United Nations Development Programme

Guidance notes on building critical infrastructure resilience in Europe and Central Asia

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List of Acronyms

AD	After disaster
ADB	Asian Development Bank
AL	Albania
ARM	Armenia
ARNAP Foundation	Disaster Risk Reduction National Platform of Armenia
AZ	Azerbaijan
BBB	Build Back Better
BN	Billion
BD	Before a disaster
BY	Belarus
CA	Central Asia
CAREC	Central Asia Regional Economic Cooperation
CC	Climate Change
CDRI	Coalition for Disaster Resilient Infrastructure
CI	Critical Infrastructure
CISA	US Cybersecurity and Infrastructure Security Agency
CPR	Cardiopulmonary resuscitation
CRED	Centre of Research on the Epidemiological Disasters
DHS	Department of Homeland Security
DoA	Department of Agriculture
DoD	Department of Defence
DoE	Department of Energy
DoHHS	Department of Health and Human Services
DoT	Department of Transportation
DoTr	Department of Treasury
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EBRD	European Bank for Reconstruction and Development
EC	European Community
ECA	Europe and Central Asia
EE	Eastern Europe

EIB	European Investment Bank
EPA	Environmental Protection Agency
EU	European Union
FTX	Field Training Exercise
GARD	Get the Airports Ready for Disasters
GE	Georgia
GSA	General Service Administration
HAZMAT	Hazardous Materials Teams
ICAO	International Civil Aviation Organization
ICRC	International Committee of the Red Cross
IFIs	International Financial Institutions
IUCN	International Union for Conversation of Nature
KG	Kyrgyzstan
KS	Kosovo[1]
KZ	Kazakhstan
LDC	Least Developed Countries
MD	Moldova
ME	Montenegro
MES	Ministry of Emergency Situations
MK	North Macedonia
MOESY	Ministry of Education Sport and Youth
MS	Member States
MTACC	Ministry of Transport, Architecture, Construction and Communication
NDMA	National Disaster Management Authority
OECD	Organization for Economic Co-operation and Development
OIEWG	Open-Ended Intergovernmental Expert Working Group
PDNA	Post-disaster Needs Assessment
PHC	Primary Health Care
RA	Republic of Armenia
RB Cycle	Resilience-building cycle
RNA	Recovery Needs Assessment
SAR	Search and Rescue

1 All references to Kosovo should be understood to be in the context of United Nations Security Council resolution 1244 (1999).

SC	South Caucasus
SCADA	Supervisory control and data acquisition
SDGs	Sustainable Development Goals
SFDRR	Sendai Framework for Disaster Risk Reduction
SIDs	Small island developing States
SRB	Serbia
SSAs	Sector-specific Agencies
TJ	Tajikistan
TM	Turkmenistan
TR	Turkey
TRACECA	Transport Corridor Europe-Caucasus-Asia
TTX	Tabletop Exercise
UA	Ukraine
UN	United Nations
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNFCCC	United Nations Framework Convention on Climate Change
UNDRR	United Nations Office for Disaster Risk Reduction
USA	United States of America
UZ	Uzbekistan
WB	World Bank
WB & TR	Western Balkans and Turkey
WEF	World Economic Forum
WHO	World Health Organization

Executive summary

Critical infrastructure systems are the cornerstones of societies and communities as they provide services for their functioning and ensure a crucial contribution is made to their sustainable and resilient development. They are complex, interconnected and interdependent systems and their networks provide vital support to everyday life and activities.

With the advancement of the sustainable development agenda, the importance and roles of the critical infrastructures have emerged as an important basis for their resilient development. They are exposed and vulnerable to existing and to emerging risks and threats that are eroding their structures and functions, exacerbating existing vulnerabilities and undermining sustainable and resilient development.

The COVID-19 pandemic affected the countries and territories across the globe in an unprecedented way impacting societies and economies at their core, including the critical infrastructure systems. Across the region, different approaches to these efforts emerged—ranging from more advanced to basic ones. Some countries and territories have already embarked on a resilience-building journey, others are preparing for one.

To achieve the objectives of resilience and sustainability, a prerequisite is to shift the paradigm from risk to resilience, to adopt an all-hazard, all-of- society and life-cycle approach to infrastructure. At the same time, one has to understand critical infrastructure as a comprehensive, interconnected and interdependent system that designs policies, provides resources and implements activities throughout the resilience-building cycle, while leaving no one behind.

These policies and approaches need to be future-oriented. What this means is that within the resilience building of critical infrastructures possible and preferred futures should be considered. Thus, the definition of ***critical infrastructure resilience*** can be understood as the *ability of these systems to anticipate, withstand or absorb shocks and stresses while adapting to the new conditions that would result in a quick recovery and transformation to better cope with stresses and shocks in the future*.

The most efficient way to contribute to resilience-building efforts in Europe and Central Asia (ECA) is through the formulation of Guidance Notes on building critical infrastructure resilience, which is one of the initial categories of documents elaborated in the region. In that regard, this document design represents a practical framework for building critical infrastructure resilience in the region and beyond.

The aim is to overcome identified gaps and challenges, while providing insights into the developmental stage of critical infrastructure resilience today, promoting good practices and identifying the potential and emerging opportunities. Undertaking this exercise through a systematic approach contributes to the enhancement of building critical infrastructure resilience in the countries and territories of Europe and Central Asia.

Accordingly, key stakeholders from the public and private domains will be better able to understand the building of critical infrastructure resilience and thereby better able to design appropriate policies and normative and institutional frameworks and to develop and implement various measures and actions in public-private cooperation. The guidance and actions provided should be used to review and implement the process of building the critical infrastructure resilience cycle, based on a system-wide approach that acknowledges a range of perspectives: the all-risk (hazards and threats) and all-of-society approach and the whole-of-government and life-cycle of critical infrastructure approach. The Guidance Notes' practical application are expected to boost the resilience agenda in the region and to navigate practitioners and stakeholders on the path of building the critical infrastructure resilience.

The ***Technical Checklist for building critical infrastructure resilience*** is designed as a diagnostic tool to help DRR practitioners in the Europe and Central Asia region to understand the existing level in building critical infrastructure resilience in their countries and territories. The ***General Guidance Notes for building critical infrastructure resilience in the ECA*** region contribute to mainstreaming critical infrastructure into disaster risk management and vice versa. The Guidance Notes aim to support the authorities and practitioners in the countries and territories in designing relevant resilience-building policies and to implement adequate actions in partnership with other entities, owners and/or operators before, during and after disasters.

There are 11 general Guidance Notes and 83 proposed actions that enable better identification and formulation of relevant guidelines and that facilitate a proactive approach to risk reduction and resilience-building. This means that most are to be implemented before disasters. The identification and formulation of these notes stem from the broad list of survey recommendations. Each Guidance Note results in a set of specific actions that can be implemented by institutions and stakeholders from countries and territories of the ECA region, depending on the national context and on the priorities.

The proposed ***Critical Infrastructure Resilience Plan*** aims to advance further the resilience-building domain by providing a structured and operational framework built upon existing and anticipated risk and hazards; security threats; identified needs and existing capacities and capabilities; and a defined vision, clear objectives and logically sequenced set of measures and actions for mitigation and protection that are also realistic, practical and applicable.

This plan is designed to guide overall resilience-building activities in a systematic and inclusive manner taking account of the interconnectivity and interdependencies of critical infrastructure systems that are based on an all-hazards and life-cycle perspectives. It represents a planning document that ensures the resilience-building mission of all involved stakeholders, both from the public and private domains, while protecting the critical infrastructure systems for the benefit of all society.

Lastly, following the assessment review framework and recognizing the need for transformational change in the overall approach to critical infrastructure in Europe and Central Asia, ***three potential development pathways*** were identified for enhancing overall resilience-building and anticipating the complexity of disasters and an uncertain future:

- ***Status quo scenario (Routine)—***Implementation of regular activities for critical infrastructure resilience within the existing policy, normative and institutional frameworks with only stand-alone, partial enhancements, e.g., integrated risk and hazard assessments, adoption of operational and response plans, communicationand coordination and basic education and training.
- ***Straightforward scenario (Advancement)***—Essential enhancement in building critical infrastructure resilience through improving the policy, normative, institutional and operational frameworks, i.e. greater mainstreaming of critical infrastructure resilience in the DRM systems across the region; identification of critical infrastructure sectors; modification of existing laws; an enhanced partnership between public and private entities; increased investment and provision of resources; targeted capacity-building; and more.
- ***Changing scenario (Towards Next-Gen building of CI resilience)***—Establishment of the new policy; of normative, institutional and operational frameworks; designing solutions for resilience; and implementation of measures and actions resulting in comprehensive and versatile building of critical infrastructure resilience—i.e. new legislation, the creation of a critical infrastructure coordination institution, broad capacity-building and awareness-raising, stable and sufficient provision of resources, and more.

PART I:

ESSENTIALS OF BUILDING CRITICAL INFRASTRUCTURE RESILIENCE

1. INTRODUCTION

1.1 Background

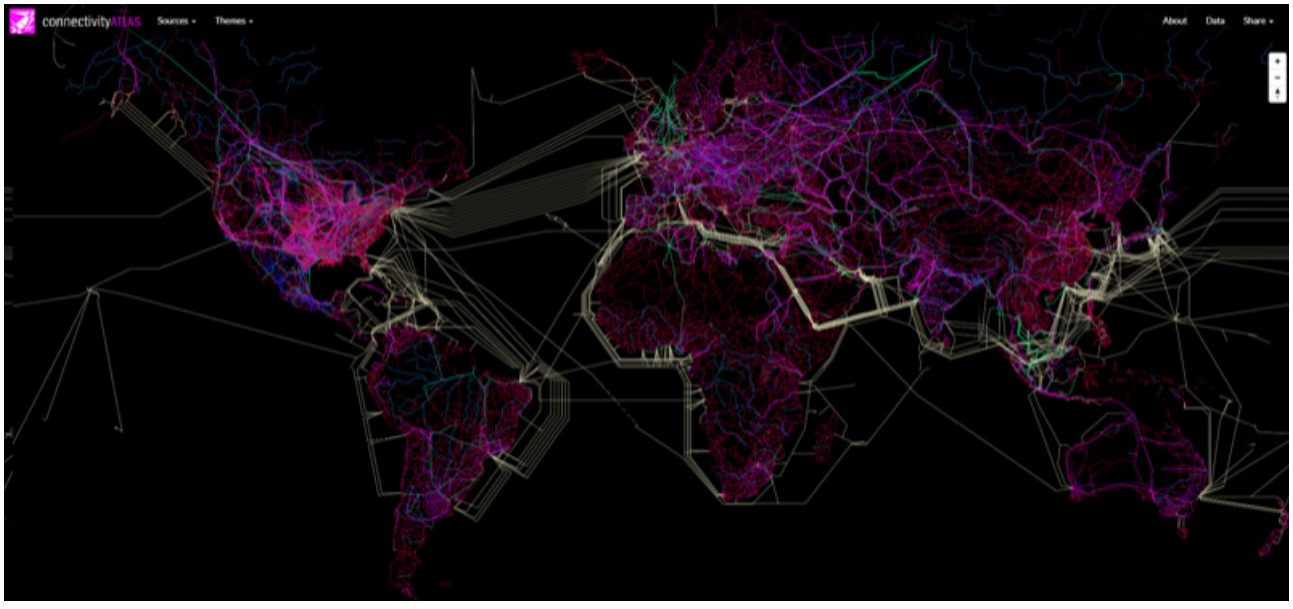
In our contemporary and ever more interdependent and globalized world, critical infrastructure systems are the cornerstones of societies. They provide communities with vital support and services for their functioning and ensure their crucial contribution to economic development, inclusion and well-being of society—aimed at leaving no one behind. They are complex, interrelated systems, networks and services essential for everyday life, businesses and social activities and underwrite the security of societies and communities.

In our hyper-connected world—as presented in the map below outlining the connectivity routes in the transportation, energy, and communications sectors globally—disaster risks are more frequent and their impacts or damages to the infrastructure systems lead to structural failures and to disruptions in services. These result in losses of life, casualties, damages; losses to households and downturns in economic activities; impacts on national security—with a consequential setback to the overall development of countries and territories.

Furthermore, local shocks at one end of the globe can cause costly disruptions at the other extremity (e.g. the Eyjafjallajökull volcanic eruption in Iceland in 2010 sundered the global supply chains and halted global aviation in Europe and beyond. This caused daily losses of US$400 mn on days with the greatest disruptions[2]).

Critical Infrastructure is "the physical structures, facilities, networks and other assets which provide services that are essential to the social and economic functioning of a community or society." *(UNDRR Terminology)*
Source: https://tinyurl.com/3dfua2st

Figure 1: Connectivity Atlas[3]



2 http://edition.cnn.com/2010/TRAVEL/04/22/volcano.travel/
3 DevelopmentSeed, University of Wisconsin-Madison Cartography Lab and Dr. Parag Khanna. https://atlas.developmentseed.org/all/

A **"systemic risk"** is a risk that is endogenous to, or embedded in, a system that is not itself considered to be a risk and is therefore not generally tracked or managed, but which is understood, through systems analysis, to have a latent or cumulative risk potential to negatively impact overall system performance when some characteristics of the system change.
Source: Global Assessment Report on DRR. Geneva, Switzerland: UNDRR. (2019) https://gar.undrr.org/

The modern world is becoming ever more multi-hazard, the nature of risk is rapidly becoming systemic in nature and the resulting disaster impacts are cascading across societal sectors and life in unpredictable ways. In that sense, a *palette* of existing, emerging risks and threats are affecting countries and territories globally in an unprecedented way, thereby exacerbating existing vulnerabilities and inequalities and creating new ones.

Additionally, there are converging and disruptive chronic stresses and acute shocks[4] (e.g. natural hazards, climate change, increased costs for CI management, improper operations, insufficient maintenance, disastrous events, terrorist acts) that are eroding the various infrastructure systems and their operations.

With the expected impacts of climate change; increased rates of urbanization; environmental degradation; the rise of new and emerging risks and threats; more frequent high-consequence and low-probability events; and other factors—and given that these trends are expected to continue—the ramifications are clear. This includes the thwarting of the development efforts and the urgent need for building critical infrastructure resilience in systems across the world.

By one estimate, from 1995–2015, disasters caused $2 to 2.5 trillion in damages and losses, most involving infrastructure systems. In the 21st century, the trend points to disasters taking fewer human lives, but generating much greater damage and economic losses compared to the 20th century.[5] This applies in particular to the most developed, high-income countries given their high valued assets, i.e., infrastructure.[6] From 1998–2017, "the USA recorded the biggest losses ($945 bn), reflecting high asset values and the frequency of events, whereas at the same time China, by comparison, suffered a significantly higher number of disasters than the USA (577 against 482), but lower total losses stood at $492 billion)" due to the lower value of its assets.

Given the increased frequency of extreme climate events, some of the largest economies are pressured by recurring and costly disasters. "The cumulative costs of the 16 separate billion-dollar weather events in the U.S. in 2017 were $306.2 bn, breaking the previous record of $214.8 bn (2005)."[7] Moreover, numerous small-scale disastrous events happening regularly and staying below the horizon in the long-term erode these systems and exert pressure on the resilience of societies and communities.

Furthermore, natural and human-made hazards; technical incidents and accidents; pandemics and biohazards; terrorist acts and security threats—these all severely affect critical infrastructure systems and their structural resistance or disrupt service provision. These ramifications have cascading effects across societies, economies and communities.

In that regard, Table 1 below presents the impacts of some major, complex global disasters and their implications for critical infrastructure systems at the local, national, regional and global levels.

4 *Chronic stresses* mean repetitive actions that are weakening the resilience texture of the critical infrastructure systems on a continuous basis, and *acute shocks* mean events that occur suddenly and disrupt their functioning.
5 Santiago Lema-Burgos, *Disaster Risk to Critical Infrastructure: Understanding critical infrastructure in the ECIS region* (UNDP, 2019), p. 1.
6 UNDRR, *Economic Losses, Poverty and Disasters 1998–2017*, 2018, p. 3. https://www.unisdr.org/files/61119_credeconomiclosses.pdf Accessed 10.08.2021.
7 https://coast.noaa.gov/states/fast-facts/hurricane-costs.html

Table 1: Impacts of some major disasters globally on critical infrastructure systems

Disastrous event	Brief description of the impact on CI systems
2005 Hurricane Katrina	Catastrophic damage was caused over an area roughly the size of the UK[8] (approx. 240,869 km^2) with a price tag of $130 bn[9] and with many CIs being damaged or destroyed.
2010 the Eyjafjallajökull volcanic eruption	Dispersion of the volcanic ash and closure of the European air spaces impacted air transport causing losses to the global airlines of $1.7 bn[10], disrupting global supply chains and affecting global economies.[11]
2011 Great East Japan Earthquake	This complex disaster (seismic events/consequent tsunami/nuclear incident) had a price tag of $309 bn[12]. It resulted in a 50% reduction in energy production, disruption in national services and disturbances of global supply chains, e.g. cars, and electronics. The meltdown of a nuclear reactor at the Fukushima Nuclear Plant exposed the surrounding areas to increased radiation.
2012 Super Storm Sandy	It resulted in damages of $68 bn and impacted the energy, transportation, communications, water and health sectors in the greater New York/New Jersey metropolitan areas.[13]
2012 India Blackouts	620 million people, or 9% of the world population, were affected.[14]
2017 Hurricane Harvey	Hurricane Harvey was the most significant tropical cyclone rainfall event ever recorded in U.S. history with damages of $125 bn.
2020 Beirut Port Explosion	A major part of the central city area was destroyed with an estimate of over $10 bn in infrastructural damages and 300,000 displaced individuals.[15]

Similar evidence can be found in the disaster profiles of the Europe and Central Asia region where in 2018 alone, 1,889 infrastructure assets in 20 countries were damaged or destroyed, amounting to direct economic losses of over $3 bn.[16] Globally, it is the second region with the highest volume of destroyed infrastructure facilities representing one-third of the total global figure. Moreover, disruption of 106 basic services (educational, health and other critical services) was recorded in that year.[17] With the projected impact of climate change[18], these numbers are expected to double.

In addition, a review of several major regional disasters reveals the significant contribution of the infrastructure systems to total damages and losses, i.e., 30 percent in the 2014 floods in Bosnia and Herzegovina ($2.4 bn), 47 percent from the same year's floods in Serbia ($1.8 bn), or 14 percent from the Albania 2019 earthquake ($1.19 bn). Furthermore, in recent years, new and complex risks and threats emerged that threatened decades of hard-won development achievements and that increased the vulnerability of the population and the infrastructure.

The prolonged impact of the COVID-19 pandemic crisis has far more negative implications than a typical health crisis. As an emerging systemic risk, it is affecting countries and territories around the globe in an

8 https://apps.dtic.mil/sti/pdfs/ADA575202.pdf
9 https://tinyurl.com/b2f2e74
10 http://news.bbc.co.uk/2/hi/business/8634147.stm
11 https://tinyurl.com/4db7kbzn
12 https://tinyurl.com/b2f2e74
13 https://repository.library.northeastern.edu/files/neu:m0419677k
14 https://jalopnik.com/the-ten-greatest-infrastructure-failures-in-modern-hist-1207427797
15 Mazen J. El Sayed, *Beirut Ammonium Nitrate Explosion: A Man-Made Disaster in Times of the COVID-19 Pandemic.* (Disaster Med Public Health Prep., 18 Nov 2020), pp. 1. https://tinyurl.com/hypejdty (Accessed on 11.08.2021)
16 UNDRR, *Monitoring the Implementation of Sendai Framework for Disaster Risk Reduction 2015–2030: A Snapshot of Reporting for 2018* (2018), p. 19, https://tinyurl.com/xeezevcv (Accessed on 6.05.2021)
17 *Ibid.* p. 19,
18 https://www.eurasia.undp.org/content/rbec/en/home/climate-and-disaster-reslience.html

unprecedented way[19], heavily impinging on societies and economies at their core, while simultaneously disrupting the supply chains and provision of services, and affecting human resources and the viability of infrastructure systems.

On the other hand, new security risks are emerging, such as the prolonged migrant and refugee crisis from 2015, which has drained the finite resources of the emergency services and has the potential for spilling over to other areas. Or the increased number of cyber-attacks against critical infrastructure assets. For instance, it is estimated that the economic and insurance impact of a severe, yet plausible, cyber-attack against the US power grid would total more than $240 bn, possibly even rising to more than $1 trillion.[20]

In February 2022, the Florida water treatment facility was hacked using dormant remote access software and the hackers tried to poison the water. The incident highlights how some critical infrastructure systems are vulnerable to hacking because they are online and use remote access programmes, sometimes with lax security.[21] These events underscore that the fragility of infrastructure is a paramount concern therefore building resilience must incorporate measures and actions/plans over and beyond the usual elements.

Resilience of the critical infrastructure system is defined as *the ability to absorb, adapt to and/or rapidly recover from a potentially disruptive event.*
Source: https://tinyurl.com/dhjb5nxu

Therefore, the importance of critical infrastructure resilience is high on the agenda of contemporary sustainable development as the *"keystone"* of nationally-led processes of building resilience and actions. Significantly, between 2020 and 2040, $94 trillion is expected to be spent on infrastructure, with the global infrastructure gap estimated at $15 trillion.[22] Thus, the adequate integration of critical infrastructure resilience-building in the DRM framework and beyond is of crucial importance, as the following quote points out:

> *"Having the capability to prevent and to prepare for infrastructural failures, and thus to manage infrastructural interdependencies, is seen as a major prerequisite for resilient societies."*[23]

Accordingly, on a regional level, the way the ECA region addresses risk factors in all new investments in the public and private sectors and how it further mainstreams DRR into current and future policies, plans, programmes and projects will determine the outcome of developing the critical infrastructure resilience agenda over the next decade. Many countries and territories in the region voiced their need for such resilience building and for further mainstreaming across the DRR domain through an all-hazard approach and a multi-risk, multi-stakeholder *"infrastructure-life-cycle"* perspective. This approach should result in enhancing mitigation and boosting preparedness, response and recovery.

In that regard, countries and territories need to adopt a transformative approach, one that would differentiate between resistance and resilience of critical infrastructure systems; enhance the assessment methodology of assessing existing risk and hazards; anticipate future uncertainties; and consequently, adapt planning and provide resistant construction, innovative financing, proper operations and regular maintenance.

Critical infrastructure systems need to be understood in their complexity and interdependency vis-a-vis sectors and subsectors as they incorporate key elements such as systems, assets, facilities, provision of services and human resources.

This publication can be taken as the starting point of a transformative journey with the issuing of the Guidance Notes as a tool for navigating the building of critical infrastructure resilience in the ECA region.

19 Vasko Popovski, *Assessment Study of the Role of NDMAs in COVID19 crisis response and impact of COVID-19 on NDMAs Operations* (UNDP/UNDRR, 2021), p. 11. https://tinyurl.com/rzzjah7b (Accessed on 5.5.2021)
20 https://tinyurl.com/257ttb3s
21 https://edition.cnn.com/2021/02/10/us/florida-water-poison-cyber/index.html
22 https://outlook.gihub.org/
23 Coalition for Disaster Resilient Infrastructure (CDRI), The Resilience Shift, *Governance of Infrastructure for Resilience (White Paper) V1* (November 2021), p. 11. https://tinyurl.com/2p9h6ths (Accessed on 15.11.2021).

1.2 Purpose of the Guidance Notes

The purpose of this **document** is to provide an overview of the existing context of building resilience in Europe and Central Asia and to present a set of key principles for classification, systematic review and assessment of CI applicable to ECA countries and territories. Case studies and recommendations, with a technical checklist as a tool for facilitating the resilience-building process in the region and beyond, will also be included. In addition, an annex will contain case studies from the region that highlight nationally led efforts, best practices and present recommendations for the way forward in building resilience.

2. WHY DOES BUILDING CRITICAL INFRASTRUCTURE RESILIENCE MATTER?

2.1 Conceptual and terminological framework of critical infrastructure

The notion of critical infrastructure is a relatively a new concept that emerged predominantly during the 1990s and comprises vitally important sectors, such as energy security, energy systems, gas and oil pipelines, telecommunications, the economy, transportation, water and wastewater sectors.[24] Critical infrastructure became important since the 9/11 terrorist attacks and the Madrid 2004 and London 2005 bombings when it became clear that countries' vital sectors, i.e., infrastructure systems, could be intentionally targeted.

Therefore, CI become an important component of national security systems in most countries. Following these tragic events, efforts to mainstreaming CI were made on both sides of the Ocean, i.e. the Patriot Act and the adoption of the first ever *Green Paper on a European Programme for Critical Infrastructure Protection*[25] initiating the more coherent CI mainstreaming across EU policies and member States. Nevertheless, there is no uniform definition of the term, critical infrastructure, among international organizations, countries and territories globally. The table below summarizes the definitions by major players in this research area.

Table 2: Definitions of critical infrastructure in major international and supranational organizations

#	Entity	Year	Definition
1	US DHS	2008	The assets, systems and networks, whether physical or virtual, are so vital to the US that their incapacitation or destruction would have a debilitating effect on security, national economic security, national public health or safety, or any combination thereof.
2	EC[26]	2008	An asset, system or part thereof located in the member states which is essential for the maintenance of vital societal functions, health, safety, security, economic or social well-being of people. Its disruption or destruction would have a significant impact on an MS as a result of the failure to maintain those functions.

24 DCSINT Handbook 2006, *Critical Infrastructure Threats and Terrorism* (Handbook No.1.02), p. 1.
25 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52005DC0576
26 https://tinyurl.com/34n3dhfs

#	Entity	Year	Definition
3	OIEWG[27]	2016	The physical structures, facilities, networks and other assets which provide essential services for the social and economic functioning of a community or society.
4	UNDRR[28]	2017	The physical structures, facilities, networks and other assets provide services that are essential to the social and economic functioning of a community or society.
5	OECD[29]	2019	Systems, assets, facilities and networks that provide essential services for the functioning of the economy and for the safety and well-being of the population.
6	EU[30]	2020	Physical and information technology facilities, networks, services and assets that, if disrupted or destroyed, would have a serious impact on the health, safety, security or economic well-being of citizens, or the effective functioning of governments in EU states.

In the majority of countries and territories at the regional level, policy and normative documents contain no definitions of critical infrastructure except in cases presented in the Table 3:

Table 3: Several regionally accepted definitions of critical infrastructure

#	Country/ territory	Subregion	Definition
1	Albania	WB&TR	The physical structures, networks and other assets necessary for the economic and social functioning of a society or community. This includes a chapter on protecting critical infrastructure and cultural heritage[31] (*Law on Civil protection—45/2019*) .
2	Bosnia and Herzegovina[32]	WB&TR	Systems, networks and facilities of particular importance, the destruction or endangerment which can cause serious disturbances in the free movement of people, transport of goods and provision of services, negatively affect internal security, human health and lives, property, environment, external security, economic stability and the continued functioning of state institutions. (*Law on the Security of the Critical Infrastructure—2019*)[33]
3	Montenegro	WB&TR	Systems, networks, facilities, or parts thereof located on the territory of Montenegro, whose interruption, i.e. interruption of deliveries of goods or services through these systems, networks, facilities, or parts thereof that may have serious consequences for national security, health and human life, property, environment, security of citizens and economic stability, i.e. performing activities of public interest (*Law on designation and protection of the critical infrastructure—2019*)[34]

27 https://www.preventionweb.net/drr-framework/open-ended-working-group/
28 https://www.undrr.org/terminology/critical-infrastructure
29 https://www.oecd-ilibrary.org/sites/fc4124df-en/index.html?itemId=/content/component/fc4124df-en
30 https://ec.europa.eu/home-affairs/tags/critical-infrastructure_en
31 https://www.parlament.al/Files/Akte/20190724173027ligj%20nr.%2045,%20dt.%2018.7.2019.pdf
32 On a state level in Bosnia and Herzegovina, there is no accepted definition of critical infrastructure, but on the entity level, Republika Srpska has adopted a legislative act containing a definition of this term.
33 https://tinyurl.com/3sn2re5t
34 https://me.propisi.net/zakon-o-odredjivanju-i-zastiti-kriticne-infrastrukture/

#	Country/ territory	Subregion	Definition
4	Serbia	WB&TR	Systems, networks, facilities or parts thereof, whose interruption in functioning or interruption in delivery of goods or services, can have serious consequences for national security, health and the lives of people, property, environment, security of citizens and economic stability, that is, endanger the functioning of the Republic of Serbia. (*Law on Critical Infrastructure—2018*)[35]
5	Georgia	SC	Facilities of vital importance (that might be considered as CI).
6	Ukraine	EE	CI systems are important for the economy, national security and defence, and their malfunctioning can cause harm to vital national interests. (*Only in terms of cybersecurity as stated by the key respondent in the on-line survey*).

International Financial Institutions play an important role in sustainability and in building CI resilience, especially in the provision of funding, development of policies, standards and consequent execution of regional and national projects. However, they have no specific terminological frameworks applying definitions used by various international organizations. The World Bank, in a recent report, *Financial Protection of Critical Infrastructure Services*[36], accepts the above-mentioned Organisation for Economic Co-operation and Development (OECD) definition, adding that: *"the delivery of service requires a complete infrastructure system: (a) one or multiple physical assets connected in a network (e.g. roads, hospitals, power plants); (b) people; and (c) inputs (e.g. raw materials, fuel, electricity)."*[37] In another report, *Lifelines: The Resilient Infrastructure Opportunity*[38], the World Bank introduces the notion of resilient infrastructure (the ability of infrastructure to provide the services users need during and after a natural shock).

2.2. Overview of the term, critical infrastructure

Categorization is another important aspect of understanding building CI resilience, i.e., which systems, assets, facilities or services comprise its elements at the supranational, regional, and national levels. The *EU Green Paper on a European Programme for Critical Infrastructure Protection (2005)*[39] has a common list of 37 products or services. This includes key sectors like energy, ICT, water, food, health, financial, public and legal order and safety, civil administration, transport, chemical and nuclear industry and space and research.

Following the principle of subsidiarity, several EU member States have a national categorization of CI systems in their countries, e.g., ***France***[40], ***Germany***[41](- CI is classified as a combination of hard infrastructure

35 http://seeurban.net/wp-content/uploads/library/Serbia/3326-18-Zakon-o-kriticnoj-infrastrukturi.pdf
36 https://tinyurl.com/rw2tb69k
37 World Bank. *Financial Protection of Critical Infrastructure Services* (March 2021), p. 15. https://tinyurl.com/rw2tb69k (Accessed on 12.08.2021).
38 https://tinyurl.com/2bv7hdmd
39 EC. *Green Paper on a European Programme for Critical Infrastructure Protection* /* COM/2005/0576 final */. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52005DC0576
40 I. Ducamin, *State and Operators Cooperation for Critical Infrastructure Protection; Building Trust for Common Interest* (2016), p. 5. as cited in Marina Mitrevska, Toni Mileski, Robert Mikac, *Critical Infrastructure: Concept and Security Challenges*, Friedrich Ebert Stiftung—Office Skopje, (2019), p. 36. https://tinyurl.com/3e4fxr2a (Accessed 12.05.2021).
41 Federal Ministry of Interior, Building and Community, *National Strategy for Critical Infrastructure Protection (CIP Strategy)* (2009), p. 7. https://tinyurl.com/4wzp552u (Accessed 12.05.2021).

and soft infrastructure services), ***Slovenia***[42] (a set of criteria for the identification of eight CI sectors is defined), or ***Croatia***[43] (the normative framework recognizes 11 CI sectors that government entities can identify because of their need for continuous functioning).

In the ***United States,*** *Presidential Directive PPD-21*[44] adopted during the Barak Obama Administration in 2013, identifies 16 critical infrastructure sectors[45] whose assets, systems and networks, whether physical or virtual, are considered so vital to the country that their breakdown or destruction would impact the national security, economy and national public health safety. These sectors are *chemical, commercial facilities, communications, critical manufacturing, dams, defence industrial base, emergency services, energy, financial services, food and agriculture, government facilities, health care and public health, information technology, nuclear reactors, materials and waste, transportation systems and water and wastewater systems*[46] and the Directive designates associated Federal SSAs.

The Critical National Infrastructure in the ***United Kingdom*** consists of 13 national infrastructure sectors: *chemicals, civil nuclear, communications, defence, emergency services, energy, finance, food, government, health, space, transport and water.* Several sectors have defined the subsectors: emergency services, for example, can be split into police, ambulance, fire services and coast guard. The difference between the UK and others is the approach that not everything within the national infrastructure sector is deemed critical, but only critical elements thereof (assets, facilities, systems, networks or processes and workers), which if affected would result in significant loss of life, casualties or economic and social consequences and would significantly impact the national security, national defence or functioning of the state.[47]

On the other hand, the Russian Federation has a broader understanding of the concept. Besides *"critically important objects"* and *"potentially dangerous objects"*, there are other related concepts, such as *"life support objects"* (e.g., water pump stations or food stores) and *"regime objects"* (e.g., military units). On a normative level, in 2015 amendments to the 1994 Federal Law on the protection of the population and the territories from emergencies of natural and technogenic nature defined the list of "critically important objects/facilities" in 6 sectors and 48 subsectors: *nuclear and/or radiation hazardous facilities; chemically hazardous facilities; biological hazardous facilities; technogenic hazardous facilities; fire and explosion hazardous objects; and objects of public administration, information and telecommunications infrastructure.*[48] This approach has also been adopted in most Central Asia countries.

In the ***Europe and Central Asia region,*** there are several examples of identifying CI systems that include various sectors. These are stipulated in CI laws, DRM-related laws, or defined in policies and other documents, as presented in the Table 4 below.

42 https://www.gov.si/assets/ministrstva/MO/Dokumenti/Studija-SPOTKI.pdf
43 https://narodne-novine.nn.hr/clanci/sluzbeni/2013_08_108_2411.html
44 https://tinyurl.com/tncvt4p9
45 https://www.cisa.gov/critical-infrastructure-sectors
46 These sectors are presented in alphabetical order.
47 https://www.cpni.gov.uk/critical-national-infrastructure-0
48 Christer Pursiainen, *"Russia's Critical Infrastructure Policy: What do we Know About it?" European Journal for Security Research* (2021) 6:21–38, p. 25. https://doi.org/10.1007/s41125-020-00070-0 (Accessed on 9.5.2021).

Table 4: Critical infrastructure sectors in countries and territories of the ECA region

#	Country/ territory	Subregion	CI Sectors
1	Albania[49]	WB&TR	*Power generation, transmission and distribution systems; production, refining, treatment, storage and distribution of gas through pipelines; oil and production of its products, storage and distribution through pipelines; telecommunications* (networks, systems); *water supply; agriculture, production and distribution of food; public health* (hospitals, health centres and ambulances); *transport systems* (fuel supply, railway network, airports, ports, domestic transport); *financial services* (banking, clearing); *security and defence services.*
2	Bosnia and Herzegovina[50]	WB&TR	*Industry, energy and mining* (incl. input resources, facilities, transmission systems, storage, transport of products, energy and energy, distribution systems); *information and communication infrastructure* (electronic communications, data transmission, information systems, provision of audio, and audio and video media services); *traffic* (road, rail and air traffic and inland waterway traffic); *health care* (health care, production, transport and supervision of medicines); *communal activities, communal infrastructure facilities* (especially in the field of production and delivery water treatment, wastewater treatment and disposal, production and delivery of thermal energy, waste disposal from residential and commercial premises, and more); *water management* (regulatory and protective water management facilities); *food and beverages* (production and supply of food and beverages, food and beverage safety system, inventories); *finance* (banking, stock exchanges, investments, systems insurance and payments); *production, storage and transport of hazardous materials* (chemical, biological, radiological and nuclear materials); *public services*; *education*; *cultural and natural assets* (religious buildings, cultural monuments, spatial cultural and historical units, archaeological sites, landmarks, works of art and historical objects, archives, film material, old and a rare book, as well as protected natural assets prescribed by the Nature Protection Act). *Law on the safety of the critical infrastructure in Republika Srpska (2019)*[51]
3	Montenegro[52]	WB&TR	*Energy, transport, water supply, health, finance, electronic communications, information and communication technologies, environmental protection, functioning of state bodies,* and other areas of public interest.
4	Serbia[53]	WB&TR	*Energy; traffic; water and food supply; health care; finance; telecommunication and information technologies; environmental protection and functioning of state bodies.*
5	Turkey[54]	WB&TR	*Electronic communication; energy; water; critical public services; transport; and banking and finance.*

49 https://qbz.gov.al/eli/ligj/2019/07/18/45
50 At the state level in Bosnia and Herzegovina, there is no accepted categorization of CI, but at the entity Level, Republika Srpska has adopted a legislative act which contains the category, critical infrastructure.
51 https://tinyurl.com/w7swd87e
52 https://me.propisi.net/zakon-o-odredjivanju-i-zastiti-kriticne-infrastrukture/
53 http://seeurban.net/wp-content/uploads/library/Serbia/3326-18-Zakon-o-kriticnoj-infrastrukturi.pdf
54 https://websites.fraunhofer.de/CIPedia/index.php/Critical_Infrastructure_Sector#Turkey

International Finance Institutions have a different approach to identifying areas/sectors of the CI systems that they are supporting through various financial mechanisms. The ***Asian Development Bank*** under the *infrastructure domain*[55] focuses primarily on energy, digital technology, transport, urban development and water. The ***European Bank for Reconstruction and Development*** focuses on municipal *infrastructure and transport*. For the ***European Investment*** Bank provision of *reliable and smart infrastructure* is key for economic growth, sustainability, creation of jobs and competitiveness. Priority areas for investments are cleaner transport, digital networks, energy efficiency and sustainable urban development, including the development of social infrastructure, affordable housing and key public buildings.[56]

The ***Islamic Development Bank*** has introduced a novel approach[57] of financing r*esilient and sustainable infrastructure* by investing in urban and agricultural development, energy and transport. On a strategic level, the ***World Band Group*** helps developing countries build *smart infrastructure* that supports inclusive and sustainable growth, expands markets, creates job opportunities, promotes competition and contributes to a cleaner future.

Infrastructure improves lives by connecting people to opportunity and achieving the Sustainable Development Goals (SDGs) will be possible by ensuring rural roads and safe transport for access to health and education facilities; electrification of clinics, schools and households in rural areas to improve digital connectivity; improved road safety and clean cooking to reduce mortality and morbidity; and digital and other skills needed for implementing infrastructure investments.[58]

As the review of categorization efforts globally, regionally and nationally demonstrate, various approaches have been adopted to identify the essential categories of CI sectors, based predominantly on national contexts, approaches and priorities. These categorizations generally include *"the energy, water, food, transport, telecommunications, health care, banking and finance sectors"*[59] as traditional core sectors for the functioning of countries. Most are *"object-oriented"*—this means that the particular physical assets/facilities or locations are considered within the individual sectors rather than "service-oriented".

Some countries only include human resources as part of critical sectors (e.g., the United States). This involves both professional employees of the facilities' operators and private security guards. Nevertheless, when categorizing the CI sectors, both the national and local/community levels need to be considered, especially where the latter (the basic communal infrastructure, e.g., schools, medical or educational facilities and community centres) are central to daily life. Accordingly, investments in building resilience and sustainability of these infrastructures also include low-cost and high-value assets and facilities at the local level.

2.3. Current and future risks to critical infrastructure

Disasters pose the most significant challenges for the functioning of vital CI systems. Existing natural and human-made hazards result in an increased number of events with greater intensity, magnitude and impacts resulting in loss of lives and higher volume of damage and losses. The consequences to societies and communities—existing vulnerabilities are greatly exacerbated; new ones are created and social inequalities became more entrenched. With the foreseen consequences of climate change, i.e., increase in the mean annual temperature, changed pattern of precipitations, frequent extreme weather events, extended extreme heatwaves, the pressure on the fragility of the CI systems will be higher thereby resulting in dam-

55 https://www.adb.org/what-we-do/focus-areas
56 https://www.eib.org/en/about/priorities/infrastructure/index.htm
57 https://www.isdb.org/what-we-do/sectors
58 https://www.worldbank.org/en/topic/infrastructure/overview
59 https://ehs.unu.edu/blog/5-facts/5-things-about-critical-infrastructures.html

ages and destructions, failures and disturbances and disruptions in the provision of services.

Consequently, climate change is included as a security risk to resilience even though its impact cannot be precisely predicted, but its potential to significantly affect the resilience of countries, societies and communities is identified as a general threat to security, e.g. in Germany, U.S. and other countries: "Climate change poses escalating risks to stability and security, with potentially far-reaching consequences, from the risks to fragile states from more volatile weather to the combined effects of rising sea levels and storm surge on the survival of island nations and coastal populations."[60]

Table 5: Risks and hazards to critical infrastructure systems

Natural hazards	Human-made & technological hazards	Security risks
• Geophysical (earthquake, mass movements, landslides, rockslides, mudflows, volcanic activities and emissions, tsunamis) • Hydrometeorological (floods, flash floods, avalanches, drought, heatwaves and cold spells, severe convective and winter storms, typhoons, hurricanes, wildfires) • Biological (epidemics, epiphytotic, epizootics) • Cosmic phenomena (solar flares, geomagnetic storms, meteorites, asteroids)	• Industrial accidents/pollution • Transport accidents • Large scale power outages • Environmental degradation and pollution • Radiation • Dam failures • Factory explosions • Chemical spills	• Hostile governments • Terrorism • Proliferation • Cybercrime • Climate change • Transnational crime • Civil wars and wars • Untrusted investments • Population density • Supply chain attacks

In Europe and Central Asia from 2000 onwards[61], a total of 1,337 disasters were fatal for 55,000 people, affecting more than 17 million citizens with a price tag of approx. $30 bn. The *Regional Snapshot of the aggregated data reported by Member Countries across the Europe and Central Asia region (2020)* shows that 18 countries reported disaster-related damages to 3,318 critical infrastructure facilities, while 14 countries reported 536 damaged facilities in 2019.[62] The ***hydro-meteorological hazards*** dominate the profile followed by other natural hazards. Estimates show a 60 per cent rise in the cost of damages due to extreme weather events in the region over the next 30 years.[63]

The cost of infrastructure recovery from climate change-induced hazards will increase due to the more consequential impact of these events. On the other hand, schools, health facilities and roads are regularly damaged from small-scale weather events which do not grab headlines. Based on available data from 83 countries since 2005, on average more than 3,200 schools, 412 health facilities and 3,200 km of roads have been destroyed every year.[64]

In addition, a range of ***technical and technological disasters*** are threatening the resilience textures and various national and local infrastructure systems, e.g. the Beirut Port Ammonium Nitrate Explosion in 2020,

60 https://reliefweb.int/report/world/climate-change-must-be-tackled-global-security-risk
61 https://public.emdat.be
62 UNDRR—Regional Office for Europe & Central Asia, *Sendai Framework Monitoring in Europe and Central Asia: A Regional Snapshot*, p. 19. https://tinyurl.com/69chscnd (Accessed on 8.5.2021).
63 https://www.eu-circle.eu/
64 https://tinyurl.com/7zcxyu2y

or the disastrous cross-border events with their fateful consequences on the population and on the critical infrastructure systems in two or more countries. A recent regional example is the collapse of the Sardoba dam in May 2020 and consequent flooding of large areas in Uzbekistan and Kazakhstan which affected some regional and local critical infrastructure facilities and disrupted essential services. These disasters took place during the COVID-19 pandemic, placing a burden on the national systems and on a population already struggling from the pandemic's impact.

In addition, ***an anthropogenic threat*** to CI resistance looms that stems from poor governance, improper operation, negligence, organizational failures and poor maintenance or insufficient investment in the rehabilitation and upgrading of ageing facilities and assets. For example, most of the rail transport infrastructure in Bosnia and Herzegovina is obsolete with "nearly half of railway infrastructure deemed unsafe, outdated and unreliable, unable to provide suitable international transit on the network."[65] Another example is from Italy where insufficient and improper maintenance[66] was one of the reasons for the destruction of critical infrastructure, i.e. the collapse of the Ponte Morandi bridge in Genoa on 14 August 2018 killing 43 people and leaving 600 homeless.

We are living in new and post-normal times with more and more complex disasters in the news headlines (e.g. Japan 2011 earthquake); the greater number of damages and losses in accountant sheets (e.g. Hurricane Season of 2017 in the Mexican Gulf countries or Hurricane Ida from August 2021, "the strongest hurricane to hit Louisiana in at least 165 years"[67]); and disruption to global supply chains resulting from events in one country or one region (e.g. Icelandic Volcano Eruption of 2010, or COVID-19 pandemic).

Collapsed Ponte Morandi bridge in Genoa
Source: https://tinyurl.com/hwnjcw

This means that when we are thinking about building critical infrastructure resilience and inclusiveness, we have to do it in a non-linear way, learning from the past, understanding the present and anticipating the future. We are facing uncertain futures with more and more climate change impacts pandemics, cyber-attacks and high-consequence and low probability events on the ***"Future Risks Menu"***. It is expected that climate change will cause local changes in average and extreme temperatures, and also changes in rainfall patterns, their duration and intensity, destroying roads, rail tracks, and airports across the world.

Extreme weather events will have an additional impact on the resistance and resilience of the coastal and mainland CI systems. Roads and rail tracks around the coast of England are predicted to be swamped due to rising tides,[68] or the U.S. East Coast transportation infrastructure will be vulnerable due to rising sea levels during this century[69]. Rising levels of the oceans and the seas will result in coastal flooding and the medium confidence scenario for projected sea-level rise for 2100 for the SSP3-7.0 scenario is 1.03 m in Poti, Georgia, and 0.67 m for Bar, Montenegro.[70] This will impact national infrastructure systems, businesses and the provision of services to coastal communities.

65 European Commission, Brussels, 6.10.2020. SWD (2020) 350 final. *COMMISSION STAFF WORKING DOCUMENT Bosnia and Herzegovina 2020 Report*, p. 77. https://tinyurl.com/nvk56shs (Accessed 7.5.2021)
66 https://tinyurl.com/923r6s6b
67 https://www.nytimes.com/article/tropical-storm-ida-hurricane.html
68 https://earth.org/how-climate-change-will-impact-global-transport-sector/
69 https://tinyurl.com/5fjk2xwc
70 https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool

Climate change is expected to lead to drier conditions in southern Europe and higher temperatures in Central Asia and the South Caucasus, i.e., the mean temperature would rise by the end of the century (2071- 2099) and would be higher than the global average increase. These changes could have disastrous consequences for the whole region, with glaciers in the high mountains retreating and an increased probability of flooding from overflowing rivers. This would be exacerbated by the outdated and ageing infrastructure and limited resources for mitigation and response. Thus, climate change would accelerate the water dam ageing process resulting in potential dam failures, increased maintenance and repair costs, loss of functionality and effectiveness, and more.[71]

Moreover, all CI sectors, as well as agriculture, would be impacted by extended seasonal droughts. Azerbaijan, Georgia and Kazakhstan are among the countries with critical assets most exposed to natural hazards and climatic risks.[72] The future is not so sanguine, since under the five scenarios, in the near term (2021-2040), the 1.5°C global warming level is very likely to be exceeded under the very high GHG emissions scenario[73], and the number of extreme climate events will increase resulting in more frequent infrastructure failures and disruptions.

Other items from the *"Future Risks Menu"* can be found in the potential ***cybersecurity threats, pandemics, biohazards and other predominantly high-consequence, low-probability events*** affecting CI resilience globally. Among the others, one threat is rising manifestly, set between current and future domains and seriously utilizing existing vulnerabilities, its impacts felt in different sectors and aspects of everyday life. It is the *cyberattacks on the CI systems* that are increasing in frequency, the numbers of sectors targeted, with a load of data being stolen or misused, and potentially overtaking the whole infrastructure systems, e.g., the ransomware attack on the Colonial Pipeline in the States,[74] which led to the disruption of nearly half the supply for south-eastern parts of the country and affecting the airline, transport and logistics sectors.

A recent review[75] profiled the following sectors as most exposed and vulnerable to cyberattacks: health and the telecommunications/industrial network sectors. *Health care facilities* experience identity thefts, health care frauds and attack processes, even while the telecommunication/industrial sector is easily subjected to unauthorized access, data and identity thefts, disruption of electric control systems, grid failures and other problems. In that regard, there are several examples of unauthorized access to government and public sector domains.

Lastly, the ***COVID-19 pandemic crisis*** affected countries and territories globally in an unprecedented way claiming thousands of human lives, resulting in devastating impacts across sectors and seriously affecting societies and communities. Although an infectious disease, it has affected CI sectors, businesses and the public well-being. It has exerted undue pressure on the health facilities, overstretched the health emergency resources, disrupted the global and regional supply chains, exacerbated the infrastructure vulnerabilities and spent the finite resources of national and local governments.

The negative ramifications of the fiscal downturn involved cutting operational and maintenance funding for roads or rail tracks, and delayed investments in new and resilient infrastructure, e.g., *"as of August 2020, state and local governments had delayed or cancelled almost $10 bn in infrastructure projects due to the pandemic"*[76]. It has also stopped revenues accruing to infrastructure owners and operators which had a domino effect on the rate of functional investments for maintenance and development of infrastructure systems. For example, the transport sector has been particularly affected, with huge economic

71 https://www.preventionweb.net/news/ageing-dams-pose-growing-threat-un

72 UNDRR, *Making Critical Infrastructure Resilient: Ensuring Continuity of Service—Policy and Regulations in Europe and Central Asia* (2020), pp. 19–20. https://tinyurl.com/6p8mcdk8 (Accessed on 6.5.2021).

73 https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Full_Report.pdf

74 https://www.nytimes.com/2021/05/11/business/colonial-pipeline-shutdown-latest-news.html

75 https://www.spear2020.eu/News/Details?id=120

76 https://tinyurl.com/yc2fuyaz

losses for civil aviation. The International Civil Aviation Organization (ICAO)[77] has estimated that European international traffic will suffer economic losses of between $57 billion in the best-case scenario and $98 billion in the worst-case scenario, and domestic traffic between $10 and $18 billion as a result of the virus.

Furthermore, there are so-called *pandemic-induced shocks* to the essential and everyday functioning of the critical infrastructure, an inability to provide services or not having beneficiaries for some services due to the changed daily routines and massive lockdowns. Most notably, the transportation, water and wastewater, health, government, emergency and ICT services were exploited to the maximum. Given the seriousness of the direct, indirect and prolonged impacts of the pandemic crisis, the region is not prepared for another crisis of this magnitude and intensity.

Moreover, the pandemic crisis led to an increased digital transformation in the ECA region[78] and globally for securing the normal life provision of services and the enabling of activities, but increased digitalization led to increased exposure and vulnerability of the ICT sector requiring additional assets for secure functioning and digital security. The COVID-19 pandemic highlighted the lack of an adequate pandemic risk framework and a lack of expertise and related critical infrastructure.[79]

Therefore, the global pandemic crisis underscores the need for a sustainable, resilient and inclusive critical infrastructure, one capable of adaptation and transformation to a new reality, and able to continue to function while being adaptive to the needs of customers and beneficiaries, leaving no one behind in the process.

2.4 Impacts on the critical infrastructure systems and their interdependency

Any of these events, individually, cascading cumulatively over time, significantly impact the CI systems, causing massive damages, destroying facilities or disrupting the provision of services that are vital for the functioning of societies and communities. In that regard, Rinaldi et al. (2001)[80] identify the basic types of failure propagation in a CI system:

1. *Cascading failure*—disruptions in one infrastructure cause the failure of the element in a second infrastructure, disrupting the second one (e.g. an electric power outage disrupted the water supply infrastructure in July 2007 in North Macedonia).
2. *Escalating failure*—an existing disruption in one infrastructure exacerbates an independent disruption to a second infrastructure by increasing the severity or time for recovery of the second failure (e.g. disruption in ICT network disrupts the transportation sector).

- **Deutsche Bahn** suffered a massive service interruption when its systems were attacked by the global WannaCry epidemic of 2017

- **FedEx** was clobbered by the NovaPetya ransomware outbreak of 2017 resulting in TNT Express not operating for days and in cumulative losses of $375 mn

Source: https://tinyurl.com/547uf3bj

3. *Common cause*—two or more infrastructure networks are disrupted simultaneously: elements within each infrastructure fail because of some common cause (e.g. the action of a disaster on the infrastructure, as in the May 2014 Floods in Serbia which affected various public and private national and local infrastructure systems. This included the open pits of the Tamnava Zapadno polje mine, Veliki Crljeni and parts of the Kolubara mining basin. These were submerged and the thermal

77 https://www.icao.int/sustainability/Pages/Economic-Impacts-of-COVID-19.aspx
78 https://tinyurl.com/9n4fzfpc
79 Vasko Popovski, *Assessment Study of the Role of NDMAs in COVID19 crisis response and impact of COVID-19 on NDMAs Operations* (UNDP/UNDRR, 2021), p. 40. https://tinyurl.com/rzzjah7b (Accessed on 12.5.2021)
80 S.M. Rinaldi, J.P. Peerenboom and T.K. Kelly, "Identifying, understanding and analysing critical infrastructure interdependencies, *IEEE Control Systems Magazine*, 2001; 21(6), pp. 11–25. DOI: 10.1109/37.969131

power plant "Nikola Tesla A" in Obrenovac, which produces 63 percent of electrical energy for the whole of Serbia[81], was closed for 10 days).

In that regard, another characteristic of the CI systems is their ***interconnectivity and interdependence.*** It is a relationship among two or more CI sectors where the impact of one system can spill over to other systems. Rinaldi et al[82] describe four types of infrastructure interdependencies:

i. *Physical connections or dependencies*—if the state of each is dependent on the material output(s) of the other, e.g. financial services systems are dependent and connected to the energy system.

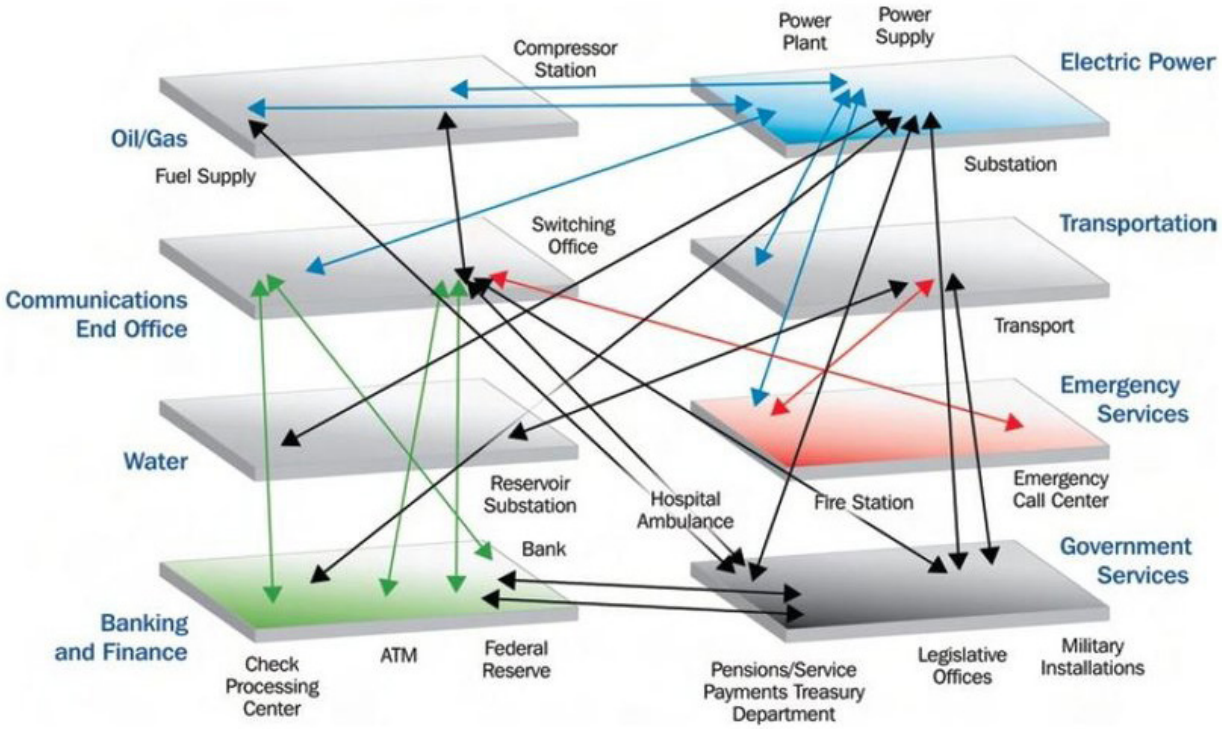
ii. *Cyber dependencies*—where one infrastructure uses information transmitted from another system through the information infrastructure, e.g. SCADA systems in the water sector.

iii. *Geographic interdependencies*—when elements of multiple infrastructures are in close spatial proximity, i.e. two or more critical infrastructure systems are located within the boundaries of the same disturbance zone.

iv. *Logical interdependency*—when two infrastructure systems are logically interdependent if the state of system depends on the state of the other via a mechanism that is not physical, cyber, or a geographic connection, e.g. a power crisis and the banking and financial services systems.

The figure below illustrates the interconnectivity and complex interdependent relationship among various CI systems where stresses and shocks are transmitted throughout their structures and beyond.

Figure 2: Critical Infrastructure interdependencies[83]



81 https://tinyurl.com/ruet2fnn

82 S.M. Rinaldi, J.P. Peerenboom and T.K. Kelly, *"Identifying, understanding and analysing critical infrastructure interdependencies"*, IEEE Control Systems Magazine, 2001;21(6), pp. 14–16. DOI: 10.1109/37.969131

83 Mark Ehlen and Vanessa N. Vargas, *Multi-Hazard, Multi-Infrastructure, Economic Scenario Analysis*. 2012. DOI: http://dx.doi.org/10.1007/s10669-013-9432-y. https://tinyurl.com/bzmvewxr (Accessed on 21.8.2021).

Consequently, building CI resilience should ensure resistance and inclusiveness of the infrastructure systems thereby resulting in prevention and mitigation of failures and disruptions and enabling them to anticipate, absorb and withstand, respond and recover while the critical infrastructure systems maintain their functions and continue to provide their services.

3. CRITICAL INFRASTRUCTURE IN THE GLOBAL RESILIENCE AND SUSTAINABLE DEVELOPMENT FRAMEWORK AND INITIATIVES

3.1 Sendai Framework for Disaster Risk Reduction 2015–2030

The issue of building critical infrastructure resilience is prominently featured as one of seven targets—***"Target D: Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030."*** Moreover, it is adequately reflected in the four priorities, i.e. DRR mainstreaming and integration within and across all sectors and addressing disaster risk in publicly owned, managed or regulated services and infrastructures (*Priority 2*); strengthening disaster-resilient public and private investments (*Priority 3*); and promoting the resilience of new and existing critical infrastructure (*Priority 4*). Furthermore, critical infrastructure is included in the set of 38 indicators developed for measuring global progress in the implementation of the Sendai Framework.[84]

3.2 Sustainable Development Goals (SDGs)

Similar to DRR, which is mainstreamed in almost all goals, resilient infrastructure is at the core of sustainable development since "all goals are underpinned by infrastructure development".[85] In particular, ***SDG 9 Industry, Innovation and Infrastructure*** *seeks to build resilient infrastructure, to promote inclusive and sustainable industrialization and to foster innovation where infrastructure provides the basic physical systems and structures essential to the operation of a society or enterprise.* Therefore, sustainable, resilient and inclusive infrastructure needs to be developed, including regional and transborder infrastructure (Target 9.1), to upgrade it for sustainability (9.2) and to facilitate sustainable and resilient infrastructure development in developing countries.[86]

On the other hand, three more SDGs are related to the fulfilment of the Sendai Framework Target D i.e., ***SDG 11 Sustainable cities and communities*** (Indicator 11.5.2), ***SDG 7: Affordable and clean energy*** (report on infrastructure, including green infrastructure, damages concerning Sendai Framework commitments[87]) and ***SDG 13: Climate Action*** (integration

84 https://www.preventionweb.net/sendai-framework/sendai-framework-indicators

85 The Economist Intelligence Unit. *The critical role of infrastructure for the Sustainable Development Goals* (EIU, 2019), p. 5. https://tinyurl.com/5arb55pk (Accessed on 12.5.2021).

86 https://www.globalgoals.org/9-industry-innovation-and-infrastructure

87 UNDRR, *Addressing the infrastructure failure data gap: A governance challenge*, 2021, p. 18. https://tinyurl.com/y3z8pjka (Accessed on 15.11.2021).

of resilience in national and local strategic and policy documents ensuring the incorporation of resilience to disaster and climate risks. Nevertheless, "it has been shown that infrastructure either directly or indirectly influences all of the SDGs, including 72 percent of the targets."[88]

3.3 Paris Agreement

The Paris Climate Agreement does not directly refer to building CI resilience, but touches on the overall importance of averting, minimizing and addressing loss and damage associated with the adverse effects of climate change, including extreme weather events and slow onset events, and the role of sustainable development in reducing the risk of loss and damage. In particular, Article 7 establishes "the global goal on adaptation of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change to contribute to sustainable development."[89]

3.4 Coalition for Disaster Resilient Infrastructure (CDRI)

This Coalition for Disaster Resilient Infrastructure is a partnership of national governments, UN agencies/programmes, multilateral development banks and financing mechanisms, the private sector, and knowledge institutions that promote the rapid development of resilient infrastructure to respond to the SDGs' imperatives of expanding universal access to basic services, enabling prosperity and decent work through its strategic priorities.

These include: *technical support and capacity-building* (i.e. disaster response and recovery support; innovation, institutional and community capacity-building assistance; and standards and certification); *research and knowledge management* (i.e. collaborative research; global flagship reports; and a global database of infrastructure and sector resilience), and *advocacy and partnerships* (i.e. global events and initiatives; marketplace of knowledge financing and implementation agencies; and dissemination of knowledge products).

From the ECA region, only Turkey is a member State of this coalition. The recommendation is for other countries and territories from the ECA region to join the initiative. In particular, these Guidance Notes on building CI resilience in Europe and Central Asia can be interlinked with the *"Global Study on Disaster Resilience of Airports"*[90] currently under preparation.

3.5. Habitat III—New Urban Agenda[91]

Physical and social infrastructure is embedded within all principles and should enable urban development and services for all. Moreover, resilient infrastructure is one of the enablers of sustainable and inclusive development.

88 S. Thacker et al, *"Infrastructure for sustainable development", Nature Sustainability*, vol. 2, 2019, pp. 324–331.
89 World Bank Group, *LIFELINES The Resilient Infrastructure Opportunity,* (World Bank, 2019), p. 27. https://tinyurl.com/2bv7hdmd (Accessed on 12.5.2021).
90 https://www.cdri.world/global-study-disaster-resilience-airports
91 https://habitat3.org/wp-content/uploads/NUA-English.pdf

3.6 European Forum for Disaster Risk Reduction (EFDRR)[92]

Within the scope of this year's forum, the participants underscored the need to invest in new and green infrastructure systems and services to address dangerously ageing assets. They noted that the systemic nature of risk, cascading and complex interdependencies required innovative infrastructure solutions. More importantly, the *EFDRR Roadmap 2021–2030 for a climate and disaster-resilient Europe and Central Asia*[93] in *Area 3: Supporting investments in resilience* identifies investment in the protection of critical infrastructure and systems from the impacts of climate change and from future cascading and cumulative risks.

4. STATE OF PLAY IN BUILDING CRITICAL INFRASTRUCTURE RESILIENCE IN THE ECA REGION

4.1 General disaster risk profile of the ECA region

The Europe and Central Asia region stretches from the Adriatic Sea in the west to the borders with China in the east. Its disaster profile is complex with almost all-natural and human-made hazards being present—ranging from geophysical (earthquakes, landslides, mudflows, rock falls), hydro-meteorological (floods, storms and avalanches), climatological (extreme temperatures, droughts and wildfires), to biological ones (disease epidemics and insect/animal plagues).

The regional risk context is complex with many past conflicts, inter-ethnic tensions, potential food security issues, industrial and transport accidents, a high environment degradation rate, air pollution and legacy of uranium sites in the Central Asia countries and toxic sites across the region. Furthermore, the projected impact of climate change, increased urbanization, poverty levels and the threat of pandemics and other low-probability, high-impact risks will only aggravate the regional profile resulting in the increased frequency, complexity and severity of disastrous events.[94]

In terms of occurrences, hydro-meteorological and climatological disasters dominate the profile accounting for 75 percent of 366 disastrous events recorded between 2000 and the first half of 2020[95], followed by geophysical disasters and epidemics. Within this total number of events, floods were the most frequent type of disaster with 45 percent of recorded events, followed by extreme temperatures, earthquakes, storms, landslides, wildfires, droughts and epidemics.

Serbia is the most exposed to the effect of *extreme temperatures,* followed by Ukraine, North Macedonia and Belarus. *Earthquakes* are present in all subregions, but the most vulnerable are Turkey, Central Asia and Albania. *Storms* are dominant in Turkey, Ukraine, Armenia and Georgia, whether the *landslides* are determined by the mountainous relief in Central Asia countries (Tajikistan, Kyrgyzstan) and Turkey. *Droughts* are the dominant slow-onset disaster seriously affecting Moldova, Tajikistan and Bosnia and Herzegovina. *Wildfires* are frequent in Uzbekistan, Turkey North Macedonia and Montenegro. Finally, epidemics of local infectious diseases are most frequent in Tajikistan.[96]

92 https://efdrr.undrr.org/
93 https://www.undrr.org/publication/european-forum-disaster-risk-reduction-roadmap-2021-2030
94 Vasko Popovski, *Assessment Study of the Role of NDMAs in COVID19 crisis response and impact of COVID-19 on NDMAs Operations,* UNDP/UNDRR, 2021, p. 11. https://tinyurl.com/rzzjah7b (Accessed on 14.05.2021).
95 The author compiled the information based on the EM-DAT database. https://public.emdat.be/
96 Vasko Popovski, *Assessment Study of the Role of NDMAs in COVID19 crisis response and impact of COVID-19 on NDMAs Operations,* UNDP/UNDRR, 2021, p. 21. https://tinyurl.com/rzzjah7b (Accessed on 14.05.2021).

4.2 Impacts of disasters on critical infrastructure

No systematized and precise information or data on the disaster impacts on critical infrastructure for the region exists. Therefore, an attempt is made here to review the costs of major disasters in the ECA region for which Post-Disaster Needs Assessment (PDNA) and a Rapids Needs Assessment (RNA) studies were prepared during the last two decades. As can be seen, CI is not recognized as one set of systems/services, but is included across several different sectors, e.g. infrastructure, health, education, government, health, water and more.

This is because of the PDNA report's structure which means that for calculating the impact of the disasters on individual systems/services, additional data analysis is required. Therefore, these numbers should serve as a proxy value of assessed CI damages or losses during the most disastrous events.[97]

- ***Bosnia and Herzegovina May 2014 Floods***—As per the RNA Study[98], the total impact of the floods was audited at $2.416 bn, out of which the overall impact on the country's infrastructure systems, including facilities, assets and provision of services, was 30 percent, or $706.15 mn. The prevailing damages were losses in the *energy sector* (generation, distribution, transmission, coal mining, oil); *transport and communication* (roads, railways, bus stations, river ports, Sava River Waterway, airports, post, telecommunications); *water and sanitation* (water and wastewater systems); *floods protection* (rivers: dykes, pumps, channels, streams and torrents); *public services* (municipal facilities/buildings, assets, services); *health* (health infrastructure and assets); and *education* (education infrastructure, assets and services). The greatest damages and losses were recorded in the transport and communications sector ($412.36 mn).
- ***Serbia May 2014 Flood***—Following the disaster, the PDNA Study[99] identified total damages and losses at $1.809 bn (damages: $1.04 bn and losses: $769 mn). The overall effects on the various infrastructure sectors were determined as 47.22 percent of the total amount, or $854.22 mn. The affected sectors were agriculture, mining and energy, education, health, transport and communication, water and sanitation and governance. The greatest damages and losses were assessed to be in the mining and energy sectors—$578.40 mn.
- ***Albania's November 2019 Earthquake***[100] heavily affected 11 municipalities having an overall disaster impact of $1.19 bn, of which $1.02 bn represents the value of damages (destroyed physical assets) and $0.17 bn refers to losses. The impact on critical infrastructure was assessed in the following sectors: *infrastructure* (community infrastructure, roads, water and sanitation, communication, public buildings and energy), *education* (321 educational facilities), *health* (36 health facilities) and *emergency services/civil protection/DRR* (buildings, facilities and monitoring stations). The greatest damages were identified in the infrastructure sector ($38.08 mn) and the greatest losses were assessed to be in emergency services/civil protection/DRR ($16.03 mn).
- ***North Macedonia August 2016 Skopje Flash Flood***[101] was the deadliest disaster in the country following the Skopje 1963 Earthquake claiming 23 human casualties and a price tag of $36.37 mn (damages: $25.83 mn and losses: $4.84 mn). The infrastructure sector had suffered damages of $14.74 mn and losses of $3.96 mn, totalling 51 percent of the total amount.

97 The author made this analysis based on available open data.
98 https://tinyurl.com/3n37twb3
99 https://tinyurl.com/b2zbxf3v
100 https://tinyurl.com/2jfkzf5m
101 Following this disastrous event, a PDNA Study was prepared but it was not officially submitted to the government for acknowledgment and adoption.

- ***Georgia June 2015 Flash Floods***[102] had an economic impact of $24.3 mn in damages and $4.37 mn in losses. The critical infrastructure sector had the highest price tag with $16 mn in damages and $3 mn in losses.
- ***Moldova 2010 Floods***[103] in the Prut Valley from June 2010 hardly affected the western parts of Moldova with damages and losses totalling $41.92 mn (damages: $18.30 mn and losses: $23.62 mn). However, in this case the critical infrastructure sector had a high price tag of $18.36 mn (damages: $7.1 mn and losses: $11.2 mn).

In addition, many other disastrous events, either bigger or smaller in scale, are seriously pressuring the resilience texture of the countries and the territories of the ECA region and disproportionally affecting its populations by exacerbating existing vulnerabilities and by creating new inequalities. With the failure of critical infrastructure facilities and the disruption of services, the most vulnerable populations are impacted to a greater degree.

4.3. Findings and recommendations from the regional online survey on building CI resilience

To address the need for an overview of existing gaps and common challenges in CI resilience in the ECA region, an online regional survey was carried out in May 2021. The main objective—obtaining necessary qualitative and quantitative information from key respondents in participating countries and territories. This would provide input for elaborating regional recommendations thereby contributing to the design of the Guidance Notes.

The key findings of this survey, the contributory factors to understanding the existing context of building CI resilience, which are valid for formulating the Guidance Notes can be summarized as follows:

- In most countries and territories in the region, there is a low level of conceptual and terminological identification and definition of CI in major policy and normative documents.
- Apart from countries that have adopted CI laws, others do not have an official national categorization of CI as a basis for creating policies and actions for building resilience and inclusiveness.
- Some countries and territories have adopted CI laws and regulations, others have included CI in existing DRR laws, but most have not legally regulated this sphere. Where it exists, the approach is more reactive rather than proactive, with the main focus on protecting infrastructure than on prevention and mitigation. However, the different existing approaches across the region support the design of the Guidance Notes for boosting resilience-building efforts.
- In most countries and territories, essential aspects of the CI systems are included in the existing normative and planning documents. However, this integration is not sufficient to reflect the systemic nature of the risk and the interconnectivity and interdependence of the CI systems, which seek to better address the needs for inclusiveness and building resilience. The approach itself needs to be considered, mainly the infrastructure facilities and assets, rather than the services provided or resources allocated. Most of the sectors have *"a silo approach"* rather than an *"all-hazard"* approach or a *"CI life-cycle"* perspective.
- Throughout the region, the National Disaster Management Authorities (NDMAs) provide crucial input for CI protection alongside other DRR actors at the national and local levels. They are considered to be key institutions in multi-risk, multi-hazard and multisectoral DRM frameworks which provide supporting services for its protec-

102 https://tinyurl.com/37b4mu7a
103 https://www.gfdrr.org/sites/default/files/GFDRR_Moldova_PDNA_2010_EN.pdf

tion. Additionally, many other DRR actors are part of the regulatory framework for the protection of critical infrastructures and have competencies and responsibilities in their domains.

- The National DRR Platforms are not fully engaged in these resilience-building activities in most of the countries where they are established, but they can play a prominent role as a forum for strengthening national DRM systems. As multi-institutional and multisectoral mechanisms for advancing the DRR agenda and resilience building of societies and communities, they can contribute through a spectrum of activities.
- Resources are lacking for funding CI resilience with financial and human resources, as well as with the requisite expertise. These two areas top the funding gap. This situation is worsening: the impacts of the pandemic crisis mean existing resources are being spent, reallocated or overstretched. The private sector, i.e. owners/operators and investors are regarded as key contributors in providing the resources and in the building of CI resilience, in partnership with the NDMAs and other public domains.
- In the ECA region, there is evidence of good practices and lessons learned from building resilience activities. These lessons learned need to be codified and transformed into workable solutions for building of critical infrastructure resilience, i.e. establishing legal standards, new innovative practices and solutions, non-linear risk assessment, better operational planning, risk transfer, decentralization of critical infrastructure competencies, the introduction of green infrastructure and nature-based solutions as a modus operandi for the resilience and sustainability of societies and the communities, while leaving no one behind.
- Health, education, transport and emergency services are deemed the most important sectors following the impact of the pandemic and recent disasters mentioned above. Thus the identification and presentation of good practices were done based on PDNAs.
- Finally, a set of priority measures and actions were identified, namely building blocks for CI resilience, aimed at addressing existing and future chronic stresses and shocks, e.g. categorization of CI, policies, elaboration of legal and institutional frameworks, capacity-building, CI mainstreaming into DRM and vice versa, provision of resources, and more. These actions need to be part of national action plans for building CI resilience thereby enabling effective reduction in existing, potential and new risks. This process needs to be systematic and inclusive and involve the participation of all relevant stakeholders.

Based on the findings from the assessment review and the online regional survey, a set of ***general recommendations*** was formulated that provides the crucial foundation for developing the Guidance Notes for resilience building activities. These recommendations focus on creating the environment for enhancing the building of critical infrastructure resilience in countries and territories of the ECA region. They were included as potential actions to be undertaken in the relevant Guidance Notes. In general, they can be grouped into the following categories:

- Enhanced mainstreaming of CI resilience into the DRM framework and vice versa.
- Improvement of the policy, normative and institutional frameworks that will enable comprehensive building of resilience activities, including integration in existing, or enactment of new, strategies, policies and legislation. And building an adequate institutional framework, including coordination bodies.
- Capacity-development of personnel—from key stakeholders, high-level policy and decision-makers, through experts, professionals and citizens.
- Identification of critical infrastructure sectors following research and development studies in individual countries and territories, according to national contexts and priorities.
- Integrated risk and hazard assessment, risk modelling, operational planning and scenario development, and business continuity and contingency planning.
- Ensuring cross-sectoral coordination and cooperation alongside the establishment of working

partnerships among all involved entities, especially public-private partnerships, national and local governments and private sector owners and/or operators.

- Enhanced provision of required resources for critical infrastructure resilience.

5. ESSENTIALS OF BUILDING CRITICAL INFRASTRUCTURE RESILIENCE

5.1. The concept of resilience of critical infrastructure systems

CI systems are vital for the functioning of societies, governments, economies and the existence of communities. During the last couple of decades, their number and types significantly increased amplifying their interdependency and complexities. Their continuous performance and delivery of services is a key pillar of the functioning of the modern world.

> **Resilience** is the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.
> *Source:* https://tinyurl.com/59tdbxbx

Technological advancements, together with enhanced governance and increased needs of people, require robust, and reliable CI assets and facilities and the continuous provision of services. The frequency and intensity of disastrous events impacting infrastructure facilities and assets and disrupting services, in tandem with the continuous chronic pressures and rising uncertainties from climate change and future events, has brought the issue of their resilience to the forefront. Consequently, the issues of building the resilience of critical infrastructure systems in a way that can continuously guarantee their essential functions and services, and that can withstand the chronic stresses and acute shocks during their lifespan, emerged on the resilience agenda in 2000–2010.

The starting point on this path to build resilience is the terminological understanding of the concept. A definition put forward in 2009 described resilience as *"the ability to reduce the magnitude and/or duration of disruptive events"* while *"the effectiveness of a resilient infrastructure or enterprise depends upon its ability to* ***anticipate, absorb, adapt to, and/or rapidly recover*** *from a potentially disruptive event"*[104]. As a result, we can identify several elements of critical infrastructure resilience, i.e. *anticipation of potential disruption* (to assess, plan and prepare), *absorption capacities* (to withstand shocks/pressure or to accommodate to the unexpected), *adaptation capabilities* (to continue to function or provide services within the new situation) and *abilities to quickly recover* from the significant disruption or situations.

On the other hand, resilience of CI systems is characterized by three key features[105]: *robustness* (to maintain the operations and functions in the face of disaster, e.g. resilient design, system substitution, and other factors); *resourcefulness* (to skilfully prepare for disaster response, e.g. business continuity, training, supply chain management, and other factors); and *rapid recovery* (to return or to reconstitute normalcy

104 National Infrastructure Advisory Council. *Critical Infrastructure Resilience Final Report and Recommendations. U.S. Department of Homeland Security* (Washington DC., 2009), p. 8. https://www.dhs.gov/xlibrary/assets/niac/niac_critical_infrastructure_resilience.pdf (Accessed 30.09.2021).

105 National Infrastructure Advisory Council. *Optimization of Resources for Mitigating Infrastructure Disruptions Study* (19 October 2010). https://tinyurl.com/3zv2xew3 (Accessed on 5.10.2021).

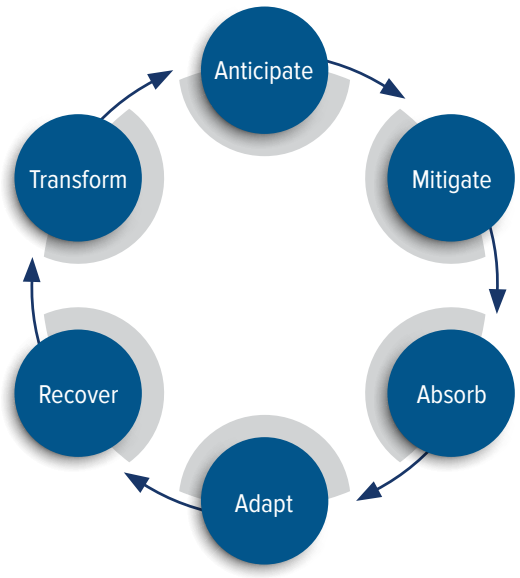
as quickly as possible after a disaster, e.g. emergency operations, immediate recovery actions, and other factors).

These features intersect with its main characteristics, i.e. critical infrastructures are complex, interconnected and interdependent systems and their impacts on one sector can have a cascading effect on other ones. In fact, resilience itself is a dynamic category that is based on the premise that the capacities of the systems need to absorb, adapt and recover from adverse repercussions. For societal systems to be resilient they also need to *transform* or *"positively change"*[106] to cope with future chronic stresses and acute shocks.

In that regard, a resilient society is based on multi-dimensional principles that contribute to sustainable and resilient development, e.g. risk and hazard awareness and their integrated analysis and assessment; sustainable risk and threat management; systematic approach for prevention, mitigation, preparedness and response to crises and disasters; a *"whole-of-society approach"* to risk reduction and building critical infrastructure resilience; a "Build-Back-Better" principle in recovery[107]; transformation for enhancement; a non-linear understanding of the future; the anticipation of new uncertainties; and the "life-cycle" of infrastructure systems.

Accordingly, the concept of transformation can be added to the CI resilience-building framework that pertains to critical infrastructure, as presented in the cycle graph below. Consequently, CI resilience can be understood as the ***ability of these systems to anticipate, withstand or absorb shocks and stresses, while adapting to new conditions that would result in a quick recovery and transformation as a way to better cope with chronic stresses and acute shocks in the future.***

Figure 3: The cycle of building resilience of the critical infrastructure system



Relevant measures and actions while building the CI resilience cycle need to be implemented before, during and after disasters. Accordingly, the resilience-building phases are presented in Table 6 below, including their correlation with the four phases of the DRM cycle.

106 Vasko Popovski, "Crisis Management and the Concept of Resilience: Case of the Republic of Macedonia", International Scientific Journal *Contemporary Macedonian Defence/Sovremena makedonska odbrana*, No. 3 4. (Ministry of Defence of the Republic of Macedonia, 2018), p. 83.
107 *Ibid*, p. 87.

Table 6: Phases in building critical infrastructure resilience

Before disaster	DRM Phase	During disaster	DRM Phase	After disaster	DRM Phase
Anticipation **Mitigation**	Prevention/ Preparednes	**Absorption** **Adaptation**	Response	**Recovery** **Transformation**	Recovery

Following this methodological framework, different phases are briefly described as follows:

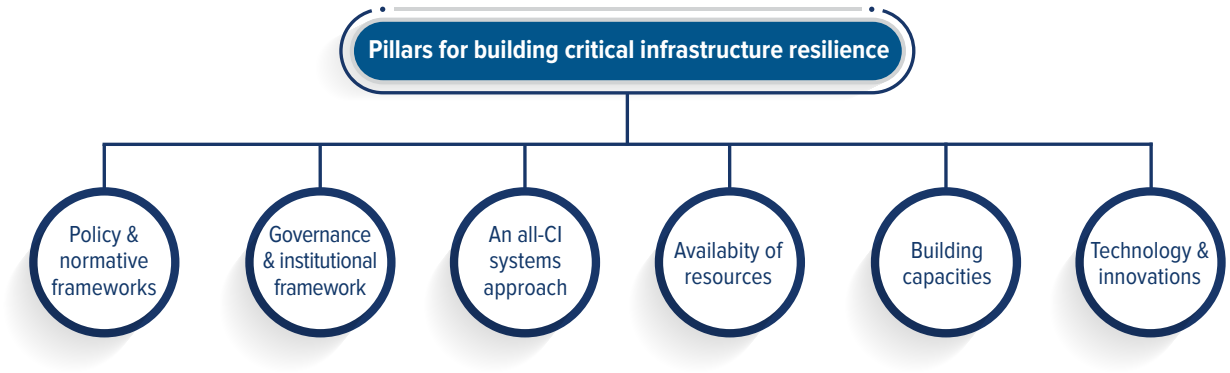
- ***Before a disaster,*** one needs to ***anticipate*** and ***mitigate*** potential disruption and adverse impacts contributing to proactive risk management: *"Anticipating the potential consequences of disasters can help determine the actions that need to be started before the disaster strikes to minimize its effects."*[108] Within the framework of the prevention phase, the owners/operators of critical infrastructure systems can identify and assess all potential risks and hazards to which their systems are exposed, and plan and implement measures and actions for mitigating future adverse impacts, failures and disruptions of systems. *Preparedness* is embedded within the essential texture of these preventive mitigation activities aimed at avoiding potential infrastructure failures and severe disruption of services. As mentioned above, the element of resourcefulness (e.g. skilfully preparing for a disaster response as expressed in business continuity, training, supply chain management, and more) can be identified during this phase of building CI resilience.
- ***During a disaster or during the response phase,*** these systems need to ***absorb*** the shocks and pressures, while accommodating the unexpected and minimizing the consequences of the adverse event. ***Adaptive capabilities*** of CI systems refer to continuity in operations, functions and provision of services within the parameters of the new situation, and the term emphasizes the element of robustness. ***Adaptation*** of the CI systems needs to be driven by the prevailing, changing and potential risks and threats. All actions that would be taken during this phase need to be timely, effective and efficient.
- ***Following disasters or during the recovery phase,*** the CI systems need to ***rapidly/quickly recover*** and reconstitute normalcy as quickly as possible, e.g. reconstruction and rehabilitation using the Build Back Better principle, and more. Moreover, these systems need ***to transform*** themselves, anticipating future disruptions, failures and adverse situations and be able to better cope with chronic stresses and acute shocks. This transformability relates both to the structures of these systems and to their operation and management. *"Lessons learned"* and good practices are among the most efficient tools allowing all key actors to contribute to the enhancement of resilience in an inclusive and participatory manner.

5.2 Pillars for building critical infrastructure resilience

In general, the six main pillars of CI resilience-building in the ECA region comprise those elements that are part of contemporary approaches to sustainable and resilient development and they provide a framework for the formulation of the Guidance Notes. Within the framework, the main components of the CI systems are integrated, e.g. *sectors* (facilities/assets/services), *resources* (human/material/technical) and *key stakeholders* (owners/operators, authorities, general/specialized public).

108 Lelisa Sena and Kifle Woldemichael, *"Disaster Prevention and Preparedness"* (Lectures for Health Science Students, Jimma University, 2006), p. 2. https://tinyurl.com/m4kewued (Accessed on 3.10.2021).

Table 7: Pillars for building critical infrastructure resilience



1. Policy and normative frameworks— Sound policy and legislative frameworks are the preconditions for mainstreaming CI resilience in DRM and vice versa. This principle does not imply that the country and territories in the ECA region need to have a unified approach to creating these frameworks, but such a perspective is needed to initiate the process of integrating CI resilience-building across sectors according to their national contexts and priorities. Presently, CI legislative acts or their mainstreaming into other laws, are insufficient for various reasons, i.e. a lack of clearly defined CI policy concepts, poor integration in strategic documents and mainly focus on the protection of assets and facilities. Therefore, it is essential to re-examine the approach by shifting it from the protection of critical infrastructure to one of building comprehensive resilience.

This will result in a set of actions allowing for the following measures: the review of the existing and adoption of new strategic and policy documents or their adoption; the amending of existing legislation or the enacting new critical infrastructure laws and by-laws; ensuring the integration of comprehensive CI resilience principles across legislative acts pertaining to other sectors; and designing and adopting new resilience-building standards and ensuring their implementation in all relevant sectors during the whole CI life cycle.

2. Governance and institutional framework—A comprehensive governance and institutional framework are crucial for building CI resilience across Europe and Central Asia. Throughout the region, diversity in risk reduction approaches and CI management are found in a situation when there are no dedicated entities for CI protection, or when they are not as yet established. The results from the regional online survey showed that in most cases the NDMAs are responsible for overall CI resilience followed by others, i.e. public or private owners and operators, government commissions and specialized bodies, sectoral ministries or the local authorities. This is mainly due to the existing reactive approach, which focuses on protection without considering CI resilience as a whole and the complexity and interdependency of the sectors. The approach is to regard it as the extended domain of the emergency management services or the civil protection competencies. Following the ***whole-of-government*** and ***all-of-society*** approaches in building resilience, one needs to overcome the existing *"siloed approach"* and to ensure institutional building takes place within the partnerships established between the governments and the private sectors. This ensures that all key stakeholders are on board this venture of building resilience.

In particular, it is essential to appoint coordination entities, to systematize the roles, responsibilities and the design and to implement adequate resilience-building measures and actions. In that regard, the National DRR Platforms, as multi-institutional and multisectoral mechanisms for DRM advancement and resilience-building of societies and communities, can significantly contribute through an array of supporting activities and services.

Furthermore, building transboundary resilience should be included in fostering CI regional or subregional partnerships, cooperation and coordination. Consequently, building CI resilience should be delivered as a whole, integrated package thereby ensuring the sustainable and resilient development of countries and territories.

3. An All-CI systems approach—Building resilience is the responsibility both of the owners, operators or NDMAs and of other important DRR actors on the national and local levels. The above-mentioned *"siloed approach"* to critical infrastructure only relates to physical parameters, such as assets and facilities, operation/maintenance, without considering the full set of functions and services provided, including resources, limited cooperation and coordination, or fragmented resilience-building. In most countries and territories of the ECA region, apart from the government authorities, the entities of the so-called *"traditional critical infrastructure sectors"* are most active in mitigation and protection activities (e.g. energy, water, food, transport, telecommunications, health care and banking and finance). Contemporary DRM is guided by the principle that DRR is not the exclusive purview of national and local governments, but the responsibility of all stakeholders, including of the communities and individual members of the public.

In this way, resilience-building is a result of their interactions and essential risk governance will be achieved by integrating all critical sectors, by the participation of all relevant key stakeholders and by the provision of infrastructure-related services. Various key stakeholders have different roles and responsibilities during the six phases of the CI resilience-building cycle, as presented in the table below.

Table 8: Stakeholders' roles in phases of building resilience in the CI cycle

#	Stakeholder	Anticipation	Mitigation	Absorption	Adaptation	Recovery	Transformation
1	Government (national/local)	✓	✓	✓	✓	✓	✓
2	Owners/operators (public/private)	✓	✓	✓	✓	✓	✓
3	NDMAs	✓	✓	✓	✓	✓	✓
4	Investors	✓	✓			✓	
5	Designers/ Contractors	✓	✓			✓	✓
6	NGOs	✓	✓			✓	✓
7	R&D, academia	✓	✓		✓	✓	✓
8	End-users	✓				✓	✓

4. Availability of resources—The functioning and viability of infrastructure systems are imperative before, during and after disasters, and therefore adequate resources for supporting their needs to be planned and established. The term *"resources"* should be understood in its complexity, unifying different aspects—ranging from financial resources, through material and technical means, to human and professional ones. During the COVID-19 pandemic the importance of the CI of human resources/workers proved to be significant and vital for their operation and for the non-disruptive provision of services. This principle of building CI resilience needs to be seen in correlation with private sector involvement, both in the roles of the owners and operators of the systems, or external actors, that can provide additional resources, investments, knowledge or expertise.

As the results of the regional survey show, the lack of financial resources is the most serious constraint, followed by the lack of educated and professionally trained human resource staff, the current lack of adequate expertise at the national level, as well as lack of knowledge, and the shortfall in technical and organizational resources.

In all countries and territories, the funding provided for resilience-building policies and for the implementation of measures or actions are insufficient. In that regard, the existing financial gap between needed investments and available resources is vast in the ECA

region, i.e. Azerbaijan—$8 bn, Kazakhstan—$84 bn and Turkey $405 bn.[109]

Therefore, investments in CI systems need to be proactive and *ex-ante*, enabling the building of resilience and of transforming CI systems into responsive systems rather than reactive structures. Following disasters, they need to ensure financing of recovery efforts and of a resilient rehabilitation of affected infrastructure. These investments need to be increased both by the public and the private sectors following the critical needs assessments and the priorities established throughout the countries and territories in the region.

5. Building capacities is one of the key pillars for having a resilient and sustainable infrastructure. According to the Economist Intelligence Unit: *"Countries often lack human resources with the required skills to plan, deliver and manage sustainable, resilient infrastructure at the scale required to meet demand, particularly in developing countries, where the lion's share of the world's infrastructure gaps exist."*[110] The capacities of all stakeholders across the CI sectors, alongside the DRM systems, need to be developed to cope with all risks, hazards and threats, and with complex disasters that have low probability and high impact outcomes. To summarize, a complex task needs to be implemented continuously while targeting various roles and responsibilities of the DRR actors—from sensitization on building resilience among policy formulators and decision-makers to conducting professional education and specialized training of professionals and emergency responders, through knowledge dissemination to other key stakeholders and raising awareness of the general population. Feedback from the respondents in the regional survey emphasized the need for ongoing capacity development, especially specialized knowledge and expertise that is missing in public domain entities.

Therefore, the capacity-building portfolio should be based upon the all-hazard life-cycle, an inclusive and systematically organized approach. This capacity-building process needs to be systemic, with the participation of all relevant stakeholders, and located at the centre of building CI resilience in the countries and territories of the ECA region.

6. Technology and innovation are among the main features of the contemporary approach to building disaster resilience. Although frequently utilized in risk reduction efforts, they are still not fully mainstreamed within practices, given the financial costs and need for specialized resources and knowledge. Consequently, their application should be the departing point for designing resilient policies, norms, codes and standards during the *World 4.0* era, while utilizing new and emerging technologies and smart solutions. Moreover, building CI resilience needs to include the dimension of future-proofing of infrastructure systems aimed at anticipatory resilience as a futures-oriented knowledge system that addresses new extreme weather events, changing climate and emerging security risks. Accordingly, the CI design should be more innovative, intuitive and secure, ensuring resilience beyond the existing frameworks. In that regard, partnerships need to be established for advancing the research and development agenda with relevant partners, e.g. academia, the private sector and NGOs. Moreover, innovative solutions are sometimes related to the application of cost-effective solutions, such are green infrastructure or nature-based solutions[111]. They are "approaches that weave natural features or processes into the built environment to promote adaptation and resilience."[112]

Nature-based solutions by IUCN are: "actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits".
Source: https://tinyurl.com/2p9bu83x

109 https://outlook.gihub.org/

110 The Economist Intelligence Unit, *The critical role of infrastructure for the Sustainable Development Goals* (EIU, 2019), p. 12. https://tinyurl.com/drfvmth3 (Accessed on 15.10.2021).

111 https://portals.iucn.org/library/node/49070

112 FEMA, *Nature-Based Solutions*. Federal Emergency Management Agency (14 October 2021). https://www.fema.gov/emergency-managers/risk-management/nature-based-solutions (Accessed on 15.11.2021).

PART II:

GUIDING THE BUILDING OF CRITICAL INFRASTRUCTURE RESILIENCE

1. INTRODUCTION

This section consists of the technical checklist and practical Guidance Notes for building CI resilience thereby contributing to its enhancement throughout the countries and territories in the region and beyond. The idea behind this endeavour was to design a practical framework to overcome existing gaps and challenges in building CI resilience through providing insights into the existing context; identifying the potential and emerging opportunities; and contributing to enhancing the overall resilience-building process by using a systematic approach in ECA countries and territories and beyond.

Consequently, this document aims to support the policy creators and decision-makers, government professionals, practitioners, owners and operators and other stakeholders to better understand the building of critical infrastructure resilience. And accordingly, to design appropriate policies, legal and institutional frameworks, and to develop and implement various measures and actions via public-private cooperation and coordination.

The guidance provided and concomitant actions should be used to review and implement the building of the critical infrastructure resilience cycle, according to the system-based viewpoint while acknowledging various other approaches: those pertaining to all-risk, hazards and threats, all-of-society, whole-of-government and the life-cycle of critical infrastructure.

2. TECHNICAL CHECKLIST AND THE GUIDANCE NOTES FOR BUILDING CRITICAL INFRASTRUCTURE RESILIENCE

2.1 Technical Checklist for building critical infrastructure resilience is designed as a diagnostic tool to help the DRR practitioners in the Europe and Central Asia region understand the existing level of building CI resilience in their countries and territories. There are 39 activities and for each one the beneficiaries can note whether an activity exists or is in a developmental phase. In the *"Notes"* section, they can enter relevant information and data, or they can provide additional clarifications. Every activity for building resilience that is on the technical checklist is connected to the relevant Guidance Notes, and the proposed actions ensure logical sequencing and continuity.

Table 9: Technical checklist for building critical infrastructure resilience

#	Resilience-building action	Yes	No	In progress	Notes
Before disaster (DRM cycle: Prevention) RB Cycle: Anticipation					
1	CI resilience framework exists, i.e. terminological definition and categorization.				
2	CI resilience is included in the strategic and policy documents (e.g. national/local/sectoral).				
3	Existing normative framework integrates CI resilience, e.g. CI law and by-laws, DRM law or in sectoral and other legislative acts, SOPs.				
4	Existing institutional frameworks define CI resilience entities, e.g. national CI coordination body/entity, NDMAs, ministries, owners/operators, and other stakeholders.				

#	Resilience-building action	Yes	No	In progress	Notes
Before disaster (DRM cycle: Prevention) RB Cycle: Anticipation					
5	Development of sectoral guidance for CI resilience.				
6	Adoption of CI sectoral risk and hazard assessments.				
7	Sectoral CI assessments are integrated into the national/local risk and hazard assessments.				
8	Development of risk modelling for evaluation of CI security.				
9	Application of ICT solutions for all risks, hazards and threat assessments of the CI sectors.				
10	Development of disruptive scenarios and performing stress tests for the assessment of CI resilience.				
Before disaster (DRM Cycle: Prevention) RB Cycle: Mitigation					
11	Establishment of public-private cooperation and coordination for CI resilience.				
12	Private sector contribution to efforts building resilience with the provision of adequate resources, knowledge and expertise.				
13	Contribution of the National DRR Platform to CI resilience-building (if established).				
14	Cross-border or subregional cooperation for CI resilience-building.				
15	Sharing of CI-related information and data for risk-informed and evidence-based decision-making.				
16	Development of capacities for CI building resilience.				
17	Ex-ante investment in CI resilience based on identified priorities.				
18	Incentive schemes for CI resilience.				
19	Existence of risk transfer mechanisms for CI systems.				
20	Identification of structural and non-structural measures for CI resilience is based on integrated risk and hazard assessments.				
21	Implementation of structural measures for CI resilience.				
22	Implementation of non-structural measures for CI resilience.				
Before disaster (DRM Cycle: Preparedness) RB Cycle: Mitigation					
23	Development of CI disaster preparedness plan.				
24	Existence of human resources and implementation of CI sector specialized education and professional training.				
25	Supply of material-technical resources, including specialized equipment.				
26	Conduct of scenario planning and delivery of multisectoral training.				
27	Engagement of communities and individuals to increase their readiness				

28	Early warning, alert and emergency information systems, i.e. general and CI sector-specific.				
#	**Resilience-building action**	**Yes**	**No**	**In progress**	**Notes**
Before disaster (DRM Cycle: Prevention) RB Cycle: Mitigation					
29	The existence of a business continuity framework and adoption of business continuity plans for CI systems.				
30	Conducting inclusive and multisectoral simulation or field training exercises for testing disaster preparedness.				
During a disaster (DRM cycle: Response) RB cycle: Absorption/Adaptation					
31	Implementation of the CI response plans.				
32	Managing failures and disruption of services threatening the functionality of the critical infrastructure				
33	Conducting works to restore CI normal, pre-event functionalities.				
After disaster (DRM cycle: Recovery) RB cycle: Recovery					
34	Post-disaster damage and losses assessment of the affected CI sectors.				
35	Recovery framework is established.				
36	"Build Back Better" is applied in CI reconstruction and rehabilitation.				
After disaster (DRM cycle: Recovery) RB cycle: Transformation					
37	Evaluation of the response with recommendations.				
38	Evaluation and codification of good practices and lessons learned				
39	Application of good practices and lessons learned.				

2.2 General Guidance notes for building critical infrastructure resilience in the ECA region

have contributed to enhanced CI mainstreaming into DRM and vice versa. The overall framework has been formulated to strengthen CI resilience based upon the above-mentioned resilience-building cycle and the pillars highlighted. The Guidance Notes aim to support the authorities in the countries and territories to design relevant resilience-building policies and to implement adequate actions, in partnership and coordination with other entities, CI owners and operators before, during and after disasters.

There are 11 general Guidance Notes and 83 proposed actions that enable better identification and formulation of relevant guidelines and of a proactive approach to risk reduction and building resilience. This means that most are meant to be implemented before disasters. The identification and formulation of these notes stem from the detailed list of survey recommendations and existing global best practices. Each guidance notes results in a set of specific actions that can be implemented by institutions from ECA countries and territories, depending on the national context and the priorities.

Table 10: Guidance Notes for building critical infrastructure resilience

#	Guidance Notes	Stage	RB Cycle	DRM Phase
1	Create an enabling policy and an institutional and normative environment for building CI resilience, one that ensures "whole-of-government" and "all-of-society" approaches and greater mainstreaming of critical infrastructure resilience into the DRM framework and vice versa.	BD	Anticipation	Prevention
2	Ensure all-hazard and risks and security threats approaches are adhered to through increased knowledge, integrated and inclusive assessments and operational planning.	BD	Anticipation	Prevention
3	Realize the entire spectrum of the critical infrastructure system approach through the integration of all sectors and the establishment of partnerships for critical infrastructure resilience.	BD	Anticipation	Prevention
4	Enhance the human capacities for building critical infrastructure resilience.	BD	Mitigation	Prevention
5	Make investments for building CI resilience.	BD	Mitigation	Prevention
6	Strengthen the preparedness of critical infrastructure systems.	BD	Mitigation	Preparedness
7	Develop and implement business continuity and recovery plans of the critical infrastructure sectors.	BD	Mitigation	Preparedness
8	Manage failures and disruption of services to ensure the functionality of critical infrastructure.	During a disaster	Absorption/ Adaptation	Prevention
9	Assessment of post-disaster damages and losses.	AD	Recovery	Prevention
10	Resilient recovery through the prism of "Build Back Better".	AD	Recovery	Recovery
11	Transform critical infrastructure systems.	AD	Transformation	Recovery

A) BEFORE A DISASTER

1) Anticipation

***Guidance Note #1: Create an enabling policy, an institutional and normative environment for building CI resilience while ensuring a "whole-of-government" and "all-of-society" approaches and greater mainstreaming of critical infrastructure resilience into the DRM framework and vice versa*.** Recent disastrous events—including the increased number of extreme weather events; security risks and new and emerging threats; the unprecedented impact of the COVID-19 pandemic; the major depreciation of the critical infrastructure assets and facilities across the region; and the need for major investments for rehabilitation—brought into focus the need for enhanced and comprehensive building of CI resilience.

Initial actions are aimed at enabling the environment for mainstreaming CI resilience in the DRM systems and vice-versa. The systematization of the processes for building resilience allows for the creation and adoption of resilience-informed decisions, policies and legislative solutions.

Potential actions

1. *Adopt the terminological definition of critical infrastructure,* including the critical services incorporating DRR and CCA, and its alignment with global and national frameworks for sustainable and resilient development and national contexts and priorities.
2. *Develop a methodology for identifying national CI systems and categorizing the sectors,* conducting the identification and mapping exercise and establishing a national registry/platform of critical infrastructure. These activities should be undertaken using an inclusive and participatory approach between the public and private domains. The principles of categorizing national critical infrastructure should be aligned both with the national context and with international standards. For example, the countries and territories in the Western Balkans and Turkey subregion are predominantly guided by the European Programme for Critical Infrastructure Protection.
3. *Implement research studies on the resilience aspects of the CI systems* understanding their interconnectivity, interdependency and complexity alongside the systemic nature of risks, including resilience during uncertain times.
4. *Sensitize key stakeholders on the critical infrastructure and DRM* aimed at sharing a joint vision for resilience, e.g. NDMAs and related stakeholders on aspects of critical infrastructure resilience vs operators/owners on resilience and contemporary DRM.
5. *Create and implement long-term strategic frameworks for building critical infrastructure resilience* through its integration and mainstreaming into strategic and policy documents, both from the DRR and sectoral spheres. This action should result in an update of the existing ones or in the enactment of new ones following the approach of building resilience thereby contributing to risk-informed decision-making.
6. *Establish a modern legislative foundation for critical infrastructure resilience*. This action will consist of a review of existing laws with a view to their enhancement, the enactment of new critical infrastructure legislative acts or the modification and amendment of existing DRM laws. During this process, it is extremely important to advocate for laws that will address previously identified gaps, blank spots and challenges and that will harmonize critical infrastructure services across the region.
7. *Establish the institutional framework for building CI resilience* consisting of the adoption of critical infrastructure protection systems, i.e. designating coordination entities, systematizing their roles and responsibilities, designing and implementing awareness-raising activities and establishing national critical infrastructure centres responsible for operations, consulting and inspection.
8. *Improve the understanding and knowledge* of policymakers and decision-makers, national and local authorities, NDMAs and other national and local government authorities, the private sector, academia, NGOs and other entities to acknowledge the importance of building critical infrastructure resilience and of its protection.
9. *Develop specific sectoral resilience guidelines* outlining the measures and activities that the public and private domains entities, including the owners and/or operators, need to implement for building resilient critical infrastructure systems.
10. *Ensure cross-sectoral cooperation and coordination* at every level and among all stakeholders. In this way, the interdependencies of critical infrastructure sectors will be addressed.
11. *Integrate critical infrastructure resilience* aspects and priorities across the national/local development strategies and plans.
12. *Identify possibilities for further decentralization of critical infrastructure sectors* thereby assigning the local authorities more governance powers to manage existing, anticipated and new risks.

Guidance Note #2: Ensure the following approaches—the all-hazard, risks and security threats perspectives—are assessed through increased knowledge, integrated and inclusive assessments and operational planning—CI systems are complex, interconnected and interdependent systems that are

exposed and vulnerable to the palette of existing and new risks and to threats resulting in potential failures and disruptions in the provision of services. To understand the potential fallout from adverse events and to better prepare for unpredictable outcomes, the starting point is to evaluate the hazards underlying risk-informed and evidence-based decision-making.

In the case of building CI resilience, no uniform approach exists as yet therefore the classical risk assessment of natural and human-made hazards need expansion by adding resilience, i.e. systematic, complex and emerging risks and the interdependencies of the CI systems, including the system capacities. In addition, the collection of various disaggregated data on CI will support this endeavour by integrating innovative solutions, e.g. big data/open data.

Potential actions:

13. *Collect reliable and quality disaggregated data* from different sources, owned or managed by different entities in a uniform format for analysis and evaluation of potential risks. Moreover, this data will enable consistency in analysis and decision-making processes during other phases of the DRM cycle, especially concerning post-disaster damage and loss assessments.
14. *Engage the private sector,* including the insurance industry, in data collection and sharing through a broadened partnership, by introducing social corporate responsibility or other arrangements.
15. *Implement the multi-risk, multi-stakeholder assessment of exposure and vulnerability of CI systems* taking into account disaster and climate risks, security threats and resilience of the critical infrastructure systems, led by the NDMAs. This should be undertaken in an inclusive manner by a multidisciplinary team of experts, in coordination with the owners and/or operators from the public or private domains. During this phase, risk-modelling should be performed for the evaluation of CI security, threats and vulnerabilities.
16. *Design and apply ICT solutions* for support of the all-hazards assessments, i.e. web-based applications on CI risk exposure and vulnerability, GIS tools and platforms, and others, including innovations for resilience. This includes: big data analysis; open data sources; crowdsourcing of data or citizen science methods and tools for co-opting citizens in collecting and sharing information; and data of relevance for the resilience of critical infrastructure and services.
17. *Implementation of sound ICT information security policies and actions* by the national and local authorities, NDMAs, systems owners and/or operators and other entities that are regularly updated on the latest cyber risks and threats—thereby preventing cyberattacks and ensuring both business continuity of their operations and the provision of services.
18. *Develop disruptive event scenario*s for the assessment of critical infrastructure resilience.
19. *Conduct periodic multi-risk, and multi-threat CI stress tests* to identify their resilience to potential failures and disruptions and to unexpected or uncontrollable events, e.g. high probability, low consequence events, extreme weather events.
20. *Incorporate the CI risk assessments in a comprehensive way* into the existing and new operational planning and response documents thereby ensuring better preparedness, response and recovery.
21. *Establishment of the cross-border and/or subregional approach* in risk assessment of cross-border critical infrastructure.

Guidance Note #3: Achieving an all-CI system approach through integrating all sectors and the establishment of partnerships for resilience—Building CI resilience requires both the system to be understood in its complexity, interconnectivity and interdependence, i.e. all critical infrastructure sectors and key stakeholders from the public, private and social domains, including owners and/or operators. The main pillars of this Guidance Note are the "all-of-society, "whole-of-government" and "life-cycle of the critical infrastructure" approaches.

Thus, essential disaster risk governance will be achieved because all critical sectors are integrated, all key stakeholders are included and can participate, and the provision of infrastructure-related services is ensured. Furthermore, trust between the public and

private domains is safeguarded and information and data are shared among the competent authorities and institutions for building resilience activities.

Potential actions:

22. *Include the private sector* in all related processes and activities since it is a driver of transformational change in building CI resilience, e.g. policies, normative and institutional frameworks, standardization and implementation of actions and measures for resilience, technological and innovative solutions.
23. *Utilize public-private partnerships* as a modus operandi for building CI resilience, combining public sector knowledge and private sector expertise and resources.
24. *Leverage the power of partnerships for building CI resilience*, including the role of the National DRR Platforms that can contribute through various activities, the institutionalization of dialogues of stakeholders from different areas and sectors of governments and the provision of incentives for research and development.
25. *Facilitate information and data exchange for building CI resilience* utilizing existing solutions and platforms or establishing new ones with the NDMAs as the most prominent entities for best facilitating this process. Within the scope of this section, the private sector in particular should participate, including the insurance and financial industries.
26. *Utilize the information and knowledge-sharing* for designing and adopting risk-informed decisions.
27. *Create awareness among the population* on building CI resilience through continuous awareness-raising activities.
28. *Establishing and implementing mechanisms for regular M&E* that can be a practical and beneficial tool for enhancing the building of CI resilience, and provide input for the transformational aspect of the process. Alongside external entities, the NDMAs can participate in these activities as emergency services providers.
29. *Promote and share new knowledge and practices* among emergency responders, operators, researchers and communities.
30. *Establishing accountability frameworks* for owners and/or operators from the public and private domain aimed at ensuring systematic implementation of policies, measures and actions.

2) Mitigation

Guidance Note #4: Enhance human capacities for building CI resilience—CI human resources constitute its core. Until now they were not a primary focus of the resilience-building efforts. But success and resilience can only be achieved if, alongside structural resilience, the resistance of assets and facilities and the undisrupted provision of services, human resources are included. This should be accompanied by capacity-development.

Potential actions:

31. *Map the key stakeholders* and conduct a functional analysis of their human capacities.
32. *Define a methodological framework* and approach for capacity-building for key sectors and various institutions, e.g. national/local authorities, NDMAs, CI owners and/or operators, academia, NGOs.
33. *Establishing specialized groups* within key institutions for training and capacity development, in parallel with the design and implementation of customized capacity development programmes and training (based on the Training of Trainers) approach.
34. *Design and publishing of a "cookbook"* on CI resilience aimed at different target stakeholders and educational levels.
35. *Design and implement* customized HR capacity-development programmes and training in relevant institutions and entities.
36. *Evaluate the effectiveness* of professional employee training.
37. *Collect and share good practices and lessons learned* for advancing the resilient-building pro-

cess and its transformational potential in the wake of disasters.

Guidance Note #5: Investments for building CI resilience—As pointed out, insufficient financial investment in critical infrastructure is the major challenge in building resilience. Across the region, significant gaps in financing infrastructure projects have been identified and investments are lower than in other regions. Furthermore, the pandemic crisis and its cascading effects across society and development sectors highlighted the underinvestment in CI systems, which is exacerbating current problems and creating new structural and other vulnerabilities.

Therefore, stable and sustainable investments in building CI resilience are required both for ensuring the resistance of assets and facilities, uninterrupted services and building the capacities of key entities from the public and private domains. "On average the net benefit of investing in more resilient infrastructure in low- and middle-income countries would be $4.2 trillion with $4 in benefit for each $1 invested."[113] Investments in CI resilience need to go beyond the provision of funds and also include investments in mitigation measures.

In that regard, both national and local governments need to ensure that their development planning, budgeting and decision-making duly consider critical needs today rather than subsequently. Development planning needs are ahead of the resilience and risk reduction curve and will also be a crucial to build resilient infrastructure.

Potential actions:

38. *Create or enhance the existing policy and normative framework for investments* in CI resilience aimed at leveraging funding to meet this goal.
39. *Prioritize investments* for CI resilience based on risk assessments and evaluations.
40. *Allocate funds for building CI resilience* ex-ante from the regular budgets and financial sources.
41. *Investments in building CI resilience* is needed in partnership with private sector owners, operators of existing systems, and external investors given the economic attractiveness of using existing financial mechanisms and the new ways of financing resilience, e.g. innovative, alternative financing.
42. *Establish incentives for investment* in CI resilience, both for owners/operators and the authorities, i.e. subsidies, cost-benefits, insurance schemes, and more.
43. *Utilize the risk transfer mechanisms* for enhanced resilience of critical infrastructure, i.e. insurance and reinsurance, catastrophe bonds and reserves.
44. *Utilize alternative and non-traditional sources,*[114] e.g. crowdfunding, blockchain and others.
45. *Identify priorities* for conducting mitigation measures, based on prioritized at-risk sites, In regard to the most vulnerable critical infrastructure systems, with inclusion and participation of key stakeholders, including the affected communities.
46. *Design and implement structural measures* for CI resilience, e.g. construction of extreme weather event-proof facilities, retrofitting of existing buildings and infrastructure facilities.
47. *Design and implement non-structural measures* for CI resilience, e.g. adoption of resilience-oriented codes and standards, mainstreaming of resilience-based design (for example, earthquake-resistant design), research and development.

- **Structural measures** are any physical construction to reduce or avoid possible impacts of hazards, or the application of engineering techniques or technology to achieve hazard resistance and resilience in structures or systems.
- **Non-structural measures** are measures not involving physical construction which use knowledge, practice or agreement to reduce disaster risks and impacts, in particular through policies and laws, public awareness raising, training and education.

Source: UNDRR https://tinyurl.com/w3vddcre

113 https://tinyurl.com/nrzdh55u
114 https://rocys.ici.ro/documents/spring2019/article_11.pdf

Guidance Note #6: Strengthening preparedness in CI systems—The building of the CI resilience approach is based on the preparedness of institutions and professionals and on resilient CI systems. This readiness should be based upon the all-hazard, life-cycle, inclusive and systematically organized response that is based on a well-established partnership with all key stakeholders

Potential actions:

48. *Customized development* of preparedness measures and actions for public and private domain *entities.*
49. *Develop disaster preparedness plans and capacities* for a timely and effective response.
50. *Implementation of security policies and measures* and of safety standards for critical infrastructure systems and services.
51. *Strengthen the CI resilience structures* and supply material and technical resources.
52. *Conduct specific CI sector employee training* and maintenance of specific skills and knowledge.
53. *Conduct scenario planning and deliver multisectoral training* for preparedness and response to existing and new risks and threats, with support from the NDMAs.
54. *Building up and running* early warning, alert and emergency information systems.
55. *Provide information to the public and support communities* in building CI resilience, e.g. engage communities and individuals in increasing their readiness to access critical facilities, or to the loss of critical services.
56. *Develop the ability to adapt to potential uncertainties and futures,* i.e. the introduction of foresight and future-proofing methodologies and tools, and the extension of capacities and resources.
57. *Implementation of inspections and performance evaluations* of the CI systems.

Guidance Note #7: Development and implementation of business continuity and recovery plans of the CI sectors—This practice is limited in its application, or is in the early stage of implementation in the region. In practice, most key systems, e.g. defence, water, energy, health, airports, ICT or providers of critical services, e.g. financial sector, have some plans to continue providing services, but they are not interconnected or interdependent with the CI system. These plans include both mitigation and preparedness, including contingency planning, that ensure continuous functioning and operations during disasters, as well as essential frameworks for recovery. It is also important to ensure that the infrastructure assets/facilities/services continue to function, as part of the overall CI system and independently.

Potential actions:

58. *Sensitize* the emergency responders, owners and operators and other key stakeholders on the importance of business continuity and contingency and disaster recovery planning.
59. *Adopt* relevant policy guidance, legal solutions and SOPs, and ensure their implementation.
60. *Create business continuity and recovery plans* that include robust measures and actions, define roles and responsibilities and allocate relevant resources.
61. *Conduct simulations* to test the business continuity and contingency and disaster recovery.

B) DURING A DISASTER

3) Absorption and 4) Adaptation

Guidance Note #8: Managing failures and disruption of services to enable CI functioning—During the disaster response phase, the resilient CI systems absorb the shocks while responding to the unexpected. They adapt to minimize the negative consequences of the adverse event, while continuing to operate and function. NDMAs, in partnership and coordination with the owner and operators from the public and private domains, national and local authorities and other competent entities, need to ensure that the operation and functionality of the CI facilities, assets and services will be enabled following the initial shock. Failures, disturbances and disruption of services will be addressed in a timely and efficient manner thereby

ensuring that the critical infrastructure still functions after the shock.

Potential actions:

62. *Initiate and implement* the CI's disaster response plans.
63. *Coordinate and cooperate* with the emergency responders and operational forces in a timely manner.
64. *Identify and implement* disaster-response measures.
65. *Identify* the potential risks and threats and map failures, disturbances and disruption of services.
66. *Inform* the general public and affected communities and beneficiaries on the status of the affected infrastructure's assets and facilities and critical services.
67. *Prioritize actions* to restore the essential functionality of the CI and provision of critical services following the checklists and standard procedures.
68. *Restores* the normal, pre-disaster functionalities of the CI systems.

C) AFTER A DISASTER

5) Recovery

Guidance Note #9: Post-disaster damages and losses assessment—Functional CI is essential for the quick and successful recovery of affected communities and businesses and for the return to normalcy. Hence the key is that the national and local authorities carry out a timely multisectoral assessment of the disaster's impacts on the CI systems. This process needs to be inclusive, with the participation of private sector owners and operators and other key stakeholders who can support the collection of damage and loss data. NDMAs could be key partners in this process given their previous engagement with the PDNA, the Resilience Recovery Framework and the existing internal expertise.

Potential actions:

69. *Adopt uniform* models for assessing infrastructure-related disaster damages and loss of data.
70. *Adopt methodologies and SOPs assessing* for post-disaster damages and losses.
71. *Establish and train* a core group of practitioners and experts for PDNA implementation and refresh their knowledge on a regular basis.
72. *Conduct a rapid post-disaster damage, economic losses and needs assessment.*
73. *Initiate and conduct the implementation of PDNA* in the events of major disasters in the countries and territories of the ECA region.
74. *Utilize crowdsourced information and citizen science* for collecting additional information and data on damages to critical infrastructure assets and facilities.
75. *Adopt the Disaster Recovery Framework*—its focus is on long-term resilience to future disasters through a set of actions to ensure recovery in several sectors, including infrastructure.

Guidance Note #10: Resilient recovery through the prism of Build Back Better—The main approach is to identify what needs to be done during the recovery process to protect the CI from future disasters. The scope of actions is wide and includes such measures as enhancement of building codes, reconstruction and rehabilitation to meet new resilience designs and standards, use of new materials, application of green infrastructure or NbS, and more.

Potential actions:

76. *Develop guidelines for resilient recovery* applying BBB principles.
77. *Sensitization* of the key practitioners on the importance and benefits of the BBB approach.
78. *Identification and prioritization* of CI facilities to be reconstructed or rehabilitated using the BBB approach.
79. *Information- and good practices-sharing.*

6) Transformation

Guidance Note #11: Transformation of the CI systems—This is the last phase of the CI resilience-building cycle and it represents its transformation. Risk and threats evolve, there are more and more unprecedented and unexpected events, or high consequence, low probability events, that weaken the CI resilience texture. To achieve resilience, the CI systems need to anticipate future failures, disruptions and adverse situations, while being able to better cope based on the experiences and lessons learned from past events and recent experiences. This transformability relates both to the structures of these systems and to their operations and management. Lessons learned and good practices are some of the most efficient tools that contribute to the enhancement of CI resilience.

Potential actions:

80. *Learn from past disaster events* to update the CI design, or to establish services and enhance operational measures and actions.
81. Evaluate and codify good practices and lessons learned.
82. *Document the good practices and lessons learned* by creating interactive digital knowledge hubs accessible to a wide range of stakeholders.
83. *Refine the approach of building resilience* with the aim for the CI systems to emerge better, stronger and more resilient, i.e. revising risk and threats assessments, reviewing standards and procedures, integrating new technologies and innovation, and other actions.

3. DEVELOPMENT OF CRITICAL INFRASTRUCTURE RESILIENCE PLANS

3.2 Essentials of the draft Critical Infrastructure Resilience Plan

Further to the formulation of the general Guidance Notes on the mainstreaming of building CI resilience-in the countries and territories of the ECA region and the profiling of the technical checklist for the prioritized sectors, the next step was to produce a draft planning document which could serve as a departure point in building resilience. As previously mentioned, the CI systems provide vital structural support and services for the functioning of societies, for their economic development aiming to leave no one behind. Therefore, the draft Critical Infrastructure Resilience Plan aims to advance further CI protection by providing a structured and operational framework for building resilience.

This plan is designed to guide the overall activities around building resilience activities. It is a joint mission by various key stakeholders, one involving national and sectoral authorities and critical infrastructure entities.

This proposed structure of the ***Critical Infrastructure Resilience Plan*** is a result of an analysis and assessment of the relevant data and information, research on the ECA region, virtual consultations with respondents and the latest trends in the domain of building critical infrastructure.

Consequently, in the table below the draft content of the General Critical Infrastructure Resilience Plan and Critical Infrastructure Resilience Plans for prioritized sectors is presented. The content is related to the general CI system and sectors, but it can be modified following the national context, existing CI normative frameworks and associated priorities.

Table 11: Draft content of the Critical Infrastructure Resilience Plan (General CI Resilience Plan and Sectoral CI Resilience Plan)

#	Section	Description	General Critical Infrastructure Resilience Plan	Critical Infrastructure Resilience Plans (Sectors)			
				Education	Health	Transport (Road)	Transport (Airports)
1	Executive Summary	• An overview of the main points of the Plan	X	X	X	X	X
2	Abbreviations		X	X	X	X	X
3	Table of content		X	X	X	X	X
		General Part of the Plan					
4	Introduction	• Background and context of the CI resilience • Approach and the methodological framework	X	X	X	X	X
5	Aim and objectives of the Plan	• Aim and objectives of the Plan • Principles of the Plan	X	X	X	X	X
6	Normative and institutional frameworks for CI resilience	• Vertical and horizontal relations with other global, regional and national strategic, programme and planning documents for DRM and CI resilience. • Institutional framework for CI resilience	X	X	X	X	X
7	General profile of the country/territory	• General information on the territory, geography, administrative division • Demography incl. vulnerable groups of citizens • Hydrology, forestry and similar, climate conditions • Socio-economic development, infrastructure development, environment, education, health, and more.	X	X	X	X	X

#	Section	Description	General Critical Infrastructure Resilience Plan	Critical Infrastructure Resilience Plans (Sectors)			
				Education	Health	Transport (Road)	Transport (Airports)
		General Part of the Plan					
8	Disaster profile of the country/territory	• General information on hazards and brief information on the past disastrous events • Disaster hot-spots and exposed and vulnerable population (location/number/gender/vulnerabilities) and critical infrastructure (type/location), and others. • Prevailing hazards and potential hazards • Climate change projections • COVID-19 pandemic impact	X	X	X	X	X
9	CI System/Sector Profile	• CI Sector overview • CI Sector risk matrix • Needs for CI protection • CI Sector key entities/stakeholders (public/private) • CI coordination and cooperation	X	X	X	X	X
		Specific Part of the Plan					
10	CI System/Sector vision, missions, scope, priorities	• CI System/Sectoral visions, mission, scope, priorities • Time framework of the validity of the CI Resilience Plan	X	X	X	X	X

#	Section	Description	General Critical Infrastructure Resilience Plan	Critical Infrastructure Resilience Plans (Sectors)			
				Education	Health	Transport (Road)	Transport (Airports)
		Specific Part of the Plan					
11	Action Plan Matrix with defined roles/ responsibilities	• Activities and measures implemented by the CI sector entities and key stakeholders • Measures and actions for prevention and mitigation • Early warning mechanisms and preparedness • Operational protocols for reaction and response for profiled natural and human-made hazards • Disaster needs assessment • Operational protocols for response to COVID-19 pandemic including response to other hazards in the times of pandemic • Post-disaster needs assessment • Resilient recovery framework	X	X	X	X	X
12	Resources for CI resilience	• List of humans, material, technical and other resources from the CI sector entities • Lest of resources of key stakeholders	X	X	X	X	X
13	Coordination and cooperation for CI resilience	• Coordination links and mechanisms between the CI sector entities and the key stakeholders on the horizontal and the vertical levels • Types and modalities for cooperation, e.g. SOPs • Information-sharing protocols • Public/private partnerships for CI resilience	X	X	X	X	X

#	Section	Description	General Critical Infrastructure Resilience Plan	Critical Infrastructure Resilience Plans (Sectors)			
				Education	Health	Transport (Road)	Transport (Airports)
		Specific Part of the Plan					
14	Training and professional education	• Curricula for the professional education/training of the CI sector entity and other personnel • Implementation of training activities and drills	X	X	X	X	X
15	Communication and media management	• Policies and personnel for public communication • Communication tools and channels (general public, media, incl. adaptive platforms for vulnerable groups of citizens)	X	X	X	X	X
10	Financing the CI Resilience Plan	• Financial frameworks for sustainable financing of the Plan from internal and external sources	X	X	X	X	X
10	Monitoring and measuring effectiveness	• Monitoring and evaluation • Codification of lessons learned and good practices • Intervals and procedures for regular and incident updates of the Plan	X	X	X	X	X
10	Annexes	• Glossary of terms, maps, resource lists, supplies and more.	X	X	X	X	X

4. CONCLUDING REMARKS

4.1 Conclusions

CI systems are the cornerstones of societies and communities. They provide services for their functioning and making a crucial contribution to their sustainable and resilient development. They are complex, interconnected and interdependent systems and networks providing vital support to everyday life and activities. As the sustainable development agenda moves forward, CIs play a key role in ensuring resilience. For societies are exposed and vulnerable to the current and emerging risks and threats that are eroding their structures and functions, exacerbating existing vulnerabilities and undermining sustainable and resilient development

The COVID-19 pandemic affected the countries and territories across the globe in an unprecedented way impacting societies and economies at their core, including the critical infrastructure systems. Across the region, there are different approaches to efforts to counter these negative trends. These range from more advanced to basic ones, and to those not sufficiently elaborated. Some countries and territories have already embarked on the path to build resilience, others are preparing for this undertaking. Others are still resisting understanding the need for CI assets and facilities.

To achieve resilience and sustainability, the paradigm needs to shift from risk to resilience, to co-opt the all-hazard, all-of-the-society and life-cycle approaches and to design policies that are future-oriented. Thus, critical infrastructure resilience can be understood as the a*bility of these systems to anticipate, withstand or absorb shocks and stresses while adapting to the new conditions that would result in a quick recovery and transformation to better cope with stresses and shocks in the future.*

The most efficient and effective way to contribute to the efforts to build resilience in Europe and Central Asia is through the formulation of the relevant Guidance Notes. They provide the latest insights on the current status on CI in the region, present the findings of the regional survey, identify challenges and gaps, present subregional case studies on resilience-building of priority sectors, and formulate the conceptual framework of the plan document. Its practical application will boost the resilience agenda in the region.

4.2 Potential resilience building of critical infrastructure pathways

Following the assessment review framework and the need for transformational change of the overall approach to enhanced building of critical infrastructure resilience in the ECA region, alongside consideration of the increased frequency and magnitude of disasters, the anticipation of their complexity and of possible uncertain futures, three potential development pathways were identified:

- ***Status in quo scenario*** is based on the assumption that the present situation in relation to critical infrastructure resilience will stay the same. Both DRM and CI systems will continue to function as usual within the existing policy, normative and institutional frameworks. Only small actions for the enhancement of critical infrastructure resilience can be identified, e.g. integrated risk and hazard assessments, adoption of operational and response plans and communication and coordination. Available human, material and technical resources will continue to be utilized as per existing procedures.
- ***The straightforward scenario*** is based upon the premises of the essential enhancement of the policy, legislative and institutional framework, i.e. greater mainstreaming of critical infrastructure resilience in the DRM systems across the

region, identification of critical infrastructure sectors, modification of existing laws, an enhanced partnership among public and private entities, increased investment and provision of resources, targeted capacity-building, and more.

- ***The changing scenario*** is based on the assumption that the establishment of new policy, normative and institutional frameworks and measures and actions will result in comprehensive and versatile building of critical infrastructure resilience, i.e. new legislative acts, the appointment of a critical infrastructure coordination institution, broad capacity-building and awareness-raising, stable and sufficient provision of resources, future-proofing of critical infrastructure, and more.

Figure 4: Potential building of critical infrastructure resilience pathways (in the Scenario column, add / between Countries and Territories)

SCENARIO	STATUS IN QUO SCENARIO	STRAIGHTFORWARD SCENARIO	CHANGING SCENARIO
MODEL	***Routine***	***Advancement***	***Towards Next-Gen CI resilience-building***
FRAME	Regular, ongoing activities for the resilience of the critical infrastructure	Enhancement of the policy, normative, institutional and operational frameworks	Establishment of the new frameworks and solutions for building critical infrastructure resilience
TIMEFRAME	0–12 months	12–24 months	24–36 months
PROGNOSIS	Current one	Expected	Least expected
FINANCIAL RESOURCES	$	$ $	$ $ $
COUNTRIES TERRITORIES	Most of them	Some of them	Few of them

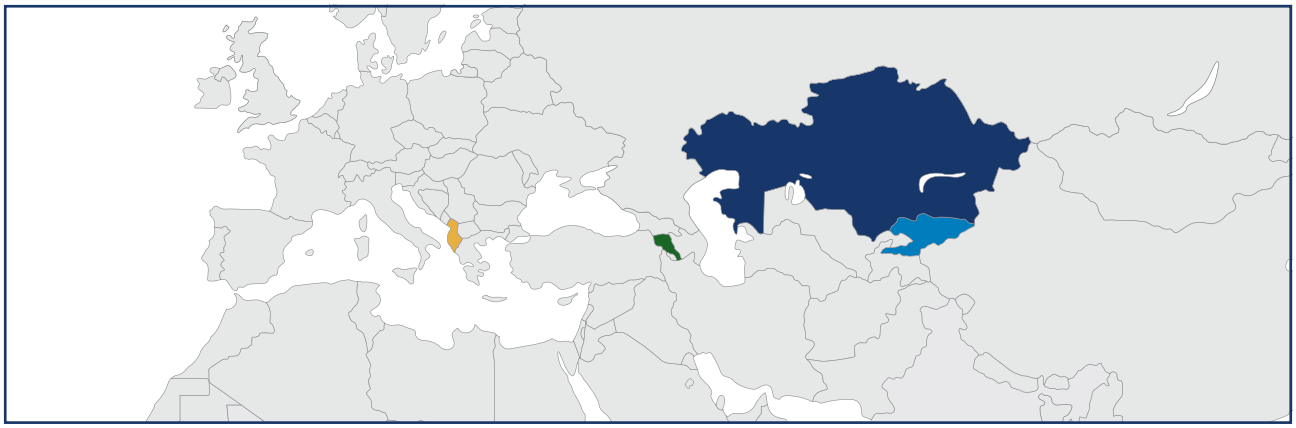
ANNEX I:

FOCUS ON FOUR COUNTRIES, THREE SUBREGIONS AND FOUR CRITICAL INFRASTRUCTURE SECTORS

1. INTRODUCTION

In this section, snapshots of four CI sectors from four countries in three subregions in Europe and Central Asia are presented i.e. **Albania** from the Western Balkans and Turkey subregion *(education sector)*, **Armenia** from the South Caucasus subregion *(health sector)*, **Kazakhstan** *(transport—airports)* and **Kyrgyzstan** *(transport—roads)* from the Central Asia subregion. They provide information on the sector contexts, existing gaps and challenges, best practices, emerging lessons learned and recommendations on the way forward.

Figure 5: Map of countries focused on in Annex I



2. CRITICAL INFRASTRUCTURE SECTOR: EDUCATION

The Sendai Framework Snapshot shows that across the ECA region in 2018 a total of 564 educational facilities in 18 countries were damaged by disasters, in 2019 a total of 261 in 14 countries.[115] This gives an insight into the high vulnerability of the education infrastructure and the potentially severe impacts on the lives of students, education professionals and on the resilience of the local communities.

The impact of a complex disaster, such as the COVID-19 pandemic, has also reverberated throughout the sector, e.g. disruption of basic educational services. The infrastructure of education facilities is important in all phases of the DRM cycle and "resilient schools not only provide space for learning and development but can also serve as centres to coordinate response and recovery efforts and as emergency shelters."[116]

The contemporary sustainable and resilient global framework emphasizes their importance and resilience:

- The ***Sendai Framework*** includes education facilities as one of the sectors affected in the *Target D: Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including by developing their resilience by 2030* and the need for promoting the resilience of new and existing educational facilities is emphasized.
- ***SDG targets 4 and 4.7*** promote education for sustainable development and building and upgrading inclusive and resilient education facilities for all, as well as mainstreaming and integrating DRR into the existing and the new education curriculum.

115 https://tinyurl.com/69chscnd, p.1 9.
116 UNDDR, *Disaster Risk Reduction and Resilience in the 2030 Agenda for Sustainable Development*. https://tinyurl.com/rcc5bx8v (Accessed on 14.9.2021).

- ***Worldwide Initiative for Safe Schools***[117] incorporates the resilience-building aspects of the schools in its framework of activities based on three pillars: safe school facilities, school disaster management and risk reduction education.

2.1 CASE STUDY: ALBANIA (SUBREGION OF WESTERN BALKANS AND TURKEY): BUILDING RESILIENCE IN THE EDUCATIONAL SECTOR FOLLOWING THE NOVEMBER 2019 EARTHQUAKE

Although the education sector is not part of the official classification of CI sectors in Albania, through the case study of the transformative approach to strengthening the resilience of educational facilities in the affected municipalities following the November 2019 Earthquake, aspects of building resilience in the education critical infrastructure are considered, and emerging recommendations provided.

2.1.1 Disaster profile[118] of Albania

- According to the World Risk Index[119], Albania is classified as a country with a high disaster risk (8.46), ranking it 60 out of 181, and a very high exposure, a high lack of adaptive capacity and low susceptibility, vulnerability and coping capacities. Floods (riverine and flash floods) are the most frequent disasters and the earthquake in November 2019 was the most deadly and costly disaster.
- Albania is vulnerable to the *impact of climate* change and its temperatures are expected to rise, and precipitation to decrease, but to fall with a higher intensity. Given the projected trends, in the future climate change impacts will pose additional stress to key sectors and CI.
- The *COVD-19 pandemic crisis* severely impacted Albanian society and its economy which was still recovering from the devastating 2019 earthquake—from 8 March 2020 to 25 September 2021, 167,893 cases and 2,640 deaths were recorded.[120]
- Relations between DRR and education are fragmented, most educational facilities do not meet the current regulations on safety and accessibility, especially in rural areas, and the existing level of investment in school construction, rehabilitation and infrastructure maintenance is low, i.e. only 6 percent of the total pre-university budget for 2019.[121]

117 https://www.preventionweb.net/files/45656_worldwideinitiativeforsafeschools.pdf
118 Image: Flaticon.com'. This cover has been designed using resources from Flaticon.com
119 *World Risk Report 2020*. https://tinyurl.com/yr5umjav (Accessed on 19.9.2021).
120 John Hopkins University of Medicine, Coronavirus Resource Center. See https://coronavirus.jhu.edu/map.html
121 Republic of Albania Council of Ministers, UN, EU, WB, *Albania Post-disaster Needs Assessment, Volume B*, Tirana, February 2020. pp. 21–22. https://tinyurl.com/rzevt6st (Accessed on 23.9.2021).

2.2. November 2019 earthquake impact on the education sector

- The earthquake struck on 26 November 2019 (3:54 AM) with a magnitude of 6.3 on the Richter Scale. An epicentre was 15 km west-southwest of Mamurras. There were 51 human casualties, over 1,000 people were injured, 202,921 citizens were affected and over 17,090 displaced.
- Extensive damages were recorded in 11 municipalities in three areas i.e. the capital city Tirana, the coastal region, including the city of Durres, and rural areas nearby, i.e. Kamza, Kavaja, Kruja, Kurbin, Lezha, Mirdita, Rrogozhina, Shijak and Vora. The PDNA Study assessed the damages and losses at $1.142 bn[122], out of which $979 mn represents damaged assets and infrastructure and $163 million—the total losses in these municipalities.
- In these municipalities a total of 321 educational institutions[123] were affected, which is 24 percent of the total pre-disaster number of institutions, i.e. 1,340 educational institutions on different educational levels. A total 76 education facilities were severely destroyed and are unfit for use and need to be demolished, 75 were partially destroyed and 170 sustained light damage. Almost two-thirds of the affected educational facilities were built before the 1990s with poor design and construction.
- Concerning the education process, 55 education facilities have not reopened and its 21,000 students were relocated to other schools in the vicinity of their settlements. The education facilities' recovery needs were assessed at $109.95 mn with 88 per cent requiring construction or reconstruction at a cost of $96.7 mn.

2.3 Recovery of affected educational critical infrastructure in Albania

Following the devastating earthquake in November 2019, Albania embarked on building resilience in the critical educational infrastructure in affected areas. The foundation of these efforts is the #EU4Schools programme[124] funded by the EU and implemented by UNDP in Albania. The main aim of this comprehensive programme is to support national and local governments in reducing further social and economic losses and to accelerate the recovery process through educational facility repairs and reconstruction of 63 educational institutions benefitting 24,529 children, students and teachers and 1,087,897 indirect beneficiaries in the affected municipalities. $75.3 mn was allocated for this project from April 2020 until end 2023.

2.3.1 Measures for building resilience of affected education critical infrastructure

- ***"Build Back Better/Build Back Together"—#BuildBackBette***r implies the building of resilient educational facilities for the future with more robust structures, resistant to earthquakes and natural hazards, in line with the highest international standards of quality, safety and accessibility. The focus is on[125] *stronger buildings* (based on the Eurocode 8 standard); *high accessibility* (fully accessible for people with disabilities); *energy and environmentally friendly* (increased energy efficiency, use of renewable energy sources and being friendly to the environment); *digital solutions and technology* (equipment will be projected and installed) and *health and safety* (all facilities will have the necessary equipment to ensure health and security of all personnel and children and dedicated spaces for socio-psychological services).

122 This amount equals 7.5 percent of the country's GDP for that year.
123 Republic of Albania Council of Ministers, UN, EU,WB. *Albania Post-disaster Needs Assessment*, Volume B, Tirana. February 2020, p. 20. https://tinyurl.com/rzevt6st (Accessed on 23.9.2021).
124 https://www.al.undp.org/content/albania/en/home/projects/eu4schools.html
125 https://albania-undp.medium.com/?p=e30977e572f9

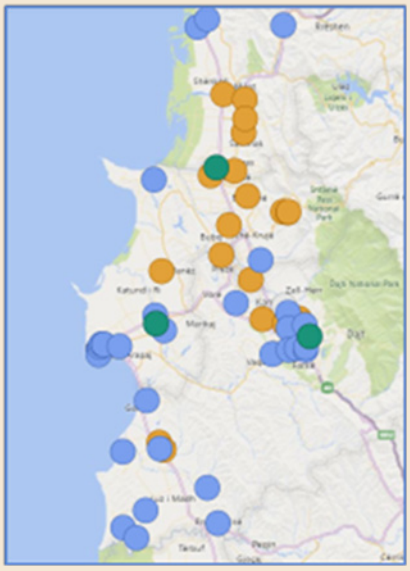
#BuildBackTogether includes extensive, inclusive public consultations with the programme beneficiaries and communities on the ***#TheSchoolIWant*** approach. This is a unique, forward-looking and innovative model for the broader region. It brought together local authorities, public institutions, communities and individuals in designing and implementing the recovery activities and in promoting transparency ownership and sustainability of the investments. Affected communities are at the centre of the resilient recovery process, with 1,427 children, students, parents and teachers from affected municipalities participating in 53 consultation sessions organized until now. This consultative process contributes to the enhanced technical design of the facilities that will be based on the needs of beneficiaries.

- ***Transparency, accountability and communication***—The core action is the establishment of the transparency tool #EU4Schools portal which provides transparent and real-time information on the reconstruction and rehabilitation of 58 educational facilities serving as a communication channel with the programme beneficiaries and the public at large. It is an online publicly accessible Business Intelligence dashboard that contains background information, progress rates, Q&As, reports, a gallery and feedback.

Figure 6: EU4SCHOOLS web portal[126]

- ***Effective and efficient works***—Until September 2021 in total 15 education facilities in Durres, Kamez, Kavaja, Kruja and Kurbin were finalized and handed over to the local authorities, enabling 3,350 students and teachers to learn in modern and functional facilities like their peers in the EU. In parallel, technical designs for additional 30 education facilities were finalized and civil construction works are progressing on 21 other facilities.
- ***Enhanced sustainability and ownership of new and resilient education facilities***—To achieve lasting sustainability and resilience of facilities, an *Operation and Maintenance Manual* was prepared, including a detailed cost estimation for maintenance needed during the following period. Accordingly, the local authorities can plan the requisite allocation of financial resources and implement operations and maintenance in a timely manner.

In addition, all external infrastructure works were done by the municipalities thereby also contributing to full ownership of the works and the facilities, e.g. infrastructure connection, road accessibility and landscaping.



Source: #EU4Schools web portal

- ***Piloting a local-level DRM module in the Lezhe municipality***—UNDP designed and implemented a set of resilience-building actions, i.e. an inclusive and participatory municipal risk assessment; a local GIS platform with data and information for the multi-risk profile for Lezhe; a Municipal Civil Emergency Plan and the Municipal DRR Strategy, the first in the country. These pilot activities are

126 http://eu4schoolsportal.al/ (Accessed on 15.9.2021).

deemed an added value to the ongoing building of resilience since various aspects of the broader critical infrastructure assets in the municipality are perceived both through the prism of their strategic importance and of integrating their attributes into the GIS platform for enhanced risk assessment and emergency planning.

2.3.2 Challenges of building resilience in Albania's education critical infrastructure

Non-systemic approach to risk governance and a more reactive than proactive DRM system.
DRR is not fully mainstreamed and integrated into the strategic programmes and sectoral and multisectoral plans.
Low level of integration of the **risk and hazard assessments** and operational plans of the CI sectors.
Insufficient adoption rate of the **risk and hazard assessments** of the CI facilities and respective DRM/civil emergency plans.
Absence of a systemic approach in building resilience in the facilities constructed before the 1990s.
Weak enforcement of seismic and other building standards
Insufficient implementation of non-structural measures, i.e. capacity-building, professional training, awareness-raising.
Insufficient funding for actions that build resilience, i.e. following the #EU4SchoolsProgramme.
Limited role of MoESY in DRR mainstreaming into the education sector and vice versa.

2.3.3 Recommendations and follow-up actions

- Building resilience of the education critical infrastructure starts with urban planning in the cities and the municipalities. There should be more schools and educational facilities constructed in adequate locations allowing for bigger facilities, as per the needs of the local populations, with resilient design and constructed according to latest standards.
- Strengthening the role of municipalities through continuous coordination and collaboration with the civil protection structures and decentralization of DDR competencies.
- Implementation of national building codes and standards, Eurocode 8 and other codes need to be additionally enforced, especially for such types of buildings.
- Detailed inventory and inspection are required for the smaller and rural municipalities to prioritize the most vulnerable education facilities and to initiate similar building of resilience-activities.
- Systematic implementation of non-structural measures, i.e. enhancement of the education curriculum on DRR, preparation and testing of civil emergency plans and other documents, professional education and regular conduct of training drills.
- Additional strengthening of the role of MoESY in DRR-related areas of curricula development, standards formulation, for example.
- Finally, to ensure the resilience of the education critical infrastructure in Albania, this project must be fully integrated into national and local priorities and into budget frameworks; then replicated and scaled up ensuring that all education facilities will be rehabilitated as needed.

3. HEALTH CARE CRITICAL INFRASTRUCTURE SECTOR

The Sendai Framework Snapshot for the ECA region shows that in 2018 in total 1,085 health facilities were damaged by disasters and in 2019 this number was 67 based in 18 countries.[127] The data from the PDNAs of the three biggest disasters in the Western Balkans region shows a significant impact on the health sector (infrastructure/assets) and the biggest damages were assessed following the May 2014 floods in Bosnia and Herzegovina ($62.76 mn), the earthquake in Albania ($12.01 mn) and floods in Serbia ($6.75 mn).

These impacts affected health care facilities and contributed to the disruption in health services provision, which have cascading effects on the health and well-being of the affected population. Therefore, the global sustainable and resilient framework accords special attention to help building the resilience of health care systems.

- The ***Sendai Framework*** includes health facilities in the *Target D* and "at least four of the seven targets are directly linked to health, focusing on reducing mortality and injuries, improving people's well-being, early warning and promoting the safety of health facilities and hospitals."[128] In its priorities, building resilience is emphasized through the health infrastructure, DRR integration, capacity-building of professionals, promotion of disaster medicine and an inclusive and participatory approach in designing health policies and measures aimed at risk reduction.
- The focus of the ***SDGs target 3.d*** is on strengthening the capacities for early warning, risk reduction and management of health risks as an additional input for the development of resilient health systems in countries and territories globally.

3.1 CASE STUDY: ARMENIA (SOUTH CAUCASUS SUBREGION): BUILDING RESILIENCE IN HEALTH INSTITUTIONS DURING COVID-19

Although the critical infrastructure in Armenia has no legal framework, through the case study of the comprehensive approach to strengthening resilience of key health facilities, including mainstreaming it into the national DRM system, recommendations have been put forward.

3.1.1 Disaster profile of Armenia

Table 12: Overview of probability and impacts of hazards in Armenia[129]

Hazard	Probability	Overall impact	Human impact
Earthquake	High	High	High
Landslides	High	High	Low
Hail	High	High	Average
Extreme weather events	High	High	Low
Mudflows	Average	Average	Low
Dam collapse	Average	Average	Average

127 https://tinyurl.com/69chscnd

128 UNISDR, *Disaster Risk Reduction and Resilience in the 2030 Agenda for Sustainable Development*. https://tinyurl.com/rcc5bx8v (Accessed on 18.9.2021).

129 MES, *Presentation of the GARD Programme in Armenia*, 2014. (Note: the pandemic hazard was added by the author following the impact of the COVID-19 pandemic on Armenian society and communities.)

Hazard	Probability	Overall impact	Human impact
Drought	Average	High	Low
Wildfires	High	Average	Low
Pandemics	High	High	High
Accidents at nuclear power plants	High	High	High
Accidents at various industrial enterprises	Low	Low	Average

- According to the World Risk Index[130], Armenia is classified as a country with a medium disaster risk (5.73) ranking of 105 out of 181, characterized by medium exposure and low susceptibility, vulnerability, coping and adaptive capacities.
- Its climate future is projected to be characterized by consistent warming across all seasons, highly variable precipitation with an increase in the average annual rainfall and less precipitation during the summer months which can be heavier. On the other hand, the opposite trend will be found in eastern and southern areas of Armenia—receiving the least precipitation.[131] Consequently, these projected changes are expected to result in more intensive extreme climate-related events, i.e. storms, hail, floods, droughts, heatwaves, mudflows, wildfires and more.
- The *COVD-19 pandemic crisis* affected Armenian society and communities in an unprecedented way with socio-economic and health sectors absorbing the biggest impacts. From 1 March 2020 to 25 September 2021, there were 257,620 COVID-19 cases and 5,239 deaths[132].
- The health sector was significantly put under pressure by the immediate effects of the pandemic and it faced constraints in the number of available facilities/hospital beds, health personnel and ambulance services in the ***marzes***[133].

3.2 Context and measures for building resilience of the health care critical infrastructure in Armenia

- ***Preparedness and response of medical facilities***—Within the framework of the UNDP COVID-19, *Rapid Response Programme and the subproject, "Hospital Safety and Emergency Response Preparedness"*, a set of activities was implemented—the purpose was to review the preparedness and response capacities of the "Vagharshapat Medical Centre", "Ijevan Medical Centre" and the "Professor O. Yolyan Haematology Centre".[134]

The assessment process included:

- Identification of hazards
- Analysis of hospital vulnerability (structural safety, non-structural safety and emergency management)
- Recommendations on risks reduction and professional capacity-building.

130 *World Risk Report*, 2020. https://tinyurl.com/yr5umjav Accessed 18.09.2021
131 *Climate Risk Country Profile: Armenia (2021)*, The World Bank Group and the Asian Development Bank. https://tinyurl.com/5cpunthb (Accessed on 20.9.2021).
132 John Hopkins University of Medicine. Coronavirus Resource Center. https://coronavirus.jhu.edu/map.html (Accessed on 25.9.2021).
133 *Marzes* are the regions in Armenia. As per the existing regional divisions there are ten marzes (regions) and the City of Yerevan. The *Marzes* are as follows: Aragatsotn, Ararat, Armavir, Chirak, Gegharkunik, Kotayk, Lori, Syunik, Tavosh and Vayotz. https://www.gov.am/en/regions/ (Accessed on 29.9.2021).
134 http://www.arnap.am/?p=9460

The goal was to establish a model of DRR capacity development for medical institutions taking account of the COVID-19 crisis, potential future pandemics, existing risk exposure and mainstreaming of lessons learned from the Spitak Earthquake in 1988. The approach was comprehensive and involved the application of several research tools: the World Health Organization (WHO) "Hospital Safety Index" methodology; DRM planning tools for medical institutions; "Methodological guidelines for assessing the level of the seismic vulnerability of buildings and structures"[135]; and existing DRM and emergency policies reviewed from the health care perspective.

In particular, the following activities were implemented: risk and hazard assessment and seismic vulnerability assessments of these hospitals; development of DRM plans and their testing through the conduct of training and staff exercises on earthquakes and pandemics; and formulating recommendations and designing follow-up actions. The assessments were made using a multisectoral approach by specialized groups—health specialists from MoH (organizational issues/medical equipment), MES, the Seismic Service[136] and the National DRR Platform using available toolkits.

- ***Development of DRM plans for health institutions*** by MES, in close collaboration with UNDP and the National DRR Platform, in an inclusive and participatory manner to ensure continuous and effective DRR management and emergency response processes (planning, implementation, monitoring and evaluation). All-natural and human-made hazards and technical, incidents including nuclear incidents from the Metsamor nuclear plant, were included. The DRM plan defines the roles and responsibilities of the key DRR entities, medical staff, patients and other stakeholders and needs to be regularly tested, i.e. via situational games, simulation and training exercises, which MES and MoH approve.
- ***Assessment of the seismic vulnerability of the hospital buildings*** was done based on the following instructions: *"Methodological instructions for the inspection of the technical condition of residential, public and industrial buildings and structures"* (Annex No. 1 of decree No. 282-N of the Republic of Armenia Minister of Urban Development, dated 8 December 2009) and decree No. 957-A of the RA Minister of ES, dated 23.10.2014, on *"Methodological guidelines for the assessment of the degree of seismic vulnerability of buildings"* and *"Rapid Visual Screening of Buildings for Potential Seismic Hazards"* FEMA 154 standard.
- ***Hospitals on the territory of Yerevan City*** are integrated into the risk and hazard assessment which has a GIS component for building assessments, including of hospitals.
- ***Other organizations are implementing similar activities.*** WHO developed DRM Plans for seven other health facilities, i.e. preparedness, response and recovery, and can be considered to be initial contingency plans. UNFPA assessed the readiness of the maternity hospitals, provided protective equipment and held consultations with key stakeholders.[137] *Red Cross Armenia* has various programmes on training for emergency and CPR.

135 Approved by the Republic of Armenia Minister of Emergency Situations Order No. 957-A, dated 23.10.2014.
136 Armenian National Survey for Seismic Protection and Seismic Hazard Assessment Complex Center, Yerevan, Armenia
137 UNITED NATIONS ARMENIA, *UN Country Team in Armenia: Country Results Report 2020* (March 2021), p. 60. https://tinyurl.com/22jne8p7 (Accessed on 23.9.2021).

3.3 Challenges to building resilience of the critical health care infrastructure in Armenia

Legal gap, i.e. new DRM law is still not adopted, health institutions' legislative acts on emergency response are not available and the Health Action Plan from the National DRM Strategy has not been adopted.
Capacities of health facilities are not used rationally during emergencies and disasters, i.e. the main burden is on hospitals with no capacities for mass casualties in rural areas.
Insufficient level of knowledge and preparedness among health personnel for a disaster-response.
Not all regional hospitals have an emergency or infectious diseases department, and when they exist, there is insufficient staff, medical equipment and professional training.
Triage is not fully institutionalized and protocols are missing.
Absence of **sufficient level** of certifications for doctors and nurses for CPR or Basic Life Support[138], especially at the primary unit level.
Lack of psychological support for emergency responders.
Infrastructure challenges for business continuity, e.g. lack of alternative power supply (generators).
Insufficient financial and technical resources for building resilience in the health care sector.
An insufficient number of emergency cars/ambulances.
Only assigned hospitals for the treatment of COVID-19 have protocols.

3.4 Recommendations and follow-up actions

- The *"Hospital Safety and Emergency Response Preparedness"* project initiative is an excellent example of how to strengthen building resilience of key health critical infrastructure (hospitals) during a pandemic, which is done through a comprehensive assessment of the structural and non-structural elements and resources. Consequently, such types of assessments need to be replicated and scaled up in other regions in the country covering the most prioritized health facilities in all ten marzes (regions), with an assessment of one or two clinics or hospitals in the cities.
- Overcome the normative gap with the adoption of the new DRM law, relevant legal solutions for the health sector and the adoption of the Health Sector Action Plan of the DRM Strategy.
- Roles and responsibilities of health facilities need to be revised to lessen the pressure on hospitals and to enhance the provision of key health services by other facilities, e.g. by establishing well-prepared and equipped emergency rooms in polyclinics. In that regard, the recommendation is also to establish protocols on cooperation and coordination, on response and provision of triage and on its institutionalization.
- Despite the intentions of MoH to merge the hospitals and polyclinics into one medical entity, it is recommended to keep them separated enabling better decentralization in medical services provision to the population and generally for safety reasons.

138 *Basic Life Support* generally refers to the type of care that first-responders, health care providers and public safety professionals provided to anyone experiencing cardiac arrest, respiratory distress or an obstructed airway. It requires knowledge and skills in CPR, using automated external defibrillators and relieving airway obstructions in patients of every age. See https://www.redcross.org/take-a-class/performing-bls/what-is-bls

- The community dimension in the provision of first aid needs to be strengthened with the greater role of community members. This can be done through targeted and specialized knowledge and training and ensuring continuity of services by introducing community ambulances.
- Enhanced preparedness and response of the medical facilities need to be followed by stable and sustainable financing, provision of adequate medical equipment and professional education and training of general and specialized personnel, e.g. annual training of MES, MOH and health facilities staff at least once per year.
- The pandemic risk/biohazards need to be further integrated into the strategic and normative frameworks, as do risk and hazard assessments, operational planning documents and SOPs.
- Health assessments were piloted and MoH needs to standardize them.

4. BUILDING RESILIENCE OF THE TRANSPORT SECTOR (ROADS)

On average, road transport accounts for more than 80 percent of all passenger travel and freight movements, where "roads are the first social network".[139] Global transport activities will significantly increase by 2050, i.e. the annual passenger traffic is expected to increase by 50 percent and global freight traffic by 70 percent[140]. This will put additional pressure on finite resources, and the fragile road transport infrastructure networks and poor-quality road infrastructure systems will not only lead to disruption of transport services, affecting supply chains, but will also induce additional economic, social, environmental and other costs, as well as losses for providers, operators and beneficiaries.

Climate change will challenge the resilience of the road systems exposing their vulnerability due to more frequent and intensive extreme climate events, i.e. powerful flash-floods could wipe out roads and bridges, and cascading landslides will cut mountains sections, erosion could affect the stability of roads and tunnels. Extreme temperatures can impact the texture of the pavements causing potholes or affect the endurance of the bridge joints.

Considering the existing level of investments in road infrastructure across the region, this would additionally affect their proper maintenance and rehabilitation. To bridge this gap only in the Central Asia and South Caucasus subregions, the infrastructure needs for the Central Asian Regional Economic Cooperation (CAREC) countries 2016–2030 were estimated at $76.8 bn per annum, with the climate-adjusted needs for the transport sector identified as approximately $506.8 bn[141].

139 *Institut des routes, des rues et des infrastructures de mobilité* (IDRRIM), Annual Report 2017, Paris.
140 https://www.sum4all.org/publications/global-mobility-report-2017
141 https://www.carecprogram.org/uploads/2019-HLCAREC-Forum-Background-Note.pdf

4.1 CASE STUDY: KYRGYZSTAN (CENTRAL ASIA SUBREGION)—BISHKEK OSH ROAD CORRIDOR

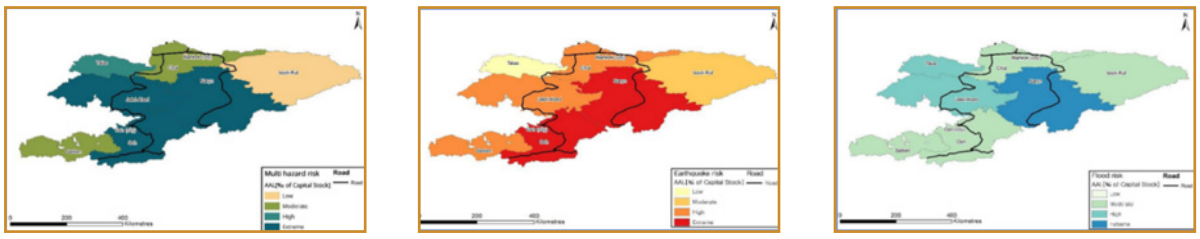
Road networks are especially important for landlocked countries and they are vital for the existence and functioning of societies and communities. Through the case study from Kyrgyzstan on the Bishkek—Osh national road corridor, the resilience-building aspects for this type of critical infrastructure are considered and recommendations for follow-up actions are presented.

4.1.1 Disaster profile of Kyrgyzstan and its transport network

- The ***hazard profile*** is determined by its territory and natural and geophysical characteristics. "Among the 70 types of worldwide natural hazards and phenomena causing severe harm to people and the economy, more than 20 occur in the territory of Kyrgyzstan."[142] According to the World Risk Index[143], Kyrgyzstan is classified as a country with medium disaster risk (7.30), ranking it 78 out of 181 with high exposure, medium susceptibility, vulnerability and adaptive capacity and low coping capacities. Moreover, the country has substantial issues with ***uranium legacy wastes*** with most of the sites exposed to one or more natural hazards, and its cascading effects can have an indirect impact on critical infrastructure.
- The impacts of the ***COVID-19 pandemic*** are causing unprecedented effects on society and communities, and during 18 March 2020 until 25 September 2021, there were 178,202 cases and 2,599 deaths[144]. The pandemic significantly impacted the transportation sector with a decrease in freight turnover (-25.2%) and passenger transportation (-45.9%) during 2020[145], as well as impacted the costs for the operation and maintenance of roads and investments in their construction or rehabilitation. A significant decrease in funding of the latter occurred due to fund reallocations for the response.
- The projected CC impacts and increased climate extremes will further affect the resilience of the road infrastructure requiring more and more funds for construction, maintenance and rehabilitation.
- The existing road transport network in the country is exposed to the impact of natural hazards, e.g. landslides, earthquakes, floods and mudflows, avalanches, rockfalls, storms and extreme weather events, which pose a threat to the functioning of the road and rail transport network in the country. As per the *United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) subnational assessment*[146], 99 percent of highways are located in moderate multi-hazard risk locations, 92 percent of highways are located in high and extremely high earthquake risk locations and 42 percent of highways are located in low flood risk locations. This situation is presented in the maps below which show that the southern parts of the country are the most disaster-prone compared to other regions.

142 Isakbek Torgoev, Y.G. Alioshin and I.T. Aitmatov, *Danger and risk of natural and man-caused disasters in the mountains of Kyrgyzstan.* Research Gate. https://tinyurl.com/v56fheu (Accessed on 21.9.2021).
143 *World Risk Report 2020*. https://tinyurl.com/yr5umjav (Accessed 21.9.2021).
144 John Hopkins University of Medicine. Coronavirus Resource Center. https://coronavirus.jhu.edu/map.html (Accessed on 25.9.2021).
145 http://www.stat.kg/ru/statistics/transport-i-svyaz/
146 https://www.unescap.org/sites/default/files/Kyrgyzstan%20Disaster%20Risk%20Profile.pdf

Figure 7: Maps of roads and multi-hazard (l), earthquake (m) and flood risks (r)[147]



4.2 Key features of building a resilient road infrastructure on the Bishkek—Osh road

The Bishkek—Osh Road is the most important road corridor connecting the two largest cities in Kyrgyzstan, the capital city of Bishkek and the regional centre Osh located in the Ferghana Valley, but also northern and southern Kyrgyzstan. It is the vital artery for the Kyrgyz society and economy. Both cities are the intersections of important transportation corridors, of international and domestic trading routes.

This 664 km road corridor passes through the north-east and south-west seismic zones. Landslides are predominantly present in the section passing through the Jalal-Abad region. The danger from avalanches is found in mountainous areas, especially in the road sections between 124–137 km, 198–268 km (Alabel pass), 355, 357–358 km and in the regions of Jalal-Abad and Osh. In the past decades, several deadly avalanches occurred in this road corridor, e.g. a 2012 large-scale avalanche killed 10 people and caused a road closure for over a week; a 2017 avalanche killed 4; and the 2018 incident closed the road.

Alongside landslides, rockfalls and avalanches and extreme winter conditions, e.g. snow coverage and deposits and freezing road surfaces both impact the operability of this corridor which frequently can be closed to traffic in winter disrupting the connection between the two parts of the country.

Figure 8: Bishkek-Osh Road (Section of the International Transport Corridor)[148]

147 https://www.unescap.org/sites/default/files/Kyrgyzstan Disaster Risk Profile.pdf
148 https://flagma-kg.com/ru/rasstoyanie-oshkyrg-bishkek/

4.2.1 Existing measures for building resilience of the road corridor infrastructure

- ***Road Corridor Works***—More than 90 percent of raw materials for road construction is locally supplied resulting in lower prices.
- ***Use of vulnerability assessments to climate change***—The ADB piloted this approach during building the 52 km long section of the corridor (*Bishkek and Kara-Balta*[149]) which was aimed at withstanding the potential impacts of climate change. Accordingly, a set of structural solutions were implemented (e.g. better binder composition of the asphalt, adequate subsurface, bigger side drainage to accommodate the increased volume and intensity of discharge, creation of retention dams, widening riverbeds, installation of acoustic water level sensors for early warning and adapted concrete for bridges to a higher frost standard) and non-structural measures (offsetting climate change impacts, management measures and capacity-building).
- ***Capacity Development for Road Disaster Prevention Management***—During 2016–2019 the Japan International Cooperation Agency (JICA) project[150] implemented a set of resilience-building activities for critical road infrastructure, i.e. landslide monitoring. The countermeasure plan was developed for the 85.5 km landslide of the Bishkek—Osh Road, and meteorological observation and a pilot project for snow disaster capacities were developed through the case study of snow drifting at the Too-Ashuu pass on the Bishkek—Osh Road. Various non-structural measures were implemented (e.g. preparation and dissemination of hazard maps for the road to the beneficiaries, schools, commercial facilities, tollgates and others; social media information dissemination; information boards alongside the road corridor; manuals on inspections and evaluation; and countermeasure plans for road disasters prevention and the short-term Road Disaster Prevention Management Plan).
- ***Avalanche Protection on Bishkek-Osh Road***—The JICA project[151]—a 246 km site—faced a strong risk of massive avalanches because it is located on conical slope topography, where the width of the cone is 2 km and the depth is 5 km, with an altitude difference (height) of 1,600 m. The project constructed a snow shed (arch culvert type) with road access from both sides.
- ***MES issues regular warnings on risks and hazards on the roads in Kyrgyzstan***[152] (e.g. avalanche risks and the affected sections).
- ***Construction of the alternative North-South Road corridor***—The road between *Balykchi and Jalal Abad (433 km)* is the alternative route and a high construction priority.
- ***National programming for building resilience of the road infrastructure***—*The Government Programme on Road Development 2016–2025* identifies the essential priorities and tasks to be implemented during this period that will contribute to building resilience in road transport.
- ***Regional cooperation for building resilience of the road infrastructure***—Strengthened cooperation with international organizations on enhancing readiness for disruptive events, especially in the framework of intergovernmental agreements on Asian Highway and Trans-Asian Railway networks, as well as CAREC, is important.
- ***Application of ICT Solutions for building resilience of the road infrastructure***—There are several examples: Central Asian Institute for Applied Geoscience has designed *an integrated database on landslides in Osh, Jalal Abad and Batken provinces,* and the *Database systems for roads, bridges and tunnels in Kyrgyzstan*[153] that collects and stores information and data on the conditions of the roads, bridges and tunnels; and generates Passport Data with the main details and information, managed by the Asset Management Section

149 https://blogs.adb.org/blog/designing-new-climate-resilient-roads-kyrgyz-republic
150 https://openjicareport.jica.go.jp/pdf/1000040747_09.pdf
151 https://tinyurl.com/b679uxff
152 http://ru.mes.kg/2018/02/19/lavinoopasnye-uchastki-na-avtodorogax-kr/
153 https://openjicareport.jica.go.jp/pdf/1000040744.pdf

of the Road Maintenance Department and ***Digital Avalanche Cadastre***[154]. The latter identifies avalanche locations on the Bishkek-Osh Road corridor with hazard mapping and modelling as a basis for reforestation and afforestation of avalanche-prone areas.

4.3 Challenges to building resilience of critical road infrastructure in Kyrgyzstan

Insufficient mainstreaming of risk and hazard assessments in resilience-building activities.
Inadequate road maintenance practices do not take account of climate change.
Insufficient public investment in road infrastructure, i.e. despite optimistic plans, available funds cover only 50–55 percent[155] of needs. The situation is direr at the local level since the local self-government units do not have sufficient funds for infrastructure on their balance sheets.
Lack of a proper road asset management system and road safety system, i.e. Kyrgyzstan features high on the list of countries with a high death toll from traffic accidents.
The country has still weaker institutional and organizational capacities and resources in the road infrastructure sector.

4.4 Emerging recommendations and follow-up actions

- National and sectoral strategic documents and programmes provide an excellent foundation for the creation and implementation of building resilience measures and actions.
- Creation of a new DEP and a Road Maintenance Institution with equipment suitable for the operation of newly constructed and rehabilitated roads.
- Resilience issues should be considered as early as possible in the infrastructure lifecycle, aimed at improving infrastructure resilience through policy, technical and economic measures.[156]
- Develop long-term and strategic principles for environmentally friendly and healthy transport systems based on sustainability and resilience.[157]
- Adopt an intersectoral plan for emergencies and disasters on roads for increased preparedness and response in these road corridors.
- Design with proper/stricter safety and technical requirements is to be applied to road and infrastructure construction in such high mountainous conditions.
- Establishment of emergency response services on the Bishkek – Osh Road and on other roads.
- Wide application of public-private partnerships in providing services on the roads.
- Modification of the policy for allocation of funds for maintenance of the roads on the national and local levels and increased investments for building resilience measures.
- Increased application of toll fees on additional sections will provide additional funding.
- Application of modern technologies for road construction, maintenance and repair, in line with the effects of climate change.
- Improve the professional capacities and technical expertise of key personnel.

154 https://tinyurl.com/eypytrdc
155 UNESCAP, *Study Report on Resilience of Road and Rail Infrastructure in Kyrgyzstan*, 2020, p. 8. https://tinyurl.com/627aezav (Accessed on 27.9.2021).
156 *Ibid.* p. 48.
157 *Ibid.*, p. 48.

5. CRITICAL INFRASTRUCTURE SECTOR—TRANSPORT (AIRPORTS)

Airports are one of the most valuable assets of the transport critical infrastructure and enablers of economic development of the countries and territories as transportation hubs for aviation services. Building resilience of airports is especially important for the ECA region where 9 out of 18 countries and territories, including the whole Central Asia subregion, are landlocked, with a challenging geography in terms of road and railway connectivity.

The importance of these critical infrastructure facilities was additionally confirmed during the COVID-19 pandemic crisis when airports played a crucial role as transportation hubs keeping air supply chains open and enabling air bridges for the supply and distribution of immediately needed health equipment and services. Therefore, the global sustainable and resilient framework accords special attention to building resilience of airports globally.

- The ***Sendai Framework*** includes the airport facilities in the Target D and its priorities stipulate the promotion of the resilience of the transport sector i.e. airports.
- The focus of the ***SDG targets 9.1 and 9.4 relates*** to the quality, resilience, environmentally sustainable and resource-efficiency of the infrastructure. In that regard, ***Sydney Airport***[158] is an apt example since its Sustainability Report, now under preparation, consists of actions on how to address these global challenges through airport operations, i.e. Sydney Airport contributes directly to the achievement of 10 SDGs and indirectly to five.
- ***CDRI*** plans to launch a global study on the disaster resilience of airports focusing on the structural, non-structural, as well as operational and maintenance aspects, of airports looking at the airports that have been affected adversely and at those that have successfully managed the risk of extreme events.[159]

5. CASE STUDY: KAZAKHSTAN (CENTRAL ASIA SUBREGION): GET AIRPORTS READY FOR DISASTER—ALMATY INTERNATIONAL AIRPORT

The case study presentation of building airport resilience through the Get Airports Ready for Disaster (GARD) programme highlights the practical experience of Almaty Airport and identifies challenges and recommendations for follow-up actions.

5.1 Airport Disaster Preparedness (GARD)

Like any complex system, resilience is an important part of an airport network and of the transport critical infrastructure systems. The 18 countries and territories of the ECA region have 110 international airports, of which Turkey has the largest number—36, followed by Kazakhstan—16, Uzbekistan and Ukraine—9 each and Kosovo*—one international airport. The ECA region also has some key airports both at global and regional levels, e.g. Istanbul Airport (14th busiest airport globally in international passenger traffic in

158 https://tinyurl.com/5batykcu
159 https://www.cdri.world/global-study-disaster-resilience-airports#footer

2019[160]). Almaty International Airport, Istanbul Sabiha Gokcen Airport and the Nikola Tesla Belgrade Airport are the leading regional hubs.

They are one of the most valuable critical infrastructure facilities and assets both nationally and regionally and therefore their *building of resilience matters*. Nevertheless, they are exposed and vulnerable to the effects of natural and human-made hazards, ranging from earthquakes, floods, and extreme weather events, to technical and technogenic ones, as well as cyber[161] or terrorist attacks (e.g. Istanbul Ataturk Airport[162]). These hazards are considered chronic stresses and the acute shocks that are wakening the resilience texture of the airports for a longer time.

However, airports are part of the transport systems that play a major role in disaster response and humanitarian assistance, i.e. serving as major hubs for the provision of quick-paced operations and transportation of disaster relief and aid aimed at saving lives and providing immediate support. In that regard, the GARD programme, established in 2009, as a public-private partnership initiative between UNDP and the Deutsche Post DHL Group is focused on contributing to global airport preparedness to better respond to disaster relief following a major disastrous event: "GARD builds local capacity at airports to increase the level of preparedness for the response of staff and managers. To date, GARD has been implemented in 53 airports in 26 countries and trained 1,340 staff."[163]

The scope of the programme involves presentation of the GARD methodology for airport managers and official representatives of civil aviation authorities in order to assess airport emergency preparedness, and was developed jointly by DHL and UNDP. The programme also includes an assessment of the current preparedness capacities to gauge if these operations are managed in a timely and efficient way. The programme also includes the development of an action plan with recommendations; the training of competent airport staff and relevant government authorities on managing disaster relief operations at the airport in the immediate aftermath of a disaster, i.e. this involves protocols and work methods for management of the disaster relief phase.

Through the development of reliable and effective emergency response plans to manage the delivery of humanitarian supplies to affected people, GARD workshops have helped countries to mitigate the effects of possible natural disasters and allowed airports to become support centres for emergency response in neighbouring countries. Furthermore, GARD is contributing to alignment with the SDGs, especially SDGs 9, 11, 13 and 17[164]. GARD was implemented in five airports in five countries of the ECA region, as presented below.

Figure 9: GARD interventions in the ECA Region

Source: Prepared by the author

160 https://tinyurl.com/yfzdnm8
161 https://www.stormshield.com/news/ten-major-cyberattacks-against-the-airport-industry/
162 https://www.bbc.com/news/world-europe-36658187
163 UNDP and Deustcshe Post DHL Group, *Get Airports Ready For Disaster Results Report 2016–2019* (2019), p. 6. See https://tinyurl.com/y44t7u5s (Accessed on 1 October 2021).
164 UNDP and Deutsche Post DHL Group, *Get Airports Ready for Disaster Results Report 2016–2019*, 2019, p. 7. https://tinyurl.com/y44t7u5s (Accessed on 1.10.2021).

5.2 Disaster profile of Kazakhstan

- Country projections until 2050 note that frequent extreme weather events would occur resulting in emergencies and disasters. The climate future[165] is expected contain higher and more extreme temperatures, frequent severe droughts that can result in dust storms affecting the airport operations and frequent and intensive flooding, i.e. flash floods and mudflows.
- The COVD-19 pandemic crisis impinged on society and communities in an unprecedented way and until 25 September 2021, there were 950,006 cases and 15,503 deaths. The transport sector experienced a significant reduction in operations, e.g. passenger traffic dropped by 54 percent in 2020 compared to 2019.[166]

5.3 GARD Almaty 2017

The GARD exercise was especially important for the resilience of the Almaty International airport given its hazard profile, existing vulnerabilities and its position as the major national and regional hub. The main objective was to enhance its overall emergency and disaster preparedness and to facilitate the establishment of smooth disaster relief and humanitarian assistance. In that regard, the airport was designed and specifically prepared to fulfil the criteria and to assume the main role as a Central Asia regional humanitarian hub in the event of major disasters.

Photo credit: UNDP

Over 50 officials, experts and practitioners from the Almaty International Airport, the Committee of Emergency Situations of the Ministry of Internal Affairs, Agency of Civil Aviation of the Ministry of Investments and Development, Kazaeronavigation, Border and Customs Services, Centre for Emergency Situations and Disaster Risk Reduction, UNDP, Deutsche Post DHL Group and other humanitarian organizations participated in the five-day GARD Workshop from 18–22 September 2017.

"Working with international experts in disaster response, we expect to develop a robust action plan that allows Almaty International Airport to strengthen its role in channelling incoming relief goods to affected communities in the event of a natural disaster. In addition to assessing the readiness of our airport infrastructure and strengthening staff expertise, the workshop will lead to a series of follow-up activities, including an action plan that we can use to bolster our response to any potential emergencies."

Aibol Bekmukhambetov, President of Almaty International Airport

Source: https://tinyurl.com/y44t7u5s

165 World Bank and ADB, *Climate Risk Country Profile: Kazakhstan*, 2021, p. 2. https://tinyurl.com/5ped5hv8 (Accessed 20.9.2021)
166 CAREC and ADB, *Impact of COVID-19 on Carec Aviation and Tourism*, 2021, p. 7. https://tinyurl.com/y3jkxu3a (Accessed on 15.9.2021).

During the workshop, the participants assessed the existing preparedness level of the airport, i.e. airport operations, cargo terminal, passenger terminal and other facilities and security. They also participated in the training exercise and in the preparation of the GARD Surge Capacity Assessment Report, including the development of the specific recommendations and the action plan to ensure that the airport is prepared for future disasters.

The training exercise was adjusted to overcome the existing exposure and vulnerabilities to the flood hazard. The outputs of the GARD workshop in Almaty were followed up by an improvement in the operations and adoption of updated planning documents, i.e. Airport Emergency Response Action Plan, Emergency Action Plan on the provision of aviation fuel and lubricants, Action Plan for liquidation of the consequences of a major earthquake, Action Plan for protection of the personnel and population from the radiation accident and its consequences, and other planning documents and orders.

In general, the airport can increase the number of air operations in case of a major disaster with the provision of additional resources. Following the recommendations and established practice, the airport authorities have adopted the practice of organizing regular training drills, even during the pandemic. (See the box)

5.4 Challenges to building resilience of critical airport infrastructure in Kazakhstan

Identifying the challenges and priorities of airport preparedness that need continuous monitoring and updating.
The main focus is on emergency preparedness of airports for aviation emergencies and their consequences, e.g. whether disaster preparedness is or is not fully mainstreamed.
Risk and hazard assessments are not fully mainstreamed in national and local assessments or in operational planning documents.
Insufficient resources, i.e. human, technical and financial, for enhanced resilience, including the potential role as regional hub during disaster relief and provision of humanitarian assistance

5.5 Recommendations and follow-up actions

- Comprehensive measures should be taken to enable the airport to be ready for all kinds of emergencies.
- A robust and clear action plan, which is regularly tested, should be adopted for the provision of timely, effective and efficient services during disaster relief and delivery of humanitarian assistance.
- Stakeholder disaster management should be established in an inclusive and participatory manner to contribute to mitigation, preparedness, response and recovery from the impact of a potential disaster.
- Sufficient resources should be allocated, as well as investment in airport resilience, including in professional education and training of the staff.

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