	Cost to retrofit, mean value (URM residential typology only)	Number of avoided fatalities (over 50 years)	% avoided fatalities (entire residential buildings portfolio)
Residential buildings	R1.1	12.5 billion USD	45	0.6%
	R1.2	12.5 billion USD	495	6%

Although the total retrofit costs of R1.1 and R1.2 are similar (12.5 billion USD), Figure 37 and Figure 38 below show that BCRs for retrofit scenarios R1.1 are significantly lower than those of retrofit R1.2. The reason for this discrepancy is the difference in seismic resistance of the buildings targeted in each retrofit scenario (i.e. reinforced/confined masonry buildings are significantly less vulnerable than reinforced concrete structures with masonry infill walls). More specifically, a given retrofit investment (i.e. cost) will have a significantly higher impact in the building capacity of a vulnerable building (for example, an unreinforced masonry building) than on a structure with high seismic resistance (for example, a seismically detailed reinforced masonry building). In other words, it is significantly more expensive to achieve a specific capacity increase on a resistant building than on a vulnerable one. For this reason, the benefits achieved for scenario R1.1 are significantly lower than those obtained in R1.2, for the same retrofit cost.

Even in the case of R1.2, BCRs are lower than 1.0 throughout the country. In relative terms, Figure 38 demonstrates that the Ferghana Valley and Alaisky regions are the areas where highest economic benefits can be achieved for the same cost. These results indicate that the cost of retrofitting large numbers of residential building is difficult to justify in terms of direct economic benefits that could potentially by reducing the amount of damage to these buildings in future earthquakes using engineering retrofitting measures.

Figure 37 and Figure 38 illustrate the upper bound and lower bound spatial distributions of BCR for retrofit scenarios R1.1 and R1.2.

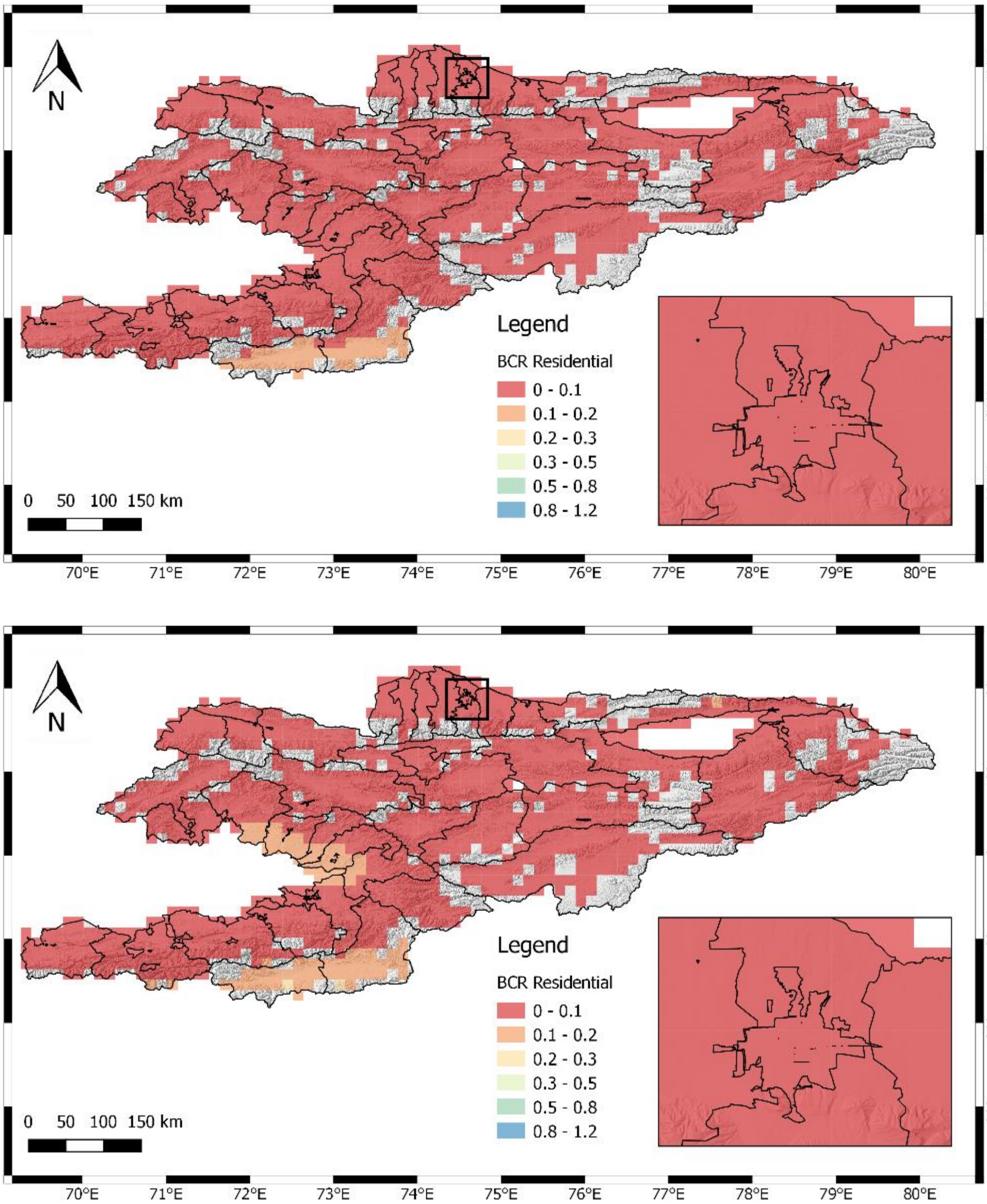

Figure 37: Lower bound (upper plot) and upper bound (lower plot) spatial distribution of BCR for residential retrofit scenario R1.1, using a discount rate of 5% (T = 50 years). The lower and upper bounds are defined as the 5% and 95% percentiles.

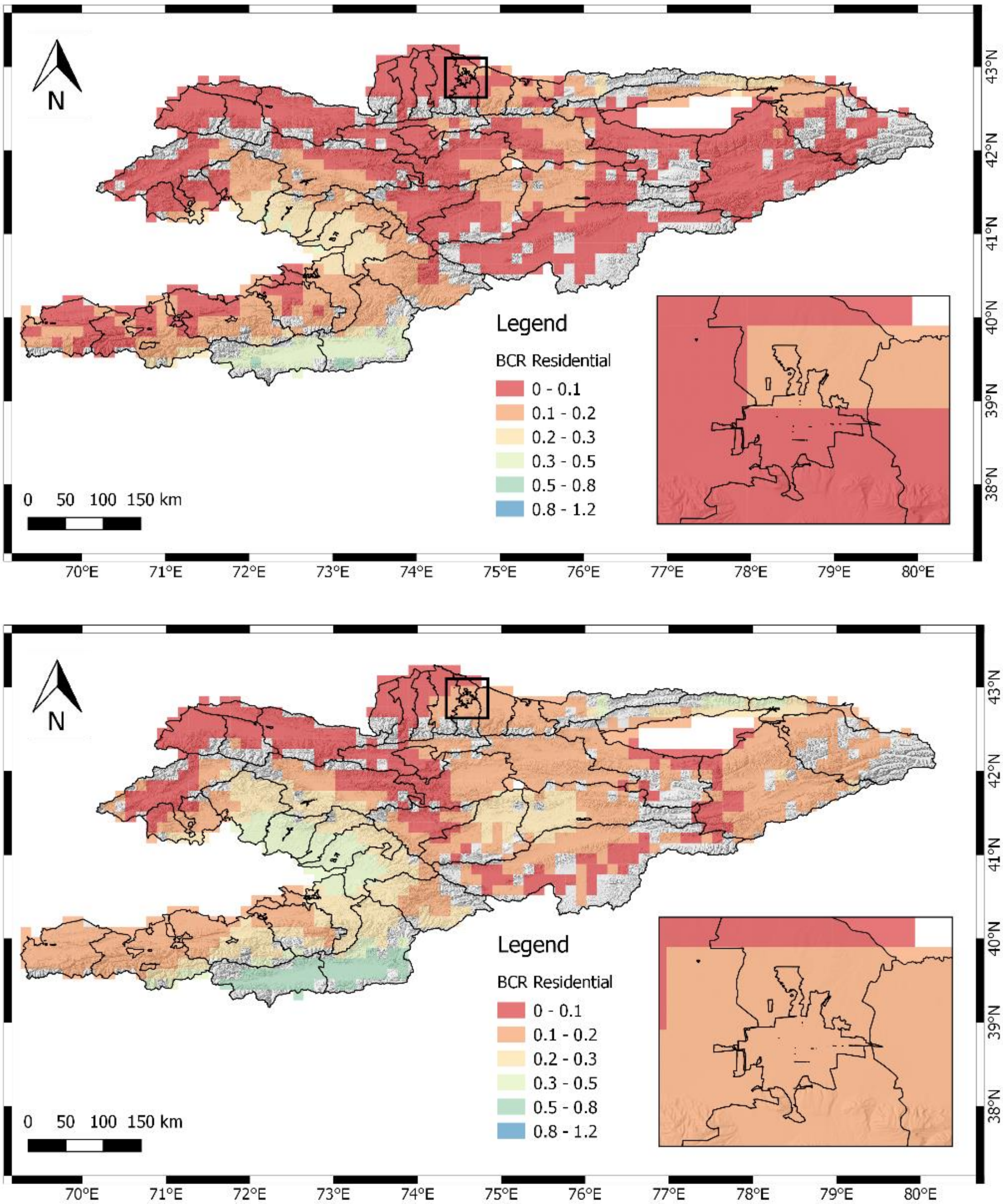

Figure 38: Lower bound (upper plot) and upper bound (lower plot) spatial distribution of BCR for residential retrofit scenario R1.2, using, using a discount rate of 5% (T = 50 years). The lower and upper bounds are defined as the 5% and 95% percentiles.

In terms of human losses, Figure 39 and Figure 40 illustrate the spatial distribution of mean avoided fatalities over a period of 50 years for retrofit scenarios R1.1 and R1.2. Mean values are obtained from the results of all the nine combinations of GMPE/V_S30 as discussed previously, resulting in a mean total reduction of 45 and 495 fatalities for R1.1 and R1.2, respectively, in 50 years. This corresponds to 0.6% and 6% reductions with respect to the number of fatalities expected without seismic retrofit.

These results indicate that very large retrofit costs for residential buildings of these structural types would only potentially achieve modest reduction in the number of fatalities.

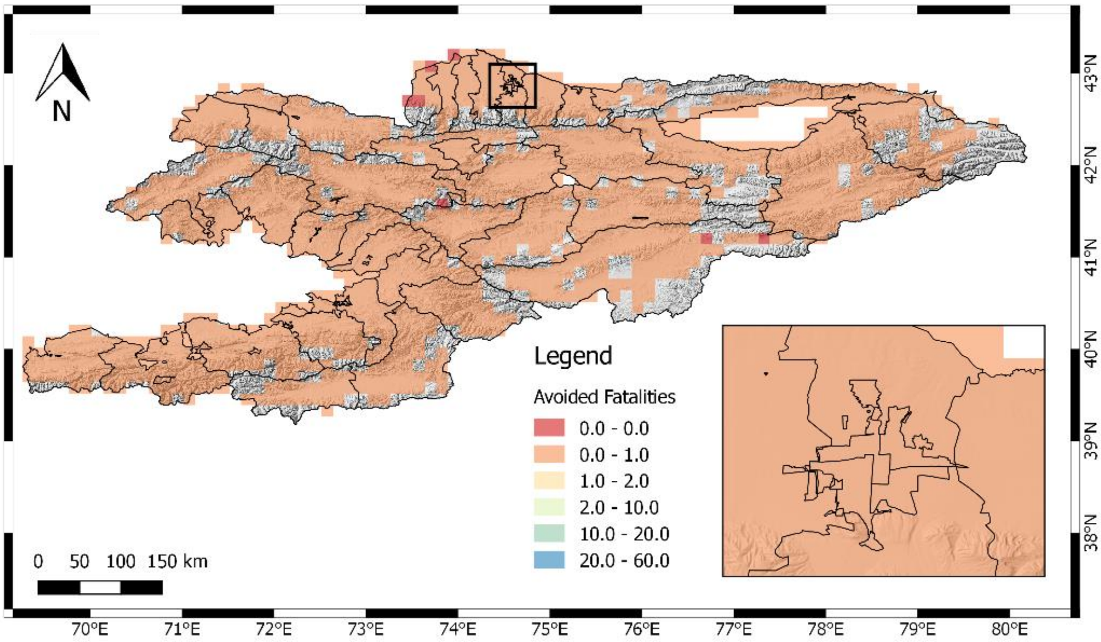

Figure 39: Spatial distribution of mean avoided fatalities for residential retrofit scenario R1.1 applied to the whole country (T=50 years).

Because the retrofit option R1.2 has a negligible effect on the collapse capacity of the retrofitted reinforced masonry buildings (see Appendix C), the reduction in fatalities achieved through retrofit scenario R1.1 is very small and significantly lower than R1.2. In the case of R1.1, the highest benefits in terms of avoided fatalities are expected in Bishkek, the Ferghana Valley region and the southernmost part of the country near the Alai Mountains.

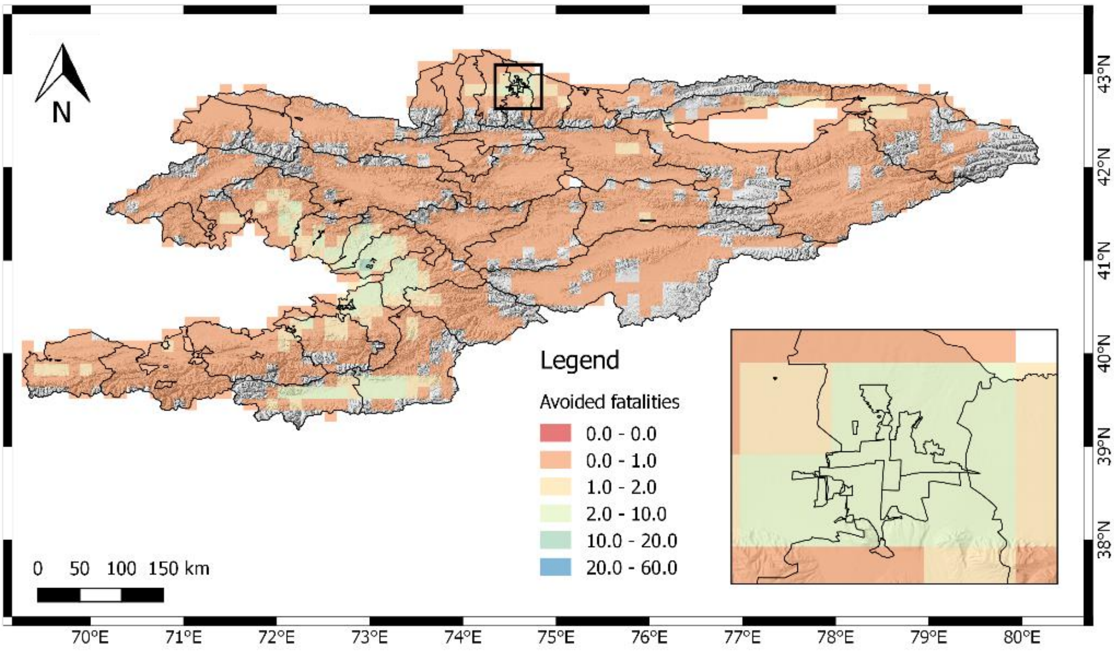

Figure 40: Spatial distribution of mean avoided fatalities for residential retrofit scenario R1.2 applied to the whole country (T=50 years).

6.5 Cost Benefit Analysis Results for Hospital Buildings Retrofit Measures

Due to the lack of information necessary to definite the area, number of floors and construction material of each specific hospital building, the risk assessment of this portfolio was conducted in a way that allows this uncertainty to be captured. As presented in detail in the risk assessment report of this project (Arup, 2017b), multiple exposure models were used to model the characteristics of each hospital building (for which the location was known). Each of these “alternative exposures” reflects a possible building area, number of floors, number of occupants and vulnerability class. This way, the full range of uncertainty in the attribution of these parameters is taken into account (Arup, 2017b). For simplicity, the range of parameters considered is not presented here. Readers are referred to Sections 4.5 and 4.6 of the risk assessment report (Arup, 2017b) for additional details.

In order to guarantee the consistency between the risk and CBA assessments, the CBA results presented in this section also reflect the uncertainty above.

Figure 41 presents the mean, lower bound and upper bound estimates of BCR and number of total avoided fatalities predicted for retrofit options H1 and H2. The illustrated mean, lower and upper bound BCRs for H1 (as an example) can be interpreted as the range of possible BCRs one can expect when retrofitting any of the unreinforced masonry hospital buildings in the Kyrgyz Republic, accounting also for the range of seismic hazard each building can be subjected to throughout the country. In terms of human loss, the predicted mean, lower and upper bound represent the range of the total number of fatalities potentially avoided in all the hospital buildings, over a period of 50 years. Lower and upper bounds are computed as the 5th and 95th percentile results, respectively.

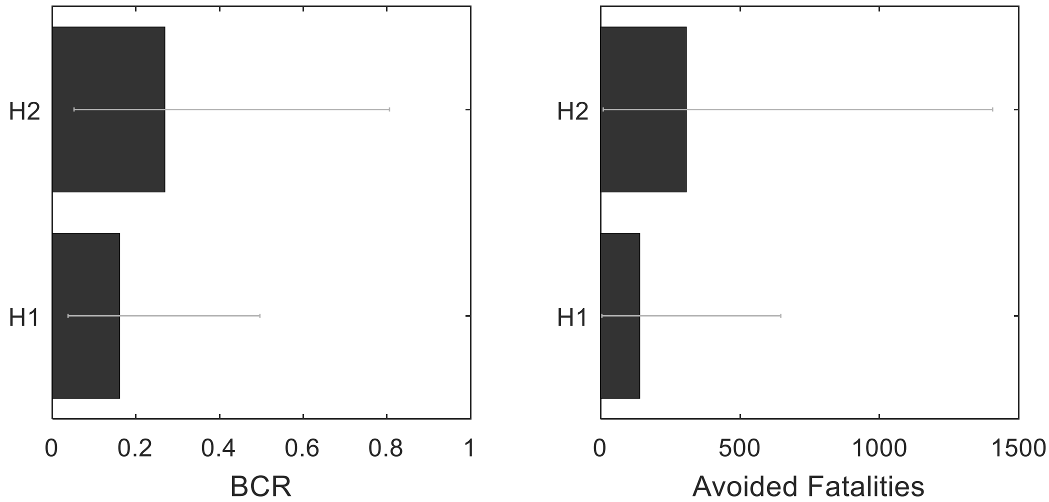

Figure 41 Mean, lower and upper-bound estimates of BCR and total avoided fatalities for hospital retrofit options H1 (conventional retrofit, Life Safety performance) and H2 (seismic isolation, Immediate Occupancy performance).

Given the level of uncertainty for the seismic risk assessment for hospitals, the CBA results in a there is a significant range of possible BCRs. However, the most likely values for H1 and H2 are lower than 1.0. This highlights the assumptions made in this work regarding retrofit costs and corresponding performance improvements that the retrofits can achieve and, more importantly, the issue raised in the methodology (Appendix C) regarding the effect of contents and indirect losses in the resulting BCRs. Losses to medical equipment and other hospitals contents, as well as the indirect effects due to loss of functionality and consequent inability to provide post-earthquake medical assistance may have a very significant impact on the cost benefit analysis results.

In future, based on a set of more accurate seismic risk assessment results for the hospital building portfolio, we recommend that further CBA is performed which includes estimation of indirect losses for hospitals. This will improve the resulting BCRs and strengthen the economic argument for retrofitting existing hospital buildings. In addition, there should be an incentive to selectively retrofit these types of facilities as they provide critical services, especially for post-disaster response and recovery.

Results are summarized for hospital buildings in Table 27 below:

Table 27: Summary of CBA results for hospital buildings.

Asset class	**Retrofit option**	**Cost to retrofit, mean value (entire portfolio)**	**Number of avoided fatalities (over 50 years)**	**% avoided fatalities (entire portfolio)**
Hospital buildings	H1	832.5 million USD	140	56%
	H2	703 million USD	310	81%

6.6 Cost Benefit Analysis Results for Fire Station Buildings Retrofit Measures

Due to the lack of information necessary to definite the area, number of floors and construction material of each specific fire station building, a similar approach was take as for the hospital portfolio. Refer to Section 6.5 above.

Figure 42 presents the mean, lower bound and upper bound estimates of BCR and number of total avoided fatalities predicted for retrofit options F1. The illustrated mean, lower and upper bound BCRs can be interpreted as the range of possible BCRs one can expect when retrofitting any of the unreinforced masonry fire station buildings in the Kyrgyz Republic, accounting also for the range of seismic hazard each building can be subjected to throughout the country. In terms of human loss, the predicted mean, lower and upper bound represent the range of the total number of fatalities potentially avoided in all the fire station buildings, over a period of 50 years. Lower and upper bounds are computed as the 5th and 95th percentile results, respectively.

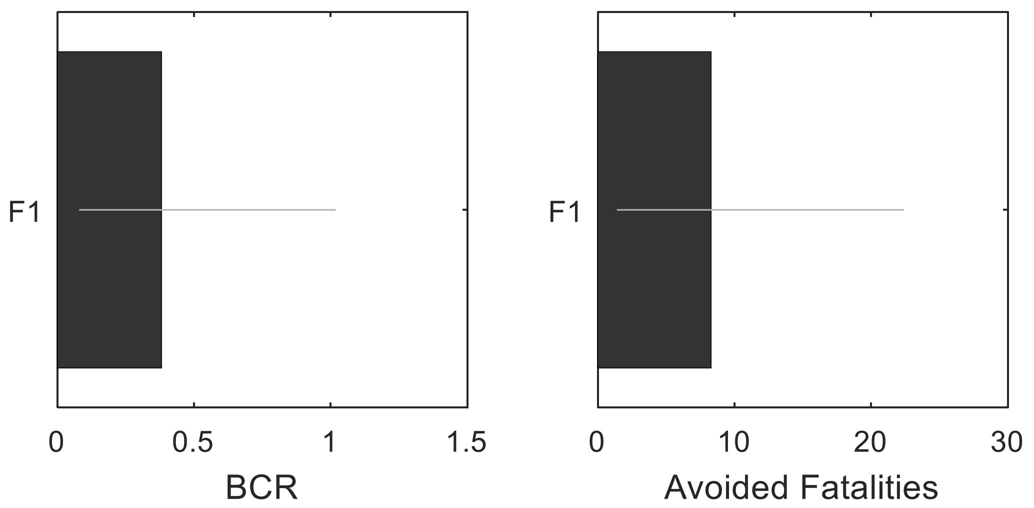

Figure 42 Mean, lower and upper-bound estimates of BCR and total avoided fatalities for fire station retrofit F1 (conventional retrofit, Life Safety performance).

Given the level of uncertainty for the seismic risk assessment for fire stations, the CBA results in a there is a significant range of possible BCRs. BCRs above 1.0 may be achieved for F1. However, the most likely values for F1 are lower than 1.0. This highlights the assumptions made in this work regarding retrofit costs and corresponding performance improvements that the retrofits can achieve and, more importantly, the issue raised in the methodology (Appendix C) regarding the effect of contents and indirect losses in the resulting BCRs. Losses to equipment and other fire station contents, as well as the indirect effects due to loss of functionality and consequent inability to provide post-earthquake response may have a very significant impact on the cost benefit analysis results.

In future, based on a set of more accurate seismic risk assessment results for this portfolio, we recommend that further CBA is performed which includes estimation of indirect losses for fire stations. This will improve the resulting BCRs and strengthen the economic argument for retrofitting existing fire station buildings. In addition, there should be an incentive to selectively retrofit these types of facilities as they provide critical services, especially for post-disaster response and recovery.

Results are summarized for fire station buildings in Table 28 below:

Table 28 Summary of CBA results for fire station buildings

Asset class	Retrofit option	Cost to retrofit, mean value (entire portfolio)	Number of avoided fatalities (over 50 years)	% avoided fatalities (entire portfolio)
Fire Station buildings	F1	333 million USD	10	20%

6.7 Discussion of Cost Benefit Analysis Results

The Benefit/Cost Ratios (BCRs) obtained when using a discount rate of 5% (Refer to Appendix C for details) are generally lower than 1.0. This can be explained by three main factors:

1. Indirect losses such as cost of replacing damaged contents and costs associated with disruption of function for schools are not considered. These can sometimes exceed direct losses depending on the building type and usage. These indirect losses are more important for higher importance assets with critical functions such as schools, (as well as hospitals and emergency response facilities), than for typical buildings such as residential buildings.

2. The computed retrofit costs are in the order of 40% of the buildings' replacement value (refer to Appendix D for further details), which we judge to be realistic for these retrofit options but is at the higher end of the economically viable threshold for carrying out retrofitting versus building replacement; and

3. As in every study of this scale, the effects of retrofits on structural capacity were derived in order to be representative of the expected range of building

properties. As a result, the achieved improvements in each building represent an average estimate, rather than the most optimized effect.

In the practical implementation of a given retrofit programme, the retrofit design shall be performed with a level of detail (ideally, building by building) that cannot be achieved in the scope of this countrywide study.

In future phases of more detailed cost benefit analysis for each asset portfolio, we recommend evaluating other options including: (a) develop retrofit options that target a greater range of seismic performance objectives (e.g. less than Life Safety) for a range of levels of site seismicity (low, moderate, high) to see the impact on BCRs, (b) the CBA should consider comparing options for combination of building replacement and retrofits and (c) the CBA should also consider the impact of indirect losses to account for loss of contents and disruption of services.

In terms of reduction of fatalities, these preliminary results show that **investing in schools retrofits has a significant payoff in terms of overall lives of school children and teachers saved** (24% overall in the country for an investment of 60 million USD for these selected retrofit options). **The results of this study provides strong evidence** to support the current initiative in the government's draft DRM strategy to invest approximately 63 million USD over the next four years **to reduce the risks to schools from natural disasters**.

It is recommended that more detailed seismic risk assessment are performed for hospitals and fire stations with better engineering data on the characteristics of these assets. That said, these preliminary results indicate that **investing in retrofits (using seismic isolation, for example) for hospitals and upgrading fire stations using less vulnerable construction types** will have significant benefit **in terms of reducing both direct and secondary fatalities as well as improving continuity of these critical services for emergency response.**

7 Seismic Risk Reduction: Key Recommendations for Stakeholders

7.1 Introduction

This section of the report gives seismic risk reduction recommendations tailored for key stakeholders in the Kyrgyz Republic and provides references to other sections of the report with recommendations and guidance relevant for each stakeholder.

7.2 National Government of the Kyrgyz Republic (National Government)

The role of National Government in Disaster Risk Reduction (DRR) is to set national policy and strategy related to disaster risk governance. To implement this, National Government must raise and allocate funds for DRR, define roles and responsibilities for national scale DRR activities, create mechanisms to monitor progress in DRR and facilitate coordination with stakeholders both in the Kyrgyz Republic and internationally. In addition, National Government should coordinate and conduct national-scale DRR activities (for example, public awareness campaigns on risk and emergency preparedness).

We are aware that the National Government is in the process of finalizing the '2016-2030 Strategy for the Emergencies Protection of the Kyrgyz Republic', the related actions and investment plan, which are aligned with the Sendai Framework. This is a key policy document relating to DRR and seismic risk reduction for the country and it is recommended that **the results of this seismic hazard and risk study are taken into account for the final strategy and action plan**. Items in the '2016-2030 Strategy for the Emergency Protection of the Kyrgyz Republic' action plan that relate to these seismic risk reduction recommendations are referenced in *italics*.

Specifically, the following recommendations apply:

To improve the understanding of seismic hazard in the Kyrgyz Republic, three projects are recommended:

1. **The existing national country-wide strong ground motion recording** network should be extended;
2. Further investigation of and study of **the characterization of active faults** in the country should be carried out; and
3. **Seismic site response effects** should be investigated in all priority urban areas.

Some of these activities may fall under *Items 17.1 and 21.2* of the 'Draft 2016-2030 Strategy'.

The National Government should provide funding for and coordinate national-scale programmes to assess seismic risk to critical physical assets and selected types of higher risk residential buildings.

Currently the 'Draft 2016-2030 Strategy' includes actions for assessing seismic risk for residential buildings *[Item 2.2]*, schools *[Item 16.2]* and for large settlements generally *[Item 2.3]*. It is recommended that **the results of this seismic hazard and risk study are taken into account in the risk reduction strategy prioritization** of these assets. In addition, it is strongly recommended that the strategy include specific actions and funding **to perform more detailed seismic assessments for critical infrastructure (roads, bridges, and other critical infrastructure), hospitals and emergency response facilities** in addition to **schools and residential buildings**. This study can be used as a basis for the updated risk assessments once additional data on the exposure and vulnerability for these asset categories has been collected.

Mechanisms should be created and funding provided to allow the **collection of post-earthquake survey data** (damage and losses). This information is important because it provides a country specific, evidence based, method for better understanding the seismic performance of buildings and infrastructure across the country.

The National Government should continue to **raise awareness about seismic risk** throughout the country using various media, programmes of community engagement and by incorporating disaster risk awareness into school curriculum.

The National Government should **define roles and responsibilities and allocate funding to government departments** to manage these seismic risk reduction strategy activities, engage with relevant technical specialists in the country and manage and disseminate seismic risk data. Preliminary guidance on budgets for selected risk reduction priorities are provided in this report.

In general, it is recommended that more emphasis should be placed on **community engagement** in the government's DRR policy's and activities. Also, it is recommended that there should be a shift in **funding towards risk reduction ahead of disasters** (such as improving the seismic performance of critical buildings) rather than post-disaster response.

Finalizing and approving the 'Law on Seismic Safety' to provide a legal basis for the current National Programme on Seismic Safety is included in the Draft 2016-2030 Strategy *[Item 11.1]* and should be a priority. Laws related to DRM should use and define **consistent DRM terminology** (e.g. for hazard, exposure, vulnerability and risk) and metrics for defining losses in terms of casualties and economic impact.

A programme for **schools risk reduction** has recently been initiated by the government supported by the World Bank *[Item 16.2]*. As a priority, similar programmes should be initiated for **hospitals and emergency response facilities** and **critical national infrastructure** (e.g. lifeline bridges).

Funding should be allocated to GOSSTROY and others to continue to **update seismic codes** and develop codes, standards and guidance documents for **seismic**

assessment and retrofit of buildings and infrastructure *[Item 2.8 relates to developing retrofit guidance for common asset types]*.

The National Government should **legally require urban centres to develop land use plans** and that they be updated at specified intervals. Funding increases will be required to support this for the local government and the Design Institute and other stakeholders involved in developing and enforcing land use plans.

Funding should be allocated to the MoES to support **emergency preparedness and response recommendations** given in this report for emergency response facilities, hospitals, schools and members of the public. Refer to Section 4 for specific recommendations.

The National Government should also work with the State Insurance Organization (SIO) and other private insurers to **strengthen the insurance markets** in the Kyrgyz Republic and make arrangements for **liquidity post-disaster**. Refer to Section 7.10 and Appendix H for detailed recommendations related to disaster risk financing and the insurance sector.

7.3 Local Government (Oblast and Rayon Level, Cities)

Local government (at Oblast, Rayon and city level) plays a key role in the following activities relevant to the seismic risk reduction strategy recommendations in this study:

- Community engagement for DRM activities including public awareness campaigns and emergency preparedness training in different sectors;
- Aspects of land use planning related to seismic risk and emergency response;
- Ensuring compliance with construction regulations;
- Seismic risk reduction programmes in different sectors (health, education, emergency response and for critical infrastructure) to ensure continuity of services post-disaster and overall reduction in losses.

One key recommendation is that the results of the seismic risk assessment are used to inform emergency response planning at local level.

National Government and national-level ministries such as Ministry of Emergency Services (MoES), GOSSTROY, Ministry of Health (MoH), Ministry of Education and Sciences (MoE) and others need **to clarify the roles and responsibilities at local government level** to carry out the adopted recommendations for seismic risk reduction in the country. The Kyrgyz Republic has moved away from a centralized government system since independence and there are advantages to shifting funding and decision making to local and city government level (for incorporation of local requirements and buy-in at local level) within national programmes. Adequate funding will be required as well as mechanisms to monitor progress.

7.4 Ministry of Emergency Situations (MoES)

The main activities that should be led by the Ministry of Emergency Situations (MoES) are:

- Input into the **requirements for emergency response for land use plans** developed by local government (open spaces, main evacuation routes, locations of emergency response facilities and supplies) and communication to communities;
- Jointly with the National Government and other stakeholders, **develop a seismic risk reduction plan for existing emergency response facilities**. Ahead of this, MoES should support the detailed engineering assessments of emergency response facilities by GOSSTROY to input into the updated seismic risk assessment for these facilities;
- Identify **gaps in emergency response** in the country and scale up programmes for training for **community first responders**. New emergency response facilities may also be required and funding will be required for the development of new facilities;
- The MoES should jointly agree with GOSSTROY **code updates** relating to seismic design requirements for new hospitals, schools and emergency response facilities;
- Coordination with the MoH to **identify hospitals that are critical for emergency response and expected numbers of causalities** for earthquake scenarios. In addition, the MoES can support the MoH in developing their emergency preparedness training programme for hospital staff;
- Coordination with the MoE **to identify school buildings that will be used for emergency response activities** (support for communities or temporary shelter). In addition, the MoES can support the MoE in developing their risk awareness and emergency preparedness curriculum for teachers and students; and
- Coordination with the MoT to **identify critical roads and bridges** (and other lifeline infrastructure) that will be used for emergency response.

Refer to Section 4.8.2 for recommendations related to MoES activities to ensure continuity of housing post-disaster.

In general, the results of the seismic hazard and risk study should be used to inform emergency response planning at national and local level by MoES.

7.5 Ministry of Construction (GOSSTROY)

The main activities that should be led by GOSSTROY are:

- **Detailed seismic assessments for critical infrastructure and building assets** to inform the updated seismic risk assessments. GOSSTROY should closely coordinate with related ministries for each asset portfolio (Ministry of Health for hospitals, MoES for emergency response facilities, Ministry of Education for schools, and Ministry of Transport for bridges). Refer to Section

4 for recommendations specific to each category including recommendations for data collection;

- **Development and updating of codes and standards** related to seismic design, assessment and retrofit;
- **Construction regulations and enforcement**; and
- **Development of guidance** for use of codes and retrofitting of common construction types. Guidance can be tailored to specific asset types or users (e.g. for schools or for single family housing).

Additional specific recommendations which result from this study include:

Code updates should include **updated seismic hazard criteria and regional seismic hazard maps**. This study can be used as an input to the updated code hazard maps. The code should also be updated to include **provisions for non-structural mitigations**. It is recommended the **code prohibit certain construction types** shown to perform poorly in earthquakes for new construction of hospitals, schools and emergency response facilities.

A number of recommendations to **improve enforcement of regulations** should be considered. Refer to Section 4.4.

In addition, maps showing the location and alignment of active geological faults should be developed along with guidelines for geological fault set back distances. These are important to develop to avoid siting critical or high importance buildings or infrastructure in locations where there is a known risk of fault rupture.

7.6 Ministry of Health (MoH)

Refer to Section 4.6 for detailed risk reduction recommendations for hospital buildings. It is recommended that the Ministry of Health (MoH) should work closely with the National Government, GOSSTROY and other stakeholders at local government level to create **an inventory of hospitals and health facilities** for the country as well as support the detailed engineering assessments of these hospitals and healthcare facilities by GOSSTROY.

After the **hospital seismic risk assessment** is completed, the MoH should input into the investment plan for risk reduction for hospitals, including seismic retrofits. Refer to Section 4.6.4 for specific hospital retrofits examples.

A programme of **non-structural mitigations (to anchor and brace equipment, contents and non-structural elements) for hospitals** should be actioned as a priority as part of this plan.

The MoH should also work closely with the MoES to implement the **emergency response and preparedness training for hospital staff**. Refer to Section 4.6.2 for more details.

7.7 Ministry of Education and Science (MoE)

Refer to Section 4.4 for detailed risk reduction strategy recommendations for school buildings.

Item 16.2 in the 2016-2030 Strategy is for the 'National Program on Reconstruction of School and Pre-School Buildings' The exact scope of this programme is not specified but we understand that the World Bank is supporting this as part of their Global Program for Safer Schools.

It is recommended that the Ministry of Education and Science (MoE) should work closely with National Government, GOSSTROY and other stakeholders at local government level to carry out the **supplemental school surveys and update the schools database**.

A revised schools risk assessment can then be performed to inform a **detailed schools investment plan, prioritization within each rayon, and provide school building specific recommendations** for school upgrades and retrofits. Refer to Section 4.5.3 for specific school retrofit examples.

The MoE should jointly with GOSSTROY agree **code updates related to seismic design of new schools, construction monitoring requirements for schools and review of model school designs.** MoE and GOSSTROY should also develop retrofit guidance tailored for schools.

The MoE should also work closely with the MoES to include **risk awareness and emergency preparedness training** in the curriculum for teachers and students. Refer to Section 4.5.2 for more details.

7.8 Ministry of Transport and Communications (MoT)

Refer to Section 4.9 for detailed risk reduction strategy recommendations for transport infrastructure (roads and bridges).

It is recommended that the Ministry of Transport and Communications (MoT) should work closely with the National Government, GOSSTROY, MoES and other stakeholders at local government level **to identify critical roads and bridges** for the country as well as support the **detailed assessments of bridges**.

An updated seismic risk assessment can then be carried out (potentially using network analyses) **to prioritize roads and bridges for upgrades/replacement and/or retrofit**. The MoT should input into the investment plan led by the National Government to carry out these improvements.

Other forms of critical infrastructure such as airports, energy production (electricity, oil and gas) facilities and related assets, water supply, telecommunication networks, rail and national defence infrastructure were excluded from the scope of this study. The critical national infrastructure assets should be considered for future seismic risk assessments and included in the seismic risk reduction strategy for the country going forwards.

7.9 Ministry of Finance (MoF)

It is recommended that the Ministry of Finance should work with other National Government ministries and stakeholders to determine the **allocation of funds** for activities adopted for seismic risk reduction as part of the overall budget for Disaster Risk Management according to the finalized 2016-2030 Strategy. The MoF could also have a role in efforts to create a **regional disaster risk financing pool** and in **negotiating donor funds** from international organisations, such as the World Bank and others, to support DRR in the Kyrgyz Republic.

7.10 State Insurance Organization (SIO)

In addition to the ongoing activities to strengthen the insurance market in the Kyrgyz Republic specified in the 'National Strategy of Sustainable Development of the Kyrgyz Republic for the period of 2013 – 2017' (National Council for Sustainable Development of the Kyrgyz Republic, 2012), it is recommended that the State Insurance Organization work with National Government to explore these measures:

- **Consider mandating insurance coverage** for building owners (many of which are public sector or housing trust-type organisations);
- Consider the **National Government's role as a potential reinsurer**;
- To take steps to **standardize insurance coverage** with respect to natural disasters, so that consumers are aware of the coverage available;
- **To provide liquidity after a major earthquake**, the SIO should work with the National Government and particularly the MoF to explore arranging ex-ante funding with organisations such as the World Bank or others;
- In the longer term, the government and SIO should consider regional engagement and explore establishing a **wider insurance risk pool** with other countries; and
- To ensure fair insurance pricing and adequate capitalization, **it is recommended that the SIO share estimates of future seismic losses** from the seismic risk assessments including the results of this study with Government agencies, in-country insurers and international insurance markets to support the development of more **accurate catastrophe models** for the Kyrgyz Republic and the wider region.

Refer to Appendix H for recommendations relating to Disaster Risk Financing and Insurance in the Kyrgyz Republic.

7.11 Communities/Individual Citizens

Through National and Local Government public awareness campaigns, communities and individual members of the public should be encouraged to:

- Have a basic awareness of seismic hazard and risk in their locality;

- Have plans in place for communicating with family member after a disaster and have basic supplies stored (i.e. several days of food and water);
- Ask questions to Local Government officials about the safety of local hospitals, schools, etc.;
- Implement basic non-structural mitigations in their homes or workplaces for contents (e.g. anchoring furniture, keeping heavy objects low down, etc.); and
- Be familiar with emergency response plans in their locality or city.

7.12 World Bank

The following recommendations relate to existing World Bank programmes in the Kyrgyz Republic or recommended future risk reduction projects for consideration.

7.12.1 Recommendations for Existing World Bank Programmes

In addition to this study, we are aware of the following World Bank supported programmes in the Kyrgyz Republic:

7.12.1.1 Urban Development Project

The Urban Development Project aims to improve the quality of municipal services and to pilot energy efficiency and seismic retrofits of urban infrastructure in participating towns. Selected outputs of the Urban Development Project included a detailed review of DRM and DRR in the Kyrgyz Republic and the roles and responsibilities of key stakeholders, including government agencies. It also includes detailed information on the codes and standards for construction and the wider regulatory environment. Selected outputs are referenced in this study (ICF Consulting Services, 2016a; ICF Consulting Services, 2016b) and it is recommended that outputs related to the review of DRM and DRR activities and institutional roles should be used to inform other projects related to DRR in the Kyrgyz Republic.

The results and recommendations of this countrywide Measuring Seismic Risk in the Kyrgyz Republic project should be incorporated into the Urban Development project going forwards.

7.12.1.2 Global Program for Safer Schools

The Kyrgyz Republic is now one of the countries participating in the Global Program for Safer Schools where funding, technical and policy support is provided to ensure school infrastructure is safe against natural hazards and other risks, including seismic risk. Currently, existing government schools programmes and policy are being evaluated ahead of the World Bank providing support for the Kyrgyz Republic schools investment plan to reduce risk to schools. This will support the National Programme for Safer Schools in the Kyrgyz Republic which is part of the updated DRM strategy (National Government of the Kyrgyz Republic, 2016).

The results of this countrywide seismic hazard and risk study and the seismic risk reduction strategy recommendations for schools should be incorporated into the Safer Schools project.

7.12.1.3 Disaster Risk Management Program

There has been a request for the World Bank to provide support for the country to update their plans and policy related to DRM and form an updated DRM investment plan.

7.12.1.4 Mainstreaming Seismic DRR into Wider World Bank Programmes

There are other current World Bank projects in the Kyrgyz Republic relating to energy, water, health and other sectors (World Bank, 2017).

It is recommended that the results for the seismic hazard and risk study and the seismic risk reduction strategy recommendations are incorporated into aspects related to assessment and development of new infrastructure related to these projects and other projects going forwards.

7.12.2 Recommendations for Future World Bank Programmes

Based on the results of this study, we recommend that the World Bank consider working with the Government of the Kyrgyz Republic on the following programmes related to reducing seismic risk in the Kyrgyz Republic:

- **A countrywide seismic risk reduction programme for hospitals**;
- **A countrywide seismic risk reduction programme for all emergency response facilities** (including fire stations);
- **A countrywide seismic risk reduction programme for critical national infrastructure** such as airports and other transport infrastructure, energy production (electricity, oil and gas) facilities and related assets, water supply, telecommunication networks, rail and national defence infrastructure. Bridges should be prioritized as part of this; and
- **Countrywide hazard and risk assessments for other natural hazards such as landslides and flooding and hazards and risks related to the impacts of climate change**.[40]
- **A study of ex-ante disaster risk funding requirements and possible arrangements** with the World Bank. These could be coupled with risk reduction programmes. Refer to Appendix H.

[40] It is strongly recommended that a follow-on project be undertaken to understand and address the risk from landslides, debris flows, rockfall and avalanche. The results of the risk assessment could inform specific risk reduction recommendations relating to landslide risk (both seismic and triggered by other factors such as rainfall and weathering). A component of this study could involve practical guidance for site selection in challenging mountainous environments.

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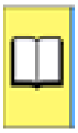
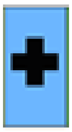
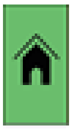
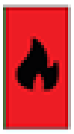
Appendix A

Retrofit Guidance and Detailed Measures

A1 Additional Guidance on Selected Seismic Retrofitting Techniques

Additional guidance has been provided for the retrofit measures for the retrofit options presented in Section 4 of this report for hospitals, schools, fire stations and residential buildings. Refer to Table A-1 below for a list of retrofit measures. This guidance is intended to give more detail as to what each retrofit measure consists of, key considerations for design and construction, which typologies the measure typically applies to and technical references for further guidance. Refer to Appendix E for descriptions of the structural typologies.

The usage types the measure is most appropriate for are shown in the upper right hand corner and use the following key:

Symbol	Usage Category
	School buildings
	Hospital buildings
	Residential buildings
	Fire station buildings

If a retrofit measure is less appropriate for a certain building usage type, the symbol will be shaded in grey.

Table A-1 Additional Guidance on Selected Seismic Retrofitting Techniques

Category	ID	Description of retrofit measure
GLOBAL	GL-1	Add new reinforced concrete walls
	GL-2	Add new reinforced concrete moment frame
	GL-3	Strengthen walls (typically unreinforced masonry or mud masonry) with reinforced concrete overlay
	GL-4	Add new steel brace frame
LOAD PATH	LP-1	Improve connection between timber floor/roof and unreinforced masonry walls
	LP-2	Add buttresses to improve performance of adobe walls out-of-plane
COMPONENT DETAILING	DET-1	Reinforced concrete jacketing of columns
DIAPHRAGMS	DIA-1	Strengthen diaphragm with reinforced concrete topping, precast
FOUNDATIONS	F-1	Strengthen existing footings
NON-STRUCTURAL	NS-1	Remove or brace chimneys
	NS-2	Remove or brace slender parapets
	NS-3	Remove unreinforced masonry partition walls and replace with light-weight partitions
	NS-4	Brace unreinforced masonry partition walls
	NS-5	Anchor tall, narrow contents
	NS-6	Brace lighting
	NS-7	Brace/anchor mechanical, electrical and plumbing (MEP) services and equipment
	NS-8	Brace suspended ceilings
REDUCE DEMAND	RD - 1	Seismic Isolation
	RD-2	Reduce mass

Appendix B

Supplemental Guidance on Seismic Assessment and Retrofit

B1 Supplemental Guidance on Seismic Assessment and Retrofit

This appendix provides additional guidance and definitions related to seismic assessments and retrofit as referenced in Section 5.

B1.1 Step-by-step Approach for Seismic Retrofit

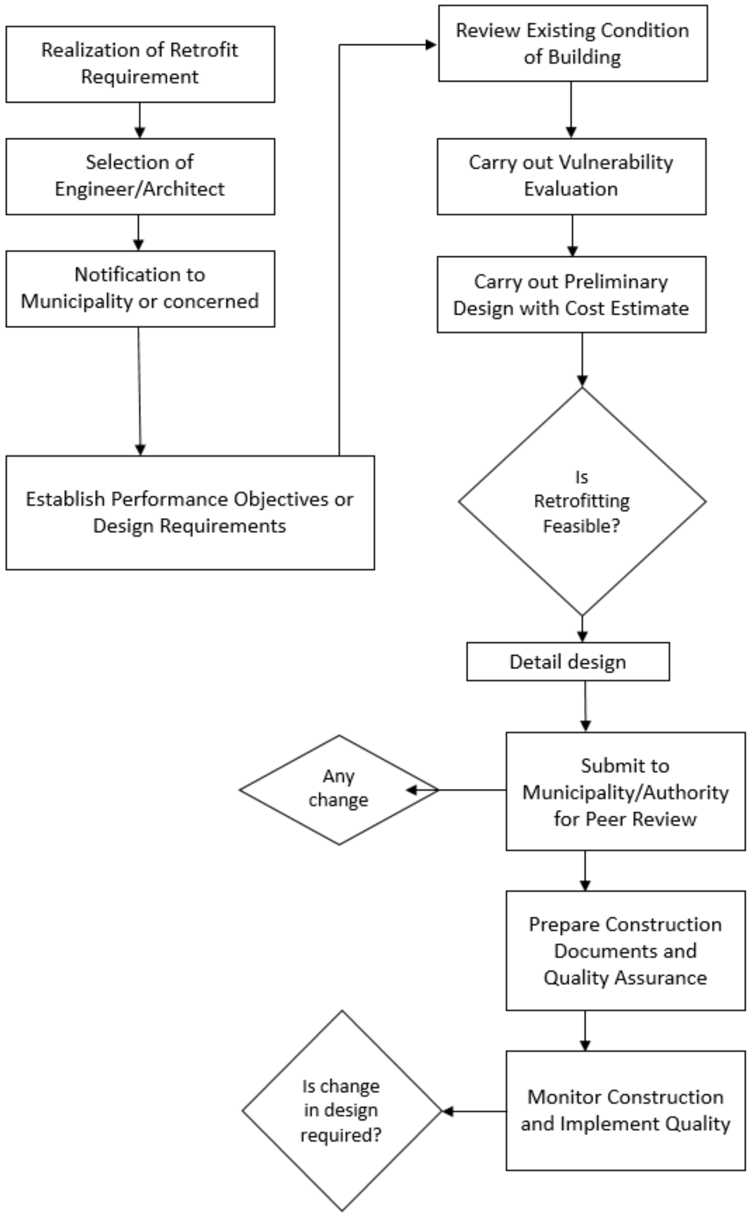


Figure B-1 Step-by-step approach to evaluation, design and construction planning process for seismic retrofit (NSET, 2013)

B1.2 Earthquake Hazards

Seismic Hazard		Description	
PRIMARY	Ground shaking	When an earthquake occurs, energy radiates outwards and causes seismic waves to propagate from the fault source to the earth's surface. When these waves reach the earth's surface, this causes ground shaking.	 © EERI
PRIMARY	Landslides/rock fall/avalanche	Earthquake ground shaking can trigger failure such as landslides, rock falls or avalanches.	
PRIMARY	Soil liquefaction	Liquefaction is when soil starts behaving like a dense fluid when it experiences a temporary loss of strength. This occurs when saturated soil experiences cyclic loading in an earthquake, and a build-up of pore water pressure.	
PRIMARY	Surface faulting	Surface faulting is when a fault plane propagates to the ground surface during an earthquake.	
SECONDARY	Seiche	A seiche is a standing wave in a body of water (such as a lake, harbour or small sea) caused by resonance of the water induced by earthquake motion.	

	Flooding	Flooding can be caused by dam, levee or dike damage or collapse in an earthquake. Landslides triggered by an earthquake can create unstable soil dams in river valleys which can subsequently fail and cause flooding downstream.	 © Arup, 2016
	Fire	Fires during or after earthquakes can be caused by electrical faults, fractured gas pipes or other damage. Lack of water supply after an earthquake can impair the ability to fight fires.	 © Steinbrugge Collection of the UC Berkeley EERC

B1.3 Seismic Design Criteria – Key Definitions

Seismic hazard quantifies how much ground shaking can be expected at a given location due to earthquake activity over a specified period of time. It should be emphasized that this does not refer to the shaking arising from an individual earthquake, but considers all plausible events within the region of interest for a specific site.

Measures of ground shaking

The level of ground shaking caused by earthquakes is often measured as a **peak ground acceleration, PGA,** (usually presented as a fraction of the gravitational acceleration at the Earth's surface, %g). This is the largest acceleration at the ground surface that occurs during an earthquake. Refer to Figure A-2. The level of ground shaking on a particular site will depend on many factors including: the magnitude of the earthquake (how much energy was released), the depth of the earthquake, the distance to the site from the earthquake epicentre and the type of ground the seismic waves are travelling through.

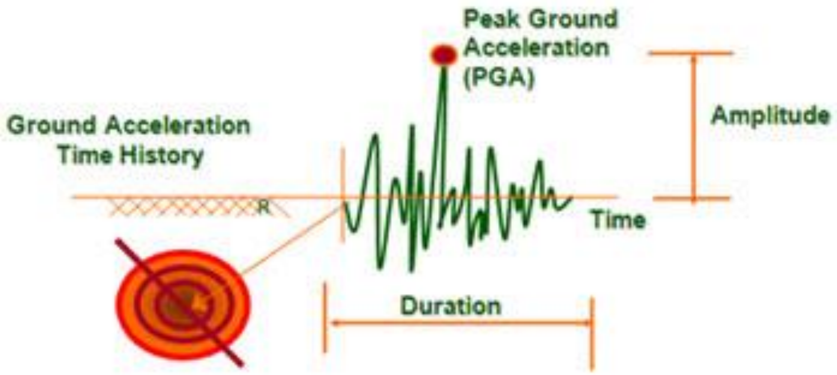


Figure A-2 Definition of Peak Ground Acceleration (PGA).

Another measure of how a specific structure responds to ground shaking is the **spectral acceleration (Sa)**. This is the largest acceleration experienced by the structure that occurs during an earthquake. In addition to the factors mentioned above that influence ground response, spectral acceleration is also influenced by properties of the structure.

Return period

Seismic design criteria is often specified as the likelihood that a level of ground shaking (PGA or peak spectral acceleration) will occur during a specified period of time (**return period**) for a certain location. Often, this is communicated in terms of a probability for a 50 year design life. For example, a 10% chance of occurrence in 50 years of exceeding a certain PGA for a certain site.

Response spectra

Response spectra are used to predict the earthquake response of buildings or other structures.

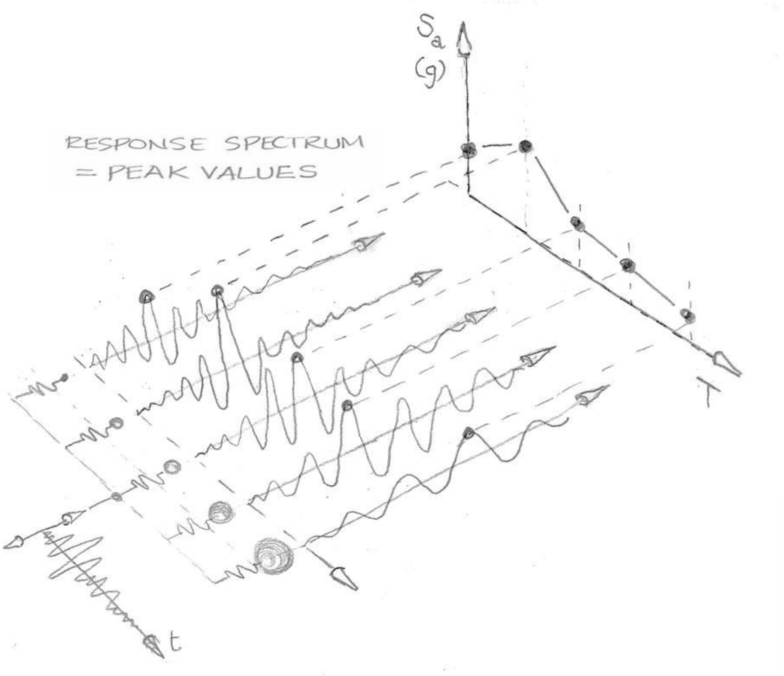


Figure A-3 Example of seismic response spectra

A response spectrum gives an envelope of the peak responses of a range of single-degree-of-freedom (SDOF) systems (each with different periods, *T*) to a specific ground motion as shown in Figure A-3. Code response spectra are a smoothed, enveloped spectra that represent the level of hazard based on seismic hazard studies for a region or country. Response spectra are a standard method of expressing seismic design criteria for structures.

Macroseismic intensity

Historically, former Soviet codes have categorized earthquake effects using **Macroseismic intensity**. This approach has been adopted in many former Soviet countries, including the Kyrgyz Republic. Macroseismic Intensity, which is an integer value (usually in Roman numerals) categorizes the effects that may arise from an earthquake at a given location (i.e. what people feel and observe and damage to buildings and infrastructure). For example, if an earthquake is felt by most people, but only causes, e.g., broken windows or overturned unstable objects, it is described as being Moderate (V), while at another location, if considerable damage arises in ordinary (non-seismic designed) buildings, with great damage in poorly constructed buildings, it is described as Severe (VIII). These examples are from the Modified Mercalli Scale (MMI), although most intensity scales follow the same general pattern. Macroseismic intensity is a measure that combines the level of hazard (ground shaking, as would be measured by PGA) with observed damage (vulnerability of buildings and infrastructure).

Table B-1 Selected Seismic Design Criteria for Retrofitting

Criteria	Comment
Target Seismic Performance Objective(s)	Collapse Prevention, Limited Life Safety, Life Safety, Immediate Occupancy or Operational. Multiple levels of performance can be considered for different levels of design earthquake.
Importance Class	Related to the importance or criticality of the building, an Importance Factor increases the design lateral load.
Seismic Hazard Level	General level of seismic hazard. This is based on PGA or Spectral Acceleration (S_A). This level often ties into different requirements to determine assessment checks or which deficiencies need to considered.
Site (Soil) Class	The type of soil for the site (rock, stiff soil, soft soil, etc.)
Secondary Hazards	Identify risk of soil liquefaction, landslide, surface fault rupture, etc.
Seismic Design Criteria	Common forms of seismic design criteria include: Equivalent static loading for linear static analysis, (from PGA, S_A and modified by site class) Design response spectra for linear dynamic response spectra analysis , (from PGA, S_A and modified by site class) Response (time) histories for response history analysis (from PGA, S_A and modified by site class and matched representative earthquake records).

Once a structural system is determined for the retrofit option, other criteria such as the **over-strength, ductility** and **damping** for either certain structural components or the building's structural system overall can be defined.

4. **Over-strength** is the reserve strength in a material, component or global building system as compared to the 'design strength'. This additional capacity is mainly due to design material factors of safety and factors of safety related to design load cases but also can be due to overdesign.
5. **Ductility** is the ability for structural components to sustain large, cyclic inelastic deformations and absorb energy without rapid degradation in strength. The intent of ductile design is to allow damage without the risk of sudden, brittle failure.
6. **Damping** is a measure of how much energy is dissipated due to damage or movement of components during the vibration of the building.

Depending on the type of structural system and sensitivity of non-structural components (facades, finishes), **drift limits** (related to how much each floor displaces relative to the floor below under lateral loading) to limit damage are set for the design.

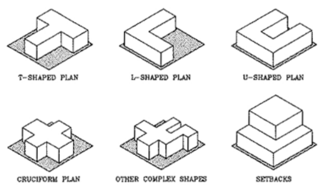
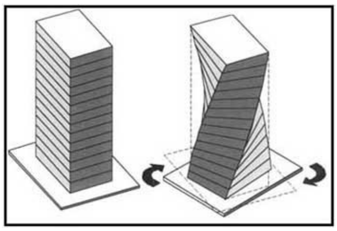
Finally, **load and deflection criteria** must be set for other design load cases (gravity, wind, etc.) and **load combinations** defined.

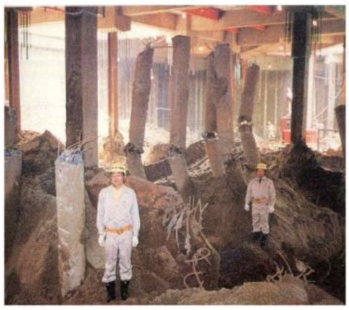
Table B-2 Description of seismic performance levels (ASCE 41-13, Table C2-3)

Target Performance Levels				
	Collapse Prevention	***Life Safety***	***Immediate Occupancy***	***Operational***
Overall Damage	***Severe***	***Moderate***	***Light***	***Very Light***
General	Little residual stiffness and strength, but load-bearing columns and walls function. Large permanent drifts. Some exits blocked. Building is near collapse and should not continue to be occupied.	Some residual strength and stiffness left in all stories. Gravity-load-bearing elements function. No out-of-plane failure of walls. Some permanent drift. Damage to partitions. Building might not be economical to repair.	No permanent drift. Structure substantially retains original strength and stiffness. Continued occupancy likely.	No permanent drift. Structure substantially retains original strength and stiffness. Minor cracking of facades, partitions, and ceilings as well as structural elements. All systems important to normal operation are functional. Continued occupancy and use highly likely.
Non-structural Components	Extensive damage. Infill walls and unbraced parapets failed or at incipient failure.	Falling hazards, such as parapets, mitigated but many architectural, mechanical and electrical systems are damaged.	Equipment and contents are generally secure, but may not operate due to mechanical failure or lack of utilities. Some cracking of facades, partitions, ceilings as well as structural elements. Elevators can be restarted. Fire protection operable.	Negligible damage occurs. Power and other utilities are available, possibly from standby sources.

B1.4 Common Seismic Vulnerabilities for Buildings, Roads and Bridges

Table B-3 Common types of vulnerabilities for buildings subjected to earthquakes

Type	Building Vulnerability	Description	
Design	Irregular building form – plan irregularities	Buildings that are regular and compact in plan and elevation have been shown to perform better in earthquakes. The image shows some examples of buildings with plan irregularities.	
	Irregular building form –irregularities in elevation	Common building irregularities in elevation include: soft storey (i.e. where one storey is less stiff or strong than others), mass irregularities, irregular foundations on sloping sites and discontinuous lateral systems such as walls which do not continue to the foundation level.	 © EERI (1995)
	Torsional irregularity (twisting)	Less regular and compact building forms are subject to torsion (twisting) under dynamic loading in an earthquake. This leads to less predictable behaviour and uneven concentrations of damage.	
	Overall lack of stiffness and/or strength	Inadequate overall strength and stiffness can lead to excessive lateral permanent building displacements (drifts), increasing damage and the risk of collapse.	 © EERI (1994)

Type	**Building Vulnerability**	**Description**	
	Lack of ductility (brittle failure mechanisms)	The principle of ductile design is that certain failure modes in the structure will be gradual and controlled (ductile) rather than sudden and brittle. Sudden, brittle failure is undesirable as there is little warning before failure. For example, unreinforced masonry is an inherently brittle material which performs poorly in earthquakes.	 © EERI (1994)
	Lack of redundancy	Structures with redundant load paths and multiple elements to resist lateral loads have been shown to perform better in earthquakes.	 © Canterbury Earthquakes Royal Commission (2012)
	Lack of tying	There must be a complete load path in order for loads generated in the structure by the earthquake to travel through the structure and down to the foundations. For example, floors should be well tied to walls and walls well tied to the foundation to transfer the earthquake loads.	
	Inadequate diaphragms/ collectors	Diaphragms (floor structure) need to have adequate strength and stiffness to transfer earthquake loads to the lateral resisting elements (walls, frames). Adequate load paths to transfer earthquake loads from the diaphragms to the walls/frames are required (collectors).	 © EERI (1994)
	Inadequate foundations	Serious damage and/or failure of foundations should be avoided as it can cause an overall lack of stability for the structure. Furthermore, limiting damage to foundations is desirable, as it is difficult to inspect and repair foundations after an earthquake. .	 © Hamada (1991)

Type	Building Vulnerability	Description	
	Pounding	Buildings should be far enough from adjacent structures to prevent damage from pounding during an earthquake. Where floors of adjacent buildings do not align, pounding can result in column damage, increasing the risk of column failure and overall collapse of the structure.	  © EERI (2006)
	Non-structural components – seismic performance of individual elements	The performance of non-structural components such as facades, parapets, lightweight partitions, valuable building contents, equipment, services, ceilings, and lighting in earthquakes must be considered. These components can be anchored or detailed to accommodate expected movement in an earthquake, to limit damage and risk to life. For example, if not properly detailed, unreinforced masonry partition walls can fail out-of-plane and pose a danger to life.	 © EERI (2006)
	Non-structural components – influence on overall building response	Interfering facades or non-structural walls built integrally with a building frame can stiffen the system. In some cases, this can worsen the performance of a building during an earthquake. An example of a 'short column' failure is shown where an infill wall has caused a brittle shear failure in the upper part of a frame column.	 © EERI (2006)
Construction	Construction not according to design intent leading to poor performance in earthquakes	Construction (for example, of concrete reinforcement details) may not follow the design intent. The general layout of the as-built structure may be different from the design intent. Poor construction quality can also be a result of a lack of local capacity and skills in a certain	

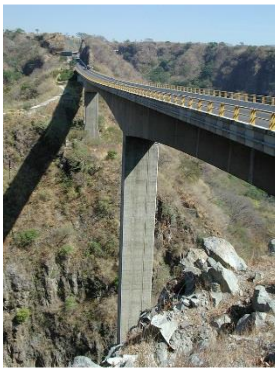
Type	Building Vulnerability	Description	
		construction technology or system.	
	Poor quality materials	A lack of availability of appropriate materials and/or poor construction monitoring can lead to poor material quality.	© World Bank, Nepal (2015)
Damage	Damage from past events (earthquakes, floods, fire, freeze-thaw, …)	A structure may have experienced damage over its lifetime which can increase the building vulnerability.	 © Katherine Coates, Arup (2015)
Deterioration	Material deterioration from age, poor quality materials, or lack of maintenance.	The level of deterioration in materials depends on the building age, environmental factors and building maintenance. In extreme cases deterioration can lead to localized failure of structural members and/or portions of the building.	 © Katherine Coates, Arup (2015)
Building modifications	Building modifications can worsen overall performance of the building in earthquakes.	These modifications can include additional floors, extensions, removal of walls, or new openings in floors or walls to accommodate services.	 © Jorge Lopez, Arup (2016)

Table B-4 Causes of damage and disruption for roads subjected to earthquakes

Cause	**Description of Road Damage**	**Disruption Level**	
Road surfaced damaged due to ground failure	Minor (DS1) Slight cracking/offset of pavement surface (SYNER-G,2013)*	Open. Reduced speeds or partially closed during repair works.	 © Tung (2004)
	Moderate (DS2) Localized moderate cracking/offset of pavement (SYNER-G, 2013)*	Closed during repairs (few days).	 © Tung (2004)
	Extensive/Complete (DS3) Major cracking/offset of pavement and subsurface soil (SYNER-G, 2013)*.	Closed during repairs (few days to weeks).	 © Tung (2004)
Road blocked due to landslide	Landslide blocking road	Closed during repairs and stabilization of slopes (few days to weeks).	 © Tung (2004)
Road blocked due to building debris/collapsed buildings	Building debris blocking road	Closed during clearance of debris (few days to weeks).	 © Tung (2004)
Road access closed/limited due to presences of dangerous buildings	Road closed due to risk of collapse during aftershocks of badly damaged buildings	Closed while buildings are stabilized or demolished (weeks).	

Cause	**Description of Road Damage**	**Disruption Level**
*per HAZUS methodology, this is defined as a few inches or less.		

Table B-5 Common vulnerabilities of bridges subjected to earthquakes

Cause	**Bridge Vulnerability**	**Description**	
Structural design flaws	Pier failure due to brittle failure (shear) – lack of ductility	If bridge piers are not adequately detailed to resist shear with proper confining reinforcement, they can fail prematurely, in a brittle manner, under earthquake loads.	 ©: Collapsed Fukae Viaduct, Monteiro R. (2011)
	Pier failure due to brittle failure – short column effect	In a bridge with a variety in the pier height, shorter columns will be stiffer and attract more lateral (earthquake) load. If this is not properly taken account in the design, it can lead to concentrations of damage in shorter piers and potentially bridge pier failures.	 © Viaduct Beltran, http://www.bridgeofweek.com/2009_11_01_archive.html
	Failure due to lack of tying in the structure and/or complete load path Lack of adequate seating to accommodate movements.	Bridges need to be designed and detailed to have a complete load path to resist earthquake loads such as adequate tying of deck to piers, piers to foundations. If movements are allowed in the bridge design (to release thermal effects, for example), adequate seating at bridge connections must be provided to accommodate displacements in an earthquake to prevent seating failure of bridge decks.	 © Cypress viaduct, lack of proper reinforcement in pier deck connections, Monteiro (2011)

Cause	Bridge Vulnerability	Description	
			 © Failure of Bay Bridge in Loma Prieta, Monteiro (2011)
Site related effects	Failure of structure (piers, unseating of deck, etc.) due to ground failure.	Due to their long spans and often proximity to softer soil sites, bridges can be vulnerable to ground failures such as soil liquefaction and/or lateral spreading. These ground deformations can cause foundation tilting, pier failure and collapse of bridge decks due to lack of seating at connections.	 © Nishinomiya-ko Bridge, Kobe Collection, EERC Library, UC Berkeley
	Lack of consideration of amplification of the ground motion due to site effects.	Ground shaking can be amplified by regional or local site conditions, leading to higher earthquake demands. If this is not taken into account in the design, it can lead to serious damage and increased risk of collapse.	 © Collapse of Cypress viaduct, Monteiro (2011)
Damage and/or deterioration	Lack of maintenance and inspection of bridges can lead to increased vulnerability.	Deterioration caused by material aging and/or lack of repair and maintenance (corrosion of steel, concrete spalling) can weaken bridge structures and increase their vulnerability. In addition any damage from past events can increase bridge vulnerability.	 ©http://www.bridgemanagement.com/gsoverview.php

B1.5 Codes and Standards for Seismic Assessment and Retrofit

This section presents an overview of selected international codes and standards related to seismic assessment and retrofit as well as relevant Kyrgyz standards.

Table B-6 Selected international codes and standards related to seismic assessment and retrofit

Country	Document name	Comment
USA	ASCE 41-13: Seismic Evaluation and Retrofit of Existing Buildings FEMA P-154: Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook, 2015 FEMA P-155: Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation	Comprehensive seismic assessment and retrofit guidance based on FEMA and other American standards and practice. Procedure for carrying out rapid visual seismic assessments.
New Zealand	New Zealand Society for Earthquake Engineering: Assessment and Improvement of the Structural Performance of Buildings in Earthquakes, 2006. New Zealand Society for Earthquake Engineering: The Seismic Assessment of Existing Buildings, Technical Guidelines for Engineering Assessment, 10 October 2016 (in Draft).	Guidance document for New Zealand practice for assessment and retrofitting of buildings. Note that the 2006 document will soon be superseded by the second draft guideline once it is finalized.
Europe	Eurocode 8 Part 3: Assessment and retrofitting of buildings, 2005	Eurocode 8 Part 3 includes general provisions for assessment and retrofitting.
Turkey	TEC 2007: Turkish Earthquake Code, 2007	The Turkish building code includes guidance on assessment and retrofit of buildings.
Russia	SNiP 1.02.07-85: Engineering surveys for construction works SNiP 13-102-2003: Rules of assessment buildings bearing structures	Russian codes include guidance on assessment of existing buildings. Selected examples are listed in this table.
Armenia	RABC 1-4.02-99 Rehabilitation, Restoration and Reinforcement of Building, 2007	Armenian Norm which includes general provisions and performance requirements for seismic retrofit of buildings.

B1.5.1 Kyrgyz standards for seismic assessment and retrofit

A desktop literature review of Kyrgyz Norms found two standards relating to the seismic assessment of buildings, SNiP 22-01-98 KR "Estimation of seismic stability of existing buildings" and KR 31-01-2001 "Redesigning the premises of existing residential buildings".

No Kyrgyz specific retrofit guidance was found during the literature review or shared by local stakeholders although we are aware that the government in partnership with the World Bank has a proposed a project to develop seismic retrofit guidance for schools ahead of a pilot programme to retrofit selected schools. It is recommended that locally appropriate retrofit guidance (and possibly associated Norms) for all common building types be developed for the Kyrgyz Republic. Appendix A of this report includes high level guidance on selected retrofit measures which could be considered when developing Kyrgyz specific retrofit guidance.

Next, the provisions of the Kyrgyz standards relating to assessment are described in more detail.

SNiP 22-01-98 KR "Estimation of seismic stability of existing buildings"

The Kyrgyz standard SNiP 22-01-98 KR "Estimation of seismic stability of existing buildings" relates to seismic assessment of existing buildings and/or requirements that apply when modifications are carried out to existing buildings. The standard applies to typical buildings only and excludes special structures such as stadiums, long span structures, theatres, airport terminals, power plants, etc.

The standard gives guidance on the vulnerability of different typical construction typologies in the Kyrgyz Republic for different levels of earthquake intensity. For each type and intensity level, specific steps of evaluation are prescribed.

The general steps for seismic assessment specified in Section 2.1 of SNiP 22-01-98 KR are:

1. Conduct a preliminary examination;
2. Carry out a desktop study of available project documentation including drawings, materials testing information and geological survey data;
3. Identify the building sub-group in accordance with section 3 of the standard and the define the necessary stages of seismic resistance assessment in accordance with Sections 5 - 11 of the standard;
4. Conduct a detailed (physical) survey with an estimate of the actual state of structures and buildings in general, the definition of the strength characteristics of the materials, the identification of defects and testing of individual elements or the whole building;
5. Assess compliance of the design to the structural requirements of existing regulations for new construction;
6. Implement analysis and checks as part of the seismic evaluation;
7. Report on conclusions and recommendations; and
8. Submit for consideration of the scientific and technical council of the organization.

The standard also references several standards for new construction used in the Kyrgyz Republic including:

9. Russian Norm SNIP II-7-81* "Construction in Seismic Areas";

10. SNIP 2.01.01 KR “Building in areas in the Kyrgyz Republic with the seismicity more than intensity 9”; and
11. SNIP 2.01.01-93 KR “Development of the territory of Bishkek based on seismic zoning and soil and geological conditions”.

KR 31-01-2001 “Redesigning the premises of existing residential buildings”

The standard KR 31-01-2001 “Redesigning the premises of existing residential buildings” gives requirements for upgrading or modifications to residential buildings. It outlines general steps for surveying to understand the existing structural system and any deterioration and damage and specifies material testing. Any upgrading and modifications must meet the Kyrgyz design and material standards for new construction.

B1.6 Seismic Analysis Methods

This appendix provides a brief discussion of different analysis methods used for seismic assessment and design. Refer to Table B-1 below for a summary of common methods.

Table B-1 Seismic Analysis Methods

	Static	Dynamic
Elastic	*Lateral Force Method* Hand calculation method used for very simple structures. The method only applies when the first vibration mode is dominant (e.g. for lower rise, relatively stiff buildings), and if the building is relatively symmetrical and regular. A global response modification factor is used which approximates the damage (ductility, damping and over-strength) in the structural system when subjected to the design earthquake.	*Modal Response Spectrum* This method is required to capture higher mode effects, and is very commonly used in standard building design, as it less time consuming than non-linear methods. A global response modification factor is used which approximates the damage (ductility, damping and over-strength) in the structural system when subjected to the design earthquake. *Linear Time History Analysis* Similar to nonlinear time history analysis, but all members are modelled as linear-elastic.
Plastic	*Pushover Analysis* Less commonly used now that non-linear time history analysis efficiency has improved. Can be difficult to justify the shape of the loading pattern for structures with a complex dynamic response.	*Non-linear Time History Analysis* Provides a more direct view of post yield behaviour than elastic analysis methods. Modelling building and analysis takes longer than elastic analysis, and is therefore often used as a checking method rather than for design, however the growth of performance-based design is changing this.

There are two main aspects that distinguish seismic analysis methods from other structural load cases (dead loads, live loads, earth pressure loads, snow loads or wind loads for typical buildings):

- Typical buildings are designed to allow some **damage** in a design level earthquake. This must be accounted for in the analysis method – either through approximate methods or by explicitly modelling the nonlinearity of response; and
- Earthquake ground motion imposes a **dynamic** load and the response of the structure is dependent on its inherent dynamic response characteristics.

Both aspects can be most directly captured by the *Non-linear Time History Analysis Method* where damage is explicitly modelled in elements and the model is subjected to a series of simulated earthquake ground motions. This method can be computationally intensive and more time consuming that other simplified methods. Site specific time history records are typically developed for this method. It is often used for performance-based design which is discussed in more detail later.

A more simplified method to capture non-linear response is *Non-linear Pushover Analysis*. Structural elements are modelled as non-linear but instead of the model being subjected to a ground motion, a uniform or triangular load pattern is gradually applied to the model. Then, the resulting non-linear response (capacity curve) is compared to a target demand based on the level of the design earthquake.

Most codes, however, tend to take a simplified approach. The provisions are prescriptive, and assume that the intended earthquake performance is implicitly satisfied by meeting the minimum code requirements for design and detailing of structural and non-structural components. The historic objective has been to allow significant damage in “design level” earthquake while providing “life-safety”, but the ramifications of this have not been quantified until recently, and are still not clearly understood by building owners and occupants. As codes often give simplified design methods (such as the *Lateral Force Method* or the *Modal Response Spectrum Analysis Method*), these methods assume typical, relatively regular designs for low to mid-rise standard buildings. If a design falls outside these assumptions, codes will often require more conservative design loads and/or sophisticated analysis methods (such as *Non-linear Pushover Analysis* or *Non-linear Time History Analysis*). Existing buildings can be complex, having evolved over time or have been designed to older codes or no code, and often using only a simplified approach (such as linear static analysis with a global force reduction factor to represent overall damage) is insufficient to understand their behaviour – both in the assessment phase and when evaluating retrofit options. In such cases, it is best practice to carry out a performance-based design (PBD) approach.

The intent of PBD is to demonstrate explicitly by performance prediction analysis that pre-identified earthquake performance objectives for the building structure are satisfied. This is generally done through advanced computer simulation which subjects a 3D mathematical representation of the structure to actual ground motions (typically scaled) recorded from past earthquakes.

On rare occasions, owners may voluntarily target performance objectives which exceed code objectives, but usually PBD is only used to verify that code-intended performance objectives are met, in order to circumvent certain code requirements (i.e. height limitations). In latter case, PBD provides higher confidence that the intended performance will be achieved during an earthquake. However, computer analysis alone is not necessarily a good predictor of actual damage when the structure is expected to sustain significant damage (i.e. code-intended performance) and there is always uncertainty in the ground motions selected to apply to the model. That is because the reliability of the models to capture the actual behaviour of the building becomes more uncertain as the structure is pushed to its limits. Good practice seismic design principles should always be adhered to based on past observations of the types of structures that have performed well in earthquakes – for example, including redundancy of structural elements and load paths, compact and regular layouts for the structure in plan and elevation, preserving symmetry and allowing damage in elements that will not endanger life (e.g. avoid damage to columns that could lead to collapse).

Appendix C

Cost Benefit Analysis Methodology

C1 General Methodology

C1.1 Introduction

The experience of past earthquakes worldwide and specifically in Central Asia demonstrated that both economic losses and human fatalities can be considerable even if the non-collapse objective had been met for many buildings (Bommer and Pinho, 2006). It is clear that looking at risk reduction objectives strictly from a collapse prevention point of view does not account for the full range of possible losses.

When assessing the possible benefits of implementing a specific seismic retrofit option, it is essential to determine the reduction of damage or (economic or human) loss one expects to achieve for all the earthquake events that may affect the building of interest in the future. As presented in the risk assessment report of this project (Arup, 2017b), this type of analysis (termed probabilistic time-based risk analysis) allows us to determine the value of losses expected *on average* in any given year (the so-called expected annual loss – EAL). Through this framework it is also possible to determine the *benefit* of a specific retrofit measure as the resulting reduction in EAL, be that in terms of economic losses or fatalities.

These calculations were undertaken using the Global Earthquake Model Foundation (GEM) (Crowley et al., 2010) OpenQuake[41] Engine (OQ-engine) (Pagani et al., 2014). The GEM OpenQuake Engine is a state-of-the-art, open and transparent tool for seismic hazard and risk assessment and offers an integrated environment for modelling, viewing, exploring and managing earthquake risk (Silva et al., 2013). Refer to Section C1.3 below.

C1.2 Assumptions for Cost benefit Analysis

Per the scope of this study, only direct losses were considered from the physical building or infrastructure components. Losses due to damaged building contents or due to disruption were excluded. The results presented in the following sections correspond to a time frame of 50 years; i.e. the reported BCRs reflect the relationship between: a) the benefit in terms of avoided economic losses during the building expected life span; and b) the initial cost of retrofit. In order to achieve a consistent comparison between initial cost and future benefits, all future economic losses (and benefits) are expressed in 2015 USD values using a discount factor (DF) that accounts for the variation of the economic value of the assets during their life expectancy (refer to Appendix C for additional details). The 2015 value of 1 USD in a future year 2015+*t* is equal to 1*DF, where DF is given by:

$$DF = \frac{1}{(1+r)^t}$$

And *r* is the assumed discount rate.

[41] http://www.globalquakemodel.org/openquake/about/

Retrofit measures were not developed and CBA not performed for bridges due to the lack of input data for this study on the structural characteristics of the bridges in the Kyrgyz Republic.

In order to guarantee the consistency between the CBA results and the risk calculations presented in the Component 3 risk assessment report (Arup, 2017b), CBA calculations were performed for each of the nine combinations of the ground motion prediction and soil condition models adopted in risk calculations, as follows:

- Ground motion prediction equations (GMPE) considered:
    - Boore et al. (2014);
    - Akkar et al. (2014); and
    - Cauzzi et al. (2015).
- Soil conditions adopted:
    - A scenario in which "rock" conditions are considered throughout the entire country (uniform shear wave velocity in the top 30m of the soil, V_S30, equal to 760m/s);
    - An option where uniform "soil" conditions are considered in all the sites where exposed assets are located (uniform V_S30=250m/s); and
    - An "intermediate" case in which V_S30 predictions are obtained using the approach proposed by Wald and Allen (2007).

The predicted reduction of fatalities was computed for the same combinations of GMPE/ V_S30, considering a time period T of 50 years.

The discount rate represents the opportunity cost for the Kyrgyz government (in this case) in investing money in the retrofit measures to determine the present value of future cash flows. A discount rate of 5% has been used for the CBA in this study. In chosing this rate, several factors have been considered: the time period over which it is applied (50 years), the wider risks for the country (political, economic), implementation risk for the investment projects and the predicted growth of the national economy. In addition, this discount rate is in line with the recommended discount rate of 5% from the National Bank of Kyrgyzstan.[42]

To test the sensitivity of the discount rate assumption, three different discount rates (*r* values) (1%, 5% and 10%) were initially used in the CBA for school buildings. Refer to Section C2.6 of this methodology for a comparison of results and discussion.

In this work, the economic benefits are determined in terms of the reduction of direct structural and non-structural losses only. However, direct losses to contents and indirect losses due to interruption of functionality may have a significant impact on the results of cost benefit analyses, especially for hospitals and fire stations,

[42] https://24.kg/english/48078_National_Bank_of_Kyrgyzstan_keeps_5_percent_discount_rate/

where the indirect losses may be of the same order of magnitude. The results presented in this report for this type of critical infrastructure may be complemented in the future to account for this issue.

C1.3 Cost benefit Analysis with OpenQuake

The engine behind the platform has various calculators, including the probabilistic event-based risk and cost benefit analysis calculators used in this work (Table C-1).

Table C-1: Description of the OQ-engine risk calculators used in the cost benefit analysis; adapted from Silva et al. (2013).

Calculator	Symbol	Purpose
Probabilistic event-based risk calculator	PEB	This calculator computes the annual probability of exceeding various levels of loss (and corresponding uncertainty), for a collection of assets in a region, based on the event-based PSHA outputs. The losses are calculated with an event-based approach, such that the losses to a set (or portfolio) of assets can be calculated simultaneously for each simulated event. This allows the estimation of the expected aggregated losses for a collection of assets.
Benefit-cost ratio calculator	BCR	This calculator is a decision-support tool for deciding whether the employment of retrofitting/strengthening measures to a collection of existing buildings is advantageous from an economical point of view. This output can be used to prioritize the regions in need for retrofitting/strengthening activities or to assess which seismic design is more economically adequate for a given region

The BCR calculator is used to compare the *benefit* of a given retrofit option with the initial cost to implement it, as follows:

- The engine starts by computing losses considering the two alternative fragility (and corresponding vulnerability) models: a) the "as-built" building fragility, based on which the $EAL_{as\text{-}built}$ is determined; and b) a set of fragility and vulnerability functions that account for the increase in building capacity due to the implemented retrofit (Section C2). The latter is used to compute the $EAL_{retrofitted}$;
- Subsequently, the accumulated economic *benefit* at a given time T (in years) after the implementation of the proposed retrofit is computed as:

$$benefit = \sum_{t=1}^{T} \frac{EAL_{as-built}}{(1+r)^t} - \sum_{t=1}^{T} \frac{EAL_{retrofitted}}{(1+r)^t}$$

Where r represents the discount rate, which serves the purpose of considering the variation of the economic value of the assets during their life expectancy, or design life (T=50 years)[43]

- Finally, the *benefit* at time T is divided by the initial retrofitting cost, leading to the benefit-cost ratio (BCR).

  This process is repeated for each retrofitted building (or location with multiple buildings), leading to a map that shows the spatial distribution of BCR for the portfolio of interest (residential buildings, schools, hospitals or fire stations).

The PEB calculator is used to compute the "as-built" and "retrofitted" EAL in terms of fatalities, based on which the reduction in human losses at time T - ΔF(T=50) - is determined as:

$$\Delta F(T = 50) = \sum_{t=1}^{T=50} EAL_{as-built} - EAL_{retrofitted}$$

In practice, seismic loss calculations for "as-built" and "retrofitted" conditions are performed using similar hazard and exposure models. The main difference is naturally the vulnerability functions used to express the building vulnerability to seismic action. As presented in the risk assessment report of this project (Arup, 2017b), the vulnerability functions for buildings without seismic retrofit were computed based on fragility curves that provide the probability of each building exceeding specific levels of damage. In the following section, the methodology used to derive fragility functions that reflect the increased seismic capacity due to seismic retrofit is presented.

[43] The OpenQuake formula has been tested against the recommended Discount Factor formula approach and produces equivalent results.

C2 Retrofitted Fragility Functions

C2.1 General Methodology

The “as-built” fragility functions used in the risk assessment for the Kyrgyz Republic were derived using the vulnerability index approach proposed by Gulkan et al. (1992) as presented in detail in the corresponding project report (Arup, 2016b). This methodology was used to compute fragility functions that, as a function of the level of peak ground acceleration (PGA) experienced by the building, provide the corresponding probability of exceeding the following damage states (Arup, 2016b):

1. Negligible to slight damage (D1);
2. Moderate damage (D2);
3. Substantial to heavy damage (D3);
4. Very heavy damage (D4); and
5. Destruction (D5).

The probability of exceeding each of these limit states depends on the building capacity in terms of stiffness, strength and ductility, and more importantly, in the relationship between these quantities (i.e. a building with high stiffness and strength may be highly vulnerable in case it has low ductility, and vice-versa).

We as engineers are not able to directly infer the effect of a specific engineering solution on building fragility. However, there are several methods we can use to estimate the effect of retrofit interventions on building stiffness, strength and ductility. Therefore, we determined the effects of specific retrofit solutions on building capacity, and used a verified approach to translate the “retrofitted capacity” into the “retrofitted fragility”.

The general methodology used to derive fragility functions that account for the effect of different retrofit options on the seismic fragility of a specific building class included the following steps:

1. Determine the building capacity that is consistent with the “as-built” fragility functions for the class of interest. Capacity is determined in terms of strength versus ductility (or force versus displacement capacity), usually referred to as a “capacity curve”;
2. Estimate the change on building capacity (strength and ductility) due to a specific retrofit measure and obtain the resulting “retrofitted capacity curve”; and
3. Use the “retrofitted capacity curve” to obtain the “retrofitted fragility functions”.

In point 3 above, the methodology proposed by Vamvatsikos and Cornell (2006) was used to “translate” retrofitted capacity curves into retrofitted fragility functions for different damage states. The same methodology was used in point 1 to infer the as-built building capacity from the as-built fragility functions. However, because this framework was originally designed to provide building fragility as a function of building capacity and not the opposite, an iterative approach was used to identify the capacity curve that matches the as built fragility more closely. In addition, it is assumed that the standard deviation of retrofitted fragility functions is equal to those of the corresponding as-built fragility curves.

A literature review was conducted in order to identify the effect of each of the retrofit options presented in Table 8 on the capacity of the corresponding building classes, as exemplified in Figure 43, adapted from the work of Calvi (2013).

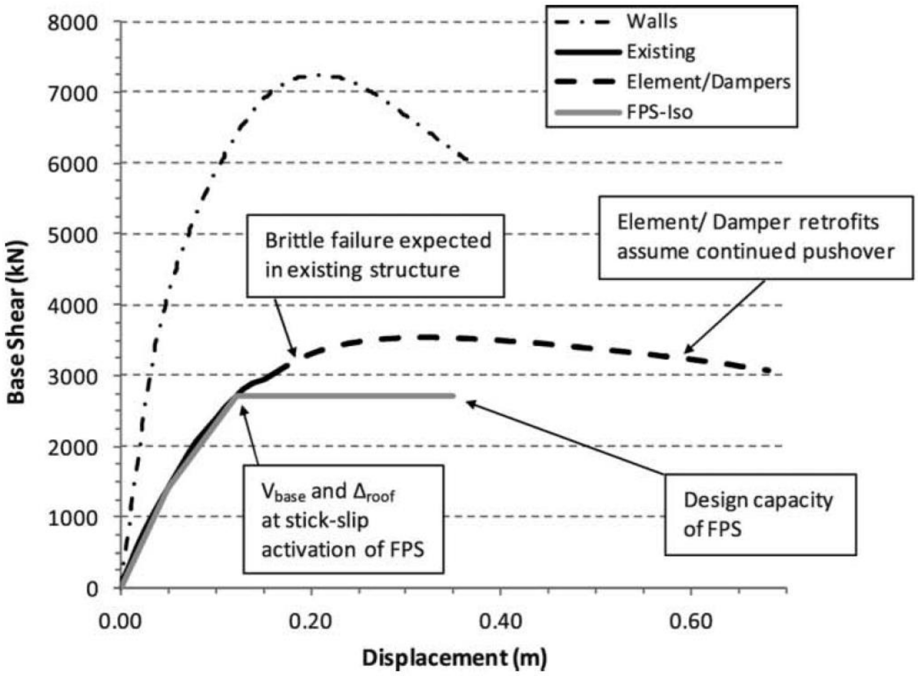


Figure 43 Example of the effect of different retrofit options on building capacity; adapted from Calvi (2014). V_{base}, Δ_{roof}, FPS-Iso and "stick-slip activation" refer to: base shear force at the building foundation; roof displacement; friction pendulum isolator (a specific seismic isolation technology); and the displacement after which the seismic isolation device is activated.

For simplicity, the retrofit effects on building response are herein presented as the relative increase/decrease of stiffness, strength and ductility with respect to the as-built capacity. Table C-2 summarizes the effects of all the retrofit measures investigated in Section 4 for each building portfolio.

Table C-2 Effects of retrofit measures on the capacity of residential, school, hospital and fire station buildings.

Asset Type	No	Ratio between retrofitted and as-built stiffness (retrofitted / as-built)	Ratio between retrofitted and as-built strength	Ratio between retrofitted and as-built ductility	Reference to the appropriate study
Schools	S1	1.00	2.00	1.10	ElGawadi et al. (2006)
	S2	1.05	1.27	2.05	Figueiredo et al. (2013)
	S3	3.00	1.90	0.80	Calvi (2013)
Hospitals	H1	1.00	2.00	1.10	ElGawadi et al. (2006)
	H2	1.00	1.00	See note 1 below	Calvi (2013); Ormonbekov and Begaliev (2002)
Fire Stations	F1	1.00	2.00	1.10	ElGawadi et al. (2006)
Residential Buildings	R1	1.50	1.25	1.00	Ashraf et al. (2002); Riahi et al. (2009)
	R2	3.00	1.90	0.80	Calvi (2013)

[1] The increase in ductility is achieved through the displacement capacity of the isolation system. It is assumed that the isolation capacity allows a “shift” in the fragility functions of D2 to D5 of two times the initial median collapse capacity (e.g. median retrofitted PGA for collapse is three times the initial value).

The resulting retrofitted and as-built fragility functions for schools, residential buildings, hospitals and fire stations are presented in the following sections.

C2.2 Fragility Functions for School Buildings

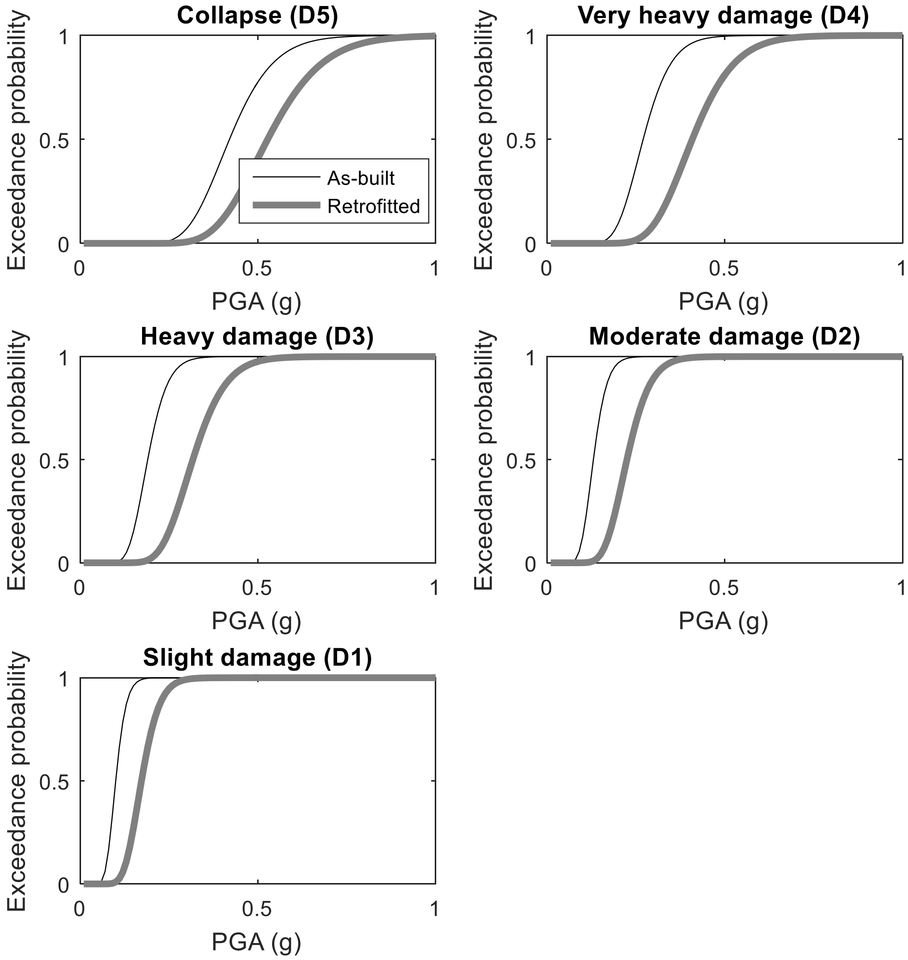


Figure 44 As-built and retrofitted fragility functions for unreinforced masonry (URM) schools buildings retrofitted with option S1.

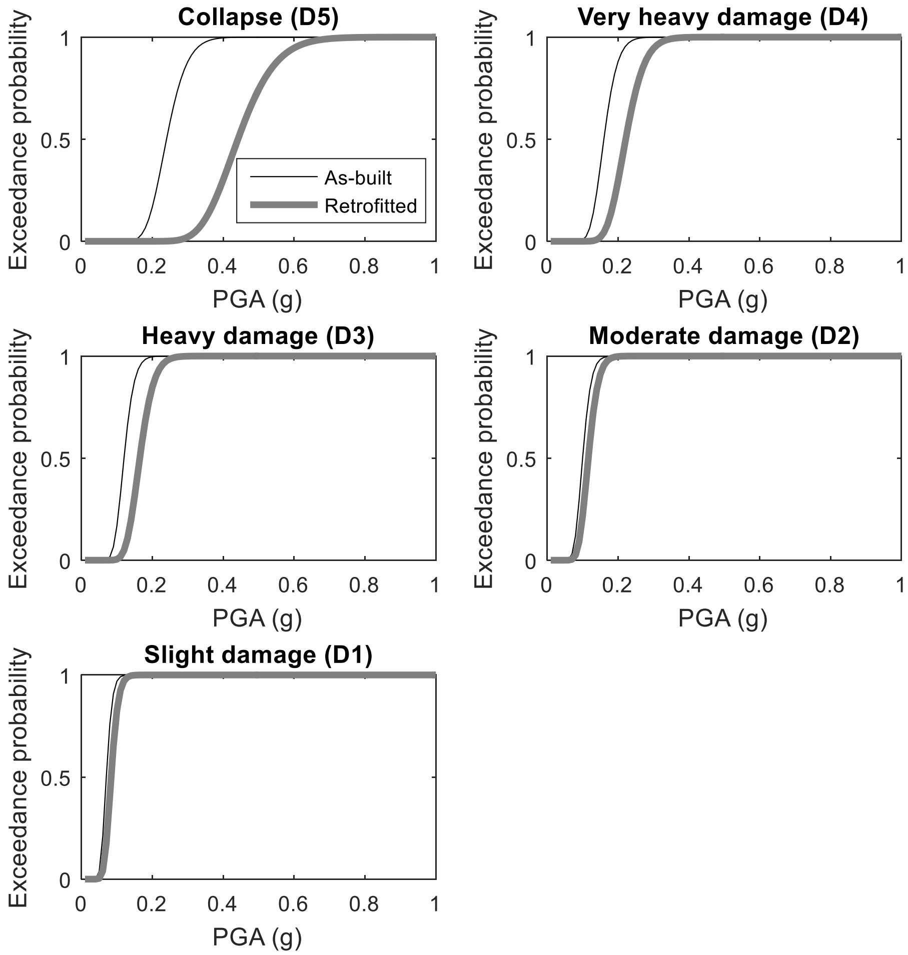


Figure 45 As-built and retrofitted fragility functions for adobe (ADO) schools buildings retrofitted with option S2.

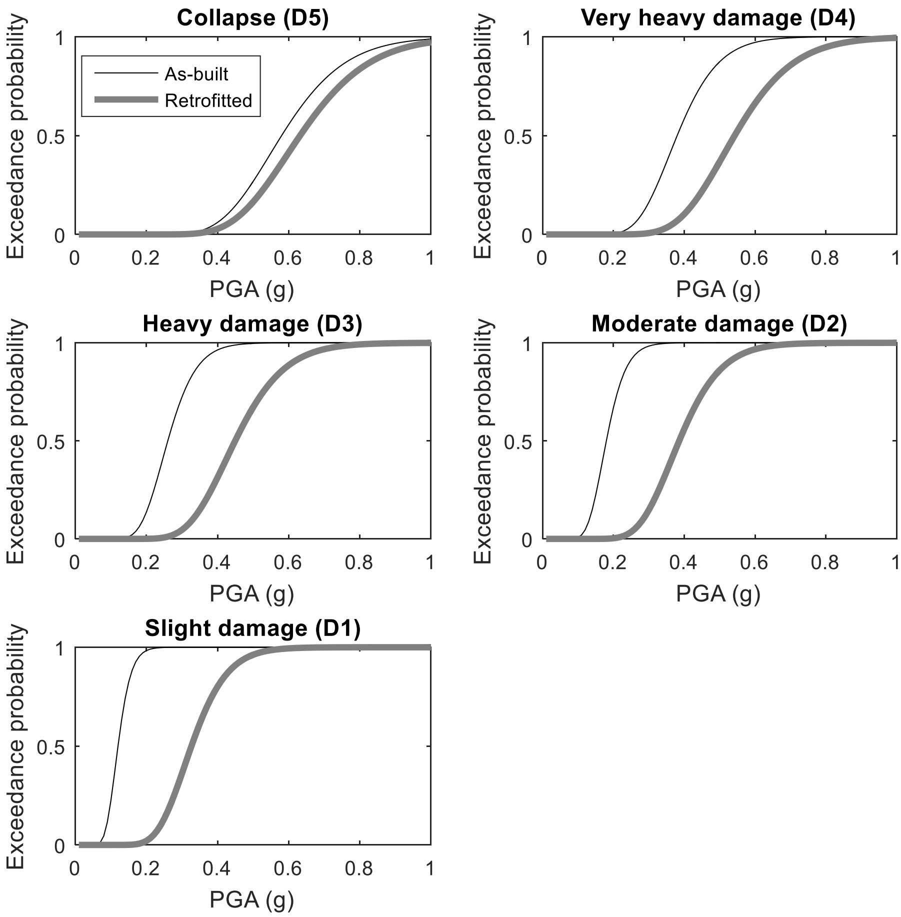


Figure 46 As-built and retrofitted fragility functions for reinforced concrete schools buildings with masonry infill walls (RC3) retrofitted with option S3.

C2.3 Fragility Functions for Residential Buildings

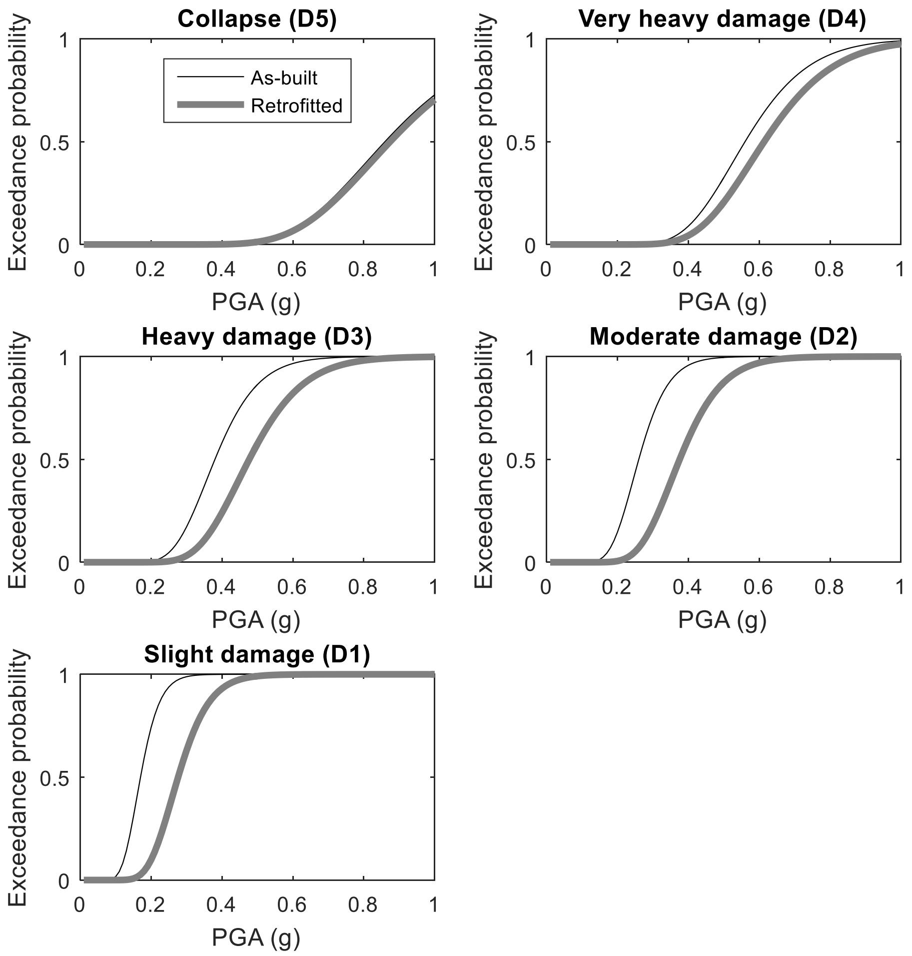


Figure 47 As-built and retrofitted fragility functions for reinforced or confined masonry (RM1 or RM2) residential buildings retrofitted with option R1.

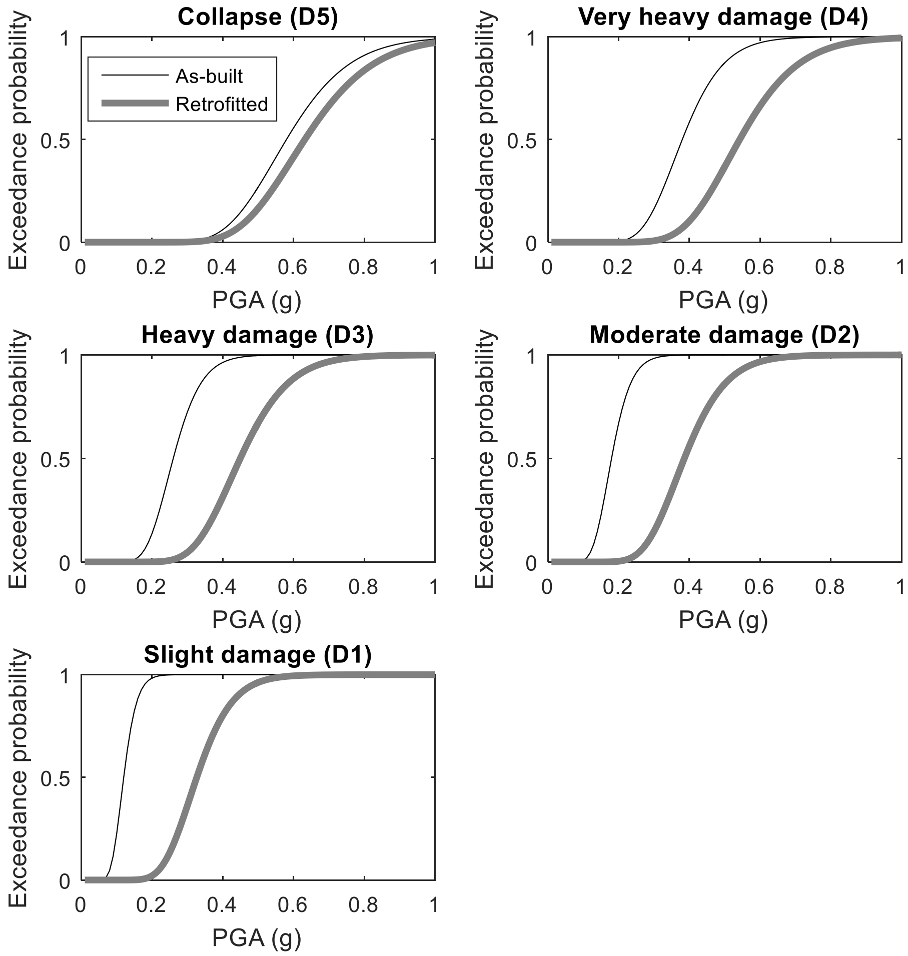


Figure 48 As-built and retrofitted fragility functions for reinforced concrete residential buildings with masonry infill walls (RC3) retrofitted with option R2.

C2.4 Fragility Functions for Hospital Buildings

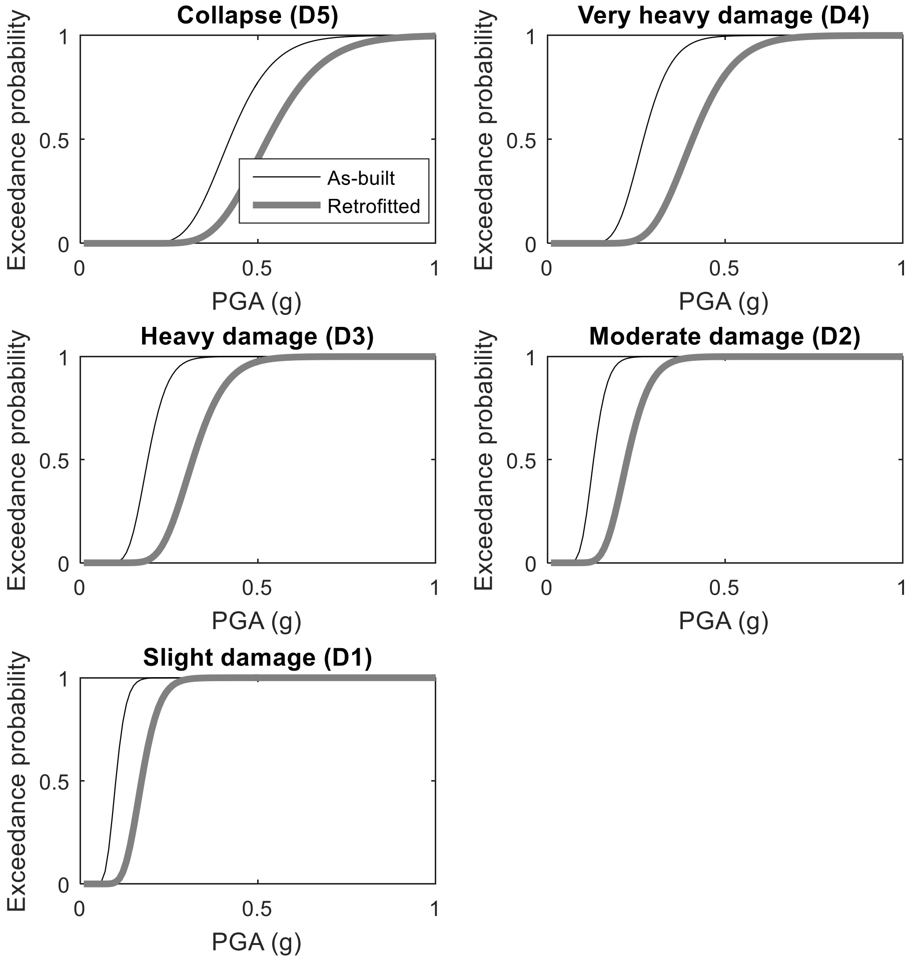


Figure 49 As-built and retrofitted fragility functions for unreinforced masonry (URM) hospital buildings retrofitted with option H1.

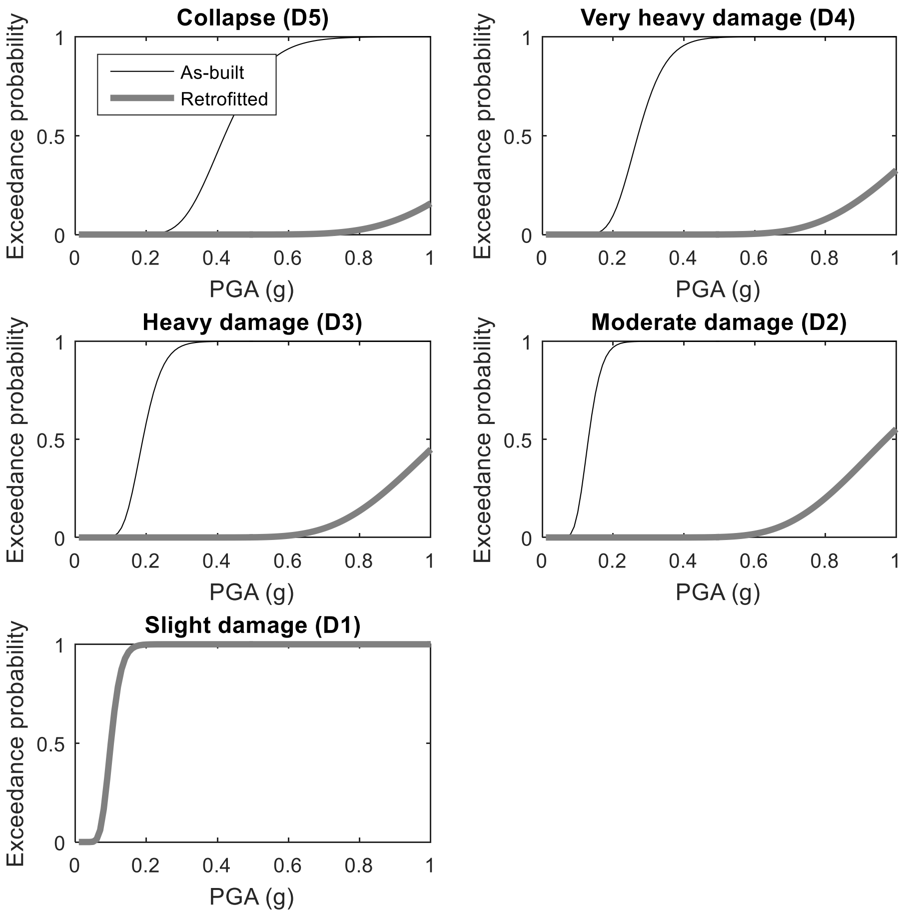


Figure 50 As-built and retrofitted fragility functions for unreinforced masonry (URM) hospital buildings retrofitted with option H2.

C2.5 Fragility Functions for Fire Station Buildings

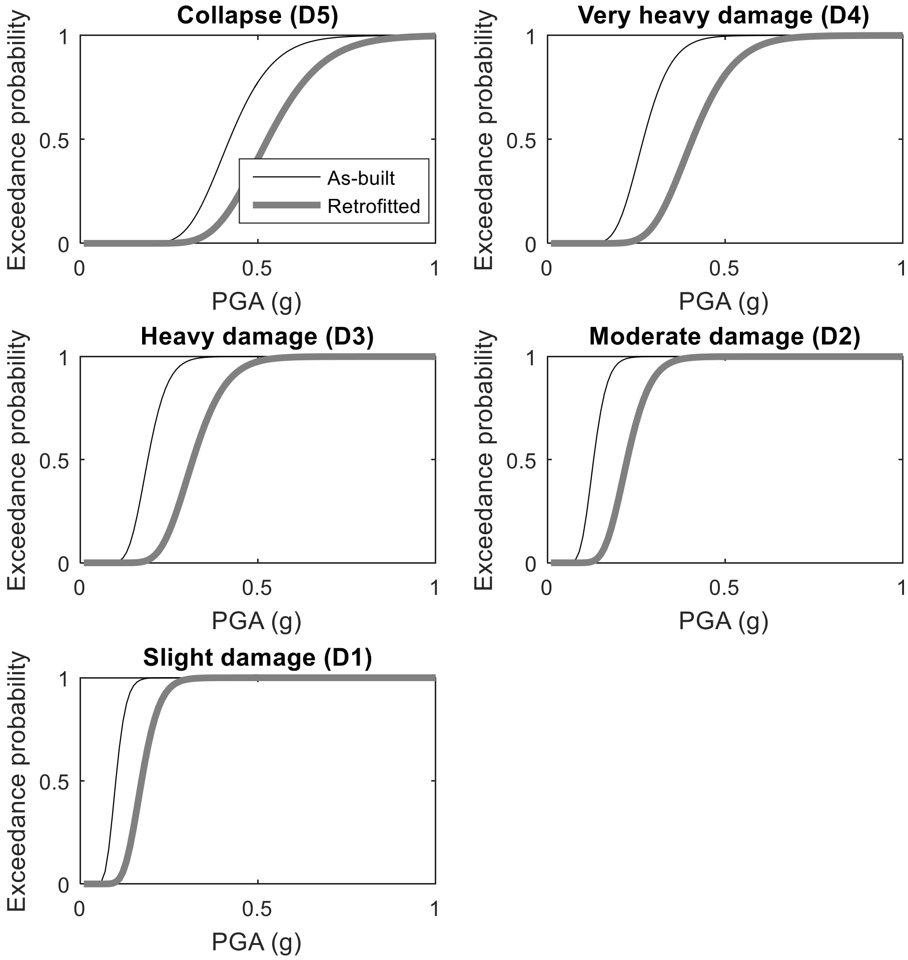


Figure 51 As-built and retrofitted fragility functions for unreinforced masonry (URM) fire station buildings retrofitted with option F1.

C2.6 Discount Rate Sensitivity Study

In order to test the sensitivity of the discount rate on the BCRs, cost benefit analyses were performed for discount rates of 1%, 5% and 10% for a combination of all the school retrofit options (S1, S2 and S3) for the country. Refer to Section 4.5.3 of this report for descriptions of the proposed retrofit measures for schools.

Figure 52 to Figure 54 illustrate the spatial distributions of mean BCR when considering the retrofit options S1, S2 and S3 simultaneously (over a 50 year time period), using discount rates of 1%, 5% and 10%.

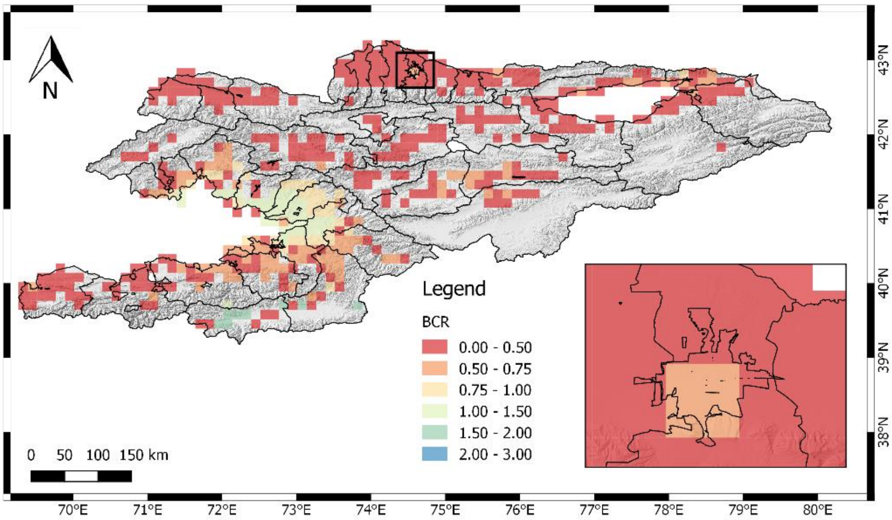


Figure 52 Mean spatial distribution of BCR for the combination of school retrofit options S1, S2 and S3, using a discount rate of 1% (T = 50 years).

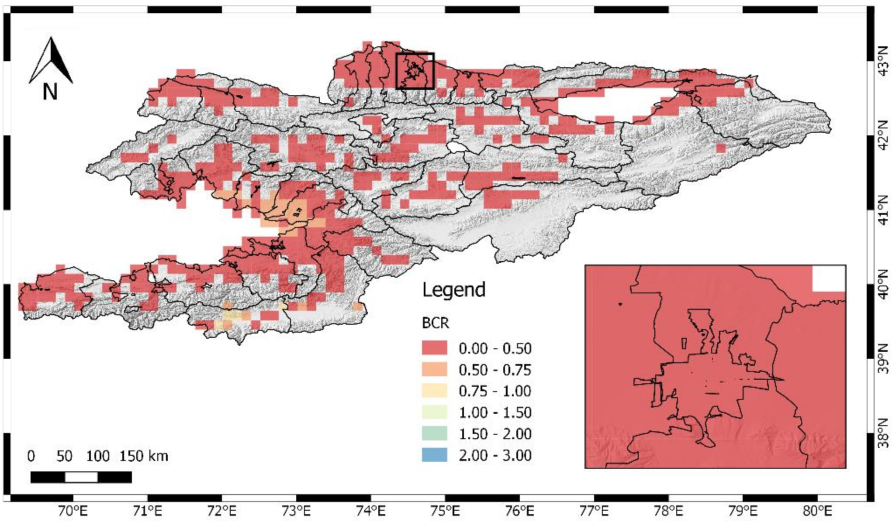


Figure 53 Mean spatial distribution of BCR for the combination of school retrofit options S1, S2 and S3, using a discount rate of 5% (T = 50 years).

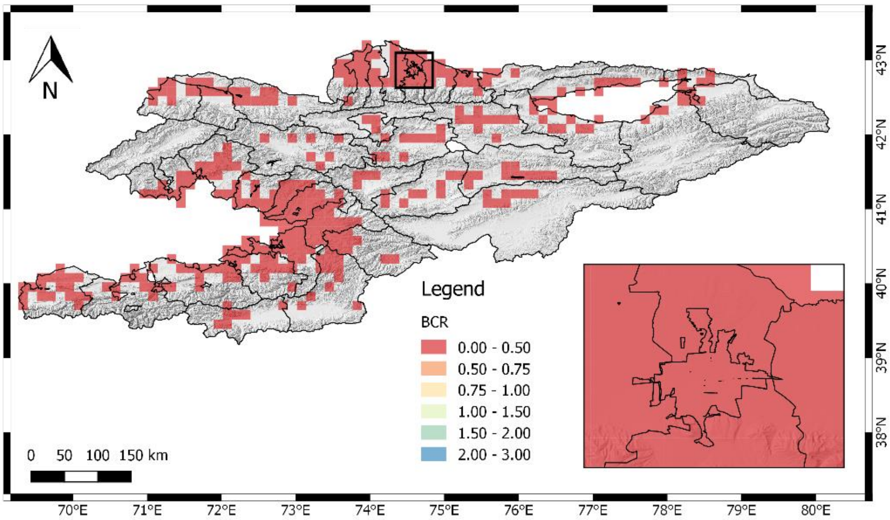


Figure 54 Mean spatial distribution of BCR for the combination of school retrofit options S1, S2 and S3, using a discount rate of 10% (T = 50 years).

As expected, the CBA results are very sensitive to the assumed discount rate with BCRs typically ranging from less than 0.50 for a discount rate of 10% to BCRs of up to 2 for a discount rate of 1%. It is clear that a value of 1% is the one leading to higher BCRs, with the highest return of investment expected the rayons surrounding the Fergana Valley near Osh and Jalal-Abad, and the southernmost part of the country near the Alai Mountains and in the Bishkek region,. The relative distribution of BCRs throughout the country is consistent across the three assessed discount rates, as expected. However, when considering 5% and 10%, the mean BCRs are lower than 1.0 in the entire territory.

Appendix D

Seismic Retrofit Cost Assumptions

D1 Seismic Retrofit Cost Assumptions

D1.1 Introduction

The seismic loss assessment of specific buildings is usually done by summing the cost to repair all the building components that may suffer damage during a seismic event. In the case of the retrofitted building classes presented in Table 8, these components can be divided into five main categories of elements (Table D-1).

Table D-1 Summary of the main groups of damageable components

Component category	Element	Applicable retrofitted building type (Table 8)
Reinforced concrete frame elements	External beam-column or slab-column joints	S3
	Interior beam-column or slab-column joints	S3
	Columns, beams and slabs	S3
Precast concrete elements	Precast walls	R2
	Precast slabs	R2
Masonry walls	Unreinforced bearing walls	S1, S2, H1, H2, F1, R1
	Masonry partitions	S3, S1, S2, H1, H2, F1, R1
	Masonry infill walls	S3
Partition-like elements[1]	Electrical components	All types
	Ceramic tiles	All types
	Sanitary system	All types
	Windows	All types
	Doors	All types
Generic non-structural components	Roof covering	All types
	Lighting	All types
	Piping and ducts	All types

[1] Partition-like components are elements whose damage and repair operations depend on the level of damage or repairs on the partitions to which they are effectively attached.

The retrofit costs computed in this work account for the cost of labour and materials of new retrofit elements (e.g. new shear walls), as well as the cost associated with the necessary rehabilitation or replacement of the components (Table D-1) affected by the retrofit operations. The costs from non-structural building components and finishes are considered as the cost to rehabilitate the affected elements to their original condition. Costs are assumed to be in 2015 USD.

The retrofit options and respective costs reflect solutions that target the improvement of seismic performance alone. However, it should be highlighted that, as demonstrated by Calvi et al. (2016), seismic retrofit operations may be used to achieve additional benefits. One relevant example is the use of retrofit solutions that are primarily designed for seismic enhancement to improve the building's energy efficiency (e.g. through the selection of appropriate materials). The cost assumptions for retrofit for the cost benefit analyses exclude such additional improvements.

In addition to the sources presented in the construction cost information report of this project (Arup, 2016c), the main sources of retrofit cost data and resulting retrofit costs are summarized in the following Table D-2. Mostly cost data from international literature for seismic retrofitting was used but some local seismic retrofit cost data was provided for schools (UNICEF, 2013). Similar to the approach taken in the replacement costs report (Arup, 2016c), international cost data for different usage types was adjusted as compared to the schools retrofit costs to develop retrofit costs for building usage types where less local cost data was available. For example, international cost data was used to understand the difference between the construction costs for the fitout and finishes in a hospital building as opposed to a school building.

Table D-2 Data sources used for the computation of retrofit costs and final cost assumptions

Asset Type	No		Data sources	Retrofit cost (as a % of the building replacement value)
Schools	S1		UNICEF (2013); Calvi (2014); Cardone and Perrone (2015); Jafarzadeh et al. (2014); Roy et al. (2013).	45%
	S2			45%
	S3			48%
Hospitals	H1			45%
	H2	1 floor	Calvi (2014); Ormonbekov and Begaliev (2002); Melkumyan (2002); Arup (2012).	85%
		2 floors		42%
		3 floors		30%
Fire Stations	F1		Calvi (2014); Smyth et al. (2004); Cardone and Perrone (2015); Jafarzadeh et al. (2014); Roy et al. (2013).	45%
Residential Buildings	R1			45%
	R2			48%

Appendix E

Kyrgyz Republic Structural Typology Descriptions

E1 Structural Typology Descriptions

This appendix provides the descriptions of the structural typologies used in this study as well as photos of representative buildings of each type.

Table E-1 Building classes considered in this study (Arup, 2016b)

Main construction Material	**Taxonomy (EMCA)**	**Simplified taxonomy[1]**	**Description**
Unreinforced Masonry	EMCA11	URM1	Unreinforced masonry with wooden floors
	EMCA12	URM2	Unreinforced masonry with pre-cast concrete floor
Reinforced Masonry	EMCA13	RM1	Reinforced and confined masonry
	EMCA14	RM2	Masonry with seismic provisions
Reinforced Concrete	EMCA21	RC1	Monolithic reinforced concrete moment frame
	EMCA22	RC2	Monolithic reinforced concrete moment frame and shear walls (dual system)
	EMCA23	RC3	Monolithic reinforced concrete moment frames with brick infill walls
	EMCA24	RC4	Buildings with monolithic reinforced concrete walls
Pre-cast Concrete	EMCA31	RCPC1	Pre-cast concrete large panel buildings with monolithic panel joints - seria 105 (Arup, 2016b and 2016c)
	EMCA32	RCPC2	Pre-cast concrete large panel buildings with panel connections achieved by welding or embedment plates - seria 464 (Arup, 2016b and 2016c)
	EMCA33	RCPC3	Pre-cast concrete flat slab buildings (columns and slabs) - seria KUB (Arup, 2016b and 2016c)
	EMCA34	RCPC4	Pre-cast RC frame with linear elements with welded joints in the zones of maximum loads or with rigid walls in one direction – seria 111 – IIS-04
Adobe	EMCA40	ADO	Buildings with adobe or earthen walls
Timber	EMCA51	WOOD	Buildings with load-bearing braced wooden frame
	EMCA51		Buildings with wooden frame and mud infills
Steel	EMCA60	STEEL	Buildings with steel frame

1 Simplified typology used in this report for an easier identification of the main construction material of each class

In addition to the descriptions above, photos of representative buildings for each type are given in Figures E-1 to E-3 below:

Unreinforced Masonry Buildings with Wooden Floors (URM1)

Unreinforced Masonry Buildings with Reinforced Concrete Floors (URM2)

Confined Masonry Buildings (RM1)

Monolithic Reinforced Concrete Frame Buildings (RC1)

Figure E-1 Structural Typologies – URM1, URM2, RM1 and RC1

Reinforced Concrete Frame with Brick Infill Buildings (RC3)

Reinforced Masonry Buildings (RM1)

Reinforced Concrete Frames and Shear Wall Buildings (RC2)

Monolithic Cast In-situ Reinforced Concrete Wall Buildings (RC4)

Adobe Buildings (ADO)

Timber Frame Buildings (WOOD)

Figure E-2 Structural Typologies – RM1, RC2, RC3, RC4, ADO and WOOD.

Pre-cast Concrete with Large Precast Panels and Monolithic Concrete Joints Buildings (RCPC1)

Pre-cast Concrete with Large Panels and Welded Plate Connection Buildings (RCPC2)

Pre-cast Concrete Flat Slab Buildings (RCPC3)

Pre-fabricated Reinforced Concrete Moment Frame Buildings (RCPC4)

Figure E-3 Structural Typologies – RCPC1, RCPC2, RCPC3 and RCPC4.

Appendix F

Past Disaster Risk Reduction (DRR) Activities in the Kyrgyz Republic

F1 National Strategy for Sustainable Development for the Kyrgyz Republic DRR

Previously, the government has developed and adopted a 'National Strategy for Sustainable Development for the Kyrgyz Republic for the period of 2013 to 2017' (Sekimov, 2015). Within this strategy, they aligned their Disaster Risk Management strategy with the five priorities of the Hyogo Framework for Action for 2005 – 2015: "Building the Resilience of Nations and Communities" as well as identified specific objectives for each priority. Progress in each of these areas has been reported in an interim report produced by Kyrgyz National Platform Secretariat (Sekimov, 2015). The DRR priorities and objectives as well as key areas of progress and current challenges in the implementation of the strategy are presented in the table below.

Table F-1 Progress against the NDS Section 5.2 (Sekimov, 2015)

No	Priorities	Objectives	Implementation
1	Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation.	To improve the legal and regulatory framework for effective disaster risk management.	Progress A 'Strategy of complex safety of the population and territory of the Kyrgyz Republic in emergency and crisis situations until 2020" has been developed by the MES and adopted. In order to integrate DRR into policies and practices, amendments to existing laws as well as new documents have been created. These include a draft law 'On Civil Protection' which defines the organization and legal norms in the field of civil protection in emergency situations as well as a law 'On Local Self-Government' which sets out local level responsibilities for DRR. Challenges It was noted that the main challenge to carrying out DRR preventative measures was delayed funding for projects which can lead to suspension of the works and reduced effectiveness of the measures. Although local governments have the remit to carry out DRR, their budgets are small (0.20% of the total local government budget) and they often require state subsidies to finance DRR activities. In addition, there is a lack of clarity about the division of powers between the state and local governments. With the support of the UNDP, a National Platform for DRR was developed in 2011 to be carried out by a combined task force of government officials, technical bodies in Kyrgyz and NGOs. Currently, there is no legal status or sustained government funding mechanism for this initiative (UNECE, 2010).
2	Identify, assess and monitor disaster risks and enhance early warning systems.	To improve risk assessment, disaster monitoring and early warning systems in the	Progress To monitor disaster risk and improve early warning systems, the MES has drafted a programme entitled 'Integrated monitoring and prediction of natural hazards with the use of GIS technology and remote sensing for the period of 2015 – 2017'

No	Priorities	Objectives	Implementation
		Kyrgyz Republic. To identify threats, vulnerabilities and disaster risks for all populated areas of the Kyrgyz Republic.	Over 6,000 schools were assessed as part of the state programme 'Repair and reconstruction of school and pre-school educational institutions in the Kyrgyz Republic for the period 2014 – 2020' and 89% of schools were deemed to be structurally unsafe. This programme has technical support from UNICEF and USAID and the aim is to inform financial planning for school risk reduction, implement structural improvements and institute disaster preparedness in the educational sector. In 2014, a project to enhance forecasting, early warning, prevention and response to emergencies has been initiated and pilot projects have been completed in selected cities (Bishkek, Osh, Karakol and others). This involves creating a single network and data communications network for the country, training for emergency response personnel as well as programmes to raise community awareness of disasters (Sekimov, 2015). In 2009, WHO carried out seismic assessments for three hospitals (two in Bishkek and one in Osh) and results showed the need to improve hospital performance to reduce risk to life as well as continue operations after an earthquake (UNECE, 2010). Challenges Aside from the UNICEF schools database, the challenge is the relative paucity of data on critical buildings and infrastructure in a format suitable for quantitative risk assessment (i.e. consistent description of structural typologies, condition/damage state). We have found reference to a unified national database that contains characteristics of buildings and infrastructure related to seismic resilience but it is noted that this database is not complete (UNECE, 2010). This data has not been shared with Arup as part of the recent seismic risk assessment.
3	Use knowledge, innovation and education to create a culture of safety and resilience at all levels to reduce the impact of disasters through better sharing of knowledge and education.	To create a national infrastructure to raise awareness about the possibilities and methods of disaster risk reduction through information exchange.	A policy has been drafted to raise public awareness about disasters through articles, radio and television broadcast but budget and capacity to deliver this are still challenges. As part of the decree RCC 21.11.2012, № 780 "On the unified system of training government forces and civil protection and awareness in the field of civil protection", over 30,000 members of the population have received emergency response training including state and municipal employees, teachers and school children (Sekimov, 2015).
4	Reduce the underlying risk factors by including disaster risk reduction measures in the development	To establish mechanisms for the identification and integration of mitigation and disaster risk management	90,000 acres of green space has been set aside and vegetation has been planted to reduce the risk of mud flows and landslides. Radiation from nuclear waste is also being monitored and surveyed (Sekimov, 2015). More work is needed to assess flood risk and risk to major water resources.

No	Priorities	Objectives	Implementation
	strategy of the Kyrgyz Republic.	policies, programs and projects for the development of the Kyrgyz Republic.	
5	Strengthen disaster preparedness for effective response at all levels in order to reduce human and material losses due to disasters.	To increase the capacity for preparedness and response to disasters at the national, regional and district levels, and at the level of local government (including the development of early warning systems), as well as capacity building for disaster risk reduction.	The Ministry of Emergency Situations (MES) has created a unified system within government to prepare and respond to disasters: - Center for Crisis Management (CCM) which is a single body of day to day management; - A single state duty and dispatch service (112); and - A unified information management system to automate activities of the Department of the State System of Civil Protection (Sekimov, 2015). Challenges remain to fund this system as well as in building capacity within the government to implement it.

Appendix G

Description of Key Stakeholders

G1 Key Stakeholders

This section describes the functions of key government stakeholders in the Kyrgyz Republic and their role in Disaster Risk Management (DRM).

National Government of the Kyrgyz Republic

The executive power in the Kyrgyz Republic comprises the Office of the President, the Parliament (Jogurku Kenesh), the Executive Body and the Courts and Justice system. This branch implements national strategic initiatives, include those related to disaster risk management in cooperation with local governments and other government agencies (UNISDR, 2010).

Steering Committee for Seismic Risk Reduction in Kyrgyz

The Steering Committee consists of representatives from different agencies of the Government responsible for disaster risk reduction and the structural performance of buildings and infrastructure, and emergency response including the Ministry of Emergency Response, the Institute of Seismology, the State Insurance Organization, the State Institute of Seismic Construction and Engineering Projects, the National Institute of Strategic Research, the National Statistics Committee and the Central-Asian Institute for Applied Geosciences (CAIAG).

The purpose of the Steering Committee is:

1. To provide strategic direction and guidance to the project team for this study ("Measuring Seismic Risk in the Kyrgyz Republic") for the Government, the World Bank and the Global Facility for Disaster Reduction and Recovery;
2. To provide an interface between the project team and the Government such that the seismic risk reduction aims and priorities of the different agencies of the Government are communicated to the project team;
3. To facilitate the compilation and communication of important input data on buildings and infrastructure from different agencies of the Government with the project team;
4. To facilitate the communication of the outcomes of the study to the different agencies of the Government (e.g. Science and Technology Committees).
5. To adopt and to have ownership of the Seismic Risk Assessment, its results and recommendations; and
6. To follow up with any necessary actions (e.g. in terms of seismic risk reduction measures) after the Seismic Risk Assessment is completed.

Ministry of Education and Science (MoE)

The Ministry of Education and Science is the body of state policy and normative and legal regulation in the sphere of education, scientific, technical and innovative activity, intellectual property, as well as in the sphere of upbringing, social support and social protection of students and pupils of educational institutions (http://edu.gov.kg/). The Ministry of Education and Science has a track record of close collaboration with other government agencies to promote awareness of seismic risk and disaster preparedness through training of students and teachers (UNISDR, 2010).

Ministry of Health (MoH)

Ministry of Health of the Kyrgyz Republic is the central body of executive authority that conducts state policy and carries out management in the sphere of protecting the health of citizens in the Kyrgyz Republic.

Ministry of Emergency Situations (MoES)

The Ministry of Emergency Situations was formed in 2005 and combined the previous Ministry of Emergency Situations and Civil Defence and the Ministry of Environmental Protection. The MoES is responsible for implementing state policy to prevent and reduce risk from natural and man-made emergencies including emergency response. This remit includes industrial safety supervision, mining supervision, hydrometeorology risks and fire safety as well as risks from natural hazards. The MoES is part of the central body of the executive state government (UNISDR, 2010).

Construction/Building (GOSSTROY)

The GOSSTROY is part of the state administration and regulates and monitors construction, architecture, urban planning, engineering surveys and transport infrastructure. In addition to having national status, it also has local branches in each oblast and rayon.

The three cores functions of the GOSSTROY are:

- **Establishing standards and rules and regulations for construction activities.** This includes approval of land development according to master plans, establishing construction guidelines and norms and guidelines for construction costs;
- **Coordination and control of building activities.** This includes the supervision of construction as well as enforcement of construction regulations and penalties for irregularities; and
- **Regulating land use and development.** This includes review and approval of design and urban planning documents and issuing licences for urban planning and construction projects. In addition, the GOSSTORY must approve of architectural and engineering designs for buildings larger than 300m^2 (ICF Consulting Service, 2016b).

Ministry of Finance (MoF)

Ministry of Finance of the Kyrgyz Republic is the central state body of executive authority with functions of the development and implementation of state policy in the sphere of state financial management and also policies in the area of internal audit and state procurement.

State Insurance Organization (SIO)

Open (Type) Joint Stock Company (JSC) "State Insurance Organization" is a specialized organization whose purpose is to create economic conditions for compensation of losses related to damage or destruction of living quarters as a result of fire and natural disasters.

Ministry of Transport and Communications (MoT)

Ministry of Transport and Communications of the Kyrgyz Republic is a state body of executive authority implementing state policy and management in the sphere of automobile, railway, electric, air and water transport, roads and railways, communications and information, radio and television broadcasting.

Ministry of Economics (MoEc)

We understand that the Ministry of Economics is involved in the development of national strategies for the country.

Institute of Seismology

Part of the National Academy of Sciences in the Kyrgyz Republic, the Institute of Seismology focusses on the following research areas:

1. Assessment of potential seismic hazard in Kyrgyzstan and developing seismic hazard maps for earthquake-prone regions.
2. Quantitative assessment of parameters on earthquake influence on soil and buildings as well as seismic risk levels in urban areas (http://www.nas.aknet.kg/eng/).

The National Statistical Committee (NSC)

This committee collects and disseminates data on national statistics on the economy, many sectors including industrial activities, energy, investments, agriculture and housing, foreign trade, as well as social and demographic information (http://stat.kg/en/).

State Institute of Seismic Construction and Engineering Projects

State Institute of Seismic Resistant Construction and Engineering Projects at the State Agency for Architecture, Construction and Housing and Communal Services under the Government of the Kyrgyz Republic carries out its activities in the sphere of seismic-resistant construction, production of building materials and products, as well as engineering inspection of buildings and structures.

National Institute of Strategic Research (NISR)

NISR's mission is implementation and development of system of high-quality scientific and analytical consulting for higher authorities, which facilitates the development of scientifically substantiated, detailed and measured government decisions. NISR's aim is to play a key role in the implementation of scientifically based approach to political decisions, for the development of which the scientific and expert communities are involved.

Central-Asian Institute for Applied Geosciences (CAIAG)

Founded in 2002 on the basis of a co-operation agreement between the Government of Kyrgyzstan and GFZ-Potsdam, CAIAG is a multidisciplinary research institute located in Bishkek and has the task of developing and undertaking geo-scientific research and application projects in Central Asia in the fields of geodynamics and geo-hazards and technical infrastructure and information management. It has served as a main contact point for international hazard and risk assessments in Central Asia. In addition, CAIAG operates dedicated monitoring networks for seismology and geodesy. CAIAG aims to build scientific capacity in the wider region in its areas of speciality and has a team of scientists to organize and deliver training courses, to prepare educational material and to establish knowledge transfer to the society and stake holders.

Appendix H

Disaster Risk Financing and Insurance

H1 Disaster Risk Financing and Insurance

Measures for specific asset portfolios such as retrofit interventions and replacement of highly vulnerable assets can reduce risk to buildings and infrastructure but there will always be significant residual seismic risk that remains. Therefore, it is important that the disaster risk reduction strategy consider financing and insurance mechanisms to fund *post-disaster* needs after an event to aid recovery and reduce economic disruption. Recommendations are provided in two key areas:

- The role of government, including funding for post-disaster recovery; and
- Ways of compensating businesses and individuals affected by disasters through insurance mechanisms.

H1.1 Risk Context for Disaster Risk Financing

This study has focussed on seismic risk and associated losses. Past risk studies for the Kyrgyz Republic have shown that losses from earthquakes are the largest contributor to overall losses from natural disasters (around 70%) and this has been reflected in losses from past events (World Bank/ISDR/CAREC, 2008). The Kyrgyz Republic is especially vulnerable to economic shocks from natural disasters as it has both a high level of risk as well as a relatively low GDP of 6.6 billion USD (and low GDP per capita) when compared to other Central Asian countries (World Bank, 2016). For example, the predicted expected annualized losses (EAL) from this study for residential buildings in the Kyrgyz Republic can be up to 4% of GDP (Arup, 2017b).

H1.2 The Role of Government

There are numerous ways for governments to fund post-disaster needs:

- Cash reserves or disaster funds: the government sets aside some money each year that can be drawn on in the event of a disaster. E.g. the original incarnation of the Fund for Natural Disasters (FONDEN) scheme in Mexico (World Bank, 2017).
    - Advantages: simple, transparent.
    - Disadvantages: funds can be challenging to build up and tempting to deplete for shorter term but pressing needs.
- Additional borrowing: in the event of disaster, the government borrows funds from external agencies. This could take the form of arranging in advance for ex-ante funds such as a World Bank Deferred Drawdown Option (DDO).[44] This is an agreement for a certain amount of credit to be released following a disaster and is often combined with support for risk reduction activities over a

[44] Note that for a World Bank DDO, the maximum credit amount is the smaller of 500 million USD or 0.25% of GDP. For the Kyrgyz Republic, this would limit the amount to 150 million USD.

longer programme. Similar ex-ante funding arrangements are offered by the Asian Development Bank, Inter-American Development Bank and others.

- Advantages: Requires no upfront expenditure. Typically less expensive than buying traditional insurance (UN/World Bank, 2010) and also may improve a country's access to credit markets on favourable terms if their credit rating is low (ADB, 2008). In addition, ex-ante funding is often tied to risk reduction programmes where the government receives support and incentives implement risk reduction measures pre-disaster.
- Disadvantages: Without World Bank or similar support it may be difficult for some countries to borrow more depending on how indebted they are and their projected economic output. The Kyrgyz Republic has a relatively low GDP and moderate level of public debt.[45]

We understand from stakeholder consultation that the World Bank may be exploring this option with the Government of the Kyrgyz Republic.

- Buying traditional insurance (or reinsurance) on the open market. E.g. insuring key assets.
  - Advantages: Transparent, relieves pressure on budgets post-disaster, encourages risk management through cost incentives.
  - Disadvantages. Not widespread, but useful for targeting at key assets. Pricing comparisons should be performed. This option can be more expensive than taking a portfolio approach.
- Joining up with other countries in the region to create a risk insurance pool. Countries can purchase insurance up to a given amount in a given year. E.g. a similar pool has been created for the Caribbean.
  - Advantages: This can be less expensive than traditional insurance, risk is spread between a number of countries. Encourages regional collaboration.
  - Disadvantages: Will take time to implement. Once implemented, the pay-outs given to certain countries could be perceived as unfair (e.g. St Lucia received a much lower pay-out than Barbados after Hurricane Tomas in 2010), requires joint working with other jurisdictions (CCRIF, 2017).

  We understand from stakeholder consultation that the World Bank may be providing support and advice to the Government of the Kyrgyz Republic to explore the creation of a regional insurance pool.
- Capital markets are now looking to diversify their risks by offering insurance linked financial products such as Catastrophe Bonds. Playing a similar role to traditional insurance, catastrophe bonds transfer defined catastrophe risk to investors where the principal is used to pay off losses in the event of a specified event. They are issued by private insurance companies but can be sponsored by the Kyrgyz government, probably with some backing from the World Bank or others. E.g the Mexican government has successfully issued catastrophe bonds, via FONDEN.

[45] Public debt grew to 53% of GDP in 2014 (World Bank, 2015, Economist Intelligence Unit, 2015).

  - Advantages: Can pay-out immediately, non-contingent debt so potentially less impact on borrowing constraints, and can be lower cost than traditional insurance (Borzenstein et al, 2016).
  - Disadvantages: Although widespread in private insurance, the sponsoring of catastrophe bonds by governments is not widespread at present so may require time to implement and some institutional changes. It is likely that this would require World Bank involvement.
- Encouraging the take up of private insurance, through stimulation of a market of suppliers and buyers for these services. This might be facilitated by better data collection and sharing, government re-insurance or other means. It is discussed in more detail in the following section.

H1.3 Insurance for Businesses and Individuals

Next, an overview of the insurance market for individuals and businesses in the Kyrgyz Republic is provided. Currently, insurance is offered for all perils (including from natural hazards such as earthquakes, floods and wind). In 2007, it was reported that individual policies had a very small level of market penetration in the Kyrgyz Republic – for example, 10,000 residential policies country wide or less than 1% of all insurable urban housing (World Bank/ISDR/CAREC, 2009). Most insurance policies are held by people who are required to buy insurance to qualify for a mortgage when buying property and there is very little voluntary take-up. Premia and deductibles are low (deductibles are rarely above 2% and are often zero) but natural hazard insurance is often bundled with other types (fire, etc.) and may still be unaffordable for many. Loss settlements are done on the basis of replacement value. Another reason for the small number who buy insurance is the dominance of the public sector (or tenancies via housing trusts) in housing provision, a lack of an insurance culture combined with widespread mistrust of insurance companies, and affordability.

Insurance companies in the Kyrgyz Republic lack skills and capacity to understand and quantify the levels of loss potential from natural hazards, including earthquakes. Insurer’s capital base requirements are very low (0.5 million USD in 2007) and generally reinsurance is not purchased unless required by large commercial clients (World Bank/ISDR/CAREC, 2009), (NCSD-KR, 2013), which increases the risk of insolvency of insurance companies in the event of a disaster. Data availability is also low.

There is a general awareness among policy makers in the Kyrgyz Republic that the insurance market is weak. We suggest that the government may consider a range of actions to tackle this, including:

- Use the results of this study to inform earthquake insurance pricing and adequate capitalization of the local insurance markets;
- Consider mandating insurance coverage for building owners (many of which are public sector or housing trust-type organisations);
- Encourage natural hazard and risk data collection and sharing among government agencies and insurance companies;

- Consider the government's role as a potential re-insurer;
- Consider the government playing a direct role in the private insurance market in partnership with private companies through establishment of an insurance pool, such as that which exists in Turkey; and
- To take steps to standardize insurance coverage with respect to natural disasters, so that consumers are aware of the coverage available.

Additionally, the government has a number of actions to address this as part of the National Strategy of Sustainable Development of the Kyrgyz Republic (2013) including:

1. Improve the legal and regulatory framework of insurance activities;
2. Establish an Institute of Actuaries for the country which could review draft laws related to the insurance industry;
3. Strengthen the system of financial supervision of insurance companies to protect all parties' interests;
4. To consider the adequacy of current requirements for mandatory insurance in order to further develop a culture of insurance;
5. Take measures to increase capitalization of insurance companies and the reinsurance system;
6. To train and retain more insurance professionals in the country; and
7. To educate the general public about insurance and benefits of insurance to create awareness.

H1.4 Conclusions and Recommendations

The following additional conclusions and recommendations result from this study:

- This is the first country-wide seismic risk study for the Kyrgyz Republic and the study has confirmed the very high potential losses from seismic risk which is likely to represent the large majority of losses from natural disasters in the country;
- To provide liquidity post-disaster, it is recommended that the government explore a combination of ex-ante funding arrangements, and steps to encourage a private insurance market. In the longer term, the government should consider regional engagement and explore establishing a wider insurance risk pool with other countries; and
- One key step in strengthening the Kyrgyz insurance markets and ensuring fair pricing and adequate capitalization would be to improve data collection on risks and losses from earthquake and other natural disasters. This data must also be communicated and shared to support the development of more accurate catastrophe models for the Kyrgyz Republic and the wider region.

Appendix I

Recommended Construction Types for New Construction in the Kyrgyz Republic

I1 Recommended Construction Types for New Construction in the Kyrgyz Republic

As part of Component 2 of this study, representative structural typologies for the country were chosen and fragility and vulnerability functions developed for these for use in the quantitative seismic risk assessment (Arup, 2016b). Refer to Appendix E for photos of the representative building typologies used for this study. Based on these fragility functions, certain structural typologies were shown to be less vulnerable to earthquake damage. It should be noted that there is uncertainty associated with the performance of these typologies and they a cover broad range of construction types. Seismic performance of individual buildings will depend on the specific form, types of floor and roof diaphragms, level of seismic detailing, quality of construction and level of maintenance during the design life.

Table 29 below summarizes the higher performing typologies and their applicability for common building usages in the Kyrgyz Republic. In addition, the table includes other recommended construction typologies to be considered for new construction in the Kyrgyz Republic (*shaded in blue*). These construction types have been selected based on their appropriateness for the county (material type, complexity of construction) and have been shown to perform well in earthquakes based on international and regional experience.

Table 29 Recommended Structural Typologies for New Construction in the Kyrgyz Republic.

Level of seismic performance	**Construction Type**	**Typology ID (if applicable)**	**Comment**	**Context**
Good – *but understood to be not as commonly used for new construction.*	Pre-cast concrete buildings –large panel buildings with panel connections achieved by welding or embedment plates.	RCPC2/c3.2	If well-constructed and maintained, these types of buildings have been shown to perform well. We understand that these were typically constructed in the Soviet era and may not be commonly used for new construction at this time. Most often used in the past for **multi-storey apartment buildings**.	Urban.
Good – *but understood to be not as commonly used for new construction.*	Pre-cast concrete buildings –large panel buildings with panel buildings with monolithic panel joints.	RCPC1/c3.1	If well-constructed and maintained, these types of buildings have been shown to perform well. We understand that these were typically constructed in the Soviet era and may not be commonly used for new construction at this time. Most often used in the past for **multi-storey apartment buildings**.	Urban.
Good	Buildings with monolithic	RCM4/c2.4	This type of construction can be used for large scale buildings such as **multi-storey hospitals** as well as	Urban.

Level of seismic performance	Construction Type	Typology ID (if applicable)	Comment	Context
	reinforced concrete walls.		other types of **health facilities**, **schools** and **fire stations** and has been shown to perform well in earthquakes. Walls can be bearing walls or combined with cast-in-place concrete frames for gravity loads. Walls can be detailed for different levels of ductility depending on the level of seismic hazard and the density of walls for the building. Also recommended for **multi-story residential and office buildings**.	
Good	Buildings with monolithic concrete frames and shear walls (dual system).	RCM2/c2.2	This type of construction can be used for large scale buildings such as **multi-storey hospitals** as well as for other types of **health facilities, schools** and **fire stations** and has been shown to perform well in earthquakes if moment frames are detailed appropriately to avoid brittle failure. This type of detailing can be more complex to design and construct as compared to type RCM4. Also recommended for **multi-story residential and office buildings**.	Urban.
Good	Hollow block reinforced masonry buildings (Refer to Figure 56, "reinforced masonry walls" type below).	n/a	Suitable for low to midrise (up to four storey) construction for **health facilities, fire stations, schools, office buildings and residential buildings**. Similar to buildings with monolithic concrete wall construction but easier to construct as reinforcement is more regularly laid out. Hollow block can be fully grouted or partially grouted. Can be used as a bearing wall system or in combination with cast-in-place concrete frames for gravity loads.	Urban, rural.
Good	Timber frame buildings with nailed plywood shear walls (Refer to Figure 55 below).	n/a	Lightweight so attracts less seismic load. Suitable for **small scale health facilities, schools, offices and residential buildings**.	Urban, rural.
Good (see requirements for special detailing)	Buildings with monolithic concrete moment frames.	RC1/c2.1	If seismically detailed (e.g. for adequate ductility, strong column, weak beam behaviour), can be suitable for **large scale hospitals, residential buildings, offices and schools**. Could be used for **fire stations** but may be more expensive compared to other construction types. More complex to design and	Urban.

Level of seismic performance	Construction Type	Typology ID (if applicable)	Comment	Context
			construct due to seismic detailing. If masonry partition walls are used, they should be isolated from the frame and have their own integrity under seismic loads (local reinforcement and/or bracing/restraint). Refer to Figure 59.	
Moderate	Masonry with seismic provisions or confined masonry.	M3 & M4/c2.3 & c2.4	Based on the information gathered for this study, this type most likely consists of small scale buildings with ductile cast-in-place tying elements around panels of unreinforced masonry (confined masonry) or providing seismically detailed ring beams at certain levels. Refer to Figure 56. Recommended for **smaller scale residential buildings**. ***Not recommended for health facilities, fire stations and schools.***	Urban, rural.
Moderate	Buildings with monolithic concrete moment frames and brick infill walls.	RC3/c2.3	Suitable for low to mid rise **residential and office buildings**. Frames should be detailed for the forces that the stiffening masonry walls induce and masonry walls should be detailed so they do not fail out of plane under seismic loading. Refer to Figure 58.	Urban.
Moderate	Buildings with load-bearing braced wooden frame.	WOOD1/c5.1	Lightweight and will attract lower seismic loads. Suitable for **small scale residential buildings**. Could be used for **rural or remote schools** in absence of capability (or material availability) to construct better performing construction types. Proper detailing at foundation level to protect the structure from moisture as well as maintenance over the building lifetime is important to ensure good performance over the design life. Type WOOD2/c5.2 is not recommended as masonry infills can fail out of plane and endanger life.	Urban, rural, remote (if good quality timber is locally available).
High (see requirements for special detailing)	Buildings with steel frame.	STEEL/c6	Typically used for low-rise (often one storey) longer span structures such as **warehouses and agricultural facilities**. Otherwise, we understand that steel construction is not commonly used in the Kyrgyz Republic. Lightweight and will attract less seismic load. Care must be taken to ensure steel members are compact to prevent local and global buckling and detailing of steel	Urban, rural.

Level of seismic performance	Construction Type	Typology ID (if applicable)	Comment	Context
			members should avoid brittle failure of welds.	

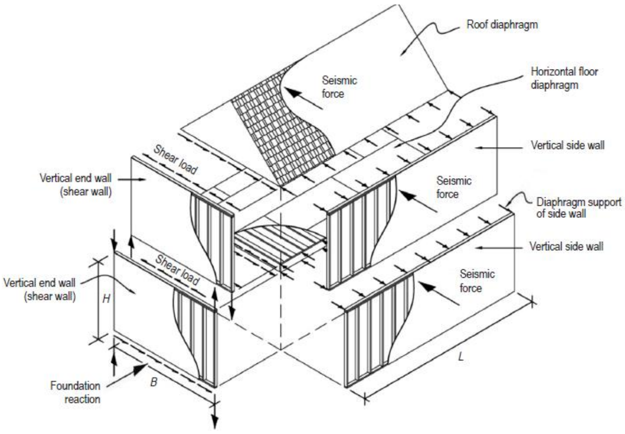


Figure 55 Example of timber frame construction with nailed plywood shear walls for residential buildings (NIST, 2014).

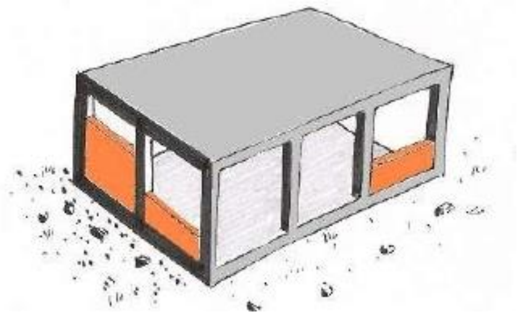
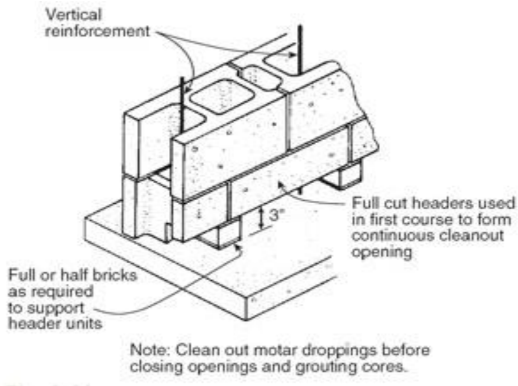
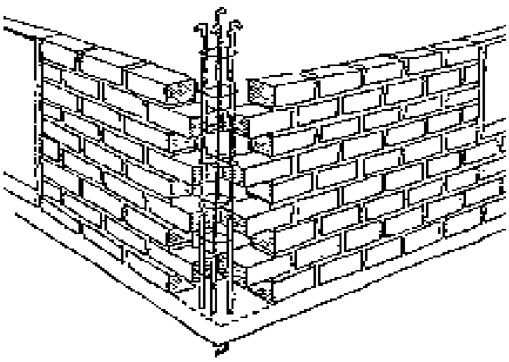
Reinforced concrete frame with masonry infill walls (RC3) Masonry walls are not reinforced or monolithically connected with the RC frame	
Reinforced masonry walls (RM1) Masonry walls are reinforced with steel rebars (vertically and horizontally), acting as structural elements	
Confined masonry walls (RM2) Masonry walls are constructed in connection with the RC 'tie' columns and beams. Walls are constructed first, then tie members.	

Figure 56: Schematic representation of different types of concrete frame with infill, reinforced masonry and confined masonry construction.

I1.1 Other Seismic Design Considerations for Kyrgyz Construction Types

This section highlights a few additional key seismic design considerations for new construction in the Kyrgyz Republic. It should be noted that it is not intended to be a comprehensive overview or guide to seismic design for new construction.

Seismic isolation is also recommended for new buildings in addition to retrofit of existing buildings in the Kyrgyz Republic. It should be considered for **higher importance, more critical buildings** where immediate occupancy or operational performance is required after the design earthquake for better continuity of critical services. Refer to Appendix A, Measure RD-1 for further advice on considerations for design of seismically isolated buildings.

Pre-cast floor construction is commonly used in the Kyrgyz Republic. If used, care must be taken to ensure that the pre-cast floor system can:

- transfer the shear and bending demands from the earthquake load generated by the weight of the floor in the plane of the diaphragm; and
- that the diaphragm load can then be transferred into the lateral system (walls or frames).

This is often achieved by a using a **reinforced cast-in-place concrete topping slab**. Refer to Figure 57 below. The diaphragm should be designed for the full expected earthquake loads (not a reduced level) so it can avoid damage during the earthquake and ensure load can be transferred into the main lateral resisting system and then down to the foundations.

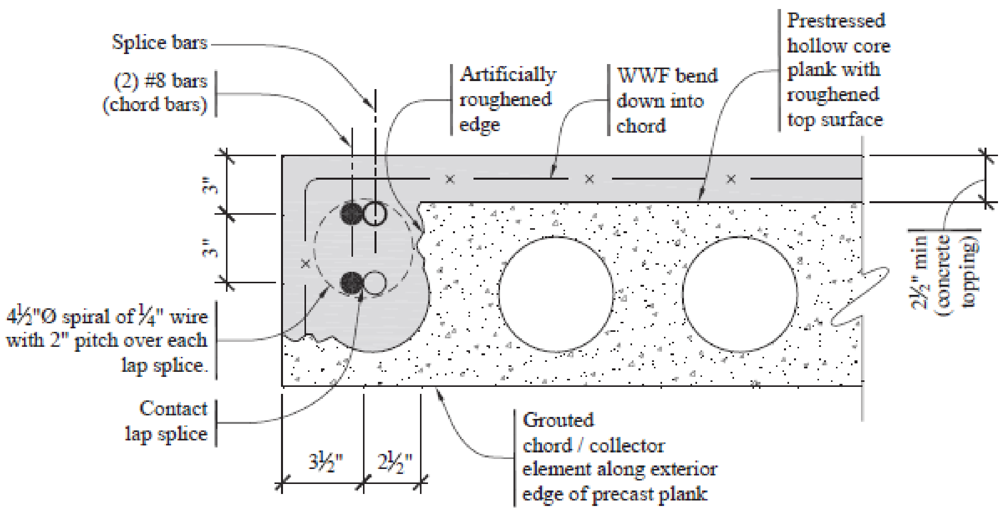


Figure 57 Example for detailing of precast floor showing reinforced topping slab and additional reinforcement for the chord and collector (FEMA P-751, 2012).

Timber or light gauge steel roof construction is commonly used in the Kyrgyz Republic. Similar to consideration for floor diaphragms, roofs should have **in-plane bracing (steel or timber) or nailed plywood diaphragms** to transfer earthquake loads in the plane of the diaphragm. Connections of the roof to the main lateral system should be designed to transfer the earthquake loads to the rest of the building and provide adequate tying to distribute loads from the roof. Refer to Figure 55.

If **non-structural walls** are provided, particularly using masonry, they should either be **detailed as isolated from the main structure** and have their own integrity under earthquake loading or considered **explicitly as part of the lateral system** in the design. Refer to Figure 58 and Figure 59 for an examples. It is a common mistake for these walls to be considered as an afterthought in the design and not reviewed by the structural engineer. This can result in changes to the global behaviour of the buildings (if the walls stiffen the building and/or create vertical irregularities) which can lead to soft storey collapse or danger to occupants from locally damaged or collapsed masonry walls.

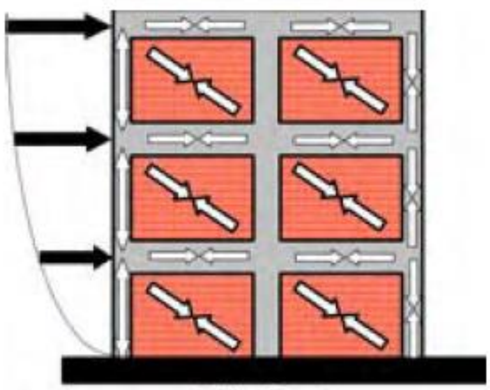


Figure 58 Infill masonry walls acting as part of the main lateral system (EERI, 2006).

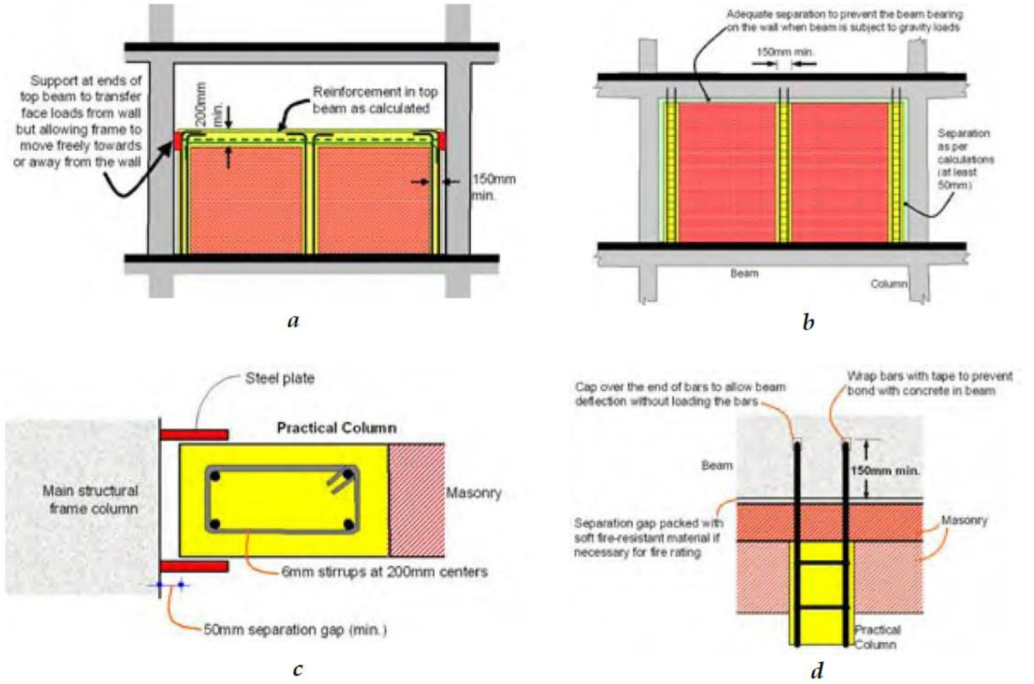


Figure 59 Examples of detailing for masonry infill walls isolated from the main structure (EERI, 2006).

As part of this study, very little information was available on foundation types used in the Kyrgyz construction. For small scale buildings, it is assumed that shallow foundation are most commonly used. In general, it is best practice for **foundations to be designed using a capacity design approach** to limit damage to the foundations from earthquake loading. In other words, the maximum load the super structure will impose on the foundations (from the combination of seismic loads and other imposed loads) should be considered and ensure the foundations have adequate capacity to resist these demands without sustaining significant damage. In areas of moderate to high seismicity, it is recommended that **tie beams are provided** to connect shallow foundations (such as pad footings) to ensure the foundation is well tied together under earthquake loading and acts as a unit. Refer to Figure 60 below.

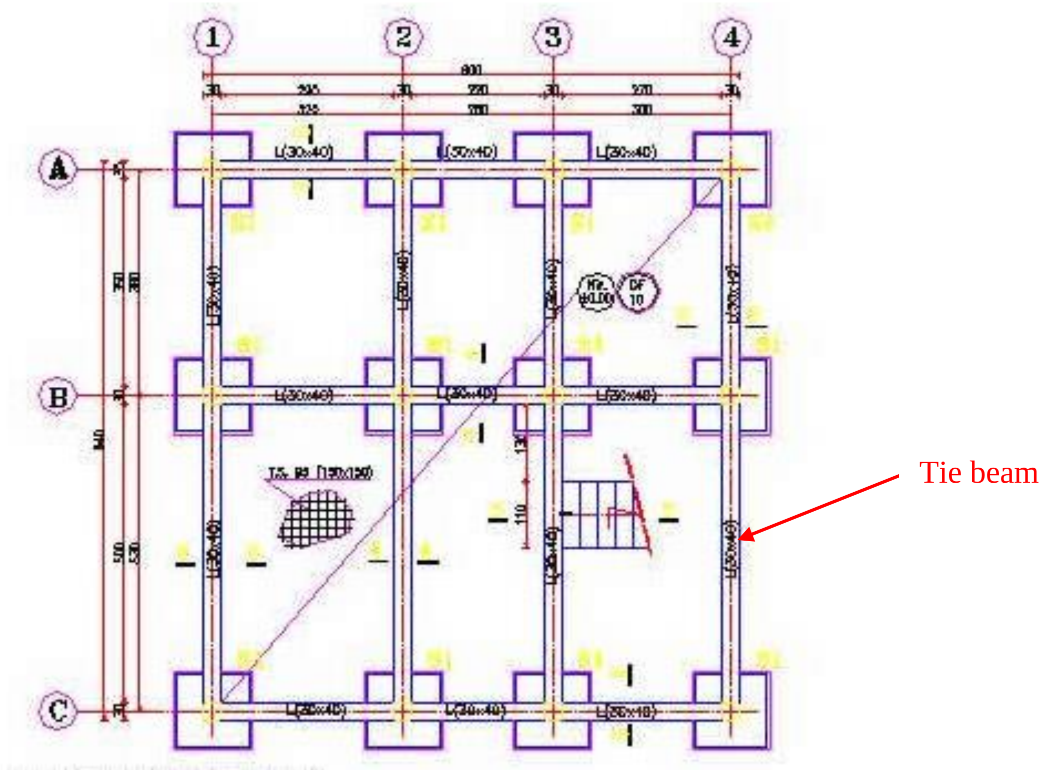


Figure 60 Example of pad foundations with tie beams (World Housing Encyclopedia, RC Moment Frame Building, Algeria).