Risk-informed Infrastructure planning Central Asia Pilot in Kazakhstan and Kyrgyz Republic

Asia-Pacific Information Superhighway (AP-IS) Working Paper Series

UNITED NATIONS ESCAP
Economic and Social Commission for Asia and the Pacific

Resilient Infrastructure planning in Central Asia: Pilot of sub-national average annual loss in infrastructure in Kazakhstan and Kyrgyz Republic[1]

[1] Cover Page: Trans-loading of containers at Khorgos – Eastern Gates SEZ ©MFA Kazakhstan. Image source: Murat Status and Prospects of Creating Dry Port in Khorgos – Eastern Gates SEZ available at: http://mfa.gov.kz/en/content-view/murat-bajmuhanbetov-sostoanie-i-perspektivy-sozdania-suhogo-porta-na-baze-sez-horgos-vostocnye-vorota

The Economic and Social Commission for Asia and the Pacific (ESCAP) serves as the United Nations' regional hub promoting cooperation among countries to achieve inclusive and sustainable development. The largest regional intergovernmental platform with 53 member States and 9 associate members, ESCAP has emerged as a strong regional think tank offering countries sound analytical products that shed insight into the evolving economic, social and environmental dynamics of the region. The Commission's strategic focus is to deliver on the 2030 Agenda for Sustainable Development, which it does by reinforcing and deepening regional cooperation and integration to advance connectivity, financial cooperation and market integration. ESCAP's research and analysis coupled with its policy advisory services, capacity building and technical assistance to governments aim to support countries' sustainable and inclusive development ambitions.

The shaded areas of the map indicate ESCAP members and associate members.

Disclaimer: The Asia-Pacific Information Superhighway (AP-IS) Working Papers provide policy-relevant analysis on regional trends and challenges in support of the development of the Asia-Pacific Information Superhighway (AP-IS) and inclusive development. The findings should not be reported as representing the views of the United Nations. The views expressed herein are those of the authors. This working paper has been issued without formal editing, and the designations employed and material presented do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Correspondence concerning this working paper should be addressed to the email: escap-ids@un.org.

Contact:
ICT and Development Section
Information and Communications Technology and Disaster Risk Reduction Division
United Nations Economic and Social Commission for Asia and the Pacific
United Nations Building
Rajadamnern Nok Avenue
Bangkok 10200, Thailand
Email: escap-ids@un.org

Acknowledgements

This report is part of the DA 11 project, RECI. The report was prepared by Prakriti Naswa and Madhurima Sarkar-Swaisgood under the guidance of Sanjay Kumar Srivastava, Chief, Disaster Risk Reduction Section and Atsuko Okuda, Chief, ICT Section in the ICT and Disaster Risk Reduction Division. Channarith Meng and Aida Karazhanova of ESCAP provided substantive inputs to the document and considered inputs of Salma Abbasi of E-Worldwide Group.

The average annual loss datasets used in this report are from the probabilistic risk analysis undertaken by the Risk Nexus Initiative led by Andrew Maskrey with Omar Mario Cardona, Mabel Marulanda, Paula Marulanda, Gabriel Bernal, and team.

The report was submitted to the Expert Group Meeting on "Digital Connectivity and E-resilience for Crises Preparedness" of 10 November and published after technical considerations and recommendations from the EGM participants. The report is also translated into Russian with support from SONCA, ESCAP.

The cover page and formatting were done by Sakollerd Limkriangrai of IDD, ESCAP.

18 November 2020

Contents

List of Figures, Tables, Boxes and Maps 5

Abbreviations 8

Glossary 9

1. Introduction 11

2. Estimating hazard risks to infrastructure 11

2.1. Concepts 11

2.2. Need for risk estimates 12

2.3. Risk modelling 13

2.4. Climate change context 14

2.5. Uncertainty and infrastructure decision making 15

3. Need for risk informed decision making 16

4. Methodology for risk modelling 18

4.1. Hazard estimation – Probabilistic approach 18

4.2. Estimating Exposure 19

4.3. Vulnerability Estimation 20

4.4. Risk metrics 21

4.5. Map Overlays 22

5. Uses of Risk Metrics 22

6. Central Asia Riskscape 27

6.1. Central Asia Pilot 27

6.2. Risk Profile of Central Asia 28

7. Country Results: Kazakhstan 30

7.1. Multi-hazard AAL and Infrastructure 31

7.2. Earthquake AAL and Infrastructure 36

7.3. Flood AAL and Infrastructure 40

7.4. Risk metrics and development indices 45

8. Country Results: Kyrgyz Republic 47

8.1. Multi-hazard AAL and Infrastructure 49
8.2. Earthquake AAL and Infrastructure 52
8.3. Flood AAL and Infrastructure 56
8.4. Risk metrics and development indices 61
9. Conclusion and ways forward 63
Bibliography 65
Annex 1: Open Source Databases 68

List of Figures, Tables, Boxes and Maps

Figure 1: Climate change 15
Figure 2: Economic cost: Asia-Pacific has lost $1.3 trillion due to natural disasters (1970-2016); EM-DAT 17
Figure 3: Stochastic series of a hazard 19
Figure 4: Risk Modelling 21
Figure 5: Risk Metrics 22
Figure 6: Loss exceedance curve - pushing the risk frontier 23
Figure 7: Exposure vs. vulnerability 24
Figure 8: Comparing adaptation options 25
Figure 9: AAL Disaggregated in North and Central Asia Countries 28
Figure 10: Scatter Plot for North and Central Asia Countries comparing Total AAL per capita and Total AAL as a percentage of GDP 29
Figure 11: (a) Exposed Value and (b) AAL Disaggregated for Kazakhstan 31
Figure 12: Provincial multi-hazard AAL to capital stock ratio for Kazakhstan 32
Figure 13: Provincial earthquake AAL to capital stock ratio for Kazakhstan 36
Figure 14: Provincial flood AAL to capital stock ratio for Kazakhstan 40
Figure 15: DRDIi values for Kazakhstan 45
Figure 16: DRDIi values across Asia and the Pacific 45
Figure 17: Holistic risk value for Kazakhstan 46
Figure 18: Holistic Risk values across Asia and the Pacific 46
Figure 19: (a) Exposed Value and (b) AAL Disaggregated for Kyrgyz Republic 48
Figure 20: Provincial multi-hazard AAL to capital stock ratio for Kyrgyz Republic 49
Figure 21: Provincial earthquake AAL to capital stock ratio for Kyrgyz Republic 53
Figure 22: Provincial flood AAL to capital stock ratio for Kyrgyz Republic 57

Figure 23: DRDIi values for Kyrgyz Republic 61
Figure 24: DRDIi values across Asia and the Pacific 61
Figure 25: Holistic Risk Values for Kyrgyz Republic 62
Figure 26:Holistic Risk values across Asia and the Pacific 62

Table 1: Estimated Average Annualised Losses over Total Investment, Asia Pacific Region (UNESCAP, 2019b) 13
Table 2 Baseline Infrastructure Investment Needs by Region 2016-2030 (USD billion at 2015 prices); ADB 2017 17
Table 3: Infrastructure Investments by Region, 2016–2030 (billion USD, in 2015 prices) 29
Table 4: Central Asia's infrastructure investment needs in Power, Transport, Telecom, WASH (ADB, 2015), billion USD 30
Table 5: Provincial multi-hazard AAL for the Kazakhstan and its contribution to total AAL 32
Table 6: Energy infrastructure across Kazakhstan in different multi-hazard risk categories 33
Table 7: ICT Infrastructure across Kazakhstan in different multi-hazard risk categories 34
Table 8: Road Infrastructure across Kazakhstan in different multi-hazard risk categories 35
Table 9: Provincial earthquake AAL for the Kazakhstan and its contribution to total AAL 36
Table 10: Energy infrastructure across Kazakhstan in different earthquake risk categories 37
Table 11: ICT infrastructure across Kazakhstan in different earthquake risk categories 38
Table 12: Road infrastructure across Kazakhstan in different earthquake risk categories 39
Table 13: Provincial flood AAL for the Kazakhstan and its contribution to total AAL 41
Table 14: Energy infrastructure across Kazakhstan in different flood risk categories 42
Table 15: ICT infrastructure across Kazakhstan in different flood risk categories 43
Table 16: Road infrastructure across Kazakhstan in different flood risk categories 44
Table 17: Provincial multi-hazard AAL for the Kyrgyz Republic and its contribution to total AAL 49
Table 18: Energy infrastructure across Kyrgyz Republic in different multi-hazard risk categories 50
Table 19: ICT infrastructure across Kyrgyz Republic in different multi-hazard risk categories 51
Table 20: Provincial earthquake AAL for the Kazakhstan and its contribution to total AAL 53
Table 21: Energy infrastructure across Kyrgyz Republic in different earthquake risk categories 54
Table 22: ICT infrastructure across Kyrgyz Republic in different earthquake risk categories 55
Table 23: Road infrastructure across Kyrgyz Republic in different earthquake risk categories 56
Table 24: Provincial flood AAL for the Kyrgyz Republic and its contribution to total AAL 57
Table 25: Energy infrastructure across Kyrgyz Republic in different flood risk categories 58
Table 26: ICT infrastructure across Kyrgyz Republic in different flood risk categories 59

Table 27: Road infrastructure across Kyrgyz Republic in different flood risk categories 60

Box 1: Dimensions of Resilience Infrastructure 26

Map 1: Kazakhstan – Multi-Hazard AAL/ ‰ of capital stock and energy infrastructure 33
Map 2: Kazakhstan – Multi-hazard AAL/ ‰ of capital stock and ICT infrastructure 34
Map 3: Kazakhstan – Multi-Hazard AAL/ ‰ of capital stock and road infrastructure 35
Map 4: Kazakhstan – Earthquake AAL/ ‰ of capital stock and energy infrastructure 37
Map 5: Kazakhstan – Earthquake AAL/ ‰ of capital stock and ICT infrastructure 38
Map 6: Kazakhstan – Earthquake AAL/ ‰ of capital stock and road infrastructure 39
Map 7: Kazakhstan – Flood AAL/ ‰ of capital stock and energy infrastructure 41
Map 8: Kazakhstan – Flood AAL/ ‰ of capital stock and ICT infrastructure 42
Map 9: Kazakhstan – Flood AAL/ ‰ of capital stock and ICT infrastructure 44
Map 10: Priority areas from socio-economic stressors in Kazakhstan 47
Map 11: Kyrgyz Republic – Multi-Hazard AAL/ ‰ of capital stock and energy infrastructure 50
Map 12: Kyrgyz Republic – Multi-Hazard AAL/ ‰ of capital stock and ICT infrastructure 51
Map 13: Kyrgyz Republic – Multi-Hazard AAL/ ‰ of capital stock and Road infrastructure 52
Map 14: Kyrgyz Republic – Earthquake AAL/ ‰ of capital stock and energy infrastructure 54
Map 15: Kyrgyz Republic – Earthquake AAL/ ‰ of capital stock and ICT infrastructure 55
Map 16:Kyrgyz Republic – Earthquake AAL/ ‰ of capital stock and Road infrastructure 56
Map 17: Kyrgyz Republic– Flood AAL/ ‰ of capital stock and energy infrastructure 58
Map 18: Kyrgyz Republic – Flood AAL/ ‰ of capital stock and ICT infrastructure 59
Map 19: Kyrgyz Republic – Flood AAL/ ‰ of capital stock and Road infrastructure 60
Map 20: Priority areas from socio-economic stressors in Kyrgyz Republic 63

Abbreviations

AAL	Average Annualised Loss
ADB	Asian Development Bank
DREIi	Disaster Risk Economic Implications Index
DRFIi	Disaster Risk Implications on Development Index
DRSIi	Disaster Risk Social Implications Index
ECLAC	Economic Commission for Latin America and the Caribbean
GDP	Gross Domestic Product
HDX	Humanitarian Data Exchange
ICT	Information and Communication Technology
IPCC	Intergovernmental Panel on Climate Change
LEC	Loss Exceedance Curve
SRES	Special Report on Emissions Scenarios
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNISDR	United Nations Office for Disaster Risk Reduction
WASH	Water, Sanitation and Hygiene

Glossary[2]

Average Annualised Loss
It is the estimated average loss annualised over a long time period considering the full range of loss scenarios relating to different return periods

Capital Stock
In reference to this report, capital stock is used to denote the total value of commercial and residential buildings, schools and hospitals in each country.

Damage
Damage is a generic term, which is not necessarily quantified, though it does not mean that damage cannot be measured and expressed as a loss.

Direct Disaster Losses
Direct disaster losses refer to damage to human lives, buildings, infrastructure and natural resources.

Exposure
is used to refer to the location of people, production, infrastructure, housing and other tangible human assets in hazard-prone areas.

Extensive Risk
Extensive risk is used to describe the risk of low-severity, high-frequency disasters, mainly but not exclusively associated with highly localized hazards.

Hazard
It refers hazardous phenomena or physical perils such as floods, storms, droughts, earthquakes, tsunamis etc.

Indirect Disaster Losses
Indirect disaster losses are declines in output or revenue, as a consequence of direct losses or owing to impacts on a supply chain.

Intensive Risk
Intensive risk is used to describe the risk of high-severity, mid to low-frequency disasters, mainly associated with major hazards.

Losses[3]

[2] All definitions from Global Assessment Report on Disaster Risk Reduction 2015 and IPCC Assessment Report 5.
[3] Gall et al. (2014)

losses are quantifiable measures expressed in either monetary terms (e.g., market value, replacement value) for physical assets or counts such as number of fatalities and injuries

Loss Exceedance Curves
A loss exceedance curve shows the probability that loss will exceed some amount within some period of time (usually annually).

Probable Maximum Loss
The probable maximum loss (PML) is the maximum loss that could be expected for a given return period, for example of 250 year.

Resilience
Resilience is used to refer to the capacity of systems (ranging from national, local or household economies to businesses and their supply chains) to anticipate, absorb or buffer losses, and to recover.

Return period
It is the average frequency with which a particular loss is expected to occur.

Risk
Risk represents a probability of loss. It is considered to be a function of hazard, exposure and vulnerability. Disaster risk is normally expressed as the probability of loss of life, injury or destroyed or damaged capital stock in a given period of time.

Vulnerability
Vulnerability is used to refer to the susceptibility of these assets to suffer damage and loss due to socially constructed factors that result in unsafe and insecure conditions in the built and human environments.

Uncertainty
An expression of the degree to which a value or relationship is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. Uncertainty may originate from many sources, such as quantifiable errors in the data, ambiguously defined concepts or terminology, or uncertain projections of human behaviour.

1. Introduction

Stretching from the Caspian Sea in the west to China and in the east, the terrain of central Asia is very diverse. The vast steppes grassland of Kazakhstan, desert of Turkmenistan, Aral Sea drainage basin, mountain ranges of the Tianshan and Karakoram are just a few features that highlight the diversity in region's terrain. Yet the region experiences similarities in the risks from natural disasters. Droughts, earthquakes, glacier lake outburst floods, landslides, and floods constitute key hazards in the region disrupting economic growth, damaging infrastructure, and stalling progress on economic and social indicators. Kazakhstan and Kyrgyz Republic, for example, are located on major earthquake fault lines. Being a landlocked region, the adverse impact of disasters on connectivity has serious implications on the economic performance of the countries. Under these circumstances, central Asian countries must ensure that infrastructure assets are resilient and can withstand impacts of climate change and disasters.

Resilience of critical infrastructure like transportation, energy, and ICTs crucial for sustainable development within central Asia. This report provides an in depth analysis of the complex multi-dimensional disaster risks to energy, transport and ICT infrastructure assets in Kazakhstan and Kyrgyz Republic. The objectives of the report are to provide policymakers with sub-national methodology to examine the cost of future disaster risks on infrastructure, b) locate current infrastructure at risk from multiple natural hazards, and c) present an overall direction for establishing long term resilience approaches.

The report is divided eight sections. The following section provides an overview of concepts of risks, damage and loss, and addressing the need to estimate risks in terms of losses. This section also includes a sub-section on incorporating climate perspective to the infrastructure planning approach. Sections five and six summarize the risk assessment methodology used to develop sub-national risk estimates. Sections seven to nine present the risk estimates within the central Asia region followed by results for Kazakhstan and Kyrgyzstan, respectively.

The methodological approach used goes beyond simple hazard mapping and shows estimated annualized losses based on hazards, exposure, and vulnerability. Through metrics of 'loss exceedance curves', 'probable maximum loss' and 'average annualized loss' the assessment points out to provinces where losses are accentuated due to multiple vulnerabilities. Finally, the report proposes various ways in which the sub-national risk estimates can be used for current and future planning of resilient infrastructure. resilient infrastructure planning.

2. Estimating hazard risks to infrastructure

2.1. Concepts

Conceptually, risks represent a potential for loss or damage to our socio-economic systems. The terms "loss" and "damage" are often used interchangeably. Losses typically refer to quantifiable

measures expressed in either monetary terms (e.g., market value, replacement value) for physical assets or counts such as number of fatalities and injuries. Damage is a generic reference to destruction which is may or may not be quantifiable. Damage to a wall maybe expressed as a loss but delays may not be quantifiable (Gall et al., 2014). In the context of disaster losses, two important categories of risk are intensive and extensive risks. Intensive risks arise from high-severity, mid to low-frequency disasters, mainly associated with major hazards such as earthquakes, tropical cyclones, riverine floods and tsunamis. Extensive risk refers to risks from low severity but high frequency hazardous events (UNESCAP, 2019a).

A related concept here is that of impact. Once a disaster strikes, the direct impact on infrastructure is in the form of complete or partial damage to infrastructure assets and to capital stock such as final goods, goods in process, raw materials, materials, and spare parts. Indirect impact is the impact on the flow of goods that will not be produced or on the services that will not rendered as result of damage to assets and stock. This impact potentially begins from the damage to the asset and unless there are alternative mechanisms, lasts through the reconstruction and replenishment period. Finally, there are cascading impacts on the performance of various economic sectors depending on and linked to the infrastructure.

The risk to infrastructure assets can range from total to partial physical damage or a reduction in overall lifespan of the assets. Infrastructure is a key to socio-economic development and holds special importance in network connectivity for the landlocked central Asia where trade is contingent upon a well-functioning infrastructure system. The medium to long term productivity downswing because of adverse impact of disasters on infrastructure assets can hinder the performance of a country in meeting its economic and sustainable developmental goals.

2.2. Need for risk estimates

Infrastructure has vital linkages to our economic development and in general to our progress on the development pathway. The need is uncontested, huge, and unmet. Additionally, infrastructure is a constrained resource and already strained from stressors like population growth, increasing urbanization, non-optimal resource use, economic growth etc. Apart from being an expensive resource, the need for infrastructure is much greater than the capital investment flowing into the sector. Most infrastructure assets have a long-life span. Therefore, when disasters damage these assets and reduce their life span use, it simply implies that the capital investments are flowing into disasters and not infrastructure led development. A study by the Asian Development bank estimated that $1.7 trillion will be required annually to meet demand for new infrastructure in Asia over the next twelve years (ADB, 2017). Central Asia's public investment in infrastructure stands at 2.6% of the Gross Domestic Product (GDP) and private investment in infrastructure is about 0.3% of GDP (ADB, n.d.). Damage to infrastructure therefore puts a huge investment at risk.

Direct losses can represent a significant proportion of these public investments in infrastructure. Preliminary estimates suggest that about $200 billion of the $1.7 trillion will be needed to ensure that the new infrastructure is resilient to disasters and climate-related events. Considering that

half of the infrastructure needed in Asia by 2050 has yet to be built, safeguarding these investments from being washed away from disasters is pertinent for countries in the region. In order to make risk-sensitive decisions on infrastructure, there is a growing need to understand the physical risks and estimate the value of losses that might occur during disasters.

Table 1: Estimated Average Annualised Losses over Total Investment, Asia Pacific Region (UNESCAP, 2019b)

	Average Annual Loss/ Total Investment (%)
Asia-Pacific	1.9
East and North-East Asia	1.8
North and Central Asia	1.3
South-East Asia	2.8
South and South-West Asia	2.5
Pacific	1.5
Developing countries in the Pacific	18.0

2.3. Risk modelling

To estimate risks, we need to break down risk to its elementary components of hazard, exposure and vulnerability, make estimates of these three components and the pathways of interaction that will constitute risk (GFDRR, 2014). Hazard is the physical manifestation of risk that has the potential to cause harm. Exposure is the degree to which a system is exposed to a hazard. Vulnerability depends on the prevailing, social, economic, political, institutional, and environmental conditions and their combined impact on the system under study. Risk is thus a function of hazard, exposure, and vulnerability.

$$Risk = fn(hazard, exposure, vulnerability)$$

Estimation of hazards requires a very wide range of data to understand the magnitude of damage that is possible due to all possible hazards. The last few decades have witnessed a significant improvement in hazard estimation and many open source data sets are available for use in estimating risks. These improvements are in statistical generation of a catalogue of hazard events that ensure a wide spectrum of hazards is captured irrespective of their historical occurrence.

Similarly, there have been technological improvements in the past which have made it possible to improve estimates for exposure levels. It is possible to have both coarse and fine resolution data for exposure levels from demographic data bases, city plans, satellite data, spatial data on infrastructure at different scales. Many open source data bases such as GeoNodes and Humanitarian Data Exchange (HDX) have made it possible to access satellite data for estimating exposure levels.

Estimations of vulnerability have also improved with greater scientific collaborations, exchange of data and improvement in methodologies. Robustness of vulnerability estimates, however, depend on the availability and quality of data. Socio-economic vulnerability can be assessed from official databases, census and surveys at different scales. Structural vulnerability examines the physical vulnerability of infrastructure to hazards by developing damage functions for every asset category.

2.4. Climate change context

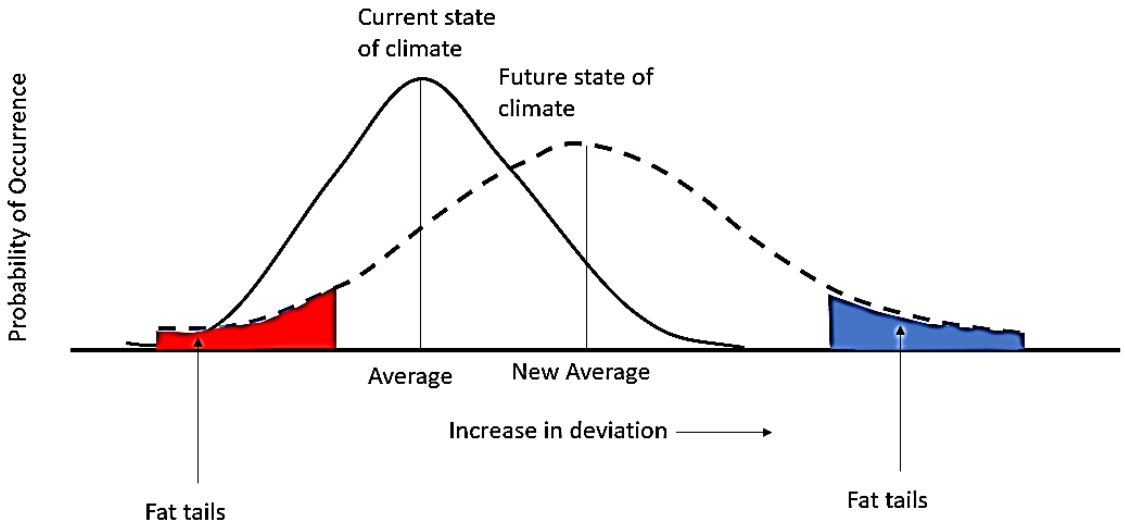
In the context of hazard estimation, factoring in the uncertainty from changing climate is equally important. A key challenge is that the pace of climate change has accelerated tremendously, particularly in the last century, leading to increasingly unaccounted and unanticipated risks from changing patterns of hazards.

According to the IPCC estimates that the CO_2 equivalent concentration in 2011 is estimated to be 430 ppm (uncertainty range 340–520 ppm), which is a significant rise from the estimated pre-industrial value of 280 ppm in 1750 (IPCC, 2014). This has translated into a 0.74°C rise, in the last one century. The fifth assessment report also says that in the baseline scenarios, not having additional mitigation efforts for emission reduction, will result in global mean surface temperature increases in 2100 from 3.7°C to 4.8°C compared to pre-industrial levels. The changes in the stock of GHG emissions in the atmosphere has led to an increased frequency and intensity of climate hazards.

The future state of climate can be explained simplistically through a normal distribution curve[4]. The average for climate variables such as precipitation and temperature has increased and so has the deviation. With regards to temperature, this implies that the mean temperature (say daily maximum temperature) has risen and the number of days with higher temperatures has also increased. The overall shift in the distribution shows higher averages and increase in spread shows greater variance. The higher probability of extremes is represented by the fat tails of the distributions.

[4] This is a pictorial depiction and does not show the probabilities or distribution associated with any climate variable or hazard.

Figure 1: Climate change



The *fat tails* of distributions signify the extremes with significant probabilities also implying that in the long run there is no limit to potential damage from these extremes (Weitzman, 2011). This can be challenging as the climate system can change and react abruptly and without any warning sign that threshold for the system has been ben breached (Stocker, 1999). This has strong implications for investments in infrastructure and the useful life and relevance of existing infrastructure. Even if the policy makers are willing and prepared for a significant increase in infrastructure investments, it is often difficult to project the range of climate events to which infrastructure will be exposed to in future.

2.5. Uncertainty and infrastructure decision making

Predicting a future state of climate is difficult because the past is not a good indicator for the future in climate variables. Most often, projections are made based on future scenarios that do not have any probabilities assigned to them. The risks also arise out of uncertainties in projections of climate hazard. The IPCC defines uncertainty as the degree to which a value is unknown. Fundamentally, uncertainty exists because of altered patterns of climate variables. Uncertainty in projections also increases due to downscaling. Global circulation models typically have coarse resolutions, which must be downscaled at finer resolutions for local contexts by making assumptions. These assumptions add to the uncertainty. Therefore, for a decision maker, there is a wide range of projections, and thus a wide range of potential impacts to include while making decisions on infrastructure investments.

Infrastructure sector is a challenging sector for decision makers *first* because of the magnitude of investments; resilient infrastructure needs additional investment. *Second* the lock ins that result from the life span of infrastructure means that the decision taken now should withstand a long period of time. *Finally*, because infrastructure is crucial to socio-economic systems, the stakes involved are high. The challenge for policy makers is that they have to make infrastructure

decisions now, amidst future uncertainty, for assets that are critical to economic development, where the lock in period can be anything from 50-100 years and the socio-economic stakes are high.

Hallegatte et al. (2007) has given a very simple and apt example to explain this. Their work shows that the future climate of Paris in 2080 under Special Report on Emissions Scenarios (SRES) A2 scenario (SRES A2 is closer to the RCP 8.5 pathway) could become the current climate of Cordoba (south of Spain). The implications are that even for a building that is constructed in 2010 to last 80 years, should face the current climate of Paris and be equipped for dealing with climatic conditions of present-day Cordoba's in 80 years. This is just one possible scenario; multiple scenarios give a much wider range making it difficult to make decisions now.

Making infrastructure compatible for a much wider range of future disasters in the long run is an extremely expensive option. It is relatively easier to prepare for averages. For instance, the infrastructure can be designed to deal with an increase in mean temperatures over a period. However, this increase in averages will be accompanied by increase in extremes as well. In terms of actual physical impact, the losses do not follow the trend of increase in averages. If the wind speed of tropical storm increases by 10% the losses will not go up by 10%, they increase at a much greater magnitude. This has important implications for how we make infrastructure decisions for future.

3. Need for risk informed decision making

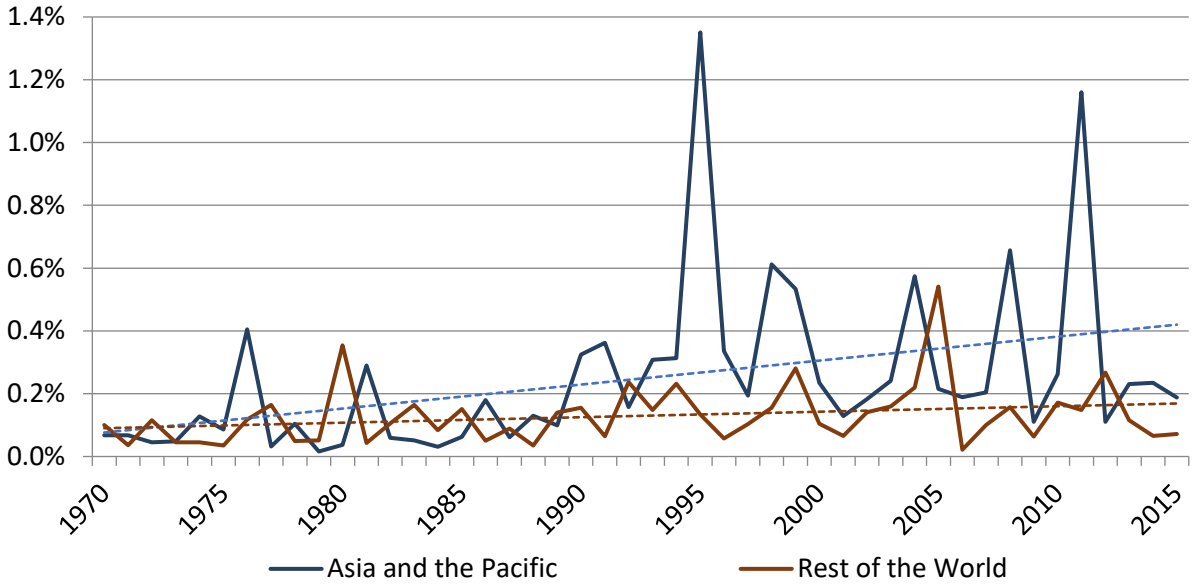
In the Asia pacific region, the investment gap for the period 2016-2030 just in the transport, ICT and Water, Sanitation and Hygiene (WASH) infrastructure is USD 196 billion (UNESCAP, 2019b). The investment gap for landlocked countries in the region is estimated to be 3.03 % of their GDP. In the transport sector for example, which is critical for the landlocked central Asia, the new demand is estimated to 1% be of the GDP and its maintenance is an additional 1.22% of the GDP. All these numbers point to a significant need for investments in central Asia in the coming years. Many of the infrastructure assets in the central Asian region need major upgradation to match the economic demands and the need for resilience.

The economic losses due to disasters are also high and projected to increase in absence of active resilience measures. The estimated average annualized losses for the world are about USD 293 billion for rapid-onset hazards. This itself represents 5% of expected annual global investment in infrastructure. Including losses by slow onset disasters will increase this number significantly. The table below estimates central Asia's infrastructure investment needs at USD 492 billion. This does not include estimates for climate or disaster adjustments which will be an additional mark-up to these baseline estimates. In central Asia, capital investment rates i.e. the ratio of GFCF to GDP has increased from 3.3% of GDP to 5.4% of GDP from 2005 to 2011. Therefore, there are significant stakes involved while at the same time the historical loss does not show a promising picture either.

Table 2 Baseline Infrastructure Investment Needs by Region 2016-2030 (USD billion at 2015 prices); ADB 2017

	Investment Needs	Annual Average	Investment Needs as % of Projected GDP
Central Asia	492	33	6.8
East Asia	13,781	919	4.5
South Asia	5,477	365	7.6
South East Asia	2,759	184	5.0
The Pacific	42	2.8	8.2
Asia & the Pacific	22,551	1,503	5.1

Figure 2: Economic cost: Asia-Pacific has lost $1.3 trillion due to natural disasters (1970-2016); EM-DAT



In Kazakhstan, for example, floods and earthquakes are dominant hazards. The floods of 2010 were extremely damaging and apart from loss of life caused, the estimated direct damage was close to USD 40 million. The floods of 1993 and 2008 caused an estimated direct damage of USD 70 million and USD 100 million respectively (GFDRR, 2017a). The direct disaster economic loss (annual loss for 2017) was USD 12.3 million in Kazakhstan.

Kyrgyz Republic also shares a similar terrain to Kazakhstan. Avalanches, droughts, earthquakes, floods, and land and mudslides are the main disasters. The country experiences on an average 200 of such emergencies which affect about 200,000 people leading to losses amounting to $30-35 million totalling 1–1.5 percent GDP (GFDRR, 2015). The annual average of 300 earthquakes often damage the vulnerable housing complexes that are not designed to the needs of an earthquake prone zone and lead to annual losses of USD 8 million. Two-third of the country's

population lives in houses that are not earthquake resilient. There are close to 5,000 identified landslide sites. Evert year about 3-4 mudslides occur because of heavy precipitation in the country. Adding to the existing risk is the changing climate putting the country at risk from hazards such as intense flooding GLOFs from its 8500 plus glaciers (GFDRR, 2017b). The direct disaster economic loss (annual loss for 2017) was USD 0.286 million in Kyrgyz Republic.

The need of the hour is not just in risk assessments, but also incorporating metrics that help bridge the gap between technical and scientific assessments and the information needs for policy makers. Policy planning process, both near and long term, need to incorporate assessments of future risk to infrastructure while making planning decisions. These risk assessments go beyond simple hazard maps but must involve a careful evaluation of the vulnerability and exposure of the infrastructure assets in the region in order to support structural transformation of infrastructure planning and implementation to be in line with supporting and achieving sustainable development goals.

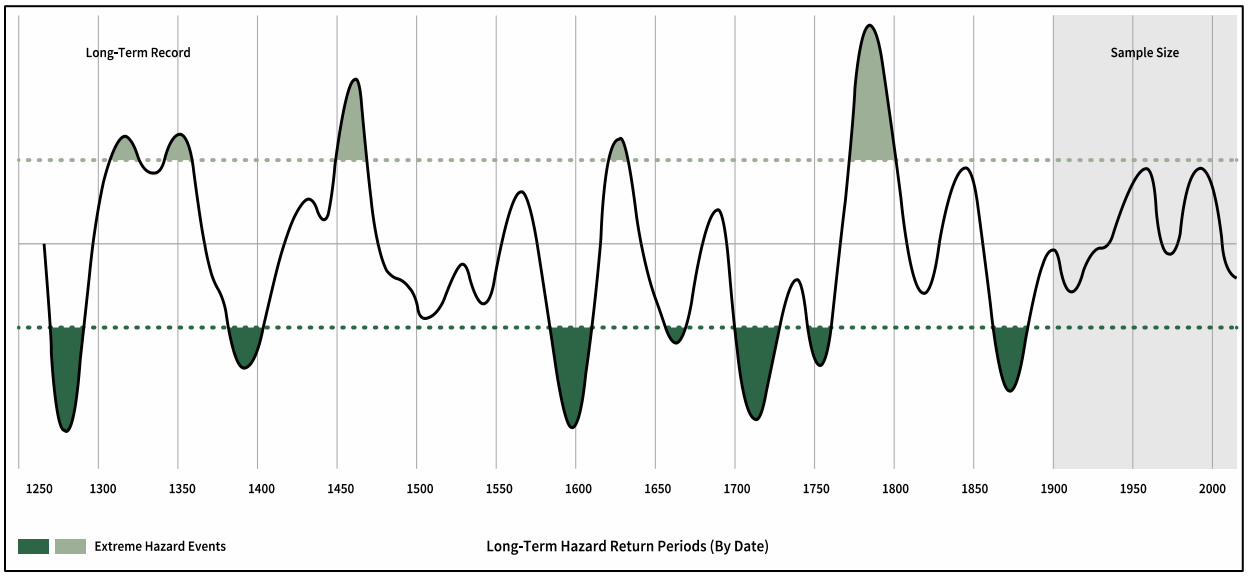
4. Methodology for risk modelling

The risk metric of 'Average Annualized Loss' (AAL) is one metric that captures the economic and social risk scape of a location. The methodology for estimating global average annualised loss was first adopted by the Global Assessment Report of 2015 (UNISDR, 2015). The AAL can in simple words be defined as an accumulating contingent liability and indicates the amount that a country should set aside annually to cover its disaster losses in the long run (Seo & Mahul, 2009). The AAL and other risk metrics from the global risk model have been downscaled to prepare a multi-hazard risk profile for Kyrgyz Republic and Kazakhstan. A special sectoral assessment for drought, a slow onset disaster, and its economic impact on agriculture sector is also pursued for Kazakhstan. These provincial assessments have wider applications for infrastructure planning. Risk modelling implies making estimates of all the three components of risks, i.e. hazards, exposure and vulnerability and then looking at all possible combinations of these three variables.

4.1. Hazard estimation – Probabilistic approach

Estimating hazards begins with determining whether to take a single hazard approach or a multi-hazard approach of hazard under consideration. Next step is to consider the cascading effect of hazards such as a tsunami after the earthquake. Once the primary hazards are identified, hazard related data is collected. Understanding of historical events, their geographic impact, intensity helps in assessing the damage potential of the hazard. Hazards are simulated using a probabilistic approach that computationally generates a stochastic set of events consistent with the statistical characteristics of historical hazards. A future hazard series going into 1000s of future years using random sampling method is generated. The idea is to simulate all the potential events that can occur in the long run. This stochastic series is subsequently used to assess loss probabilities and overall risks from these hazards.

Figure 3: Stochastic series of a hazard



Historical data on losses is a useful guide for interpretation of the risks. However, historical data on hazards alone is not adequate to guide the future estimation of hazards. The usefulness of historical data in pursuing such risk estimates is independent of the length of time of historical data available. Even if good quality weather records are available for 50-100 years, they will not tell us about the extreme events that can occur in future. This is because a data set of 50-100 years will not capture events that have a high return period or events that have possibly occurred in the last 1000 years or the nature of their extreme i.e. whether they were on the drier side of the extreme or the wetter side of extreme in case of precipitation. Extreme events happen over a longer period. In simple terms, this means that their return period is much longer for example 500 years or 1000 years. From the climate perspective, the means and variances are changing, historical data cannot capture these changes. As a result, risk estimates that are based on historical data have limitations for incorporation into policy planning. A probabilistic approach that uses random sampling methods and investigates all possible events that can happen in future is therefore a more suitable approach for risk estimation. The fundamental basis here is that most of the disasters that can happen in future may not have happened yet, because of their high return periods and hence simple trend analysis underestimates the potential risks that these hazards pose.

4.2. Estimating Exposure

Exposure looks into all the elements that are susceptible to a hazard. If the hazard occurs in an area with no exposure, typically people, assets and ecosystem, there is no risk. A corollary is that occurrences of hazards such as the tsunami pose no direct risk to a landlocked country. Exposure

modelling is possible at various scales. It can be at a small scale or a higher resolution looking at a certain category of infrastructure assets in a well-defined geographic area or it can be at a larger scale with a big geographic area. Depending upon the assessment need, the large-scale exposure mapping can be both at a coarse and a fine resolution. The approaches for estimation of exposed assets can be top down which typically employs statistical downscaling; and bottom up which often needs triangulation and validation from ground data. At a national scale, typically country level data inventories and spatial data is used. Crowdsourcing is becoming hugely popular to source local scale high resolution data. Census and other demographic databases provide information on human life in risk prone regions.

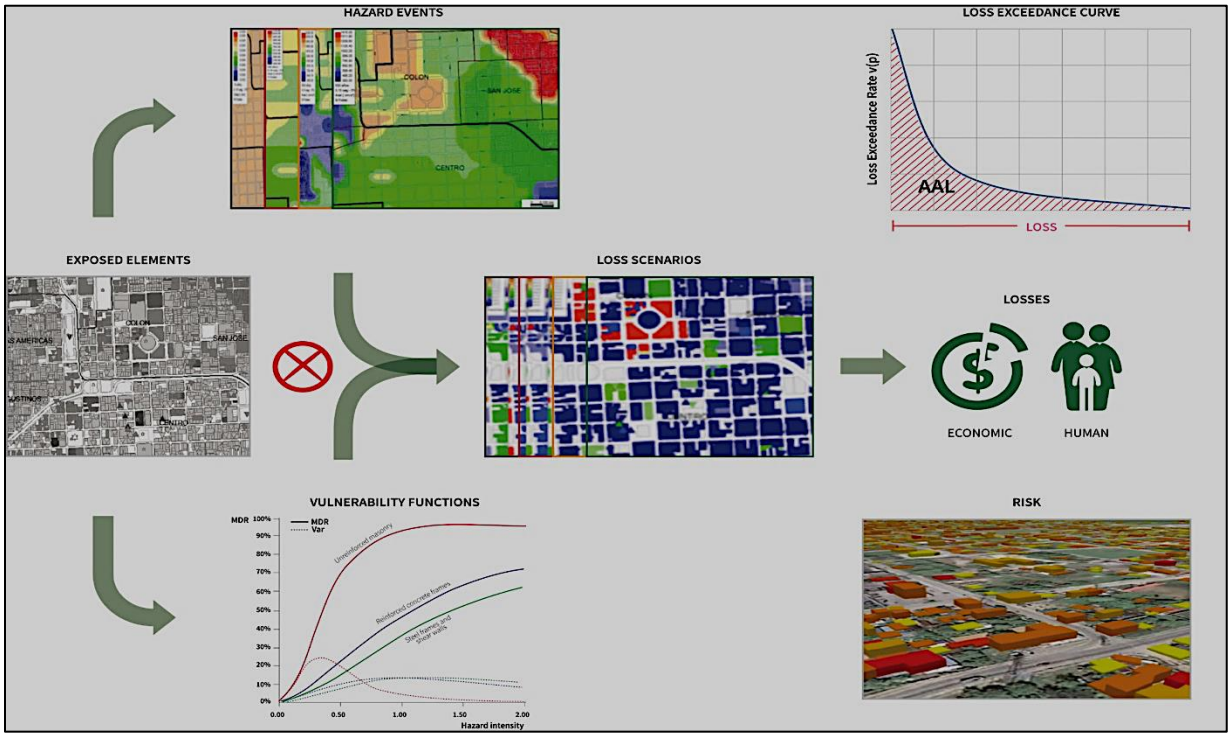
4.3. Vulnerability Estimation

The hazard modelling uses a probabilistic approach is used for hazard modelling. The vulnerability estimation uses damage functions to assess the impact of these hazards on the exposed assets. This is the estimation is deterministic and will provide assessment of damage to infrastructure assets, mortality, and economic loss from a single hazard scenario. Here the hazards under consideration are rapid onset hazards[5]. Hazard sets for slow onset hazards such as droughts, typically use deterministic approaches over probabilistic ones.

Vulnerability assessment makes use of mean damage ratios to assess the damage to different categories of infrastructure assets at various intensity levels of hazards is estimated. This also includes the best and the worst-case scenarios. The hazards, exposure and the vulnerability of the exposed elements to hazards are combined to generate thousands of loss scenarios. Therefore, loss scenarios are created for each of the exposed elements for all levels of vulnerability to a stochastic series of hazards. The losses can be direct economic losses or loss of life i.e. human causalities. The entire approach for risk modelling is summarized in the following figure.

[5] Floods, earthquake, tsunami, tropical cyclones are examples of rapid onset hazards. Drought is an slow onset hazard.

Figure 4: Risk Modelling

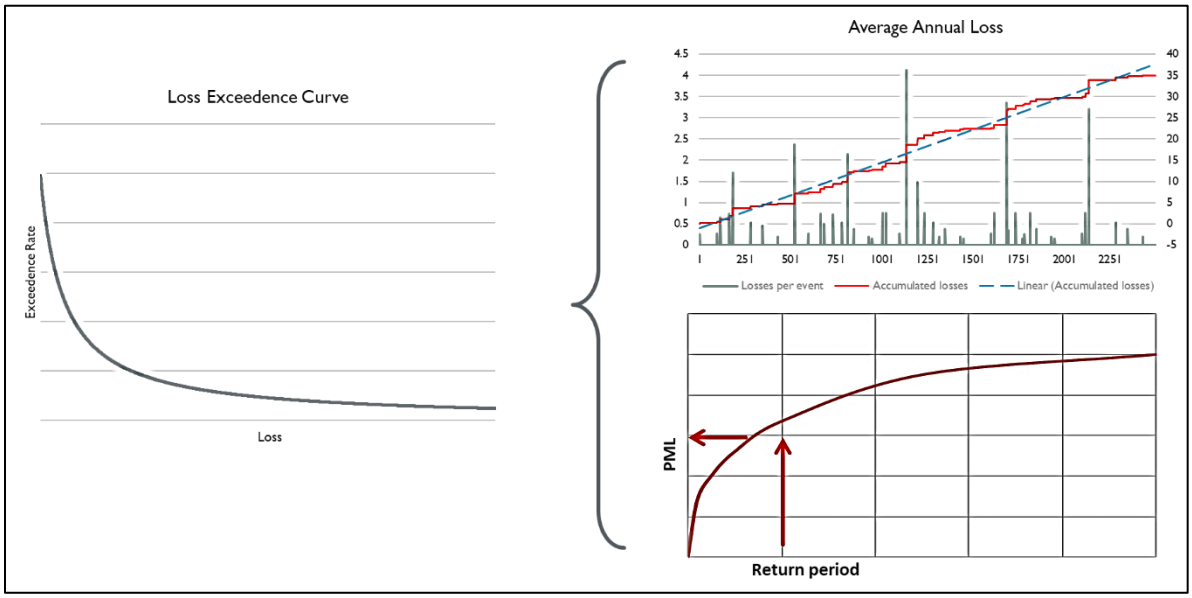


4.4. Risk metrics

An aggregate level assessment of these scenarios provides us with information to develop loss exceedance curve. The loss exceedance curve provides all the likely future levels of losses and the related probabilities attached to the losses. Two related metrics derived from this aggregate assessment is of average annualized loss and probable maximum loss. The loss exceedance curve (LEC) describes the annual frequency of occurrence for different loss values (Seo & Mahul, 2009). The inverse of a loss exceedance curve is the annual rate of the loss corresponds to its return period. The probable maximum loss (PML) is a risk metric that represents the maximum loss that could be expected, on an average, within a given number of years.

Average annualized loss is the expected loss per annum associated to the occurrence of future perils assuming a very long observation timeframe. It should not be confused with what an economy lost to disasters last year or what an economy is expected to lose to disasters the next year. It is simply an average derived from losses modelled for all combinations of hazards, exposure, and vulnerability. Some years have higher losses, some years have lower losses, and some years do not have losses at all. These losses can be modelled in economic terms as replacement costs or market value and as loss to life in terms of human causalities.

Figure 5: Risk Metrics



4.5. Map Overlays

The final step in the methodology to assess the risks for infrastructure is to overlay risk assessments on the infrastructure elements. This is a deterministic approach i.e. the outcomes are precisely determined through known relationships among states and events. The risk assessments give us metrics like average annualised loss, which in one number provide an estimate of risk at a specific location. Depending upon the scale of assessment, there may be an added level in the methodology to downscale or to upscale these metrics at a desired scale. Once the risk metrics are known, they can be charted on a map. Overlaying infrastructure elements on risk, shows different categories of infrastructure are exposed to different hazard risks. Mapping infrastructure on a metric like ratio of AAL to capital stock also gives locations where vulnerability concentrated.

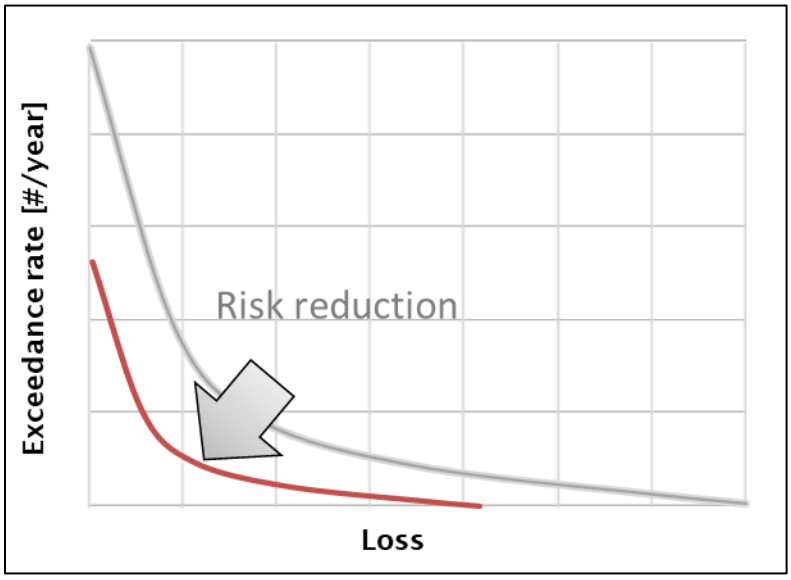
5. Uses of Risk Metrics

Hazard assessments often do not give a complete picture of the riskscape of a location. Therefore, assessments are needed for risks, which entails incorporating estimates of vulnerability, hazard and exposure components to get an overall risk picture. From a policy making perspective, estimation of risks is essential for decision making. At the same time, the metrics used for risk assessment should also be easy to understand and track over period of time. The metric of average annualised loss in one number gives an overall picture of risk for a location in terms of economic damage or potential causalities. It is easily trackable over a period of time and can be used for comparative assessment among locations, different asset categories and as

ratios with other investment patterns. For this project, the assessments have been done at a provincial scale and subsequently studied in the context of risks for key energy, transport, and ICT infrastructure. This makes the metrics relevant for both policy planning at a national and a provincial scale. Some of the possible ways that policy makers can use this metric are as follows:

1) Budget Allocation: The 'average annualised loss' conceptually is the average of all losses associated with a series of potential hazards that are modelled stochastically. From a budgetary perspective, this is the amount that should be set aside annually to cover up for expected disaster losses. The AAL in one number gives an estimate of the financing gap. Therefore, estimates of AAL can be used to guide budgetary allocation from different sources to ensure the expected losses are covered. At a provincial level, a lot of local planning and integration of risks into public and private investments can be facilitated through AAL. In addition, if the AAL numbers are high, the government can determine a strategy to engage in more individual, cooperative, and corporate sector private investments for resilient infrastructure.

Figure 6: Loss exceedance curve - pushing the risk frontier

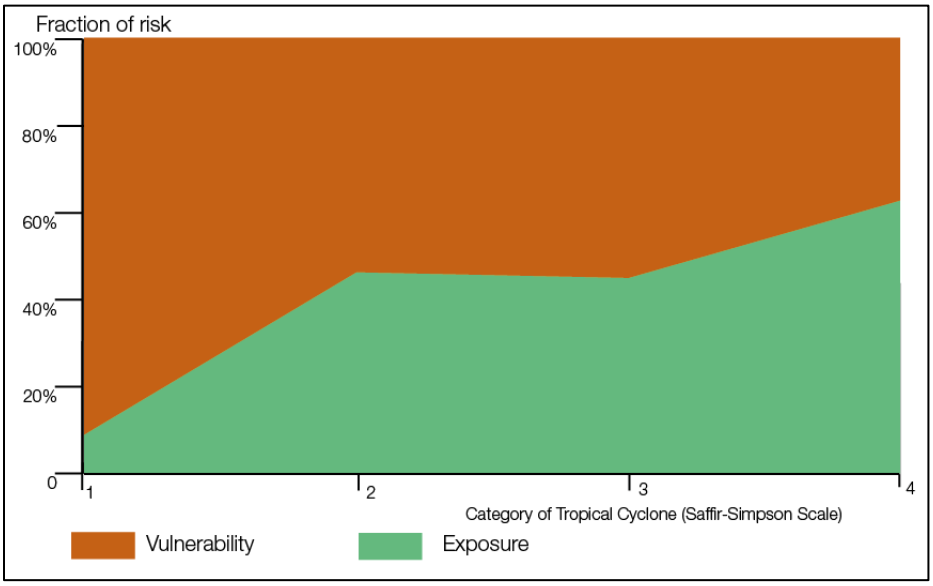


2) Resilience targets: AAL numbers are trackable. This means that over a period, the government can check progress on their policy interventions on the overall resilience of the sector or location. Policy makers find it easier to define resilience targets with risk metrics like AAL and Loss Exceedance curves. Let's take a hypothetical example to understand this. Suppose the estimated AAL was 20 million for a region but after 5 years of active policy interventions the AAL reduces to 15 million. Therefore, it gives policy makers an estimate of progress that they have made. In this specific example, the effectiveness of policy interventions resulted in a 25% reduction in risks. Similarly, the loss exceedance curves give a frontier that need to be pushed lower for increasing the resilience. The area under the loss exceedance curve the summation of average annualised loss.

3) Vulnerability vs. Exposure: The actual losses can happen for various reasons. In the context of infrastructure, the losses may happen because the infrastructure does not conform to hazard parameters of the location or it could be that the intensity of the hazard is beyond

normal estimates. The former is a case of non-resilient infrastructure or vulnerability that can be reduced with proper investments. However, beyond a point as intensity of hazard increases, it becomes increasingly complicated and expensive to reduce vulnerability. For instance, if a building must be made earthquake resilient, there are limits to its tolerance to earthquake. Let us say it can be retrofitted and then subsequently can deal with earthquakes of intensity 8 on Richter scale. However, making the building resilient enough to tolerate earthquakes beyond 8 on Richter scale may be very expensive. In which case, the approach may be to ensure resilience until 8 Richter scale and accept the impact of anything that exceeds 8. The Japanese tsunami witnessed +3-6 meters of waves because of an earthquake intensity 9.1. Even though the country actively prepares for tsunamis, the event was unprecedented and the consequences of which had to be absorbed.

Figure 7: Exposure vs. vulnerability



For infrastructure, the ratio of AAL to capital stock gives locations where vulnerability is confined. Theoretically, one would expect a fair degree of correlation between AAL and capital stock. This is because, losses will happen only where there is capital stock and where there is more capital stock, the absolute value of AAL will also be high. Higher ratios point to locations where annualised losses are disproportionately concentrated in comparison to the concentration of capital stock. These are hotspots for vulnerability concentration where investments should be channelized for reducing the vulnerability and making infrastructure more resilient to disasters. This ratio therefore is very useful from a risk management perspective where drivers of vulnerability can be targeted for increasing the resilience of infrastructure assets. Box 1 provides various conceptual dimensions of resilient infrastructure.

4) Comparative indicators: We can use these national and provincial assessments for understanding the path of the country on the sustainable development front. Looking at the AAL expenditure in comparison to a country's expenditure on capital or social investment gives estimates of the effective flow of investments. A higher AAL to capital or social investment shows that the effective investment in development is low. Some common indicators for comparison are

a. AAL and Social Expenditure
b. AAL and GFCF
c. AAL and Gross Savings
d. AAL to reserves
e. AAL to produced capital or capital stock

A composite index called Disaster Risk Implications on Development Index (DRDIi) is an average of Disaster Risk Economic Implications (DREI), Disaster Risk Growth and Financial Implication (DRGI) which is an average derived from ratio of AAL to GFCF and AAL to Gross Savings, and Disaster Risk Social Implications (DRSI). Similarly, a holistic risk index can give an idea of risk accumulation over time through a range of underlying risk drivers. These risk drives increase the impact of physical risk in a socio-economic system. Cardona (2001) in his thesis proposed the concept of aggravating factors or the underlying risk factors that increase the impact of physical risk. These variables can be used to develop a holistic risk index and compare different regions.

5) Comparing adaptation options: One advantage of sub regional assessments is that they can be used to design a localised package of resilience measures that strikes a good balance between reduction in AAL and the investment needed to implement the package. At a more local scale or fine resolution, the AAL numbers can help choose among various adaptation options. For instance, the metric can be used while determining whether a sea wall of 2 meter with an investment of USD 20 million reducing an AAL of 5 million or 2.5 meter with an investment of USD 35 million reducing an AAL of 10 million or 3 meter with an investment of 60 million reducing an AAL of 15 million is needed.

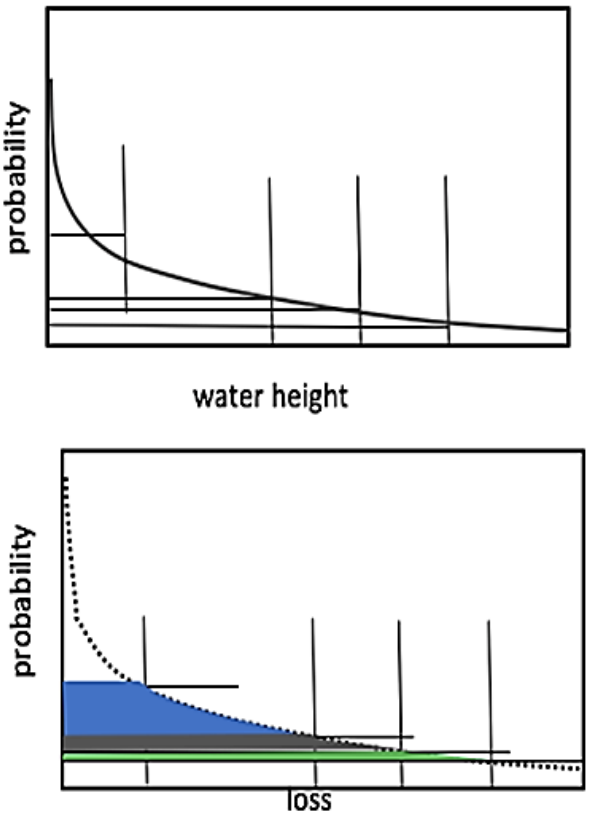
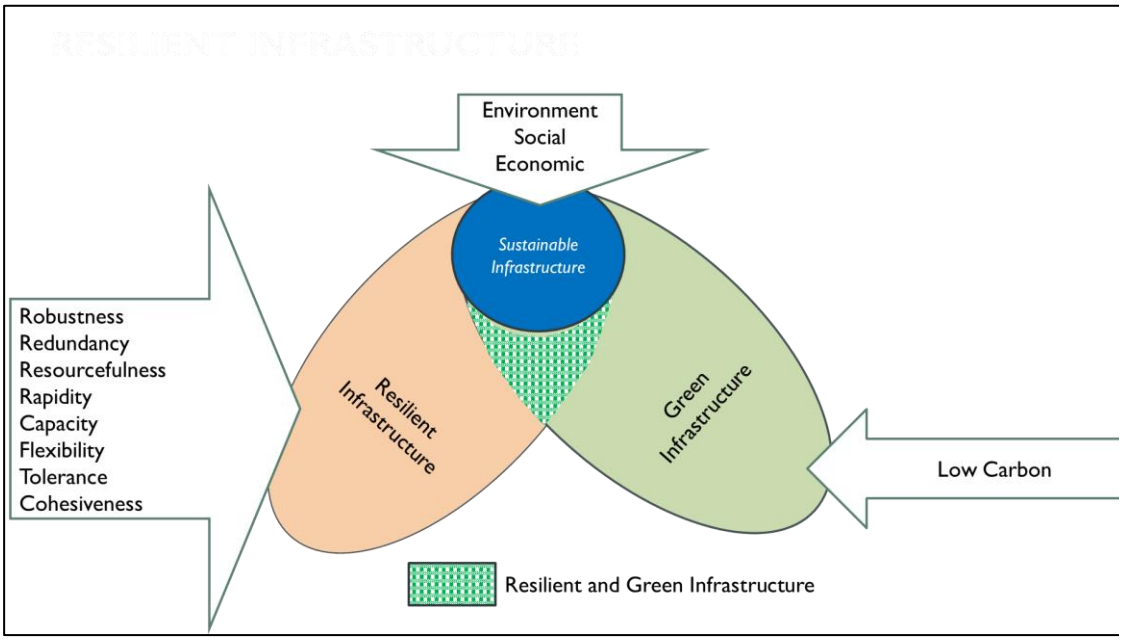


Figure 8: Comparing adaptation options

Dimensions of Resilient Infrastructure:

1. Robustness is the ability to "withstand a given level of stress without suffering degradation or loss of function" (Mcdaniels, et al. 2008).
2. Redundancy is a property that allows for alternative choices, decisions and substitutions in systems or organisations in the case of disaster or under pressure (O'Rourke, 2007). For example, communication lines among the rail, highways and roads, often have the capability to serve each other should either of them fail. If the railways fail during a disaster, the highway network can be a good alternative until the railway services are restored (Easterling, 1999).
3. Resourcefulness is the ability to "expertly get ready for, react to, and manage a disaster or disturbance as it occurs" (NIAC, 2009), implies that there is capacity to arrange and make available all the necessary resources and services needed in the event of a disaster.
4. Rapidity is the speed with which any aberration from normal due to a disaster can be overcome and safety, services and financial stability restored (O'Rourke, 2007).
5. Capacity is the ability to withstand the "known" disturbances (Mendonça & Wallace, 2006). It also includes the ability to deal with hazards of higher magnitude and unknown hazards.
6. Flexibility implies that the infrastructure system should be able to reorganize itself in a time of a disaster Jackson (2010).
7. Tolerance refers to an infrastructure system's response near its threshold i.e. – whether the system degrades as the stress increases or collapses quickly when as soon as the resilience threshold is breached (Woods, 2006)



Box 1: Dimensions of Resilience Infrastructure

6. Central Asia Riskscape

6.1. Central Asia Pilot

The risk metrics and the methodology were developed for a worldwide multi-hazard assessment as part of Global Assessment Report 2015. The central Asia pilot, builds on this methodology, generates sub-national risk metrics, and investigates specific implications for the infrastructure sector. The advantage of using this methodology is that that is provides a consistent and comparable risk estimate suited for different geographies. There are many risk models developed for specific hazards and specific infrastructure assets but their reliance on use different data sets and methodologies for single hazard assessments makes their utility in providing policy inputs at national and subnational level is limited because they cannot be compared across hazards, geographies and asset categories.

This central Asia pilot for Kazakhstan and Kyrgyz Republic, uses the same methodology, arithmetic, and exposure model to calculate the risk for all hazards, enabling the comparison of risk levels between countries and regions and across hazard types. In this way, the mapping and understanding of the risk landscape is improved, providing an estimation of the order of magnitude of losses in each country, and a calculation of the risk contributions from different hazards. The model downscales assessments prepared for the Global Assessment Report 2015 at a provincial or first-administrative level. A disaggregated picture at a sub-national level provides a much better policy input for infrastructure planning, managing progress towards SDGs and for engaging the private sector in comparison to national level risk metrics.

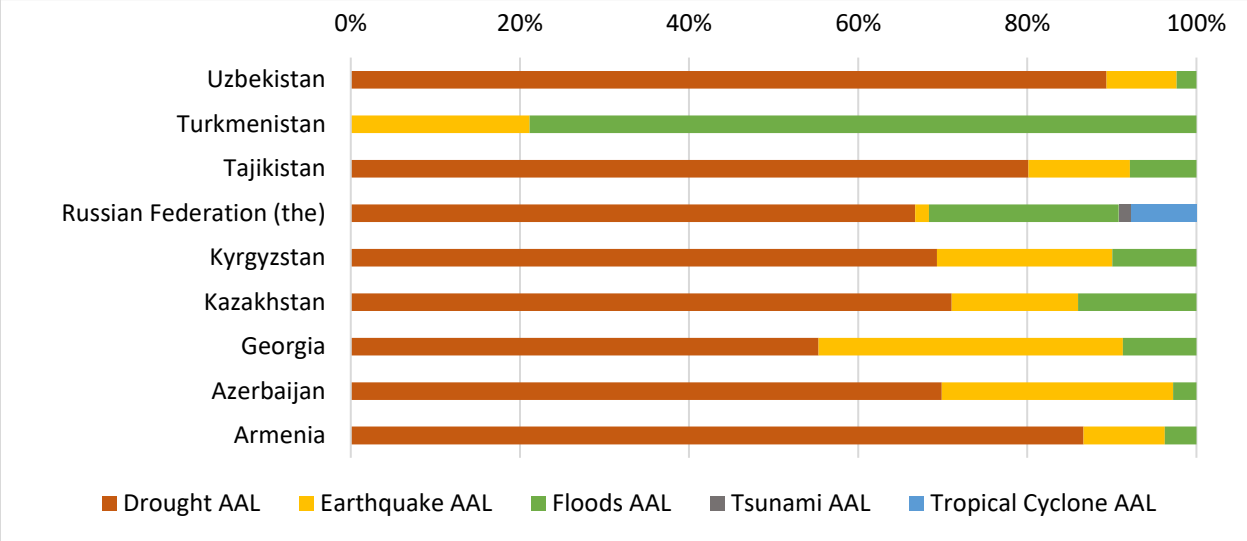
An important consideration here to keep in mind is also that the original datasets on hazard, exposure and vulnerability used were prepared for a comparative global analysis. A statistical downscaling is pursued for first administrative level is pursued. Downscaling this data any further, for example, to the second or third administrative level is not recommended as the level of uncertainty in the results would increase to unacceptable levels. Further downscaling is only possible if the model input and original data sets are supplemented with bottom up information on exposed elements, damage ratios, and physical variables needed for probabilistic hazard assessments.

In the subsequent sections provide central's Asia's risk metrics from the global assessments to give an overview of the key risks in the region, the status of Kazakhstan and Kyrgyz Republic in overall risk picture of the region using projected annualized losses and the estimates for infrastructure investment needs in the Asia and in central Asia.

6.2. Risk Profile of Central Asia

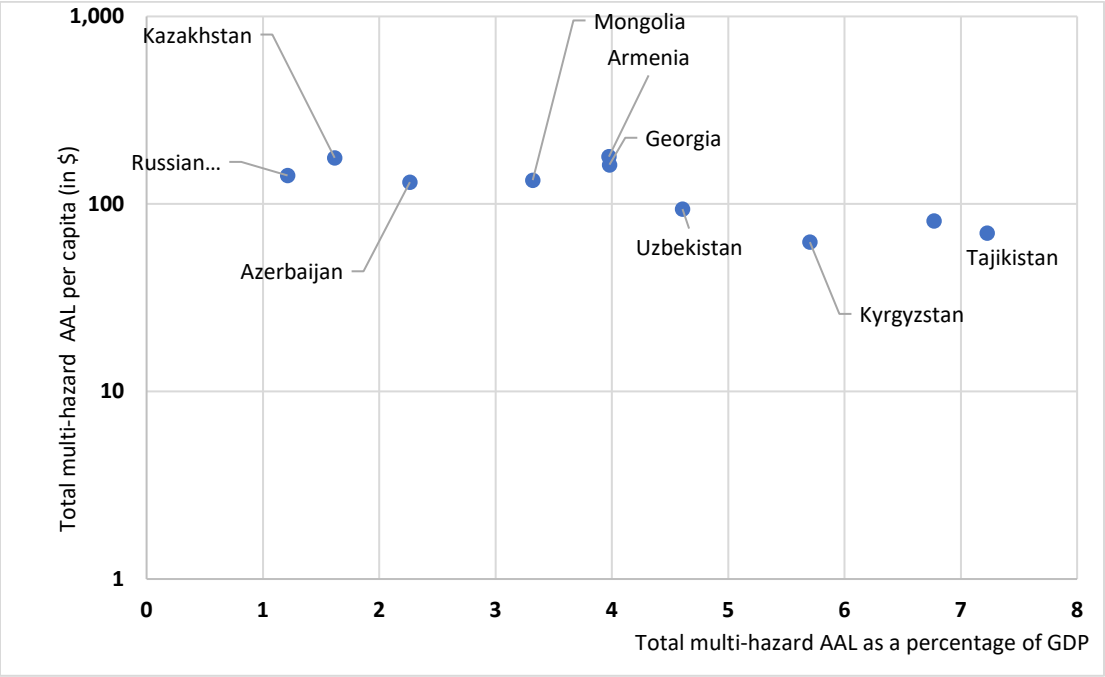
For the north and central Asia region, the droughts have a significant share in the total multi-hazard AALs. This is followed by earthquakes for all countries except for Russian Federation where flood risk losses follow droughts. In the region, about three fourth of the AAL comprises drought related losses. The total multi-hazard risks while including slow onset disasters is the highest for the Russian federation. Russia is followed by Uzbekistan, where the total multi-hazard AAL is about a quarter of the Russian federation. If we exclude the risk from slow onset disasters, the Russian Federation still tops the tally in total multi-hazard risks, followed by Kazakhstan, which is again a quarter of the AAL for Russia. Uzbekistan is fourth on this list because about 90% of its AAL is attributed to drought losses.

Figure 9: AAL Disaggregated in North and Central Asia Countries



In terms of absolute numbers, the AAL numbers for individual hazards, indirect losses and extensive risks are the highest for the Russian federation. In all cases, the losses for the country next in line ranges from one third to a quarter of losses as projected for Russia. If we compare total multi-hazard AAL per capita and total multi-hazard AAL as a percentage of GDP, then Russia and Kazakhstan flair close enough. All countries in the region are close enough with respect to per capita AAL. Tajikistan and Kyrgyz Republic experience the highest total multi-hazard AAL as a percentage of GDP. The scatter plot of per capita multi-hazard AAL against multi-hazard AAL over GDP, shows that the AAL per capital is close, but economies of Russia and Kazakhstan are very big which is why they fall in the same quadrant. Tajikistan and Kyrgyz Republic on the other had are at the other extreme end of the spectrum where the AAL is disproportionately higher in comparison to their GDP. This also shows the weak capacities to deal with disasters.

Figure 10: Scatter Plot for North and Central Asia Countries comparing Total AAL per capita and Total AAL as a percentage of GDP



AAL numbers show the long-term losses due to disasters. At the same time in central Asia the investment needs in infrastructure are estimated to be close to 492 billion USD until 2030. Adjusting this number for climate resilience implies an estimated increase of 16%. Overall and additional 1% of GDP's investment is tied to climate resilience investments in infrastructure for the central Asia region.

Table 3: Infrastructure Investments by Region, 2016–2030 (billion USD, in 2015 prices)

	Baseline Estimates			**Climate adjusted Estimates**		
	Investment Needs	Annual Average	Investment Needs as % of Projected GDP	Investment Needs	Annual Average	Investment Needs as % of Projected GDP
Central Asia	492	33	6.8	565	38	7.8
East Asia	13,781	919	4.5	16,062	1,071	5.2
South Asia	5,477	365	7.6	6,347	423	8.8
South East Asia	2,759	184	5.0	3,147	210	5.7
The Pacific	42	2.8	8.2	46	3.1	9.1
Asia & the Pacific	22,551	1,503	5.1	26,166	1,744	5.9

A disaggregation by sector shows that climate adjustment just for the power sector can increase the infrastructure investment needs by 26%.

Table 4: Central Asia's infrastructure investment needs in Power, Transport, Telecom, WASH (ADB, 2015), billion USD.

	Power		Transport		Telecom		WASH	
	1	2	1	2	1	2	1	2
Kazakhstan	73.57	92.71	49.07	52.57	14.34	14.34	4.95	5.05
Kyrgyz Republic	3.76	4.73	2.51	2.68	0.73	0.73	0.25	0.26
Tajikistan	3.54	4.46	2.36	2.53	0.69	0.69	0.24	0.24
Turkmenistan	18.98	23.92	12.66	13.56	3.70	3.70	1.28	1.30
Uzbekistan	18.57	23.40	12.39	13.27	3.62	3.62	1.25	1.27
	118.41	149.23	78.98	84.62	23.09	23.09	7.97	8.12

Column 2 gives climate adjusted estimates.

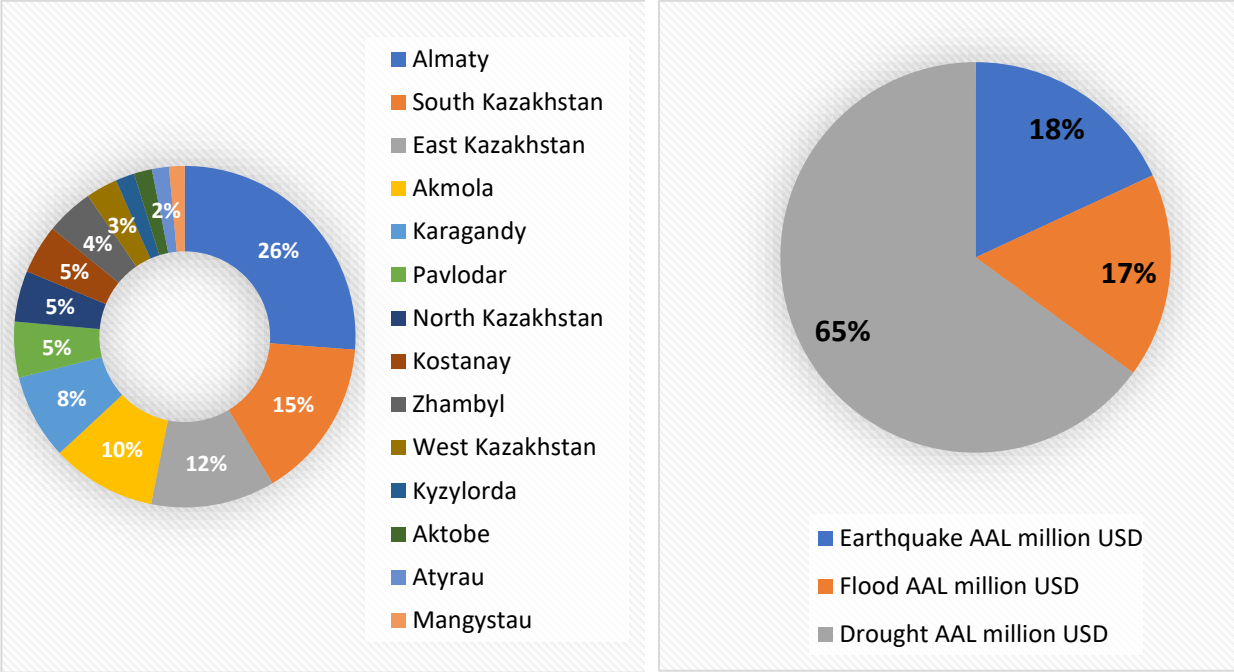
7. Country Results: Kazakhstan

The total absolute multi-hazard Average Annual Loss (AAL) for Kazakhstan is USD$ 750.46 million, which represents 0.05% of the regional multi-hazard risk. Of this total multi-hazard AAL, 51.61 % is contributed by earthquakes and 48.39 % by riverine floods. The multi-hazard AAL is heavily concentrated in the oblasts of Almaty and South Kazakhstan that together account for more than 50% of the total multi-hazard AAL (36.3% and 16.1% respectively), followed by the oblasts of East Kazakhstan (13.5%) and Akmola (10.5%). Drought risk estimation was included using a proxy value of 20% of the agricultural GDP, which for Kazakhstan means a drought AAL of USD$ 1390 million, thus increasing the total multi-hazard AAL to $2140 million, which represents 1.34% of the country's GDP. A probabilistic assessment of drought risk has also been done for different crops under RCP 8.5 climate scenario. It is not included in this report as the AAL estimates are based on damage to crops.

The results in the following sections indicate that Kazakhstan experiences a high rate of extensive risk, which emerges from the many high-frequency and low-severity disasters that cannot be modelled analytically at the global or regional scale. Evidence from countries where extensive risk has been modelled empirically, highlight that it could add about 10% to 50% to the total multi-hazard AAL. If a conservative estimate of 30% is assumed, then the total multi-hazard risk for Kazakhstan would rise to USD $975.6 million, which represents 0.61% of the country's GDP.

Multiple assessments following major disasters using the Economic Commission for Latin America and the Caribbean (ECLAC) methodology indicate that direct losses normally represent only 30 to 40% of total losses (i.e. the sum of direct and indirect losses). Considering likely indirect losses, therefore, the total average annual loss in Kazakhstan would rise to USD $1,365 million representing 0.86% of the GDP.

Figure 11: (a) Exposed Value and (b) AAL Disaggregated for Kazakhstan



In Kazakhstan the oblasts of Almaty, South Kazakhstan & East Kazakhstan have **half** of the total exposed assets and total multi-hazard AAL. Almaty has a concentration of 26% of the exposed value concentration. Drought risk is a significant risk and contributes to **two thirds** of the total AAL of the country. This is followed by earthquake and flood risk which have a similar proportion in the total multi-hazard AAL of the country.

Drought is included here using a proxy value of 20% of the agricultural GDP, which for Kazakhstan means a drought AAL of USD 1,390 million, representing 1.34% of the country's GDP. In proportion terms, drought accounts for almost 65% of the total multi-hazard AAL, where 18% is contributed by earthquakes and 17% is contributed by floods to the total USD 2140 million of multi-hazard AAL.

7.1. Multi-hazard AAL and Infrastructure

The proportion of AAL to per mile of capital stock gives the concentration of infrastructure vulnerability. In general, the locations of high capital stock tend to have high AAL. The proportions point to locations where there is a disproportionately high concentration of AAL. In Kazakhstan, Almaty has the highest multi-hazard AAL. Atyrau and West Kazakhstan have the highest relative multi-hazard AAL to capital stock ratio. This shows that there is presence of infrastructure that is not compliant with hazards in the two oblasts.

Figure 12: Provincial multi-hazard AAL to capital stock ratio for Kazakhstan

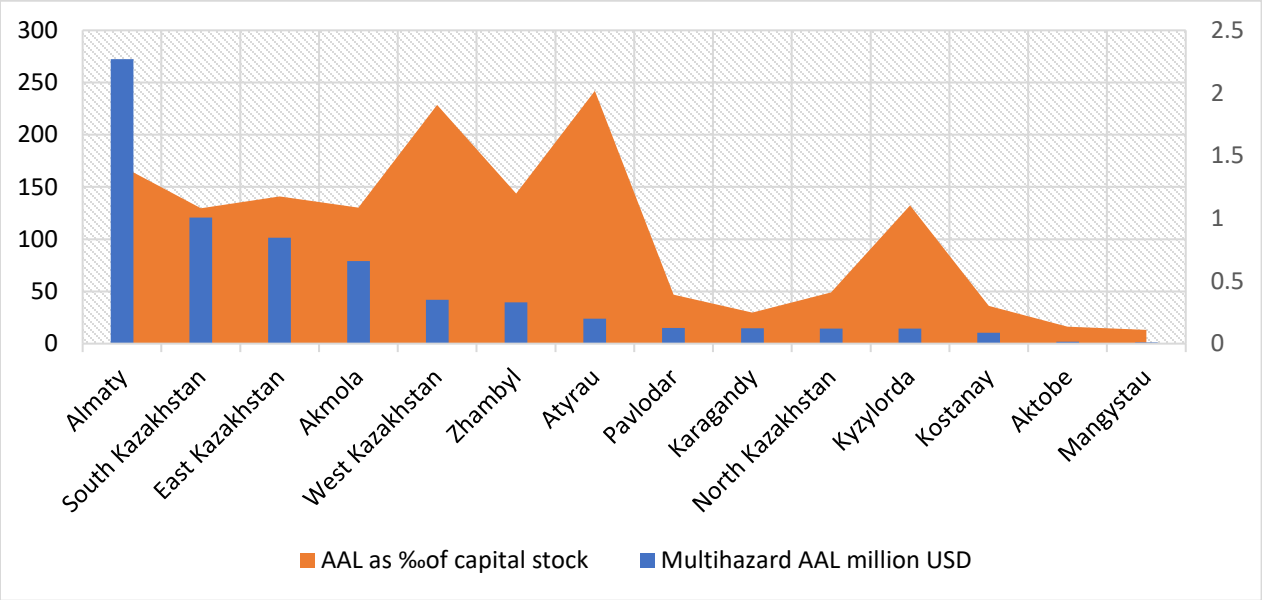


Table 5: Provincial multi-hazard AAL for the Kazakhstan and its contribution to total AAL

Province	Multi-Hazard AAL		Contribution to total value
	USD million	[‰ of capital stock]	
Almaty	272.4	1.4	36.3
South Kazakhstan	120.6	1.1	16.1
East Kazakhstan	101.3	1.2	13.5
Akmola	79.0	1.1	10.5
West Kazakhstan	41.9	1.9	5.6
Zhambyl	39.6	1.2	5.3
Atyrau	23.8	2.0	3.2
Pavlodar	15.1	0.4	2.0
Karagandy	14.7	0.2	2.0
Kyzylorda	14.5	1.1	1.9
North Kazakhstan	14.5	0.4	1.9
Kostanay	10.3	0.3	1.4
Aktobe	1.7	0.1	0.2
Mangystau	1.2	0.1	0.2
Total	**750.5**	**1.02**	**100.0**

High relative risk is shown by the ratio of AAL to per mille of capital stock. An overlaid map of 'ratio of multi-hazard AAL to ‰ of capital stock' and 'energy infrastructure assets i.e. coal, gas, solar, hydro, oil and wind power plants' shows that **73%** of energy infrastructure assets are located in oblasts that are high or extremely high relative risk locations. The split between extremely high and high is 36% and 37%. Most of these power plants in the high and extremely high relative risk locations are hydro power plants followed by gas power plants.

Map 1: Kazakhstan – Multi-Hazard AAL/ ‰ of capital stock and energy infrastructure

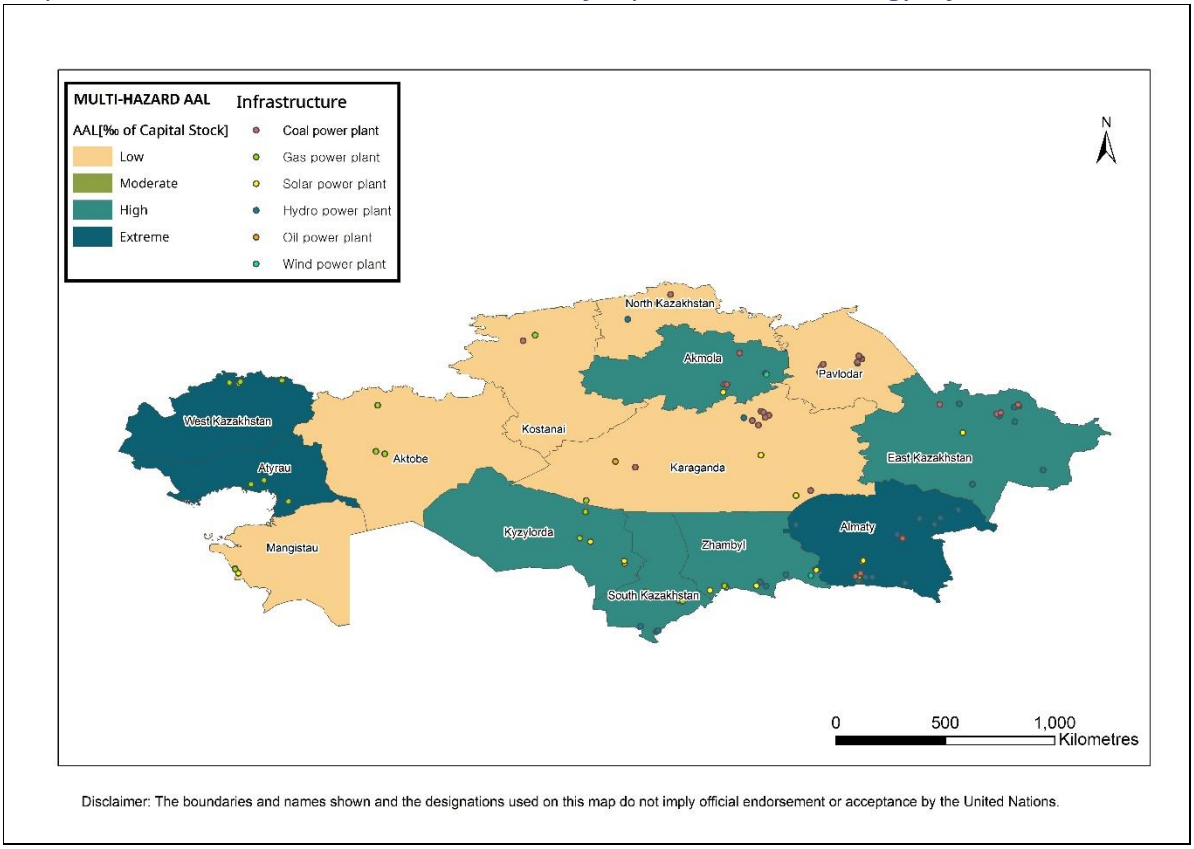
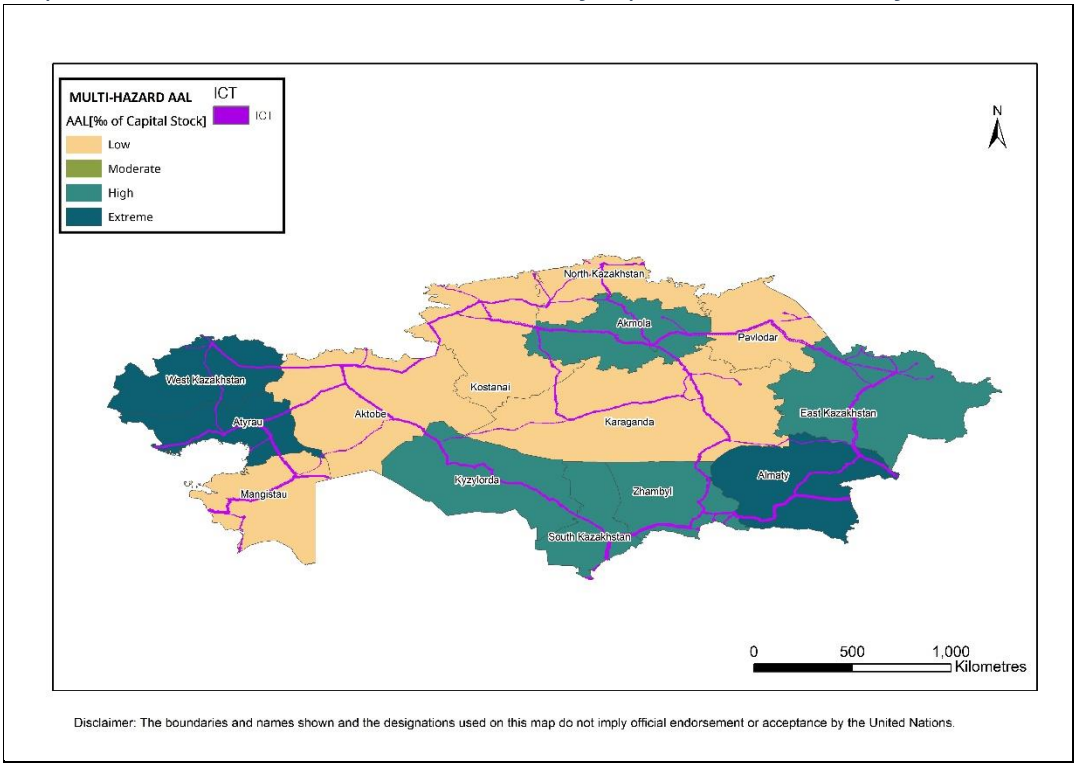


Table 6: Energy infrastructure across Kazakhstan in different multi-hazard risk categories

	Multi-Hazard Risk Class	Wind	Solar	Oil	Hydro	Gas	Coal
South Kazakhstan	**High**		4		5	2	
East Kazakhstan	**High**		1		8	0	4
Akmola	**High**	2	1				1
Karagandy	Low		2	1	1	1	8
Pavlodar	Low					1	7
North Kazakhstan	Low	1			1		1
Kostanay	Low					1	1
Zhambyl	**High**	1	3	1	5	2	
West Kazakhstan	**Extreme**					4	
Kyzylorda	**High**		3			2	
Aktobe	Low					4	
Atyrau	**Extreme**					5	
Mangystau	Low		1			3	
Astana (city)	**High**					0	2
Almaty (city)	**Extreme**		3		30	1	3

Map 2: Kazakhstan – Multi-hazard AAL/ ‰ of capital stock and ICT infrastructure

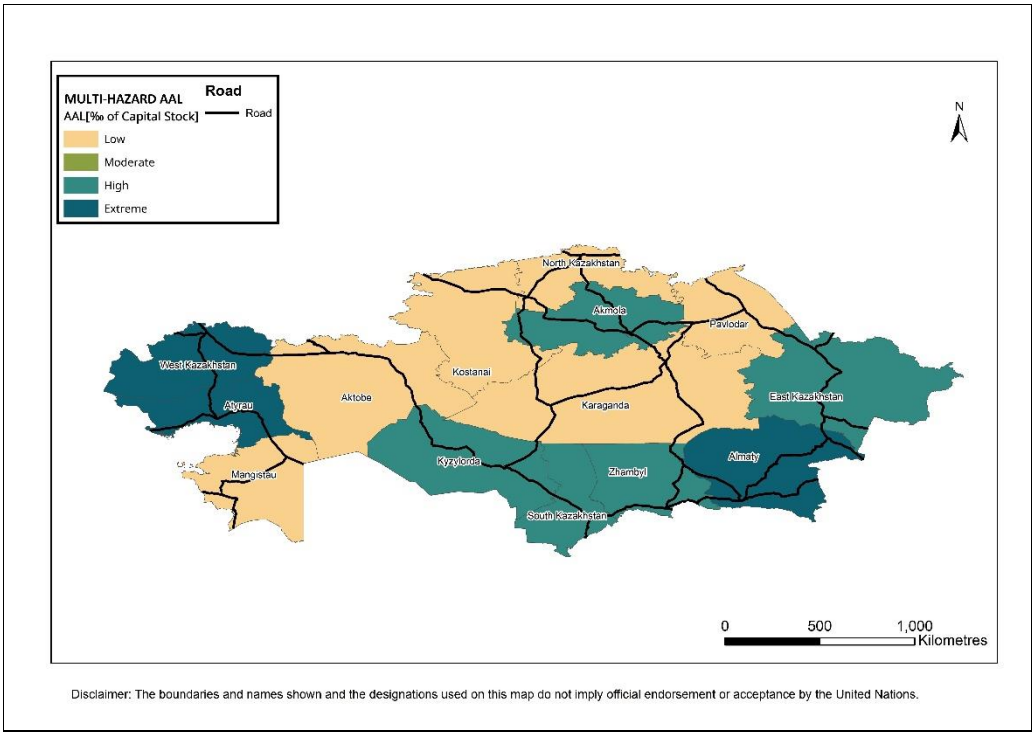


56% of ICT Infrastructure in high and extremely high multi-hazard AAL to capital stock locations

Table 7: ICT Infrastructure across Kazakhstan in different multi-hazard risk categories

	Multi-Hazard Risk Class	ICT Infrastructure concentration
South Kazakhstan	**High**	3.395%
East Kazakhstan	**High**	9.095%
Akmola	**High**	10.873%
Karagandy	Low	12.234%
Pavlodar	Low	5.139%
North Kazakhstan	Low	0.493%
Kostanay	Low	8.278%
Zhambyl	**High**	6.092%
West Kazakhstan	**Extreme**	3.446%
Kyzylorda	**High**	6.092%
Aktobe	Low	11.120%
Atyrau	**Extreme**	6.542%
Mangystau	Low	6.874%
Astana (city)	**High**	0.179%
Almaty (city)	**Extreme**	10.150%

Map 3: Kazakhstan – Multi-Hazard AAL/ ‰ of capital stock and road infrastructure



57% of highways in high and extremely high multi-hazard AAL to capital stock locations.

Table 8: Road Infrastructure across Kazakhstan in different multi-hazard risk categories

	Multi-Hazard Risk Class	Road Infrastructure concentration
South Kazakhstan	**High**	2.896%
East Kazakhstan	**High**	7.495%
Akmola	**High**	9.286%
Karagandy	Low	13.377%
Pavlodar	Low	5.852%
North Kazakhstan	Low	6.689%
Kostanay	Low	4.001%
Zhambyl	**High**	6.450%
West Kazakhstan	**Extreme**	5.793%
Kyzylorda	**High**	7.674%
Aktobe	Low	6.181%
Atyrau	**Extreme**	5.823%
Mangystau	Low	6.539%
Astana (city)	**High**	0.269%
Almaty (city)	**Extreme**	11.675%

7.2. Earthquake AAL and Infrastructure

In terms of earthquake hazard, the Almaty oblast has the highest AAL accounting for the 64.5% of the total earthquake AAL. The four oblasts of Almaty, South Kazakhstan (18.9%) and East Kazakhstan (7.1%) and Zhambyl (6.9%) have 97.4% of the total earthquake AAL. In relative terms, Almaty is the oblast with the highest value of AAL to capital stock ratio (1.3‰), followed by Zhambyl (0.8‰) and South Kazakhstan (0.7%). Almaty has more than **two-thirds** of the total earthquake risk of the country. Zhambyl has the **second highest** earthquake AAL to capital stock ratio after Almaty.

Figure 13: Provincial earthquake AAL to capital stock ratio for Kazakhstan

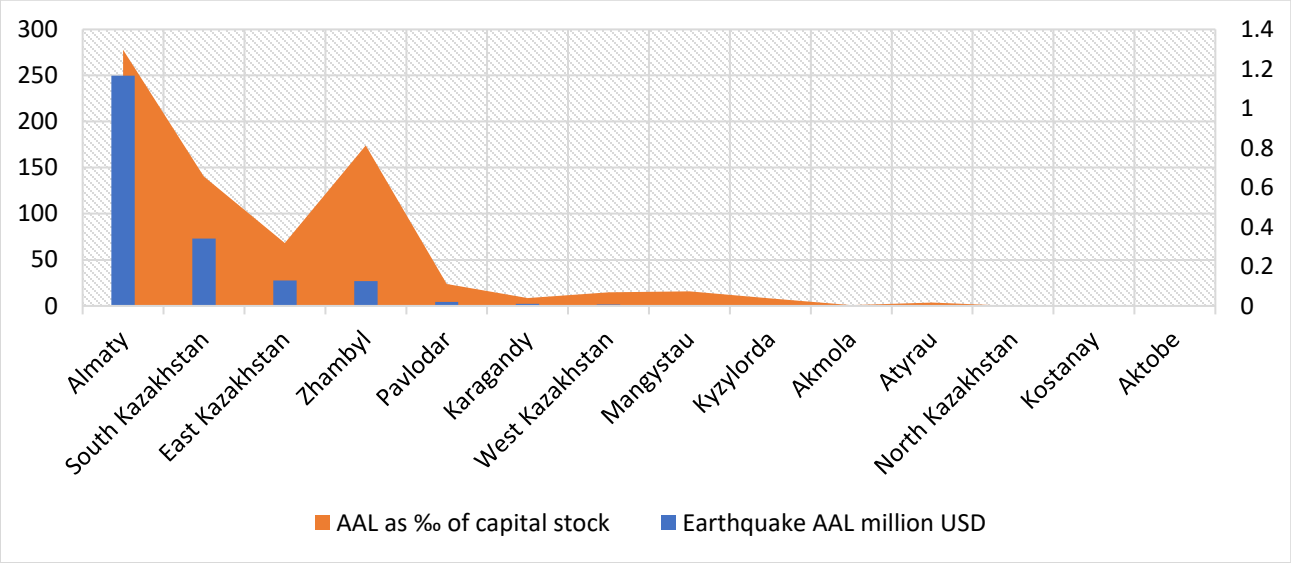
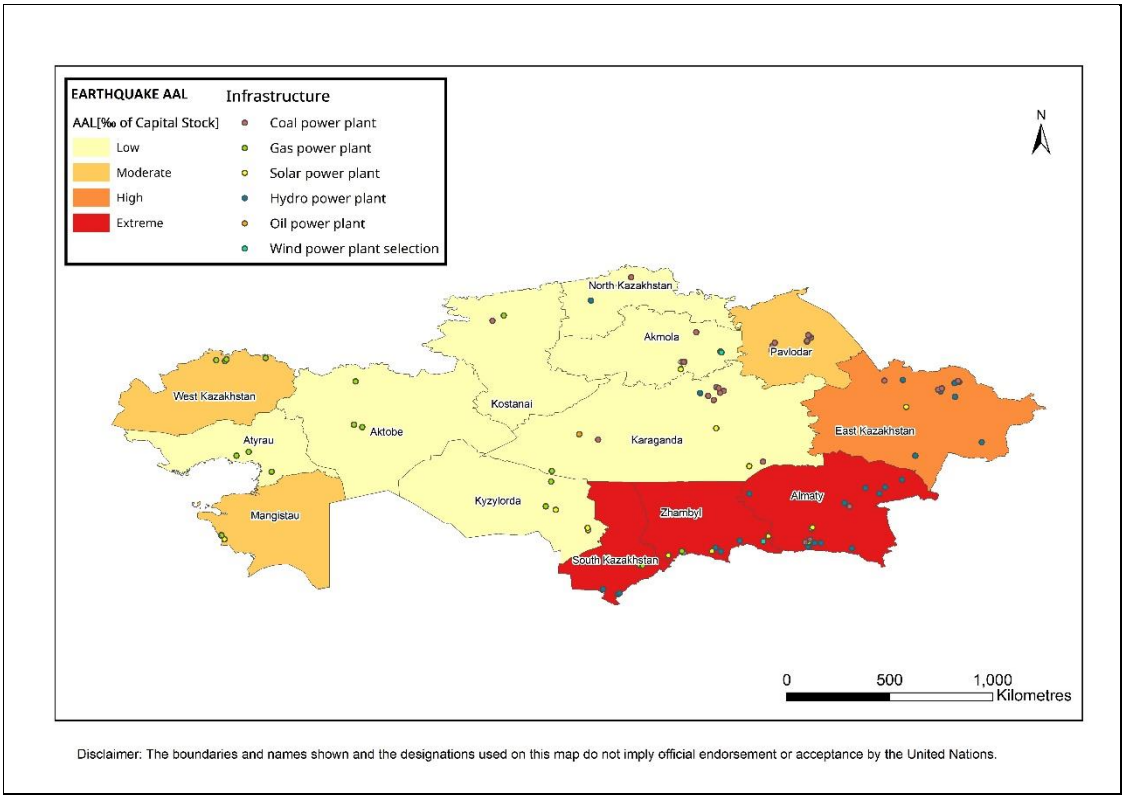


Table 9: Provincial earthquake AAL for the Kazakhstan and its contribution to total AAL

Province	Earthquake		Contribution to total value
	USD million	[‰ of capital stock]	
Almaty	249.7	1.3	64.5
South Kazakhstan	73.2	0.7	18.9
East Kazakhstan	27.5	0.3	7.1
Zhambyl	26.9	0.8	6.9
Pavlodar	4.3	0.1	1.1
Karagandy	2.4	0.0	0.6
West Kazakhstan	1.5	0.1	0.4
Mangystau	0.8	0.1	0.2
Kyzylorda	0.5	0.0	0.1
Akmola	0.3	0.0	0.1
Atyrau	0.2	0.0	0.0
Kostanay	0.0	0.0	0.0
Aktobe	0.0	0.0	0.0
North Kazakhstan	0.0	0.0	0.0
Total	**387.3**	**0.53**	**100.0**

Map 4: Kazakhstan – Earthquake AAL/ ‰ of capital stock and energy infrastructure

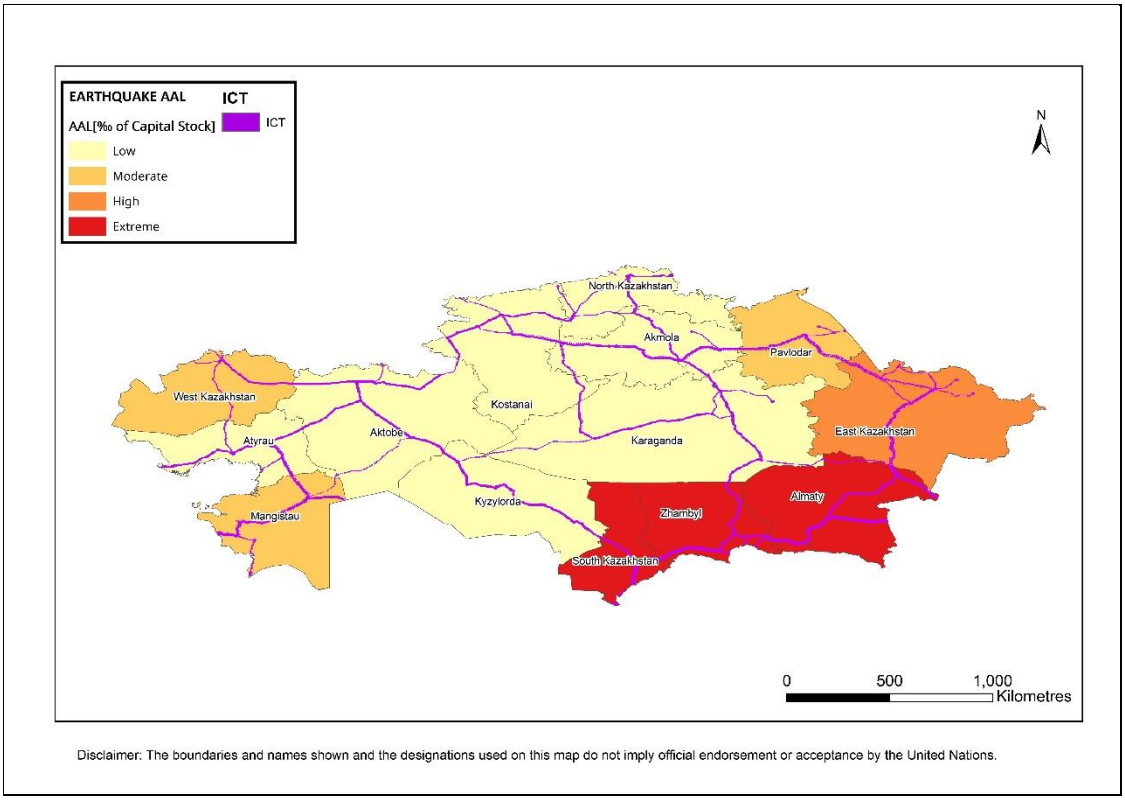


57% energy infrastructure in high and extremely high earthquake AAL to capital stock locations

Table 10: Energy infrastructure across Kazakhstan in different earthquake risk categories

	Earthquake Risk Class	Wind	Solar	Oil	Hydro	Gas	Coal
South Kazakhstan	**Extreme**		4		5	2	
East Kazakhstan	**High**		1		8	0	4
Akmola	Low	2	1				1
Karagandy	Low		2	1	1	1	8
Pavlodar	**Moderate**					1	7
North Kazakhstan	Low	1			1		1
Kostanay	Low					1	1
Zhambyl	**Extreme**	1	3	1	5	2	
West Kazakhstan	**Moderate**					4	
Kyzylorda	Low		3			2	
Aktobe	Low					4	
Atyrau	Low					5	
Mangystau	**Moderate**		1			3	
Astana (city)	Low					0	2
Almaty (city)	**Extreme**		3		30	1	3

Map 5: Kazakhstan – Earthquake AAL/ ‰ of capital stock and ICT infrastructure



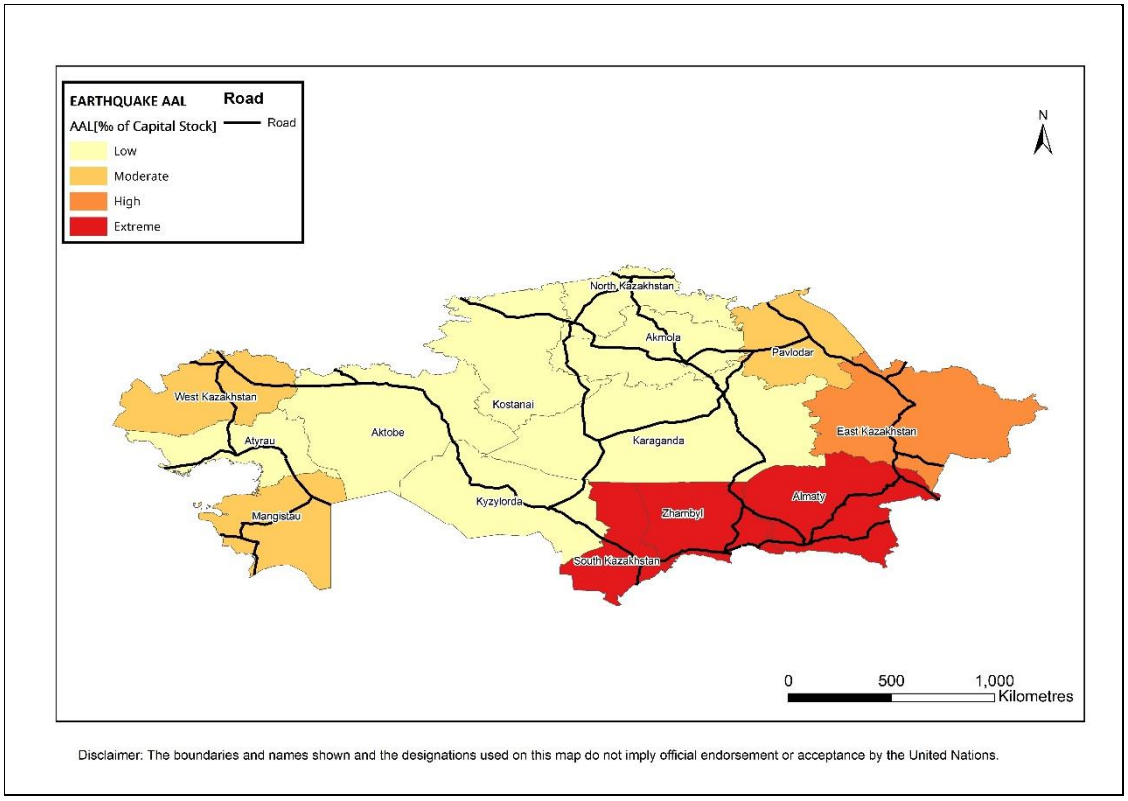
29% of ICT Infrastructure is in high earthquake AAL to capital stock locations.

Table 11: ICT infrastructure across Kazakhstan in different earthquake risk categories

	Earthquake Risk Class	ICT Infrastructure concentration
South Kazakhstan	**Extreme**	3.395%
East Kazakhstan	**High**	9.095%
Akmola	Low	10.873%
Karagandy	Low	12.234%
Pavlodar	**Moderate**	5.139%
North Kazakhstan	Low	0.493%
Kostanay	Low	8.278%
Zhambyl	**Extreme**	6.092%
West Kazakhstan	**Moderate**	3.446%
Kyzylorda	Low	6.092%
Aktobe	Low	11.120%
Atyrau	Low	6.542%
Mangystau	**Moderate**	6.874%

Astana (city)	Low	0.179%
Almaty (city)	**Extreme**	10.150%

Map 6: Kazakhstan – Earthquake AAL/ ‰ of capital stock and road infrastructure



29% of highways are located in high and extremely high earthquake AAL to capital stock locations.

Table 12: Road infrastructure across Kazakhstan in different earthquake risk categories

	Earthquake Risk Class	Road Infrastructure concentration
South Kazakhstan	**Extreme**	2.896%
East Kazakhstan	**High**	7.495%
Akmola	Low	9.286%
Karagandy	Low	13.377%
Pavlodar	**Moderate**	5.852%
North Kazakhstan	Low	6.689%
Kostanay	Low	4.001%
Zhambyl	**Extreme**	6.450%
West Kazakhstan	**Moderate**	5.793%
Kyzylorda	Low	7.674%

Aktobe	Low	6.181%
Atyrau	Low	5.823%
Mangystau	**Moderate**	6.539%
Astana (city)	Low	0.269%
Almaty (city)	**Extreme**	11.675%

7.3. Flood AAL and Infrastructure

In terms of flood risks, the major part of the flood AALs are concentrated in the oblasts of Akmola (21.7%), East Kazakhstan (20.3%), South Kazakhstan (13.1%) and West Kazakhstan (11.1%). However, in relative terms, the higher relative flood risk is in the oblast of Atyrau, which has a flood AAL to capital stock ratio of 2.00‰, followed by West Kazakhstan (1.84‰) and Akmola (1.08‰). Akmola, South-East-West Kazakhstan have **two-thirds** of the total flood AAL. **Atyrau** and **West Kazakhstan** have the highest flood AAL to capital stock ratio.

Figure 14: Provincial flood AAL to capital stock ratio for Kazakhstan

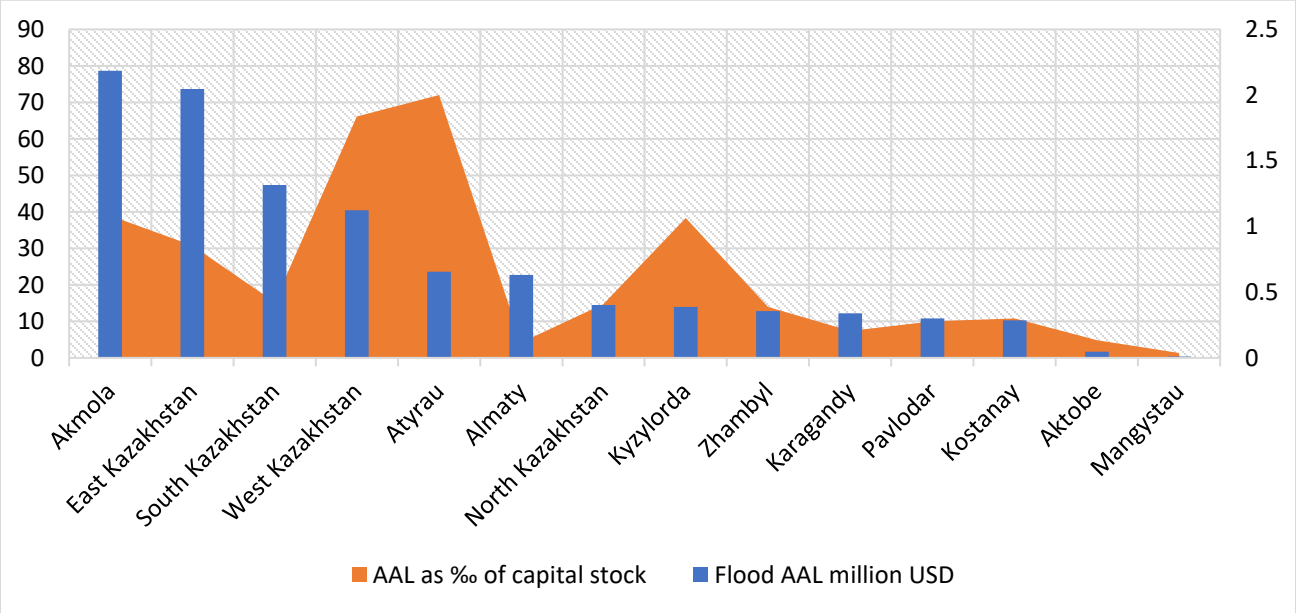
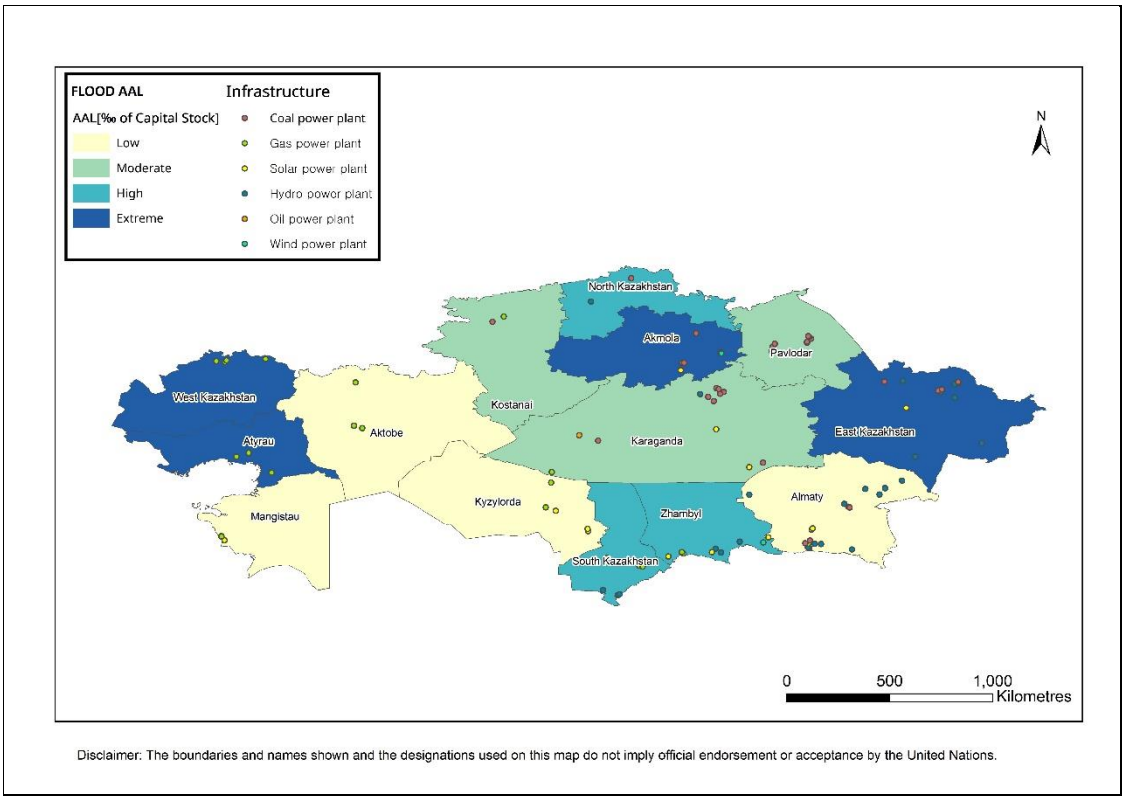


Table 13: Provincial flood AAL for the Kazakhstan and its contribution to total AAL

Province	Flood		Contribution to total value
	USD million	‰ of capital stock	
Akmola	78.7	1.08	21.7
East Kazakhstan	73.7	0.86	20.3
South Kazakhstan	47.4	0.42	13.1
West Kazakhstan	40.4	1.84	11.1
Atyrau	23.6	2.00	6.5
Almaty	22.7	0.12	6.3
North Kazakhstan	14.5	0.41	4.0
Kyzylorda	14.0	1.07	3.9
Zhambyl	12.8	0.39	3.5
Karagandy	12.2	0.21	3.4
Pavlodar	10.8	0.28	3.0
Kostanay	10.3	0.30	2.8
Aktobe	1.7	0.13	0.5
Mangystau	0.4	0.03	0.1
Total	**363.2**	**0.49**	**100.0**

Map 7: Kazakhstan – Flood AAL/ ‰ of capital stock and energy infrastructure

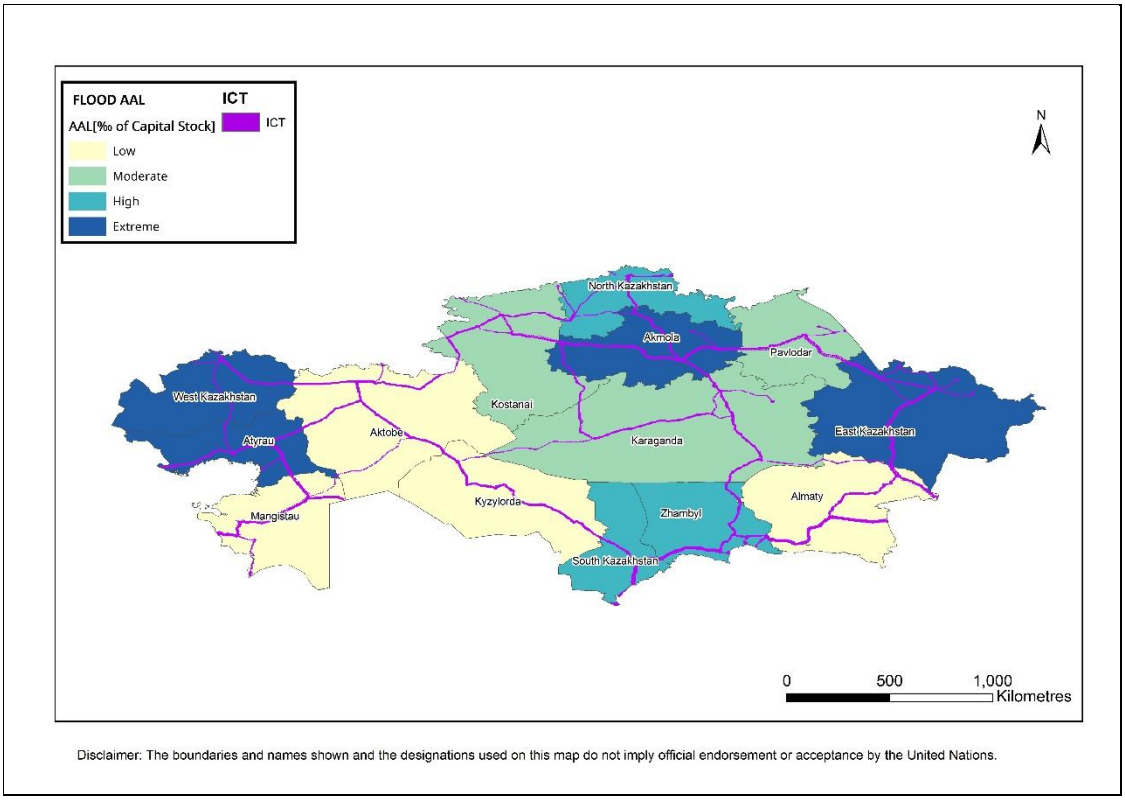


43% of energy infrastructure is in high and extremely high flood AAL to capital stock locations.

Table 14: Energy infrastructure across Kazakhstan in different flood risk categories

	Flood Risk Class	Wind	Solar	Oil	Hydro	Gas	Coal
South Kazakhstan	**High**		4		5	2	
East Kazakhstan	**Extreme**		1		8	0	4
Akmola	**Extreme**	2	1				1
Karagandy	**Moderate**		2	1	1	1	8
Pavlodar	**Moderate**					1	7
North Kazakhstan	**High**	1			1		1
Kostanay	**Moderate**					1	1
Zhambyl	**High**	1	3	1	5	2	
West Kazakhstan	**Extreme**					4	
Kyzylorda	Low		3			2	
Aktobe	Low					4	
Atyrau	**Extreme**					5	
Mangystau	Low		1			3	
Astana (city)	**Extreme**					0	2
Almaty (city)	**Extreme**		3		30	1	3

Map 8: Kazakhstan – Flood AAL/ ‰ of capital stock and ICT infrastructure

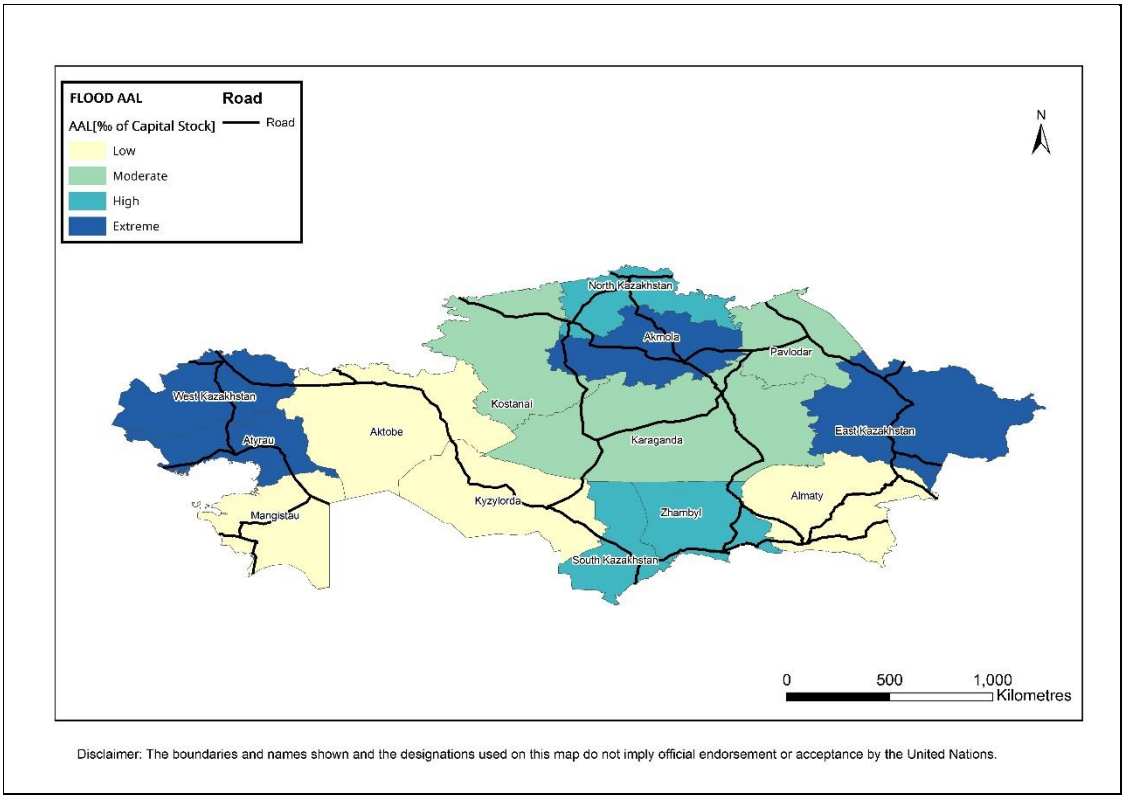


40% of ICT Infrastructure is in high to extremely high AAL to capital stock locations.

Table 15: ICT infrastructure across Kazakhstan in different flood risk categories

	Flood Risk Class	ICT Infrastructure concentration
South Kazakhstan	**High**	3.395%
East Kazakhstan	**Extreme**	9.095%
Akmola	**Extreme**	10.873%
Karagandy	**Moderate**	12.234%
Pavlodar	**Moderate**	5.139%
North Kazakhstan	**High**	0.493%
Kostanay	**Moderate**	8.278%
Zhambyl	**High**	6.092%
West Kazakhstan	**Extreme**	3.446%
Kyzylorda	Low	6.092%
Aktobe	Low	11.120%
Atyrau	**Extreme**	6.542%
Mangystau	Low	6.874%
Astana (city)	**Extreme**	0.179%
Almaty (city)	**Extreme**	10.150%

Map 9: Kazakhstan – Flood AAL/ ‰ of capital stock and ICT infrastructure



45% of highways are located in high and extremely high AAL to capital stock locations.

Table 16: Road infrastructure across Kazakhstan in different flood risk categories

	Flood Risk Class	Road Infrastructure concentration
South Kazakhstan	**High**	2.896%
East Kazakhstan	**Extreme**	7.495%
Akmola	**Extreme**	9.286%
Karagandy	**Moderate**	13.377%
Pavlodar	**Moderate**	5.852%
North Kazakhstan	**High**	6.689%
Kostanay	**Moderate**	4.001%
Zhambyl	**High**	6.450%
West Kazakhstan	**Extreme**	5.793%
Kyzylorda	Low	7.674%
Aktobe	Low	6.181%
Atyrau	**Extreme**	5.823%
Mangystau	Low	6.539%
Astana (city)	**Extreme**	0.269%
Almaty (city)	**Extreme**	11.675%

7.4. Risk metrics and development indices

The Disaster Risk Implications on the Socio-Economic Development of Countries (DRDIi) index examines the opportunity cost of disaster risk on sustainable development. For example, where the AAL represents a high proportion of a countries social expenditure, that country will have difficulties in maintaining or increasing its social expenditure and thus achieving social sector Sustainable Development Goals (SDG). Similarly, countries where the AAL represents a high proportion of capital investment will have difficulty in achieving infrastructure related SDGs.

Figure 15: DRDIi values for Kazakhstan

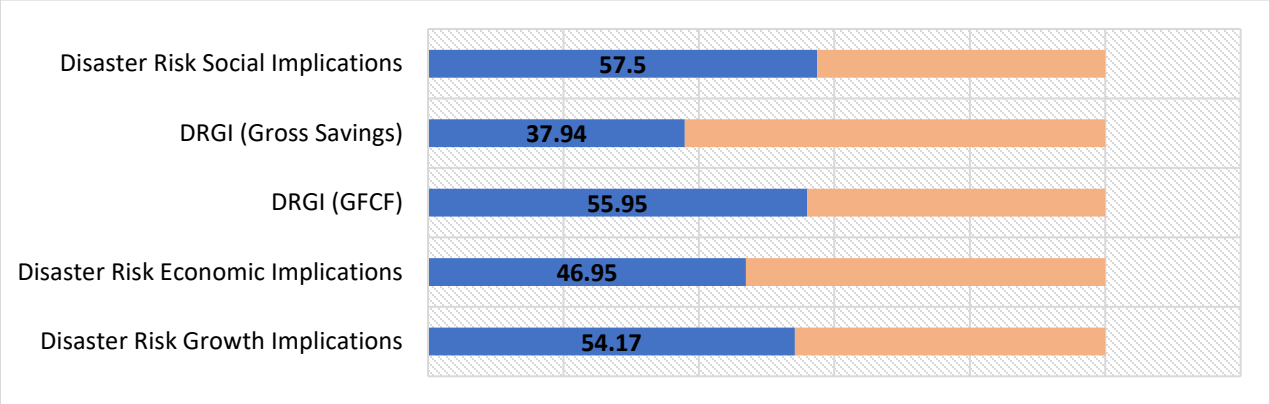
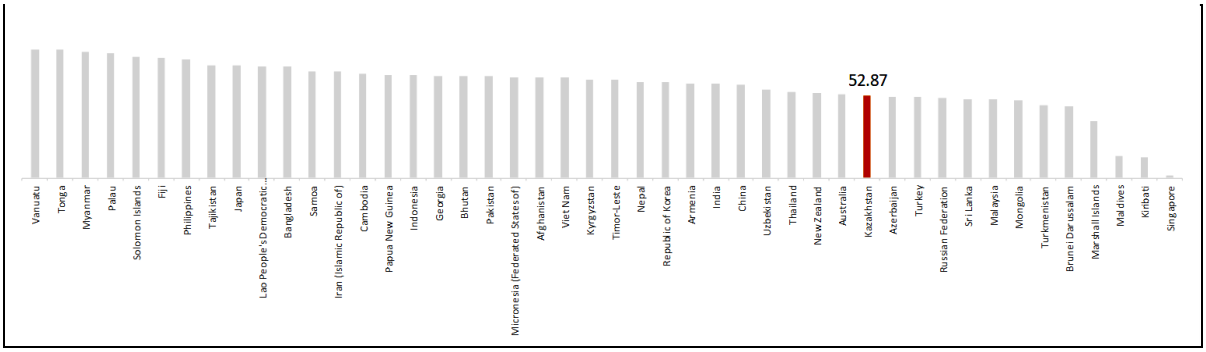
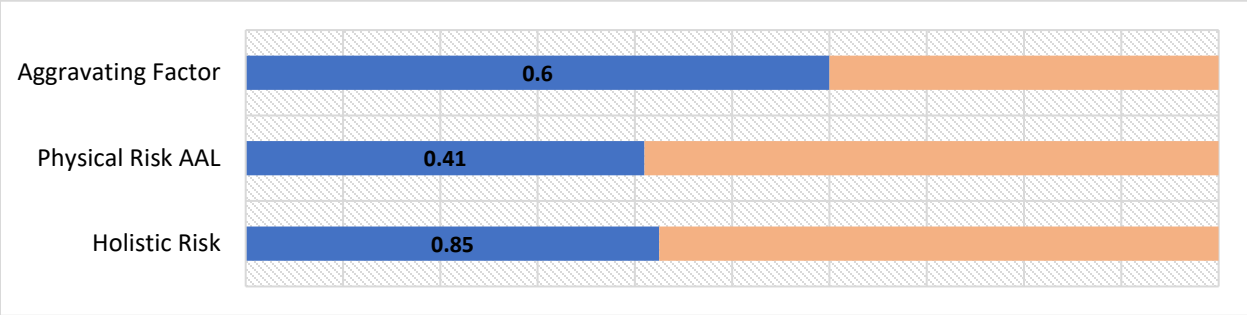


Figure 16: DRDIi values across Asia and the Pacific



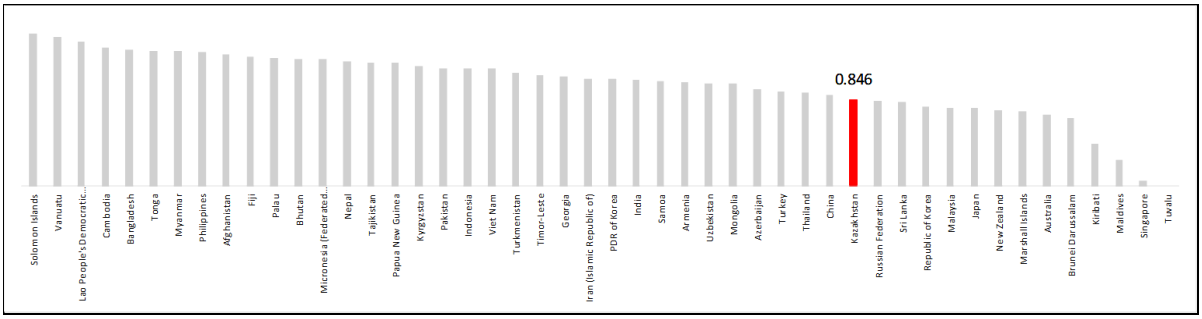
This index attempts to reveal the weight of the AAL on the social expenditure, capital investment and savings (domestic investment), reserves (financial capacity) and the produced capital or capital stock (assets at risk) of each country. It reflects the constraints to sustainable development posed by disaster risk. In the figure above, the values of economic, financial and social implications are very similar for Kazakhstan. Considering the average annual loss of 5.02‰ of capital stock, investment, savings and expenditures would be severely affected if the potential losses were paid every year.

Figure 17: Holistic risk value for Kazakhstan



The holistic risk indicator is calculated for each country by capturing how underlying risk drivers or social, economic, environmental factors– (using an aggravating factor, F), which, worsen the current existing physical risk (RF). Fourteen variables were chosen to represent the underlying risk drivers or aggravating factors. These variables are: Internet access, Access to sanitation, Access to improved drinking water, GINI Index, Unemployment, Inflation and Urban growth rate. Indicators of Lack of Resilience are: Gross National Savings, Social expenditure, Governance, Human Development Index, Ecosystems vitality, Paved roads and Infant mortality. The total risk value for Kazakhstan 0.85.

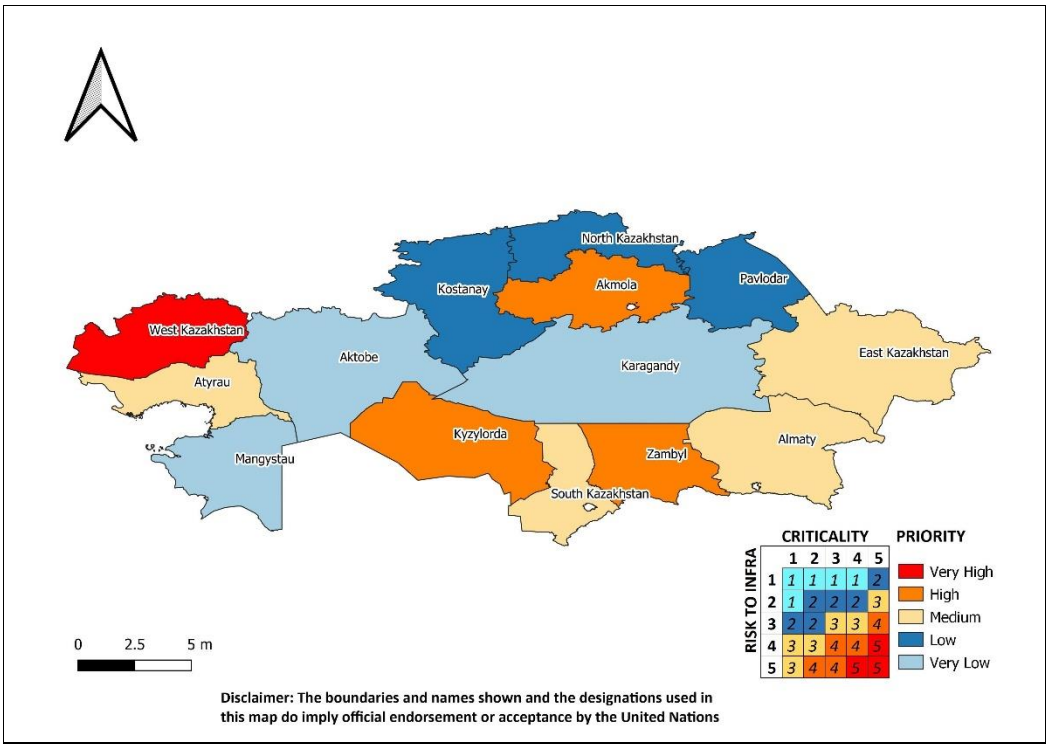
Figure 18: Holistic Risk values across Asia and the Pacific



In addition to the composite indices mentioned above, it also possible to track vulnerability and risk to infrastructure. This is particularly relevant for policy makers who would like to priority their actions by focussing on these high priority areas. Factors like poverty, population are added stressors on infrastructure availability and enhance the overall risks. The following map overlay shows different risk categories and criticality combinations that have a resultant high to low priority categorization. The risk to infrastructure is assessed from multi-hazard AAL to ‰ of capital stock ratio. The criticality is calculated from the poverty rate which here is assessed as those living below an income of 5 USD/day gives the criticality. Classifying the risk to infrastructure and the criticality in different bands gives a matrix of priority i.e. the locations where infrastructure revival in the context of the social or economic stressors, need to be prioritized. Needless to say, that merely investment in infrastructure will not be enough to

facilitate the shift low to high. Investments in mitigation of the drivers of vulnerability i.e. in reducing these socio-economic stressors will be simultaneously needed. Poverty is one such socio-economic stressor and it is possible to create combinations of one or more of such stressors with risk to infrastructure.

Map 10: Priority areas from socio-economic stressors in Kazakhstan



8. Country Results: Kyrgyz Republic

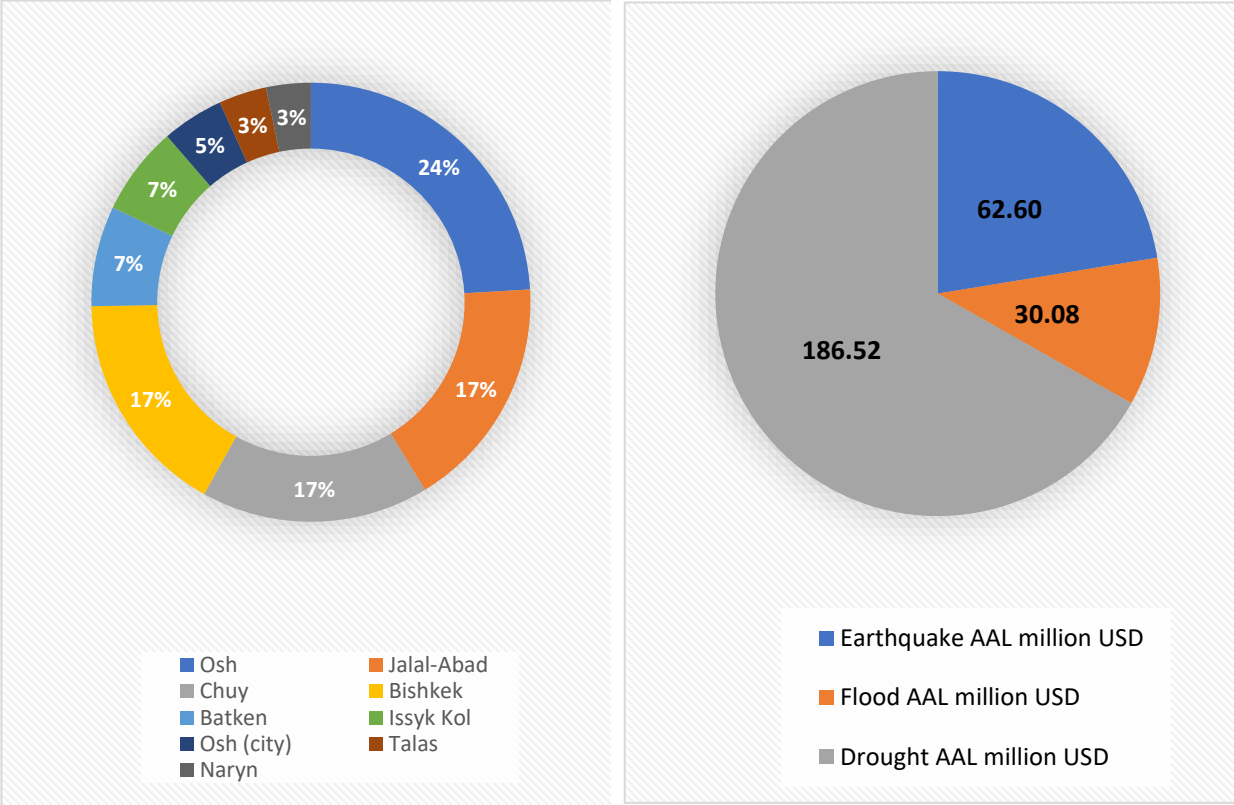
The total absolute multi-hazard Average Annual Loss (AAL) for Kyrgyzstan is USD 92.68 million, which represents 0.06% of the regional multi-hazard risk. Of this total multi-hazard AAL, 67.54 % is contributed by earthquakes and 32.46 % by riverine floods. The AAL for Kyrgyzstan represents 0.5% of the country's capital stock. The multi-hazard AAL is heavily concentrated in the oblasts of Osh and Jalal-Abad that together account for almost the 50% of the total multi-hazard AAL (28.86% and 20.49% respectively), followed by the oblast of Chuy (13.91%) and Bishkek (10.27%). Osh has a multi-hazard AAL of USD 26.75 million which includes an earthquake AAL of USD 17.88 million and flood AAL of USD 8.86 million.

Similar to Kazakhstan and other countries in central and north east Asia, Kyrgyzstan experiences a high rate of extensive risk, which manifests as large numbers of high-frequency and low-severity disasters that cannot be modelled analytically at the provincial scale. A conservative

proxy for extensive risk is assumed to be 30% of the total multi-hazard AAL. This means that over and above the total multi-hazard AAL from intensive risk of USD 92.68 million, the AAL from extensive risk will be USD 27.8 million making the multi-hazard AAL to USD 120.48 million.

Assessments following major disasters using the ECLAC methodology indicate that direct losses normally represent only 30 to 40% of total losses (i.e. the sum of direct and indirect losses). Taking into account likely indirect losses, therefore, the total average annual loss in Kyrgyzstan would rise to USD $168.68 million representing 2.23% of the country's GDP.

Figure 19: (a) Exposed Value and (b) AAL Disaggregated for Kyrgyz Republic



In Kyrgyz Republic, Osh, Jala-Abad & Chuy have more about 58% of the total exposed assets and 63% of the total multi-hazard AAL. Osh district and Osh city together have a concentration of 28.7% of the exposed value concentration and 33.3% of total multi-hazard AAL. Drought risk is a significant risk for the country and the drought AAL contributes to two thirds or 67% of the total AAL of the country. This is followed by earthquake AAL and flood ALL which have a 22% and 11% contribution respectively to the total multi-hazard AAL of the country.

Drought risk estimation was included using a proxy value of 20% of the agricultural GDP. For Kyrgyzstan this means a drought AAL of USD$ 186.52 million, thus increasing the total multi-hazard AAL to $279.2 million, which represents 3.69% of the country's GDP.

8.1. Multi-hazard AAL and Infrastructure

The proportion of AAL to per mille of capital stock gives the concentration of infrastructure vulnerability. In general, the locations of high capital stock tend to have high AAL. The proportions point to locations where there is a disproportionately high concentration of AAL. In Kyrgyz Republic, Naryn has the highest multi-hazard AAL to capital stock ratio. Naryn has the highest relative multi-hazard risk (1.2%) followed by Osh and Jalal-Abad (0.6%). This shows that there is presence of infrastructure that is not compliant with hazards in the two oblasts.

Figure 20: Provincial multi-hazard AAL to capital stock ratio for Kyrgyz Republic

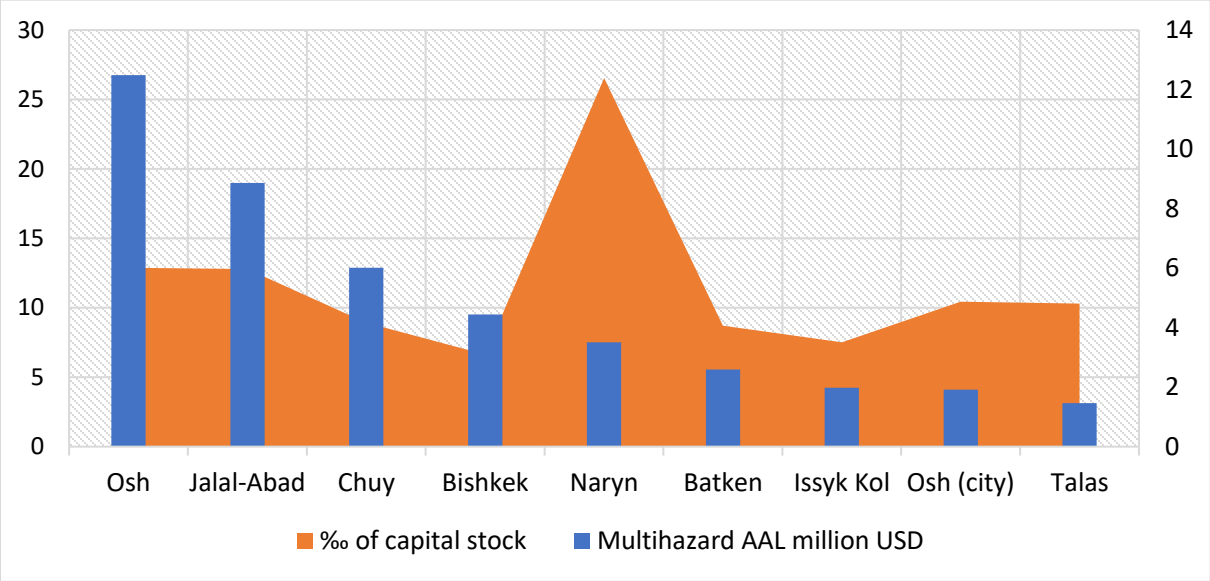
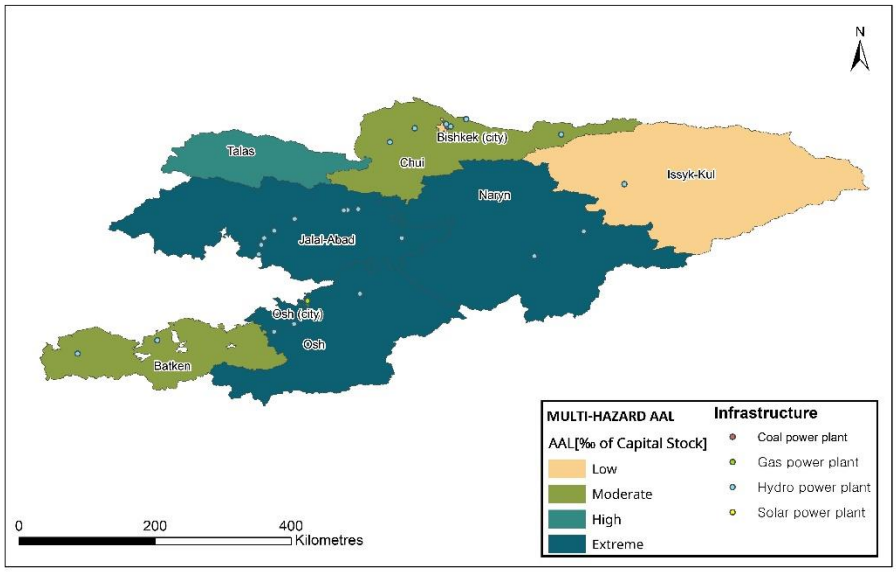


Table 17: Provincial multi-hazard AAL for the Kyrgyz Republic and its contribution to total AAL

Province	Multi-hazard AAL		Contribution to total value
	USD million	[‰ of capital stock]	
Osh	26.748	6.017	28.9
Jalal-Abad	18.994	5.968	20.5
Chuy	12.891	4.163	13.9
Bishkek	9.520	3.099	10.3
Naryn	7.523	12.389	8.1
Batken	5.550	4.068	6.0
Issyk Kol	4.236	3.508	4.6
Osh (city)	4.093	4.869	4.4
Talas	3.124	4.806	3.4
Total	**92.7**	**5.02**	**100.0**

Map 11: Kyrgyz Republic – Multi-Hazard AAL/ ‰ of capital stock and energy infrastructure



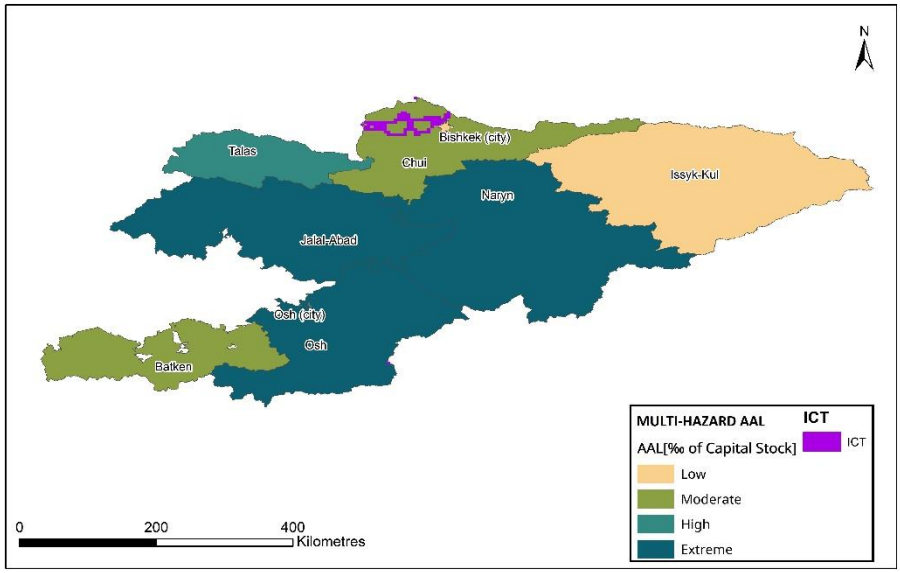
Disclaimer: The boundaries and names shown and the designations used in this map do imply official endorsement or acceptance by the United Nations.

High relative risk is shown by the ratio of AAL to per mille of capital stock. An overlaid map of 'ratio of multi-hazard AAL to percent of capital stock' and 'energy infrastructure assets i.e. coal, gas, solar, hydro, oil and wind power plants' shows that **59%** of energy infrastructure assets are located in oblasts that are extremely high relative risk locations. A majority of these power plants in the high and extremely high relative risk locations are hydro power plants.

Table 18: Energy infrastructure across Kyrgyz Republic in different multi-hazard risk categories

	Multi-Hazard Risk Class	Hydro	Gas	Coal
Batken	**Moderate**	2	0	0
Bishkek (city)	Low	1	0	1
Chuy	**Moderate**	6	0	0
Issyk-Kul	Low	1	0	0
Jalal-Abad	**Extreme**	12	0	0
Naryn	**Extreme**	2	0	0
Osh	**Extreme**	3	0	0
Osh (city)	**High**	0	1	0
Talas	**High**	0	0	0

Map 12: Kyrgyz Republic – Multi-Hazard AAL/ ‰ of capital stock and ICT infrastructure



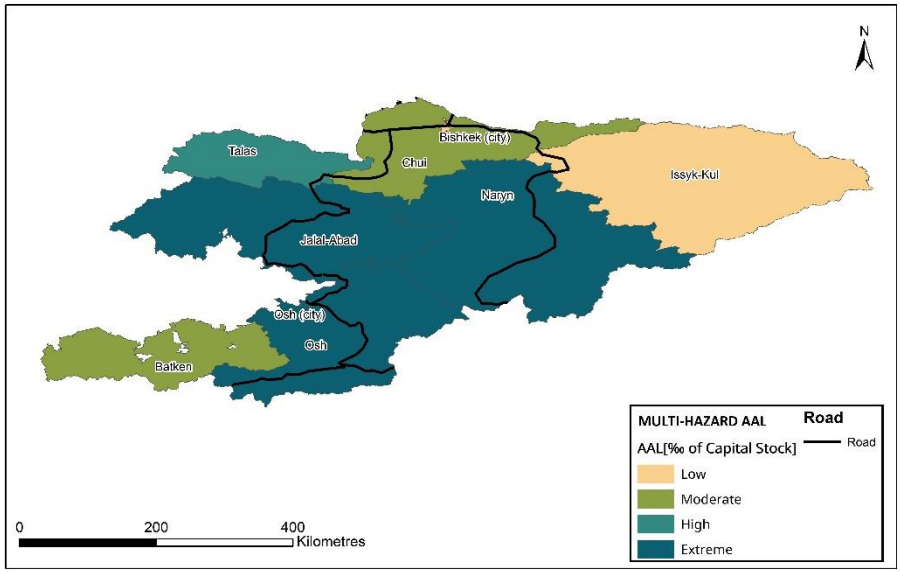
Disclaimer: The boundaries and names shown and the designations used in this map do imply official endorsement or acceptance by the United Nations.

99% of ICT Infrastructure is in moderate relative risk locations calculated from a ratio of multi-hazard AAL to capital stock at a location. Chuy has most of ICT infrastructure of the country.

Table 19: ICT infrastructure across Kyrgyz Republic in different multi-hazard risk categories

	Multi-Hazard Risk Class	ICT Infrastructure concentration
Batken	**Moderate**	0.00%
Bishkek (city)	Low	1.00%
Chuy	**Moderate**	98.68%
Issyk-Kul	Low	0.00%
Jalal-Abad	**Extreme**	0.00%
Naryn	**Extreme**	0.00%
Osh	**Extreme**	0.32%
Osh (city)	**High**	0.00%
Talas	**High**	0.00%

Map 13: Kyrgyz Republic – Multi-Hazard AAL/ ‰ of capital stock and Road infrastructure



Disclaimer: The boundaries and names shown and the designations used in this map do imply official endorsement or acceptance by the United Nations.

71% of highways located in high and extremely high relative risk locations. The extreme multi-hazard AAL to capital stock oblasts of Osh, Naryn and Jalal-Abad 68.77% concentration of highway network.

	Multi-Hazard Risk Class	Road Infrastructure concentration
Batken	**Moderate**	0.00%
Bishkek (city)	Low	0.91%
Chuy	**Moderate**	23.00%
Issyk-Kul	Low	4.72%
Jalal-Abad	**Extreme**	20.34%
Naryn	**Extreme**	19.80%
Osh	**Extreme**	28.64%
Osh (city)	**High**	0.30%
Talas	**High**	2.28%

8.2. Earthquake AAL and Infrastructure

In terms of earthquake hazard, Osh has the highest AAL accounting for the 28.6% of the total earthquake AAL in Kyrgyz Republic. The four oblasts of Osh (28.6%), Jalal-Abad (17.5%), Chuy (15.9%) and Bishkek (14.7%) have 76.6% of the total earthquake AAL. In relative terms, Osh and

Naryn have very highest value of AAL to capital stock ratio 4.02‰ and 3.95 ‰ respectively. Osh city (3.49‰) and Jalal-Abad (3.44‰) closely follow.

Figure 21: Provincial earthquake AAL to capital stock ratio for Kyrgyz Republic

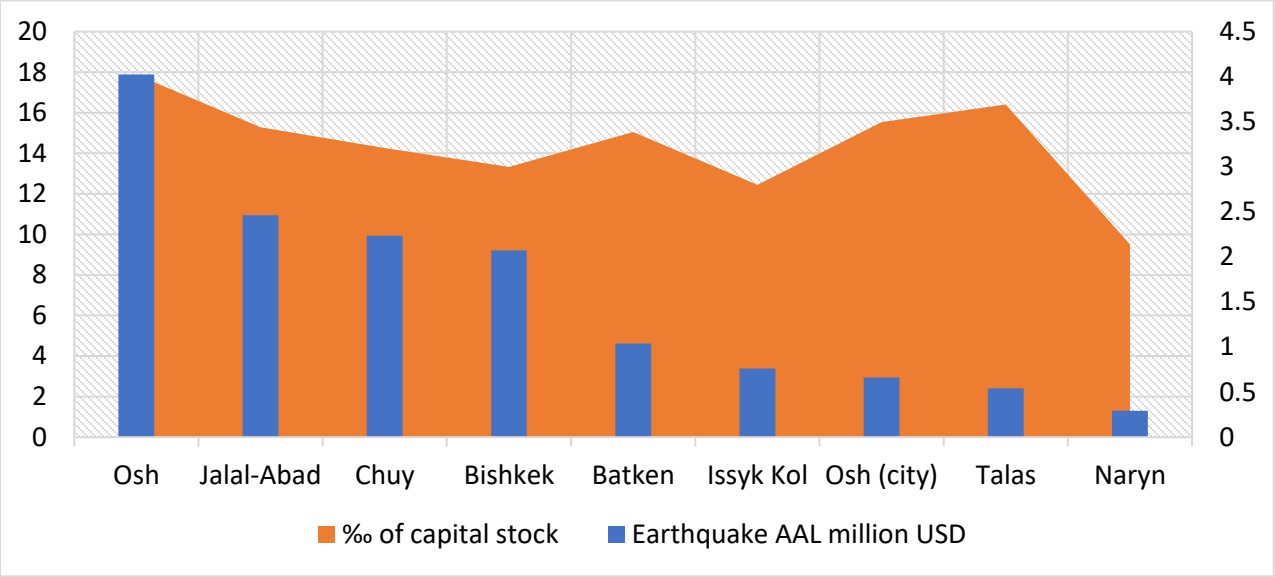
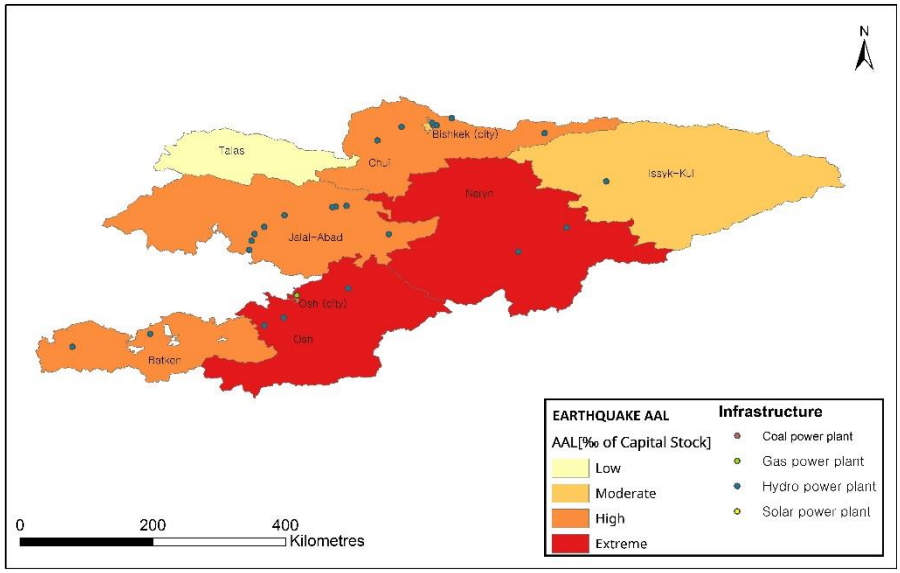


Table 20: Provincial earthquake AAL for the Kazakhstan and its contribution to total AAL

Province	Earthquake AAL		Contribution to total value
	USD million	[‰ of capital stock]	
Osh	17.88	4.02	28.6
Jalal-Abad	10.94	3.44	17.5
Chuy	9.93	3.21	15.9
Bishkek	9.21	3.00	14.7
Batken	4.62	3.39	7.4
Issyk Kol	3.38	2.80	5.4
Osh (city)	2.94	3.49	4.7
Naryn	2.40	3.95	3.8
Talas	1.30	2.00	2.1
Total	**62.6**	**3.39**	**100**

Map 14: Kyrgyz Republic – Earthquake AAL/ ‰ of capital stock and energy infrastructure



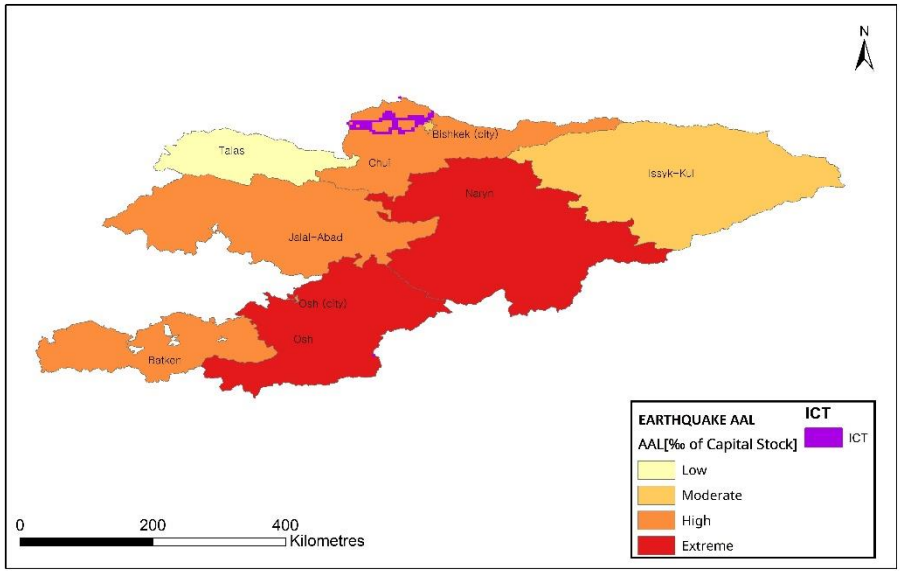
Disclaimer: The boundaries and names shown and the designations used in this map do imply official endorsement or acceptance by the United Nations.

90% of energy infrastructure is in high and extremely high earthquake relative risk locations.

Table 21: Energy infrastructure across Kyrgyz Republic in different earthquake risk categories

	Multi-Hazard Risk Class	Hydro	Gas	Coal
Batken	**High**	2	0	0
Bishkek (city)	**Moderate**	1	0	1
Chuy	**High**	6	0	0
Issyk-Kul	**Moderate**	1	0	0
Jalal-Abad	**High**	12	0	0
Naryn	**Extreme**	2	0	0
Osh	**Extreme**	3	0	0
Osh (city)	**High**	0	1	0
Talas	Low	0	0	0

Map 15: Kyrgyz Republic – Earthquake AAL/ ‰ of capital stock and ICT infrastructure



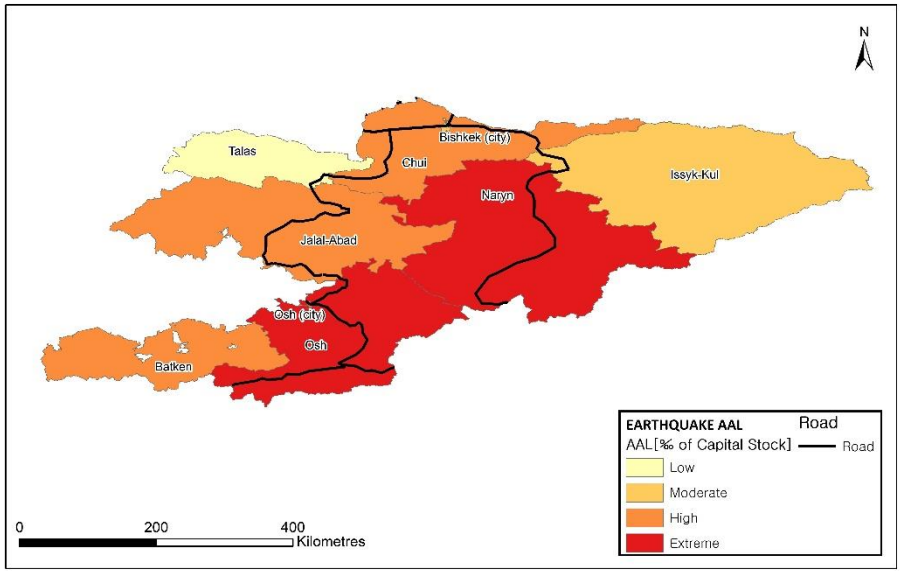
Disclaimer: The boundaries and names shown and the designations used in this map do imply official endorsement or acceptance by the United Nations.

99% of ICT Infrastructure is in high earthquake relative risk locations in Chuy.

Table 22: ICT infrastructure across Kyrgyz Republic in different earthquake risk categories

	Earthquake Risk Class	ICT Infrastructure concentration
Batken	**High**	0.00%
Bishkek (city)	**Moderate**	1.00%
Chuy	**High**	98.68%
Issyk-Kul	**Moderate**	0.00%
Jalal-Abad	**High**	0.00%
Naryn	**Extreme**	0.00%
Osh	**Extreme**	0.32%
Osh (city)	**High**	0.00%
Talas	Low	0.00%

Map 16:Kyrgyz Republic – Earthquake AAL/ ‰ of capital stock and Road infrastructure



Disclaimer: The boundaries and names shown and the designations used in this map do imply official endorsement or acceptance by the United Nations.

92% of highways are located in high and extremely high earthquake relative risk locations in the central oblasts of the country.

Table 23: Road infrastructure across Kyrgyz Republic in different earthquake risk categories

	Earthquake Risk Class	Road Infrastructure concentration
Batken	**High**	0.00%
Bishkek (city)	**Moderate**	0.91%
Chuy	**High**	23.00%
Issyk-Kul	**Moderate**	4.72%
Jalal-Abad	**High**	20.34%
Naryn	**Extreme**	19.80%
Osh	**Extreme**	28.64%
Osh (city)	**High**	0.30%
Talas	Low	2.28%

8.3. Flood AAL and Infrastructure

In terms of flood risks, the more than half the flood AAL is concentrated in the south-eastern Osh (29.5%) and Jalal-Abad (26.8%). However, in relative terms, the higher relative flood risk is in Naryn, which has a flood AAL to capital stock ratio of 8.44‰, followed by Talas (2.8‰) and Jalal-

Abad (2.53‰). Clearly, there is high concentration of absolute risk in two oblasts and a high concentration of relative risk in Naryn.

Figure 22: Provincial flood AAL to capital stock ratio for Kyrgyz Republic

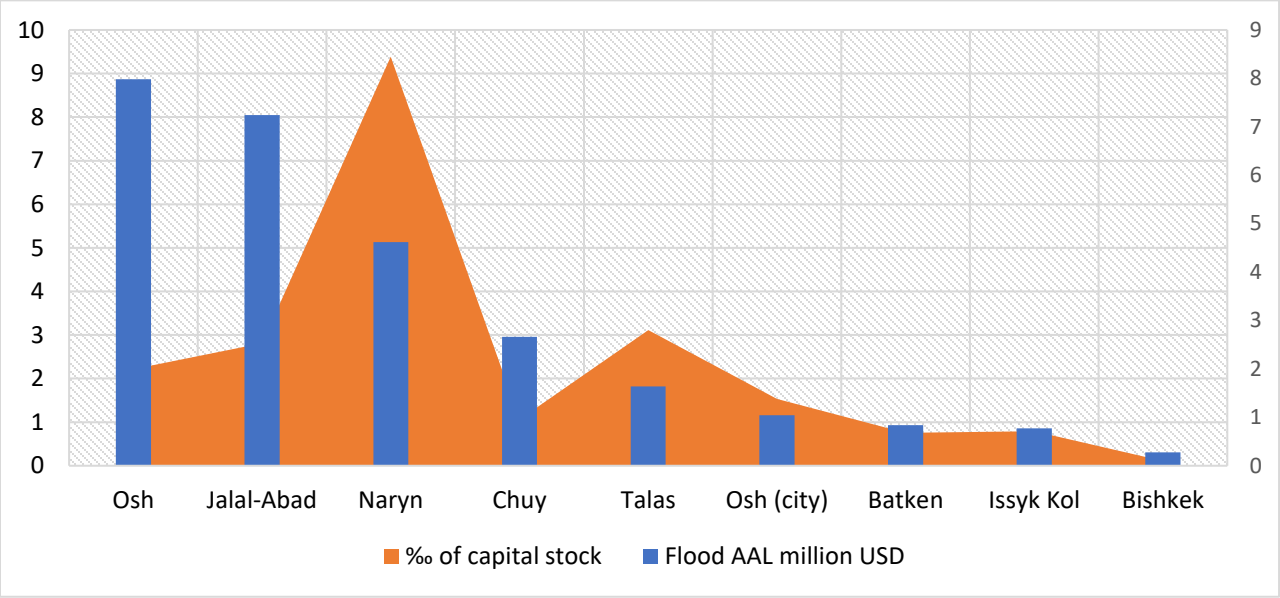
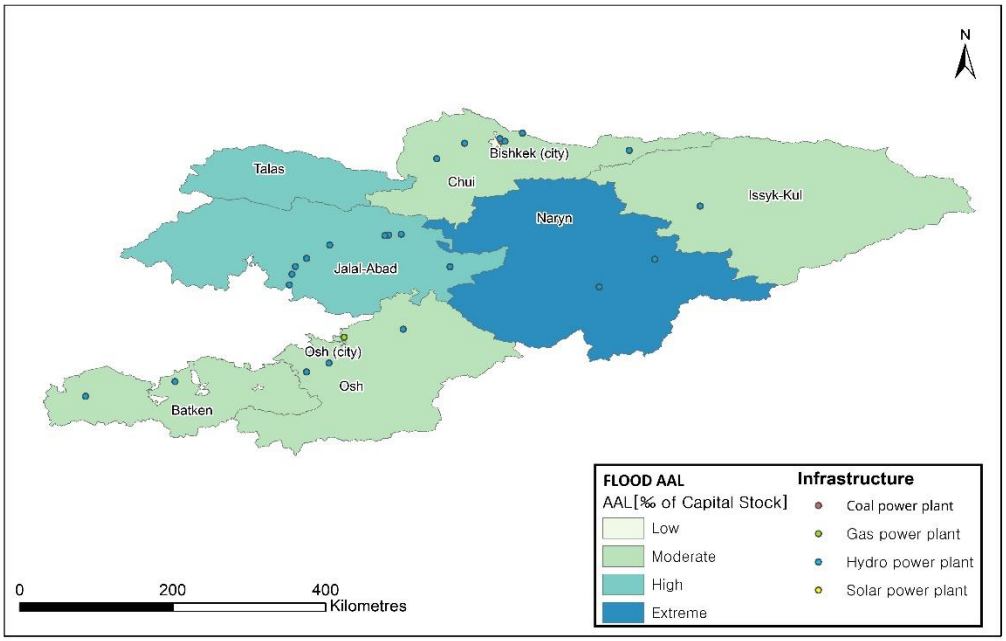


Table 24: Provincial flood AAL for the Kyrgyz Republic and its contribution to total AAL

Province	Flood AAL		Contribution to total value
	USD million	[‰ of capital stock]	
Osh	8.87	1.99	29.5
Jalal-Abad	8.05	2.53	26.8
Naryn	5.13	8.44	17.0
Chuy	2.96	0.96	9.9
Talas	1.82	2.80	6.1
Osh (city)	1.16	1.38	3.8
Batken	0.93	0.68	3.1
Issyk Kol	0.86	0.71	2.9
Bishkek	0.31	0.10	1.0
Total	**30.1**	**1.63**	**100**

Map 17: Kyrgyz Republic– Flood AAL/ ‰ of capital stock and energy infrastructure



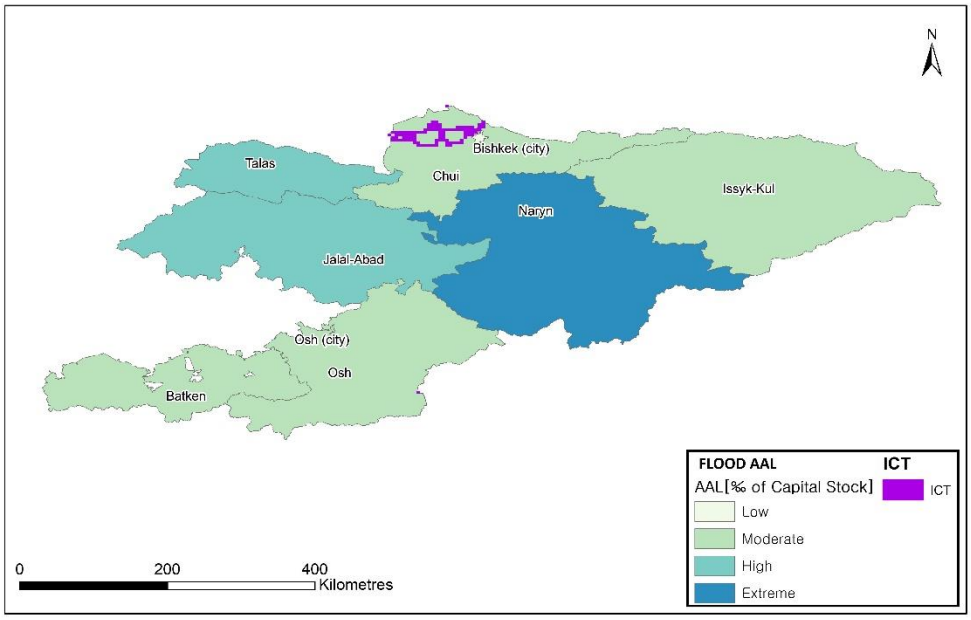
Disclaimer: The boundaries and names shown and the designations used in this map do imply official endorsement or acceptance by the United Nations.

48% of energy infrastructure is in high and extremely high flood relative risk locations.

Table 25: Energy infrastructure across Kyrgyz Republic in different flood risk categories

	Flood Risk Class	Hydro	Gas	Coal
Batken	Low	2	0	0
Bishkek (city)	Low	1	0	1
Chuy	Low	6	0	0
Issyk-Kul	Low	1	0	0
Jalal-Abad	**High**	12	0	0
Naryn	**Extreme**	2	0	0
Osh	**Moderate**	3	0	0
Osh (city)	**Moderate**	0	1	0
Talas	**High**	0	0	0

Map 18: Kyrgyz Republic – Flood AAL/ ‰ of capital stock and ICT infrastructure



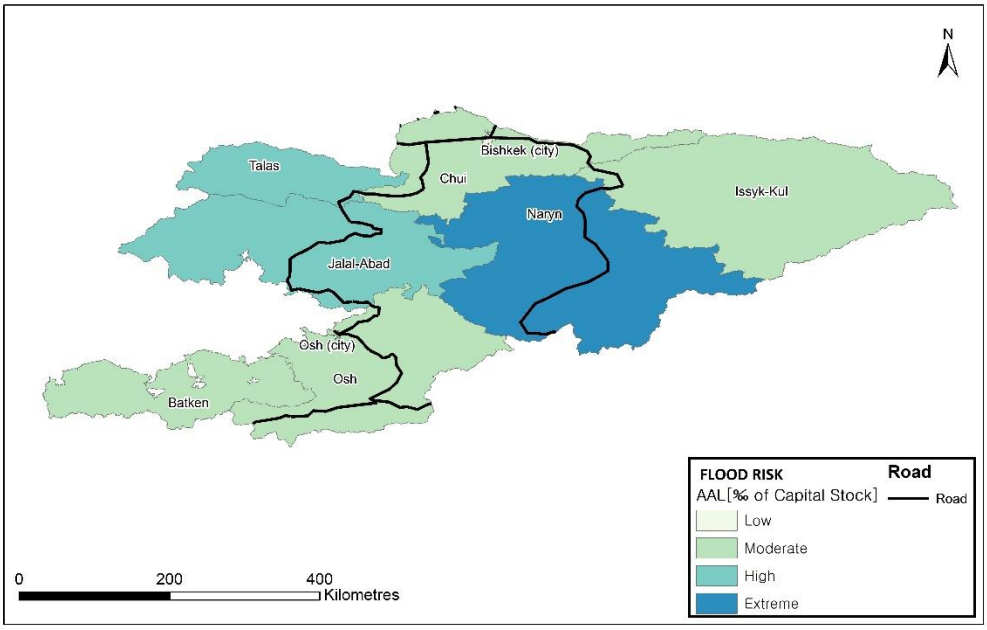
Disclaimer: The boundaries and names shown and the designations used in this map do imply official endorsement or acceptance by the United Nations.

99% of ICT Infrastructure is in low relative risk locations in Chuy.

Table 26: ICT infrastructure across Kyrgyz Republic in different flood risk categories

	Flood Risk Class	ICT Infrastructure concentration
Batken	Low	0.00%
Bishkek (city)	Low	1.00%
Chuy	Low	98.68%
Issyk-Kul	Low	0.00%
Jalal-Abad	**High**	0.00%
Naryn	**Extreme**	0.00%
Osh	**Moderate**	0.32%
Osh (city)	**Moderate**	0.00%
Talas	**High**	0.00%

Map 19: Kyrgyz Republic – Flood AAL/ ‰ of capital stock and Road infrastructure



Disclaimer: The boundaries and names shown and the designations used in this map do imply official endorsement or acceptance by the United Nations.

42% of highways are located in high and extremely high relative risk locations.

Table 27: Road infrastructure across Kyrgyz Republic in different flood risk categories

	Flood Risk Class	Road Infrastructure concentration
Batken	**High**	0.00%
Bishkek (city)	**Moderate**	0.91%
Chuy	**High**	23.00%
Issyk-Kul	**Moderate**	4.72%
Jalal-Abad	**High**	20.34%
Naryn	**Extreme**	19.80%
Osh	**Extreme**	28.64%
Osh (city)	**High**	0.30%
Talas	Low	2.28%

8.4. Risk metrics and development indices

The Disaster Risk Implications on the Socio-Economic Development of Countries (DRDIi) index examines the opportunity cost of disaster risk on sustainable development. For example, where the AAL represents a high proportion of a countries social expenditure, that country will have difficulties in maintaining or increasing its social expenditure and thus achieving social sector Sustainable Development Goals (SDG). Similarly, countries where the AAL represents a high proportion of capital investment will have difficulty in achieving infrastructure related SDGs.

Figure 23: DRDIi values for Kyrgyz Republic

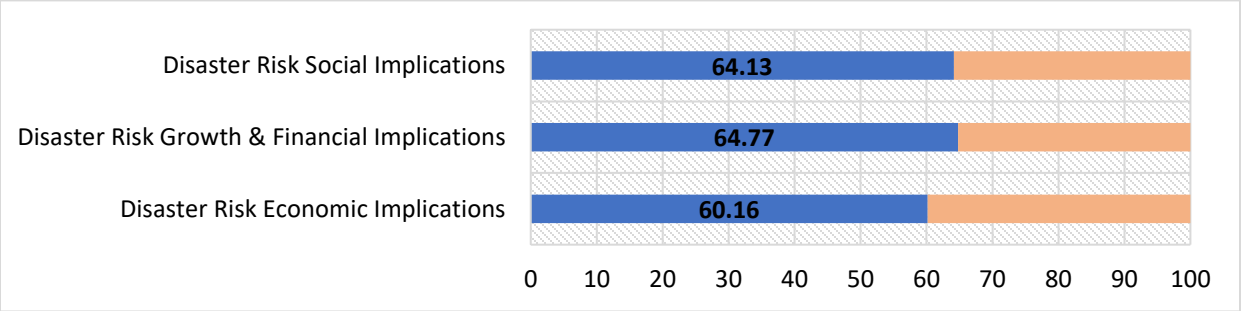
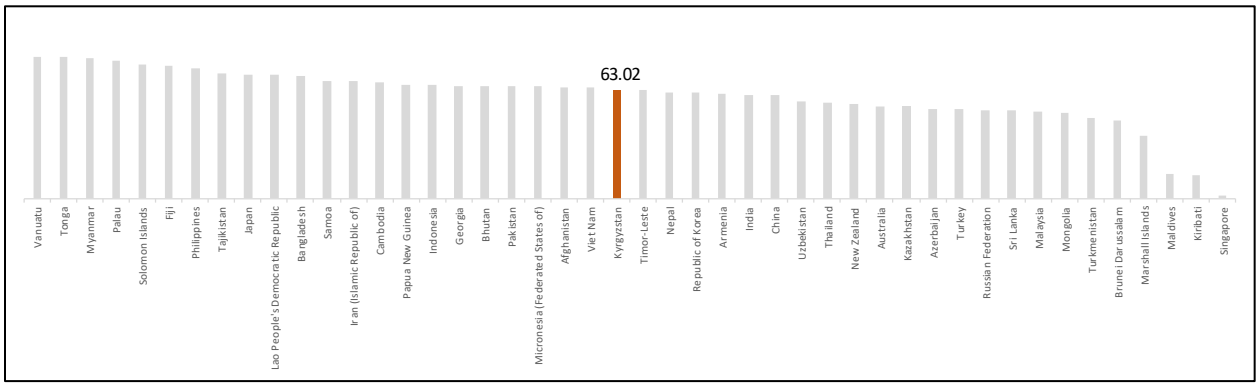
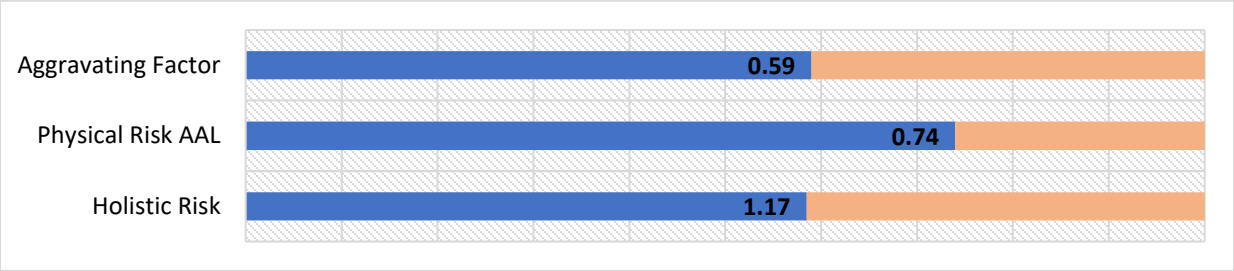


Figure 24: DRDIi values across Asia and the Pacific



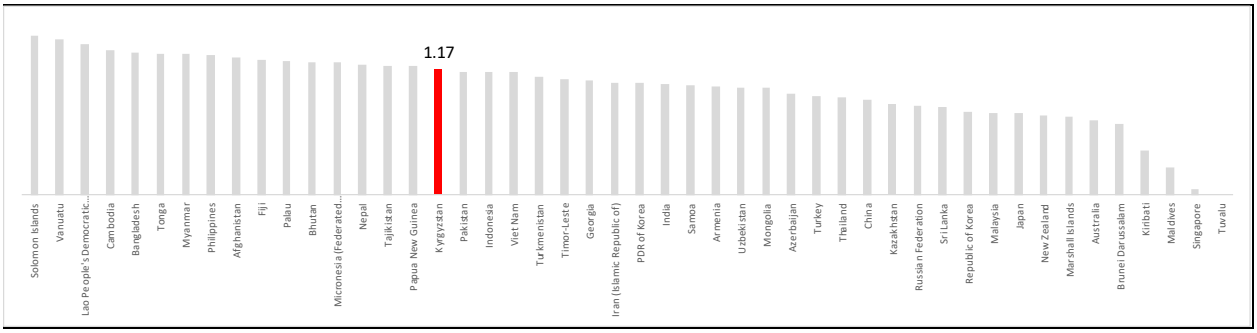
This index attempts to reveal the weight of the AAL on the social expenditure, capital investment and savings (domestic investment), reserves (financial capacity) and the produced capital or capital stock (assets at risk) of each country. It reflects the constraints to sustainable development posed by disaster risk. In the figure above, the values of economic, financial and social implications are very similar for Kyrgyzstan. Considering the average annual loss of 5.02‰ of capital stock, investment, savings and expenditures would be severely affected if the potential losses were paid every year.

Figure 25: Holistic Risk Values for Kyrgyz Republic



The holistic risk indicator is calculated for each country by capturing how underlying risk drivers or social, economic, environmental factors– (using an aggravating factor, F), which, worsen the current existing physical risk (RF). Fourteen variables were chosen to represent the underlying risk drivers or aggravating factors. These variables are: Internet access, Access to sanitation, Access to improved drinking water, GINI Index, Unemployment, Inflation and Urban growth rate. Indicators of Lack of Resilience are: Gross National Savings, Social expenditure, Governance, Human Development Index, Ecosystems vitality, Paved roads and Infant mortality. The total risk value for Kyrgyzstan 1.17.

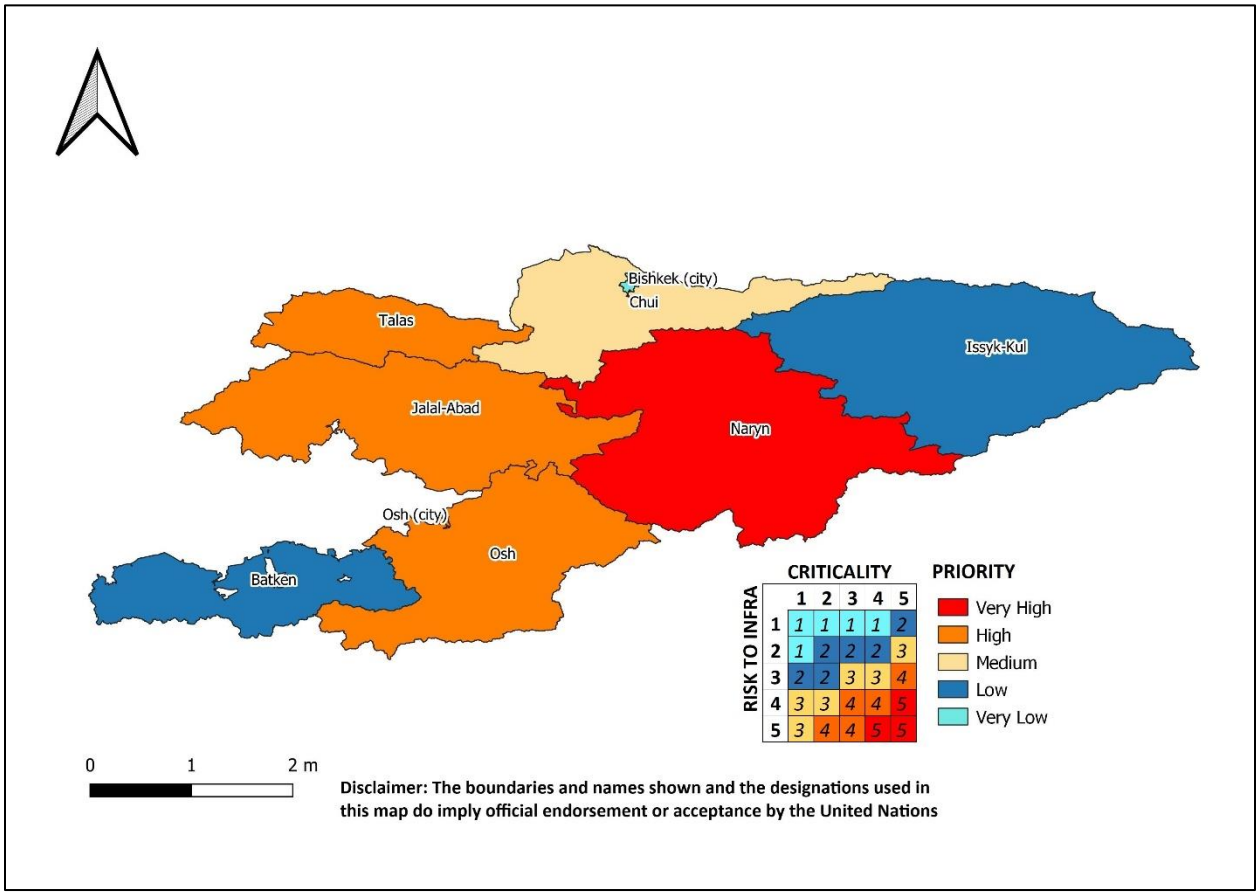
Figure 26:Holistic Risk values across Asia and the Pacific



In addition to the composite indices mentioned above, it also possible to track vulnerability and risk to infrastructure. This is particularly relevant for policy makers who would like to priority their actions by focussing on these high priority areas. Factors like poverty, population are added stressors on infrastructure availability and enhance the overall risks. The following map overlay shows different risk categories and criticality combinations that have a resultant high to low priority categorization. The risk to infrastructure is assessed from multi-hazard AAL to percent of capital stock ratio. The criticality is calculated from the absolute poverty rate. Classifying the risk to infrastructure and the criticality in different bands gives a matrix of priority i.e. the locations where infrastructure revival in the context of the social or economic stressors, need to be prioritized. Therefore, merely investment in infrastructure will not be enough to facilitate the shift low to high. Investments in mitigation of the drivers of vulnerability i.e. in reducing these socio-economic stressors will be simultaneously needed. Poverty is one such socio-economic

stressor and it is possible to create combinations of one or more of such stressors with risk to infrastructure.

Map 20: Priority areas from socio-economic stressors in Kyrgyz Republic



9. Conclusion and ways forward

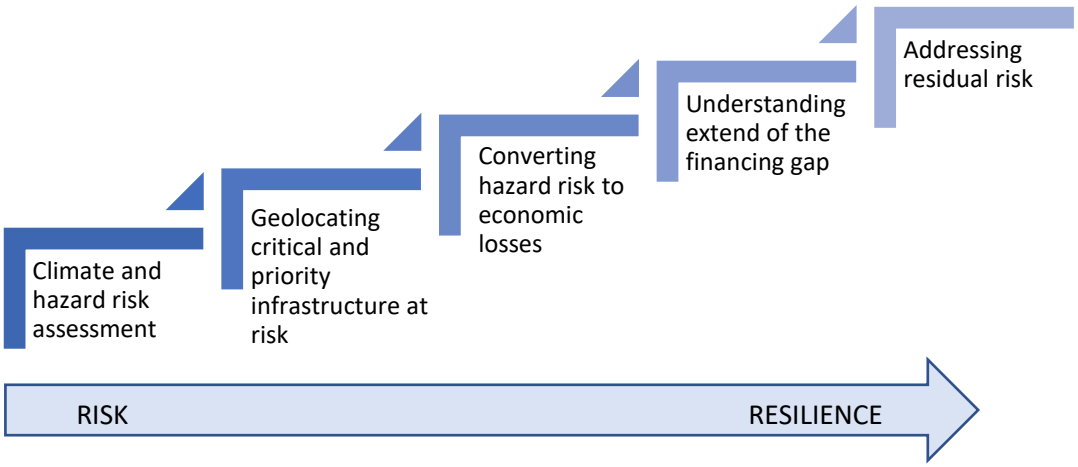
The general trend of disasters is an increasing one across the globe. Factors like climate change are increasing the frequency and intensity of disasters and ultimately amplifying the resultant adverse impacts and consequential economic losses. While this phenomenon is common for all countries, the local impacts, the capacities to deal with natural hazards and the vulnerabilities across countries and regions is different. Often it the developing countries with limited means to cope up bear disproportionate losses. Factoring in the needs and existing gaps in infrastructure, the losses can mean deviating from a pathway to achieve sustainable development goals.

In one way, disasters also represent an opportunity to build back better, have more resilient infrastructure and for policy makers to include risk metrics in their planning processes. This also implies that the risk metrics such as those of AAL are actively incorporated in planning in order to protect infrastructure investments amidst increasing risks of natural hazards, the uncertainty

about future projections and limited resources. The AAL methodology gives us a standardized estimate to measure financial resilience, that is both knowing the amount of loss that could be expected from future disasters, as well as the funds available for the Governments to use in covering those losses. Metrics like this are very effective in guiding investments, identifying locations of vulnerability and tracking the risk situation over a period of time.

Financing in infrastructure that is not resilient to current and future disasters is wasteful and something that the economies cannot afford. Financing resilient infrastructure entails assessing the needs of the economy and people. The preliminary first steps include moving beyond hazards and addressing the risks in particular to critical infrastructure. Having measures for long term economic losses for these critical infrastructure assets help understand where the gaps in financing are and finally address the residual risks.

Figure 27: Risk informed investments



Risk-informed investments in resilient infrastructure is the most efficient way to reduce the overall risk and build resilience in the long run. This report demonstrates some practical applications of risk metrics that can guide policy makers in planning, implementing and monitoring investments in resilient infrastructure. It also demonstrates methods to identify locations where investments are needed. The hazard specific projected annualized losses guide the type and capacities of infrastructure assets needed to address hazard specific vulnerabilities. The composite indices demonstrate the overall progress towards sustainable development goals. Finally, the criticality and risk to infrastructure indices demonstrate a process by which countries can prioritize investment planning.

Bibliography

ADB. (2017). *Meeting Asia's Infrastructure Needs.* Manila: The Asian Development Bank. Retrieved from https://www.adb.org/sites/default/files/publication/227496/special-report-infrastructure.pdf

ADB. (n.d.). *Infrastructure Needs, Asia and the Pacific.* Retrieved October 15, 2019, from Asian Development Bank: https://data.adb.org/dataset/infrastructure-needs-asia-and-pacific

Cardona, O. D. (2001). Holistic evaluation of the seismic risk using complex dynamic systems (in Spanish). Barcelona, Spain: Technical University of Catalonia.

Easterling, K. (1999). *Organization Space: Landscapes, Highways, and Houses in America.* Cambridge, Massachusetts, United States: MIT Press.

Gall, M., Emrich, C. T., & Cutter, S. L. (2014). *Who needs loss data? - Background paper prepared for the 2015 Global Assessment Report on Disaster Risk Reduction.* Geneva, Switzerland: UNISDR. Retrieved from https://www.preventionweb.net/english/hyogo/gar/2015/en/bgdocs/University%20of%20South%20Carolina,%202014.pdf

GFDRR. (2014). *Understanding Risk in an Evolving World: Emerging Best Practices in Natural Disaster Risk Assessment.* Global Facility for Disaster Reduction and Recovery. Washington DC: The World Bank. Retrieved from https://www.gfdrr.org/sites/gfdrr/files/publication/Understanding_Risk-Web_Version-rev_1.8.0.pdf

GFDRR. (2015). *Country Profile: Kyrgyz Republic.* Global Facility for Disaster Reduction and Recovery. Washington D.C.: The World Bank. Retrieved from https://www.gfdrr.org/en/publication/country-profile-kyrgyz-republic

GFDRR. (2017a). *Disaster Risk Profile: Kazakhstan.* Global Facility for Disaster Reduction and Recovery. Washington D.C.: The World Bank. Retrieved from http://pubdocs.worldbank.org/en/998151483041854104/kazakhstan.pdf

GFDRR. (2017b). *Disaster Risk Profile: Kyrgyz Republic.* Global Facility for Disaster Reduction and Recovery. Washington D.C.: The World Bank. Retrieved from https://www.gfdrr.org/en/publication/disaster-risk-profile-kyrgyz-republic

Hallegatte, S., Hourcade, J. C., & Ambros, P. (2007). Using climate analogues for assessing climate change economic impacts in urban areas. *Climatic Change*(82), 47-60.

IPCC. (2014). Summary for Policymakers. In O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, . . . J. C. Minx (Eds.), *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Jackson, S. (2010, February 17). *The Principles of Infrastructure Resilience*. Retrieved October 5, 2019, from Domestic Preparedness: https://www.domesticpreparedness.com/resilience/the-principles-of-infrastructure-resilience/

Mcdaniels, T., Chang, S., Cole, D., Mikawoz, J., & Longstaff, H. (2008). Fostering resilience to extreme events within infrastructure systems: Characterizing decision contexts for mitigation and adaptation. *Global Environmental Change, 18*(2), 310-318.

Mendonça, T., & Wallace, W. A. (2006). Electric Power Restoration in New York City following the 11 September 2001 Attacks. *2nd Resilience Engineering Symposium*, (pp. 209-219). Antibes -- Juan-Les-Pins. Retrieved from https://pdfs.semanticscholar.org/2848/9fe016b43f6b3f014cab893f42a39305d14d.pdf

NIAC. (2009). *Critical Infrastructure Resilience, Final Report and Recommendations.* Washington D.C.: National Infrastructure Advisory Council. Retrieved from https://www.dhs.gov/sites/default/files/publications/niac-critical-infrastructure-resilience-final-report-09-08-09-508.pdf

O'Rourke, T. D. (2007). Critical infrastructure, interdependencies, and resilience. *Bridge-Washington-National Academy of Engineering, 37*(1), 22.

Seo, J., & Mahul, O. (2009). The Impact of Climate Change on Catastrophe Risk Model. Implications for Catastrophe Risk Markets in Developing Countries. *The World Bank Policy Research Working Paper*(WPS4959). Retrieved from http://documents.worldbank.org/curated/en/277731468148518556/pdf/WPS4959.pdf

Stocker, T. F. (1999). Abrupt climate changes: From the past to the future – a review. *International Journal of Earth Sciences*(88), 365-374.

UNESCAP. (2019a). *The Disaster Riskscape Across Asia-Pacific: Pathways for Resilience, Inclusion and Empowerment. Asia Pacific Disaster Report 2019.* Bedfordshire, U.K.: United Nations Publications. Retrieved from https://www.unescap.org/sites/default/files/publications/Asia-Pacific%20Disaster%20Report%202019_full%20version.pdf

UNESCAP. (2019b). *Economic and Social Survey of Asia and the Pacific 2019.* Economic and Social Commission for the Asia and the Pacific, Macroeconomic Policy and Financing for Development Division. Bedfordshire, U.K.: United Nations Publications. Retrieved from https://www.unescap.org/publications/economic-and-social-survey-asia-and-pacific-2019-ambitions-beyond-growth

UNFCCC. (1992). *The United Nations Framework Convention on Climate Change.* New York: The United Nations. Retrieved October 1, 2019, from https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf

UNISDR. (2015). *Making Development Sustainable: The Future of Disaster Risk Management. Global Assessment Report on Disaster Risk Reduction.* Geneva, Switzerland: United Nations Office for Disaster Risk Reduction.

Weitzman, M. L. (2011). Fat-tailed uncertainty in the economics of catastrophic climate change. *Review of Environmental Economics and Policy, 5*(2), 275-292.

Woods, D. D. (2006). Essential Characteristics of Resilience: Concepts and Precepts. In E. Hollnagel, D. D. Woods, & N. Leveson (Eds.), *Resilience Engineering* (pp. 21-34). Boca Raton, Florida: Crc Press, Taylor & Francis Group.

Annex 1: Open Source Databases

Asian Development Bank

It is a central repository of ADB's public data. It has macro-economic, social, financial and environmental data of its member states.

https://data.adb.org/

EM-DAT

The Emergency Events Database (EM-DAT) has a database of occurrence and the effects of over 22,000 mass disasters in the world since 1900. The database is compiled from various sources, including UN agencies, non-governmental organisations, insurance companies, research institutes and press agencies.

https://www.emdat.be/

ESCAP Asia-Pacific Energy Portal 2018

The database provides information on current regional trends in energy and sustainable development. It is an open-access information platform, providing data visualizations for an extensive set of energy statistics, full-text policies, and interactive infrastructure maps. The Portal offers a collection of more than 200 datasets from global institutions.

https://asiapacificenergy.org/

ESCAP Asia Information Superhighway, 2018

The initiative aims to increase the availability and affordability of broadband Internet across Asia and the Pacific. The project has facilitated seamless information flow is being facilitated. Databases on ICT infrastructure, demographic features of ICT services consumption and spatial data are available.

https://www.unescap.org/our-work/ict-disaster-risk-reduction/asia-pacific-information-superhighway/about

ESCAP Statistical Database

The ESCAP Statistical Database includes country-level data related to demography, migration, education, health, poverty, gender, employment, economy, government finance, employment, transport, and the environment.

http://data.unescap.org/escap_stat/

Global Assessment Report on Disaster Risk Reduction (GAR) Risk Atlas, 2015
The GAR is a biennial publication from UNDRR and is a comprehensive review and analysis of disaster risk across the globe.

https://www.preventionweb.net/english/hyogo/gar/2015/en/home/data.php

HadGEM or the Hadley Centre Global Environmental Model
It is a coupled climate model developed at the UK meteorological Office's Hadley Centre for climate projections. The model has also been used in IPCC assessments.

https://www.metoffice.gov.uk/hadobs/hadgem_sst/index.html

Humanitarian Data Exchange
Humanitarian Data Exchange is an open data sharing platform managed by the United Nations Office for the Coordination of Humanitarian Affairs. It has socio, economic, spatial data sets from various international organizations.

https://data.humdata.org/

International Monetary Fund
IMF's repository of a range of time series data on lending, exchange rates and other economic and financial indicators.

https://www.imf.org/en/Data

IPCC
The IPCC has a Task Group facilitates the availability and consistent use of climate change-related data and scenarios in support of the implementation of the IPCC's programme of work.

https://www.ipcc.ch/data/

World Bank
The World Bank database is the bank's repository of social, economic, environmental, developmental, and macro-economic data collected since its inception.

https://data.worldbank.org/

UN Digital Library
It has a repository of all UN documents and open access publications, UN voting data and speeches, UN maps and content in 6+ languages.

https://digitallibrary.un.org/?ln=en