UNITED ARAB EMIRATES
MINISTRY OF CLIMATE CHANGE
& ENVIRONMENT

National Climate Change Adaptation Program

Adaptation of the UAE's Infrastructure to Climate Change

Risk Assessment & Options for Action

2019

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Executive Summary

As part of the National Climate Change Adaptation Program, this report presents the findings of the climate change risk assessment of the UAE's infrastructure sector. The assessment was conducted by the Ministry of Climate Change and Environment (MOCCAE) according to a framework developed from global best practices. The UAE Sectoral Climate Risk Assessment Framework consists of five steps: 1) take stock of climate trends and relevant sectoral issues; 2) identify potential impacts of climate change on the sector; 3) evaluate the magnitude and likelihood of impacts to understand the risks; 4) assess and prioritize the risks; and 5) identify potential adaptation actions.

Climate change and infrastructure

Climate change will result in higher temperatures across the UAE. Future climate projections show a 2–3°C increase in average temperatures in the summer months of 2060–2079, although the changes may vary across the emirates. Humidity is expected to increase along the coast, while rainfall patterns are projected to change, with the Northern Emirates expected to have more intense rainfall episodes. Sea level rise is expected to increase the threats of inundation along the coastline. Furthermore, the probability of extreme weather events is projected to increase in both frequency and magnitude.

The UAE's infrastructure network, such as buildings, transport, water, energy, and sanitation, are essential enablers of economic development as it drives business opportunities and facilitates the delivery of public goods and services. Considering its long service life span and significant economic value, preparing for the unavoidable impacts of climate change on the infrastructure cycle — from design, location, and construction to operation and maintenance — has never been so critical in ensuring long-term resilience.

Assessing climate risks to infrastructure

Based on an extensive review of scientific literature on the impacts of climate change on infrastructure, this report identifies the most relevant impacts, which are further assessed upon consideration of the local evidence to fit the UAE context. The impacts are translated into risks through the interaction of impacts and likelihood. In this context, risk is defined as the likelihood of impact occurrence. The shortlisted risks shown in the table below encompass the different stages of the infrastructure life cycle.

MOCCAE conducted an initial assessment of the shortlisted risks through a five-point scale ("very low," "low," "medium," "high," and "very high"). The preliminary results were then shared with stakeholders through interactive workshops, which involved representatives from the public, private, and civil society sectors, and were facilitated by subject matter experts. MOCCAE consolidated the stakeholder inputs and reflected their comments in the final assessment while further verifying the available evidence.

Based on the results above, the four "high" risks are identified as priority risks:

- Damage to coastal and offshore infrastructure;
- Increased infrastructure maintenance costs;
- Loss of business opportunities due to transport disruptions; and
- Reduced reliability of transport infrastructure and buildings.

For the "medium" risks, although they are not as critical as the "high" risks, a thorough investigation would be necessary to implement control measures to minimize the risks and prevent them from escalating into "high" risks. The "low" risks also require sporadic monitoring to determine changes in the situation that may affect the risk level.

Risk level	Impact
High	Damage to coastal and offshore infrastructure
	Increased infrastructure maintenance costs
	Loss of business opportunities due to transport disruptions
	Reduced reliability of transport infrastructure and buildings
Medium	Damage to and deterioration of transportation infrastructure
	Damage and/or disruptions in water, sanitation, and waste facilities
	Damage to and deterioration of building infrastructure
	Increased frequency and severity of hazard to infrastructure
	Displacement of the population residing within the coastline
	Increased flooding in urban areas resulting from decreased holding capacity of drainage
	Decreased access to services and economic opportunities
Low	Decreased available space for infrastructural development due to shoreline retreat

Options for action

Considering the UAE's current climate adaptation efforts, the below list of potential measures is proposed to address the priority risks to the infrastructure sector. To prioritize actions, current efforts may continue or expand, and new initiatives may be introduced. Some measures may require collaboration across authorities due to their inter-sectoral nature.

Type of measures	Damage to coastal and offshore infrastructure	Increased infrastructure maintenance costs
	Examples of potential adaptation measures	
Physical safeguards	• Intensify current mangrove and seagrass restoration activities complemented by beach nourishment projects. • Establish coastal setbacks and expand building of flood and storm surge defense structures.	• Expand modernization projects including equipment upgrade and retrofit to building, wastewater, and transport facilities to ensure stability during extreme events.
Risk management	• Explore insurance schemes to mandatorily include climate-induced damages to coastal properties.	• Explore innovative risk-sharing mechanisms that account for infrastructure maintenance.
Knowledge	• Intensify research on the response of coastal wetlands to various categories of climate-induced extreme events.	• Train maintenance staff to recognize damages associated with a changing climate and ensure proper response.
Enablers	• Consider developing a national coastal zone management program. • Introduce economic incentives and/or regulations to discourage coastal settlements.	• Expand quality assurance protocols for certain types of infrastructural facilities. • Develop regulatory measures for the implementation of higher standards in facility design.

Type of measures	Loss of business opportunities due to transport disruptions	Reduced reliability of transport infrastructure and buildings
	Examples of potential adaptation measures	
Physical safeguards	• Consider expanding different modes of transportation across all emirates. • Implement transport redundancy (backup transport systems).	• Expand installation of smart technologies. • Automate national early warning systems in the event of hazards.
Risk management	• Encourage businesses to leverage their insurance policies to account for climate change-induced risks.	• Expand insurance schemes to mandatorily include climate-induced infrastructure accidents.
Knowledge	• Encourage businesses to diversify suppliers' base to ensure continuity of business operation during climate-related disruptions.	• Incorporate climate-induced hazards in road safety and traffic awareness campaigns.
Enablers	• Develop contingency plans for transport asset failures.	• Consider implementing severe road fees or fines to deter commuters to get on the road during extreme weather and climatic events.

The assessment result reveals the priority risks affecting the infrastructure sector and the potential solutions of which will require adaptation measures that are tailored locally, thus highlighting the importance of conducting a thorough risk assessment at the emirate and facility levels. Looking ahead, infrastructure design standards must be re-examined to withstand not just historical climate trends but also future climate extremes. Considering the lock-in effects of infrastructure investments due to their long operational lifetimes, building climate-resilient infrastructure represents a practical and cost-effective decision.

Introduction

As part of fulfilling its commitments under the Paris Agreement and in line with the UAE Vision 2021 and the UAE Green Agenda 2030, the UAE Government adopted the National Climate Change Plan 2050 (Climate Plan) in June 2017. The Plan aims to consolidate the country's climate action under a single framework that specifies strategic priorities, covering both mitigation and adaptation.

The Climate Plan structures action areas around three pillars: 1) greenhouse gas (GHG) emissions management; 2) climate change adaptation; and 3) private sector-driven innovative economic diversification. Under the adaptation pillar, the following outcomes are proposed:

- **By 2020:** Climate change risk assessments are performed, and immediate measures are put in place.
- **By 2025:** Adaptation planning is mainstreamed in development policy.
- **By 2030–2050:** Continuous monitoring and evaluation is conducted to ensure evidence-based adaptation measures.

As part of the implementation of the Climate Plan, the Ministry of Climate Change and Environment (MOCCAE) launched the National Climate Change Adaptation Program. The Program aims to carry out a systematic and participatory risk assessment as a basis for planning adaptation measures in four priority sectors: public health, energy, infrastructure, and the environment.

This report focuses on risk assessment for the infrastructure sector. Specifically, it aims to establish the linkage between climate change and infrastructure to better understand their interaction; assess climate risks to the UAE's infrastructure using a risk assessment framework; and provide a list of potential adaptation measures to address the priority risks and explore opportunities to strengthen climate resilience.

In this report, infrastructure is broadly defined as "the structural elements of an economy that facilitate the flow of goods and services between buyers and sellers."[1] The scope is divided into several subcategories: transportation, buildings, water supply, sanitation and waste management, and coastal and offshore infrastructure.[a] A qualitative assessment of climate-related risks to infrastructure within these areas has been conducted, covering the different stages of the infrastructure life cycle (see Figure 1).

The report is divided into three chapters:

- **Chapter 1 sets the scene for understanding how climate change affects infrastructure.** It also describes the observed and projected climate change in the UAE, as well as the global practices on climate resilience in the infrastructure sector.
- **Chapter 2 focuses on the results of the risk assessment,** which was conducted based on available evidence, stakeholder consultation, and expert inputs, using a framework developed from global practices.
- **Chapter 3 presents adaptation measures** to help address the priority risks identified by the risk assessment. The measures include an extension of existing initiatives as well as new actions.

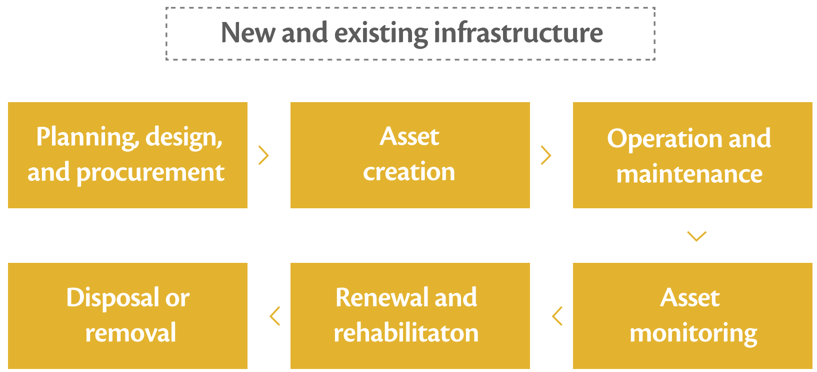


Figure 1. Stages of the infrastructure life cycle (modified from USAID)[2]

(a) Note that energy infrastructure, including power plants, transmission lines, and distribution systems, is covered in a separate report (Adaptation of the UAE's Energy Sector to Climate Change).

1. Climate Change and Infrastructure

1.1. Climate change in the UAE

The Intergovernmental Panel on Climate Change (IPCC) has reported that the observed changes in the climate system are clear and have been unprecedented since the 1950s: increasing concentrations of carbon dioxide (CO_2), warming atmosphere and ocean, melting ice, and rising sea levels.[3] These global trends are projected to continue through this century and beyond, leading to a range of adverse local impacts.

Current trends and future projections of the UAE's climate are presented in Table 1. More information on past climate trends and future projections from various sources is compiled in the Annex. The Abu Dhabi Global Environmental Data Initiative (AGEDI) study projects that the UAE could be warmer in the future, with an expected temperature increase of 2–3°C, alongside increasing humidity. However, these changes will not be the same for all seven emirates as terrain, elevation, and weather patterns vary across the country. It should also be noted that there remain varying levels of uncertainty behind climate projections due to the complex interaction of climate, economic, social, and environmental factors, as well as the relative scarcity of climate modeling research for the region.

Table 1. Current trends and future projections of the UAE climate[4]

	TEMPERATURE	HUMIDITY	SEA LEVEL RISE	RAINFALL	EXTREME EVENTS
What has been happening?	Temperature in summer months rises to about **48˚C** in coastal cities – even **50°C** in the desert regions.	Average humidity is **50-60%** in coastal areas; **45%** in inland areas. Extreme humidity reaches as high as **90%**.	Average sea level rise over the past decades in the Arabian Gulf is **0.18-0.23 cm** per year.	Annual rainfall is around **100 mm**.	**3 super cyclones** hit the Arabian Peninsula in a span of 40 years (1977-2018).
What could happen?	**2-3°C** average increase during the summer months by 2060-2079.	Increase in humidity by about **10%** over the Arabian Gulf.	**Increasing mean high tides** in coastal areas	More **intense rainfall**, particularly in Northern Emirates and Dubai.	More **frequent and severe** extreme events. Growing risk of **high-impact storms**.

In terms of precipitation, the AGEDI study reported that rainfall is projected to increase over much of the UAE. Increases of 50–100% from current amounts are projected for Dubai, Sharjah, and the Northern Emirates. Atmospheric modeling projects a 15–20% increase in rainfall over the Hajar Mountains by 2050. Despite the projected increases in rainfall, however, the number of wet days (with over 1 mm of rainfall) is projected to decrease. This implies that larger amounts of rainfall would occur during comparatively fewer rainfall events than currently observed. That said, while there might be some positive changes in terms of rainfall in some parts of the UAE, higher rates of evaporation may cancel out the increase in volume.

Sea level is also expected to rise in the UAE, increasing the threats of inundation along the coastline. Conducting climate modeling for sea level rise remains complex due to its broad suite of characteristics. Regarding extreme events, although current models cannot accurately predict their occurrence, current projections imply that they will become more frequent, their intensity more severe, and their trajectories or pathways less predictable.

1.2. Linkages between climate and infrastructure

A developed infrastructure is a necessary precondition to achieve economic development and improve living standards. The infrastructure system is characterized by a complex network of structures, facilities, and technology, encompassing a wide spectrum of services, such as transportation, aviation, power generation and transmission, housing, telecommunications, and others.

Climate change impacts on infrastructure, both direct and indirect, are likely to accelerate in the coming decades. Figure 2 shows an illustrative example of the direct and indirect impacts of climate change on infrastructure. Direct impacts occur when climate change causes damage to physical properties, which can be quantified relatively easily in monetary terms. There are instances, however, when direct impacts are not easily quantifiable, such as when climate change damages cultural assets, the intangible values of which are difficult to measure. On the other hand, indirect impacts include lost revenues for businesses, impacts on social well-being, and disruptions in the delivery of goods and services. Indirect impacts of climate change on infrastructure also affect other areas due to disruptions in power and Internet-based activities.

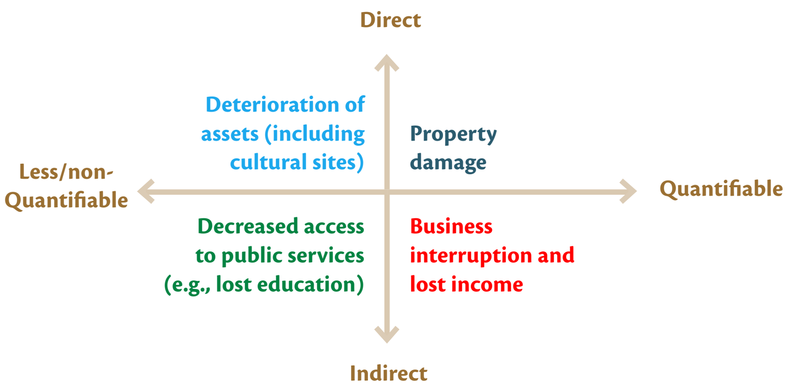


Figure 2. Examples of direct and indirect impacts of climate change on infrastructure[5]

Climate events affect various types of infrastructure in different ways and degrees, depending on the location of assets, age, materials, operations, and maintenance. There is a growing body of literature that highlights the threats of climate change on existing and future infrastructure.[6,7,8] Figure 3 highlights the observed general impacts of climate change on infrastructure systems based on a review of global evidences.

Given the wide scope of infrastructure, it is important to understand how the different types of infrastructure (e.g., transportation, power, buildings, telecommunication, etc.) relate to one another to create a complex web of modern infrastructure networks. Infrastructure components are increasingly becoming interconnected such that the disruptions or failure of one network can affect the performance of others.[9,10] As such, assessing climate risks to infrastructure investments should consider such interdependencies as a critical step toward mainstreaming climate change in investment planning.

Figure 3. Examples of climate change impacts on different types of infrastructure[11]

A unique characteristic of infrastructure — in comparison with other areas of interest under climate change — is the long-term service lifetime, spanning decades or even centuries.[b] Table 2 shows the average operational time scale of selected types of infrastructure. It suggests that an infrastructure asset can last for decades or centuries, thus highlighting the importance of making climate-smart decisions that consider climate projections as early as the design stage.

Table 2. Average service lifetime of selected types of infrastructure[12]

		Design lifetime (years)									
Type	**Asset**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
Transport	Paved roads	■	■								
	Rail tracks	■	■	■	■	■					
	Bridges					■	■	■	■	■	■
Energy	Transmission lines	■	■	■	■	■					
	High-voltage transformers	■	■	■	■						
	Generating plants and substations			■	■	■	■	■	■		
Water	Reservoirs and dams					■	■	■	■		
	Treatment plants and pumping stations						■	■			
	Drinking water distribution						■	■	■	■	■
	Storm and sewage collection systems						■	■	■	■	■

1.3. Global practices on climate adaptation in the infrastructure sector

The infrastructure sector represents a huge investment globally. According to the Global Infrastructure Outlook Report 2017 by Oxford Economics, the need for infrastructure investment is expected to reach USD 94 trillion by 2040, and an additional USD 3.5 trillion will be needed to meet the Sustainable Development Goals (SDGs) for electricity and water.[13]

(b) Typically, paved roads last only for 10–20 years as they deteriorate due to heat, erosion, flooding, and changes in soil moisture. On the other hand, bridges can operate up to 100 years or more and are affected by erosion, corrosion (if located near the coastal areas), and damage to foundation by climate-related factors.

As countries strive to mobilize such huge investments, climate change continues to pose serious damage to existing infrastructure assets. In fact, the infrastructure sector has experienced the most evident impacts of climate change as the effects are tangible and measurable. Some of the global impacts that have occurred throughout the years are shown in Figure 4. A recent extreme event that took place in the Arab region was Cyclone Mekunu, which displaced more than 230 families in the biodiversity-rich island of Socotra in Yemen. It also caused significant destruction in Oman, suspending airport operation, shutting down power, and blasting palm trees on the coasts.[14] In terms of climate actions toward infrastructure resilience, Table 3 shows relevant initiatives in Canada, the United Kingdom, and the United States.

Due to the high capital outlay of infrastructure investments globally, there have been significant efforts to estimate the cost of making the infrastructure system resilient to climate change (see Box 1). This is expected to assist decision-makers in having an in-depth understanding of the risks and the needed resources to address them.

Box 1. The high price tag of adaptation for infrastructure around the world

- **Global:** The cost between 2010 and 2050 of adapting to a 2°C warmer world by 2050 is more than USD 75–100 billion a year.[15]
- **Europe:** About USD 350–500 million annually is needed for bridges to adapt to climate change[16] and USD 933 million each year for climate-related repairs.[17]
- **Malawi, Mozambique, and Zambia:** These African countries will have to spend USD 596 million to maintain and repair roads due to damages caused by temperature and rainfall changes by 2050.[18]
- **Australia:** Assets worth more than USD 165 billion are potentially exposed to inundation and erosion hazard for a sea level rise of 1.1 meters by 2100.[19]
- **Canada:** It will take USD 133 billion to replace fair, poor, or very poor infrastructure.[20]
- **Japan:** With a one-meter sea level rise, the estimated cost of protection will be about USD 115 billion, while the value of assets at risk exceeds USD 1 trillion.[21 22]
- **United States:** Approximately USD 140–250 billion is needed for bridges to adapt to climate change over the next 50 years.[23]

2005
India
The government allocated 14% (USD 1 million annually) of the annual repair and maintenance of the Konkan Railway to repairing damage due to extreme weather events.

2007
Oman
Cyclone Gonu knocked out power lines, damaged the coastline, disrupted transportation, sunk boats, and destroyed a dam; it also affected Iran, the UAE, and Pakistan.

2007
United Kingdom
Excessive floods cost the economy over USD 5 billion, with damage to infrastructure estimated at USD 854 million.

2012
United States
Superstorm Sandy inflicted the worst damage to New York City's subway system, causing weeklong disruption and generating damage worth USD 50 billion.

2013
Canada
The cleanup and repair coasts in Calgary due to heavy rainfall and flooding reached USD 4.5 billion, the most expensive disaster in Canada at that time.

2018
Yemen
Rescue and relief efforts were undertaken when Cyclon Mekunu displaced more than 230 families in the biodiversity-rich island of Socotra, a UNESCO World Heritage site.

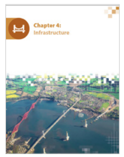
2018
Italy
At least 38 people were killed when a violent storm caused a bridge to collapse over buildings in the northern port city of Genoa, Italy.

Figure 4. Examples of global impacts of climate change on infrastructure[24]

While the current practices implement criteria and rules that ensure safety and performance, current engineering standards have yet to fully incorporate future climate considerations across the infrastructure cycle. Currently, engineers use the concept of "stationarity" as a basis for risk assessment, which implies that they largely depend on historical data to define the future. Given how the main

reliance on historical data has unreliably gauged future climate risks (extreme climate events have frequently exceeded current design parameters), stationarity is no longer a viable planning model, and thus more innovative approaches that account for climate extremes over the whole asset lifetime are necessary.

Table 3. Examples of infrastructure resilience initiatives in selected countries

Country	Initiative
Canada 	The **National Infrastructure and Buildings Climate Change Adaptation State of Play Report** (2017) stressed the importance of modifying standards in planning and design approaches for infrastructure, focusing on: • Infrastructure inventory: Develop critical infrastructure inventories, including the evaluation of vulnerabilities and identification of priority areas based on climate projections. • Critical areas: Identify high-risk areas based on recent events (e.g., new flood zone mapping). • Cost-benefit analysis: Undertake risk and cost-benefit analyses on alternatives to support decision-making on priority adaptation actions. • Climate proofing: Incorporate storms and other extreme weather events in the assessment of infrastructure and building vulnerability.
United Kingdom 	The **U.K. Climate Change Risk Assessment 2017: Evidence Report (Chapter 4: Infrastructure)** highlighted the imperative to build national capacity to perform infrastructure climate change risk assessments, including developing: • A national database: Record the location, function, and design of assets, as well as climate change adaptation measures. • Baseline scenarios: Adopt a common baseline and several standardized adaptation scenarios to provide set of common reference points, and further test the scenarios. • Risk framework: Formulate a common and internally coherent framework for risk analysis that enables different risks to be fairly compared.
United States 	The **Overarching Guide: Incorporating Climate Change Adaptation in Infrastructure Planning and Design** (2015) aimed to guide the mainstreaming of climate change risks and adaptation in infrastructure projects. It defines four strategic approaches to adaptation response, namely: • Accommodate and maintain: less costly; more pragmatic; allows adjustment over time; requires monitoring. • Harden and protect: proactive; straightforward to implement and justify; more costly; assumes reasonably accurate climate forecasts. • Relocate: proactive; more costly; suboptimal location may decrease the period of performance or service. • Accept or abandon: No extra up-front cost; proper communications needed to inform decision-makers and beneficiaries to expect lower performance or service.

2. Assessing Climate Risks to the Infrastructure Sector

2.1. Sectoral risk assessment framework

The UAE Sectoral Climate Risk Assessment Framework (Assessment Framework) consists of a five-step approach as illustrated in Figure 5. The succeeding discussions in this section are based on the application of the five steps. The process of risk assessment combines a literature review, stakeholder consultation, and expert inputs (see the Assessment Framework document for more details).

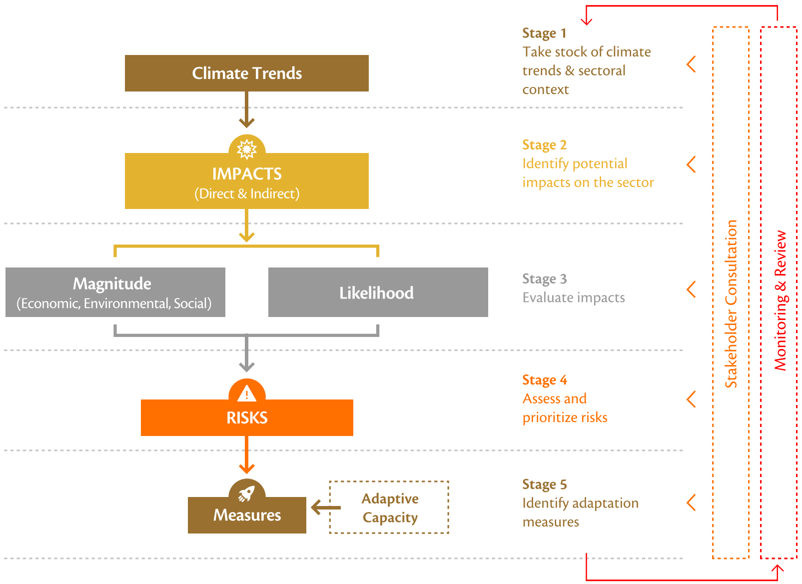


Figure 5. Sectoral climate risk assessment framework

2.2. UAE infrastructure sector

This section corresponds to Stage 1 of the risk assessment framework, which aims to contextualize the UAE's infrastructure system as well as prevailing challenges and opportunities. The UAE has strategically invested in building world-class infrastructure that created a multiplier effect in the overall economy, paving the way for the growth of other industries, such as tourism, real estate, and manufacturing. As part of the UAE Vision 2021, the government emphasizes the importance of creating and maintaining a "sustainable environment and infrastructure." To meet this goal, the UAE has set key performance indicators (KPIs) against its 2021 targets as shown in Table 4.

Table 4. Examples of national targets related to infrastructure

Indicator	Current Status	2021 Targets
Quality of Overall Infrastructure (transportation, electricity, and telephone lines)	Rank 4, as per the World Economic Forum — Global Competitiveness Report (WEF-GCR) 2017–2018	Rank 1
Quality of Port Infrastructure	Rank 4, as per WEF-GCR 2017–2018	Rank 1
Quality of Air Transport Infrastructure	Rank 3, as per WEF-GCR 2017–2018	Rank 1
Logistics Performance Index	Rank 13 (2016 Report), as per the World Bank	Top 10
Networked Readiness Index (telecommunication and information technology)	Rank 26 (2016 Report), as per WEF Global Information Technology Report	Top 10

State of infrastructure network

- **Roads.** The UAE has an extensive network of roads connecting all the emirates and also links with Oman and Saudi Arabia to facilitate trade and mobility. The Global Competitiveness Report 2017–2018 ranks the UAE first in road quality (in terms of extensiveness and condition). Despite the top-notch road quality, there are challenges regarding road safety and traffic congestion, which are being addressed by massive road construction and tight implementation of traffic rules.[c]

- **Ports.** Given its strategic location for maritime activity, the country is home to numerous ports, mostly located in the western coast, including the Port of Jebel Ali, one of the world's largest man-made harbors and one of the biggest ports in the Middle East. The ports of Fujairah and Khor Fakkan are located on the eastern coast and offer direct access to the Indian Ocean.[25] The government supports the development of ports to create jobs and contribute to economic diversification.

(c) Critical roads are at the shoreline (e.g., E11 main road link between Saudi Arabia and the UAE; Corniche and Zayed Roads in Abu Dhabi) and in causeways (e.g., E12 Yas Island to Abu Dhabi Island Road). Moreover, there are a limited number (4) of bridge links between the heavily populated Abu Dhabi Island and the mainland. There is also a lack of backup transport systems on the road corridor between Abu Dhabi and the Saudi Arabian border, with only one freeway (E11) close to the coast, providing a critical trade link.

- **Railways.** The Dubai Metro, with its 75-kilometer (km) track, is the first urban train network in the Gulf Cooperation Council (GCC). Also, the Etihad Rail will soon link the seven emirates with 1,200 km of track,[26] while plans to build a GCC railway network are also underway. Moreover, an agreement has also been signed to establish the world's first commercial Hyperloop system,[27] which will make travel time from Abu Dhabi to Dubai from 1.5 hours to just 12 minutes, with a speed of 1,079 km/hr.

- **Airports.** As a global aviation hub, the UAE has seven international airports, including the Dubai International Airport, which is the world's busiest hub by international traffic. The industry is expected to grow further given the expansion of major airports, including the development of Al Maktoum International at Dubai South (formerly Dubai World Central), which will be the world's largest airport, with five runways and a capacity for 160 million passengers. By 2030, the six largest airports in the country will have a total combined capacity of 300 million passengers annually.[28]

- **Information and communications technology (ICT).** The UAE leads in the Middle East for having a well-developed Internet infrastructure and broadband connectivity, with a high mobile penetration rate of 200%. Huawei's Global Connectivity Index 2018 ranks the UAE first in the Gulf region and 23rd in the world in terms of the broadband market.[29] The UAE is also strengthening its ICT capacity by establishing free zones, such as the Dubai Internet City and the Dubai Media City, in support of innovative technology companies.

- **Buildings.** The building industry in the UAE is an important part of the country's economy. In Dubai, for example, the government confirmed in 2017 that there were 26,653 buildings under construction, including 16,870 developers' villas, 1,238 multistoried buildings, 770 general buildings, 737 industrial buildings, and 6,111 private villas.[30] In 2017, the building projects underway in the UAE was worth USD 228 billion, most of which will be completed before Expo 2020.[31]

- **Water supply.** In 2013, there were 130 dams in the UAE, with a total storage capacity of 120 m^3.[32] While the dams in the UAE are small, they play an important role in water harvesting, enhancing the quality of groundwater and supporting tourist attractions, such as the Shawka dam at Ras Al Khaimah. As of July 2018, the DEWA had completed the engineering studies for the 250 MW Hatta hydroelectric plant.[33] Due to the limited supply of natural water in the UAE, about 42% of water comes from desalination plants using thermal desalination technology.[34]

- **Sanitation and waste management.** Increasing population and rapid urbanization in the UAE have led to an increased volume of waste that ends up in landfills. Local authorities have intensified their efforts to strengthen sanitation and waste management infrastructure. Dubai, for example, will establish the largest plant in the Middle East to convert solid waste into energy in the Warsan district.[35] The UAE is also investing in sewerage system upgrades, such as the Strategic Tunnel Enhancement Program (STEP) in Abu Dhabi, which involved the construction of 41 km of deep sewer tunnels.[36] In Dubai, the construction of a deep tunnel rain storm system is underway to strengthen the emirate's drainage infrastructure.[37]

- **Coastal and offshore structures.** About 85% of the UAE's population live in coastal areas. Many hotels, residential complexes, desalination plants, and oil platforms are located near the coasts. Breakwaters have been constructed to protect the coast from medium to high waves, in addition to the sand barriers to stop coastal erosion and sediment transport to preserve the coast. The UAE is also home to many artificial islands that are constructed for residential and tourism purposes. In Dubai, for example, one of the most popular land reclamation projects in the coastline is the Palm Jumeirah, which hosts hotels, apartment buildings, and villas.[38]

Infrastructure policy framework

The Ministry of Infrastructure Development (MOID) is the lead federal agency in charge of "organizing, planning, constructing, and maintaining infrastructure projects and organizing the federal housing sector."[39] The Federal Transport Authority — Land and Maritime (FTA) is in charge of integrating the land, maritime, and railway transport systems.[40] The General Civil Aviation Authority (GCAA) is the lead institution mandated to provide aviation services in accordance with safety and security regulations of the aviation industry.

At the emirate level, various strategies and plans related to urban planning and infrastructure development have been developed as shown in Table 5.

Table 5. Examples of emirate-level plans related to infrastructure

Key agency	Infrastructure-related development plans
Abu Dhabi Department of Urban Planning and Municipalities (DPM)	• Plan Abu Dhabi 2030: Urban Structure Framework Plan • Plan Maritime 2030 • Plan Al Ain 2030: Urban Structure Framework Plan
Abu Dhabi Department of Transport (DoT)	• Abu Dhabi Surface Transport Master Plan 2030 • Abu Dhabi Transportation Mobility Management Strategy • Al Ain Surface Transport Master Plan
Dubai Urban Planning Steering Committee	• Dubai 2020 Urban Master Plan
Dubai Roads and Transport Authority	• Dubai Autonomous Transportation Strategy • Traffic and Transport Plan 2030

2.3. Evaluation and prioritization of climate risks

Climate impacts on infrastructure

To evaluate and prioritize the risks, a list of impacts has been developed based on a review of international and local literature on climate risks to infrastructure. This section is the application of Stage 2 of the risk assessment framework, which involves the identification and characterization of climate impacts relevant to the infrastructure sector as shown in Table 6.

Table 6. Impacts of climate change on the infrastructure sector per climate signal[d]

Climate events/signals	Direct and indirect impacts
Rising temperature complemented by increasing humidity	• Damage to and deterioration of transportation infrastructure (e.g., air, land, water transport systems, including roads, rails, runways, waterways, and traffic facilities) • Damage and/or disruptions in water (e.g., dams, reservoirs), sanitation, and waste management facilities (e.g., wastewater facilities) • Damage to and deterioration of building infrastructure (e.g., public and private residential and commercial, including communication and industrial facilities, especially those along the coastal areas) • Damage to and deterioration of coastal and offshore infrastructure (e.g., oil and gas platforms, rigs, and pipelines; communication cables) • Increased cost to maintain all infrastructure not built for elevated temperature (i.e., possibly causing a change in acidity and salinity for coastal infrastructure) • Increased in frequency and severity of hazard to infrastructure due to extreme drought, sea temperature-induced episodes of red tides, and exposure to elevated temperature of vulnerable equipment (e.g., electrical at buildings) • Decreased access to services and economic opportunities and increased cost of services, including insurance due to transport service disruptions, delays, rerouting, and limited cargo capacities • Decreased access to services and (potential) economic opportunities due to damage to and/or disruptions in water, sanitation, and waste management facilities, especially those along coastal areas
Rising sea level	• Decreased available space for infrastructural development due to shoreline retreat • Displacement of the population residing within the coastline due to damages
Extreme weather and climatic events (storm, flooding, sandstorm, and fog)	• Displacement of the population residing within the coastline • Increased flooding in urban areas resulting from decreased holding capacity of the drainage system during extreme rain and storms • Increased hazard in transport and building infrastructure due to decreased operation efficiency of transportation and building units
Extreme drought	• Damage and/or disruptions in water (e.g., dams, reservoirs), sanitation, and waste management facilities (e.g., wastewater facilities) • Increase in frequency and severity of hazard to infrastructure

(d) The selection of preliminary risks involved a review of chapters from the most recent IPCC assessment reports. It also used reports from organizations of global authority to verify the evidences and check for consistencies. The risks were then localized through a review of local evidence, such as scientific and policy studies conducted in the country. Through a consultation workshop, stakeholders provided inputs, and the risks were further revised, incorporating their feedback.

Based on the long list above, a final list of nationally relevant direct and indirect impacts is developed as shown in Table 7. Note that the severity of impacts of climate change on infrastructure will be different across the UAE due to the geographical, climatic, and other differences between the seven emirates.

Table 7. Final list of impacts on the UAE's infrastructure sector[e]

Direct impacts
1. Damage to and deterioration of transportation infrastructure (e.g., air, land, water transport systems, including roads, rails, runways, waterways, and traffic facilities) due to rising temperature, possibly causing a change acidity and salinity, sea level rise, and extreme weather events, including sandstorms
2. Damage and/or disruptions in water (e.g., dams, reservoirs), sanitation, and waste management facilities (e.g., wastewater facilities) due to rising temperature and sea level, as well as extreme weather and climatic events, including sandstorms and high winds
3. Damage to and deterioration of building infrastructure (e.g., public and private residential and commercial, including communication and industrial facilities, especially those along the coastal areas due to rising temperature and sea level, as well as extreme weather and climatic events, including sandstorms and high winds
4. Damage to coastal and offshore infrastructure (e.g., oil and gas platforms, rigs, and pipelines; communication cables) due to rising temperature, causing a change in acidity and salinity, sea level rise, and extreme weather events
Indirect impacts
5. Increased infrastructure maintenance costs, especially for infrastructure not built for elevated temperature (i.e., possibly causing a change in acidity and salinity for coastal infrastructure), rising humidity, sea level rise, and extreme weather events, including sandstorms
6. Decreased available space for infrastructural development due to shoreline retreat at the event of sea level rise
7. Increase in frequency and severity of hazard to infrastructure due to extreme drought, sea temperature induced episodes of red tides, exposure to elevated temperature of vulnerable equipment (e.g., electrical at buildings), and extreme weather events, including sandstorms and heavy fog events
8. Loss of business opportunities due to transport disruptions, delays, rerouting, and decreased cargo capacities caused by rising temperature, sea level rise, and extreme weather and climatic events, including sandstorms, heavy fog, and high winds
9. Displacement of the population residing within the coastline due to infrastructure damages caused by sea level rise as well as extreme weather events
10. Increased flooding in urban areas resulting from the decreased holding capacity of the drainage system during extreme rain events and storms
11. Decreased access to services and economic opportunities due to damage to and/or disruptions in water, sanitation, and waste management facilities, especially those along coastal areas, caused by rising temperature, sea level rise, and extreme weather and climatic events, including sandstorms, high wind, and heavy fog episodes
12. Reduced reliability of transport infrastructure and buildings, resulting in decreased operation efficiency of transportation and industrial units due to extreme weather and climatic events (e.g., heavy rainfall, sandstorms, heavy fog, and heat waves)

(e) Risks will vary depending on the location, age, design, and adaptive capacity of the infrastructure or facility. Rising sea level will affect areas near the coast, but those areas that are well equipped with resources and capacity to counter the impacts of sea level rise will be less affected. Thus, while the above risks are representative of the UAE, site-specific assessments are advised in the future to fully account for the local impacts.

Evaluating the magnitude and likelihood of impacts

Table 8 presents the magnitude and likelihood of the occurrence of the direct and indirect climate change impacts in the above final list. According to Stage 3 of the risk assessment framework, the magnitude of impacts was examined from three dimensions: economic, social, and environmental, whereas the likelihood was assessed based on the estimated chance that the impact may occur in the future. The combined assessment of magnitude and likelihood results in the determination of the risk level of the impacts.

Table 8. Evaluation of magnitude and likelihood of impacts

Impact	Magnitude			Likelihood	Risk level
	Econ	Env	Soc		
1. Damage to and deterioration of transportation infrastructure	Very large	Moderate	Large	Very likely	Medium
2. Damage and/or disruptions in water, sanitation, and waste management facilities	Very large	Moderate	Large	Very likely	Medium
3. Damage to and deterioration of building infrastructure	Very large	Large	Very large	Likely	Medium
4. Damage to coastal and offshore infrastructure	Very large	Very large	Very large	Very likely	High
5. Increased infrastructure maintenance costs	Very large	Small	Very large	Almost certain	High
6. Decreased available space for infrastructural development	Moderate	Moderate	Moderate	Likely	Low
7. Increase in frequency and severity of hazard to infrastructure	Very large	Very large	Very large	Likely	Medium
8. Loss of business opportunities due to transport disruptions	Very large	Small	Very large	Almost certain	High
9. Displacement of the population residing within the coastline	Moderate	Moderate	Very large	Very likely	Medium
10. Increased flooding in urban areas	Very large	Moderate	Large	Likely	Medium
11. Decreased access to services and economic opportunities	Very large	Moderate	Very large	Likely	Medium
12. Reduced reliability of transport infrastructure and buildings	Very large	Small	Very large	Almost certain	High

In line with Stage 4 of the risk assessment framework, four priority risks are identified as "high": a) damage to coastal and offshore infrastructure; b) increased infrastructure maintenance costs; c) loss of business opportunities due to transport disruptions; and d) reduced reliability of transport infrastructure and buildings. These interrelated risks are considered as priority risks and will be the focus of succeeding discussions of this report.

- **Damage to coastal and offshore infrastructure.** The socioeconomic impacts of this risk are considered "very large" since 85% of the population and more than 90% of infrastructure in the UAE are closely located in low-lying coastal areas. Moreover, heavy rainfall can bring about flash flooding, particularly along wadis in the eastern part of the UAE.[41 42 43] In places where drainage infrastructure is weak, the frequency, extent, and risk associated with urban floods can increase significantly.[44] In terms of environmental impacts, reclamation, dredging, and oil-related activities affect the coastal areas and may endanger natural ecosystems.[45]

- **Increased infrastructure maintenance costs.** This is especially true when the infrastructure is not built for elevated temperature, rising humidity, sea level rise, and extreme events expected with climate change. As infrastructure deteriorates with age, the annual cost of corrosion globally is estimated to exceed USD 1.8 trillion, which translates to 3–4% of the gross domestic product (GDP) of industrialized countries.

- **Loss of business opportunities due to transport disruptions.** Disruptions in aviation transport service alone due to climate-induced events can have economic repercussions. In Dubai, for example, the aviation industry represents 28% of the total GDP, contributes USD 22 billion annually, and generates 250,000 jobs."[46] Climate-induced disruptions to transport services in the Middle East are also caused by frequent dust and sandstorms, particularly during the dry summer months. The primary source in the UAE, sometimes known as "heat cyclones," is the Empty Quarter (Rub' al Kali). Cooler winter mornings can also bring reduced visibility due to fog,[47] causing disruption and more road accidents.

- **Reduced reliability of transport infrastructure and buildings.** Although there are no data on the direct impacts of extreme events on the reliability of transport infrastructure, stakeholders noted that during extreme sandstorm events, road and ocean accidents occur, causing prolonged traffic and more accidents. According to a study that examines the variability of poor visibility events in the UAE and their relationship to climate dynamics, Fujairah city has the highest visibility under wet weather conditions, while Abu Dhabi city has the lowest visibility under both wet and dry conditions.[48] Moreover, fog and dust are considered major factors behind visibility deterioration in the UAE and that the effects are larger in Abu Dhabi than in Dubai. In both cities, the frequency of fog and dust events have been steeply increasing.[49] These incidents pose challenges to the responsiveness of transportation infrastructure during extreme events. As for buildings, extreme events can push less resilient building materials to their limits. For example, some high-rise buildings in the UAE are covered in aluminum composite panels, a less expensive material preferred by developers. While this choice does not compromise aesthetics, the thermoplastic core between two aluminum sheets is flammable and thus poses a higher fire risk.[50]

Other impacts fall under "medium" risks, which may be relatively acceptable in the short term, but a thorough investigation is necessary to implement control measures to minimize the risks so that the "medium" risk level will not turn into "high." The impacts with "low" risks require sporadic monitoring to determine changes in the situation which may affect the risk level. Figure 6 provides a visual way to understand and communicate the results of the assessment by plotting all impacts in a 5-by-5 risk matrix.

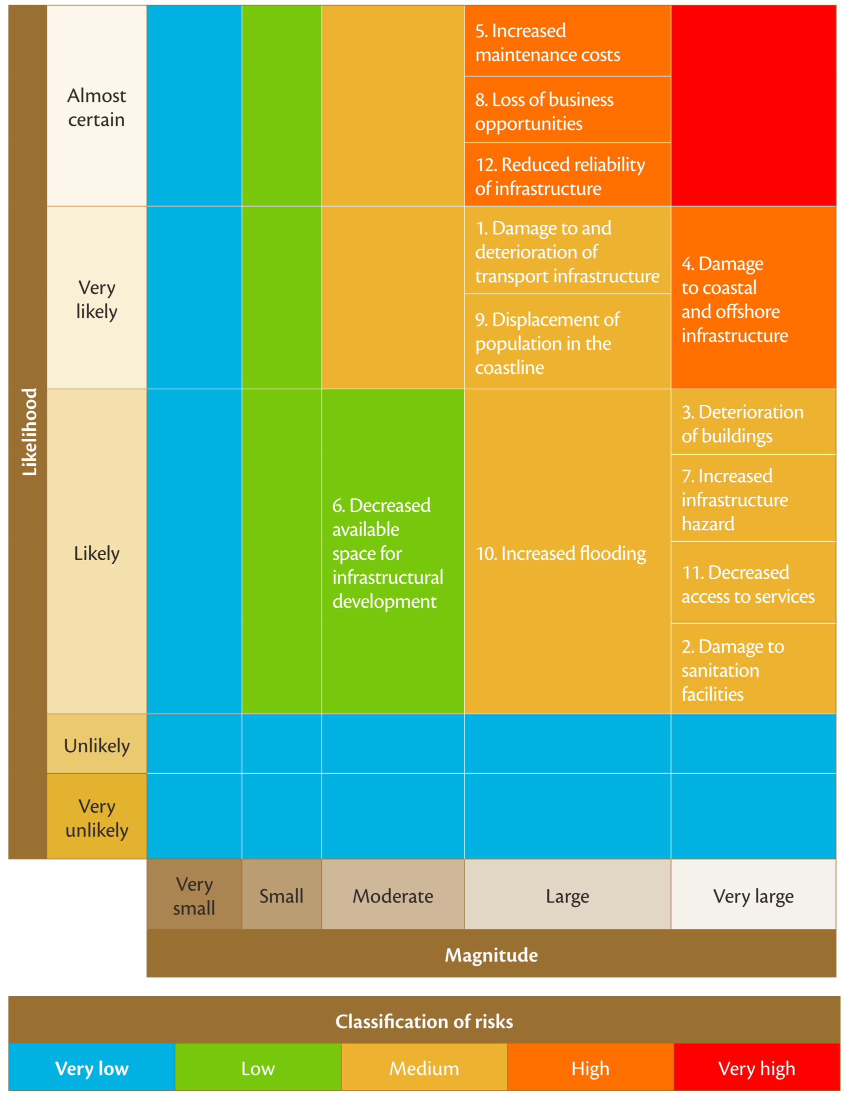


Figure 6. Risk matrix for the infrastructure sector

3. Options for Action

3.1. Initiatives on climate adaptation in the infrastructure sector

This chapter applies Stage 5 of the risk assessment framework to elaborate on potential actions to address the priority risks identified in the previous chapter. In providing recommendations, it is important to acknowledge existing initiatives relevant to climate change adaptation in the infrastructure sector. This will help identify the gaps and explore the opportunities to address them.

Measures for climate change adaptation can be generally classified into four types[f]:

- **Physical safeguards** refer to engineered structures, technological systems, and services, as well as ecosystem-based infrastructure, that support adaptation objectives.
- **Risk management** covers the regulations, incentives, and financial mechanisms, as well as early warning systems and emergency plans, that directly address climate risks.
- **Knowledge** encompasses climate data and research, risk assessment, and awareness campaigns and communication.
- **Enablers** are foundational policies not directly targeting adaptation but providing an enabling condition for improving resilience.

Tables 9–12 show examples of climate actions that are relevant to addressing the priority risks identified in the previous chapter according to the four categories. The list is not exhaustive and only intends to provide illustrative examples.[g] The measures include both options directed to address the risk itself and those that could compensate or offset the risk and help build resilience. MOCCAE recommended a list of measures based on the results of the risk assessment and existing initiatives.

(f) This typology of adaptation measures is consistent with the IPCC categories (structural/physical, social, and institutional adaptation) and the World Health Organization adaptation measure taxonomy (risk management, information, and foundations).
(g) Most of the recommendations focus on either continuing current efforts or addressing the challenges through new initiatives in line with international best practices. Some measures may require collaboration across authorities due to the inter-sectoral nature of adaptation initiatives. Note that the associated costs of the proposed measures are not considered as it is beyond the scope of this report and separate analyses are required.

Table 9. Potential adaptation measures for "high" risk (a)

Type of measures	Damage to coastal and offshore infrastructure	
	Existing measures	Additional measures
Physical safeguards	• Dubai's Realtime Coastal Monitoring; Coastal Zoning in Abu Dhabi • National Blue Carbon Project[h] • Abu Dhabi's Blue Carbon Demonstration Project • ADNOC's Artificial Coral Reef Deployment Project and Seagrass Plantation	• Expand existing coastal monitoring programs. • Intensify current mangrove and seagrass restoration activities, complemented by beach nourishment projects. • Establish coastal setbacks and expand building of flood and storm surge defense structures, such as seawalls, dikes, or levees. • Retrofit offshore infrastructure to withstand Category 5 cyclones. • Improve drainage systems to increase capacity to cope with increased rainfall intensity. • Consider relocating critical facilities, such as hospitals or water treatment plants and pumping stations, to higher elevations, if necessary.
Risk management	• Storm Response Plan • Other emergency- and disaster-related plans	• Expand insurance schemes to mandatorily include climate-induced damages to coastal and offshore properties. • Enhance design and construction standards for coastal buildings and offshore platforms to withstand impacts of climate change.
Knowledge	• Public awareness campaigns on coastal management • Knowledge-sharing and capacity-building activities on coastal management	• Promote situational awareness about infrastructure in coastal communities to enable the development of community-based solutions. • Consider introducing coastal resilience into the educational curricula, particularly in schools with proximity to the coastline. • Intensify research on the response of coastal wetlands to various categories of climate-induced extreme weather events (e.g., how wetlands act as buffers to storm surge). • Develop coastal asset training programs for urban planners, architects, and government planning officials.
Enablers	• Abu Dhabi's Coastal Development Guidelines • Plan Abu Dhabi 2030 — Urban Structure Framework Plan[i] • Other land use and zoning plans for coastal areas	• Consider developing a national coastal zone management program (e.g., coastal restoration, expansion of protected areas, etc.). • Introduce economic incentives and/or regulations to discourage coastal settlements, and integrate coastal ecosystem conservation into business models. • Review property valuation by including the value of coastal ecosystems and its rehabilitation costs. • Expand adoption and development of ISO-level standards for coastal environmental management. • Integrate ICT emergency plans in crisis and emergency management plans to ensure continuity of service during extreme events.

(h) Mangroves provide coastal protection against natural hazards, such as storm surge, coastal erosion, and tsunami. They also contribute to stabilizing the coasts and build-up of soil in response to sea level rise.
(i) The Abu Dhabi Urban Planning Council developed the Plan Abu Dhabi 2030 — Urban Structure Framework Plan, which provides conceptual guidance for the city's future expansion and development, covering the issues of environment, land use, transportation, and open space. This plan facilitates climate-smart urban planning by considering the interlinkages of these issues in the context of climate change adaptation.

Table 10. Potential adaptation measures for "high" risk (b)

Type of measures	Increased infrastructure maintenance costs	
	Existing measures	Additional measures
Physical safeguards	• Infrastructure modernization projects (e.g., Abu Dhabi's Strategic Tunnel Enhancement Program (STEP))	• Expand modernization projects, including equipment upgrade at building, wastewater, and transport facilities. • Upgrade and reinforce existing infrastructure to ensure stability during extreme events.
Risk management	• Risk insurance schemes for infrastructure	• Explore risk-sharing mechanisms that can cover repair and maintenance for multiple infrastructure categories.
Knowledge	• Relevant public awareness campaigns • Relevant knowledge-sharing and capacity-building programs	• Expand existing educational, informational, and behavioral campaigns to keep stakeholders abreast of the implications of climate change to infrastructure. • Strengthen research on how climate change affects infrastructure maintenance costs.
Enablers	• Relevant regulatory measures for design standards and refurbishment of facilities	• Explore public-private partnerships to cover deficits in infrastructure maintenance cost. • Expand quality assurance protocols for certain types of facilities. • Develop regulatory measures for implementing higher standards in designing facilities or in refurbishing existing infrastructure.

Table 11. Potential adaptation measures for "high" risk (c)

Type of measures	Loss of business opportunities due to transport disruptions	
	Existing measures	Additional measures
Physical safeguards	• Transport type diversification • Enhanced emergency services for oil and gas offshore infrastructure	• Consider expanding intermodal downshift[j] for all the emirates. • Implement transport redundancy,[k] such as those for the ports and rails of the United Kingdom. • Enhance design and construction standards for air, land, and water transportation systems to withstand impacts of climate change.
Risk management	• Storm Response Plan • Other emergency- and disaster-related plans • Relevant risk insurance policies	• Encourage businesses to leverage their insurance policies to account for climate change-induced risks to their supply chains, locations, and ability to deliver goods and services.
Knowledge	• Relevant public awareness campaigns • Relevant knowledge-sharing and capacity-building programs	• Enhance collaborative network between businesses and transportation authorities to exchange information on engineering and non-engineering aspects of the linkages between climate change and the transport system.
Enablers	• Relevant contingency and disaster-related plans (e.g., Business Continuity Guidelines of the National Emergency Crisis and Disaster Management Authority)	• Develop contingency plans for transport asset failures, which may include "ahead-of-time" contracting for emergency repairs. • Provide incentives to companies to invest in value creation, i.e., investment in revenue-generating opportunities that allow suppliers and consumers to better adapt to the impacts of the changing climate on the transportation systems.

(j) "Intermodal downshift" is the substitution of one form of transportation for another without any delay in the system in the event of emergencies (e.g., aircrafts can be used when rail or road systems are flooded).
(k) According to the U.S. Federal Highway Administration, "transport redundancy" is the "ability to utilize backup transport systems for critical parts of the system that fail." This is extremely critical in developing emergency response and recovery plans and processes.

Table 12. Potential adaptation measures for "high" risk (d)

Type of measures	Reduced reliability of transport infrastructure and buildings	
	Existing measures	Additional measures
Physical safeguards	• Installation of Automated Fog Detection Equipment in Dubai • Smart National Ambulance Initiative	• Expand installation of smart technologies, such as automated fog detection equipment in Dubai. • Implement transport redundancy to allow the possibility of rerouting during climate-induced hazards.
Risk management	• Relevant risk insurance policies • National Early Warning System (Fog)	• Automate national early warning systems at the event of hazards within the transportation and industrial systems.
Knowledge	• Road Safety Awareness Campaign • Dubai Police's Traffic Awareness Campaign	• Incorporate climate-induced hazards in road safety and traffic awareness campaigns. • Conduct regular training to emergency response personnel to ensure that their knowledge and skills on climate-induced hazards are up-to-date.
Enablers	• Road fees and fines • Truck bans • Road User Code in Abu Dhabi	• Strengthen the implementation of road regulations, particularly during extreme events.

3.2. Opportunities and way forward

Climate change adaptation involves reducing risks, seeking opportunities, and building capacity at various levels. Considering the findings from the risk assessment and examination of current initiatives, there are areas of opportunities for scaling up action as well as new innovative approaches. Key long-term strategic directions are the following:

- **Improve capacity in climate data generation, dissemination, and utilization toward enhanced decision-making on infrastructure investments.** There has been some work done in the UAE on climate projections undertaken by research institutes and universities. Still, much work needs to be done on knowledge sharing between the public and private sectors regarding the results of various climate studies in the country. Mobilizing a wide range of stakeholders that include scientists, climatologists, investors, engineers, architects, power and transport utilities, regulators, urban and land use planners, real estate and construction companies, and the like to enhance their capacity to make the best use of climate information in their respective work provides a good entry point to integrating a climate change aspect in investment planning and policymaking in the face of uncertainties.

- **Strengthen the enabling policy framework for infrastructure resilience.** This requires a holistic approach to policy development as infrastructure resilience cuts across a wide gamut of regulations at the international and domestic levels, across different sectors of the economy, different levels of the government, and multiple layers of society covering both the public and private sector domains. In the UAE context, for example, there have been significant efforts in implementing building standards and regulations in line with international best practices. This can be further strengthened by aligning technical standards at the federal and emirate levels and enhancing green public procurement, public-private partnerships, sector-specific standards, and land use planning policies (e.g., environmental impact assessments) in support of climate-smart buildings.
- **Enhance public awareness and understanding of the benefits of climate-resilient infrastructure.** Climate change adaptation for the infrastructure system requires innovative approaches to fill financing gaps. To better understand the benefits of climate-resilient infrastructure, it is important to analyze the costs, trade-offs, and "value for money" of climate change adaptation in the infrastructure sector; communicate the short-term costs and long-term benefits, and estimate the potential financial savings from adaptation; and undertake a comparative analysis of business-as-usual vis-à-vis proactive adaptation scenarios.[I]

- **Forge interagency collaboration on risk assessment of and adaptation in the infrastructure sector.** Considering the interdependencies of infrastructure networks, it is important to enhance inter-sectoral collaboration on risk assessment and adaptation by working with other sectors beyond the infrastructure system, identifying specific actors involved in different responses, and assigning individual roles and responsibilities to promote local ownership of the outcomes.

- **Consider the development of infrastructure resilience guidelines at the federal and emirate levels and encourage private sector entities to develop their own resilience plans.** Mainstreaming infrastructure resilience in development policy involves the development of an overarching strategy at the federal level that can guide the emirates and the private sector to demonstrate the different elements of resilience building through a diversity of approaches and community engagement. This is to acknowledge that vulnerabilities and adaptation solutions will vary based on the location, site, type of infrastructure, geography, and the like.

(I) For example, results from the International Institute for Sustainable Development (IISD)'s Sustainable Asset Valuation Tool (SAVi) on climate stress testing infrastructure projects revealed that climate-resilient infrastructure delivers better value-for-money for both governments and private investors.

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Annex:
Summary of Climate Change Projections

	Global	Regional (Arabian Gulf)	National (UAE)
Temperature	**2046–2065 [A]** • RCP 2.6: 0.4–1.6°C • RCP 4.5: 0.9–2.0°C • RCP 6.0: 0.8–1.8°C • RCP 8.5: 1.4–2.6°C **2081–2100 [A]** • RCP 2.6: 0.3–1.7°C • RCP 4.5: 1.1–2.6°C • RCP 6.0: 1.4–3.1°C • RCP 8.5: 2.6–4.8°C	**By the late 21st century:** 3–4°C [B] **RCP 4.5 [C]** 2050: 1.2–1.9°C 2100: 1.5–2.3°C **RCP 8.5 [C]** 2050: 1.7–2.6 °C 2100: 3.2–4.8 °C	**2060–2079: 2–3°C [D]** **2050: 2.1–2.8°C** **2100: 4.1–5.3°C [E]**
Humidity	By 2100, the combination of high temperature and humidity is expected to compromise human activities, including growing food and working outdoors (high confidence). [F]	Heat waves due to high humidity in the Gulf could increase, leading to higher exposure to heat-related diseases. [G]	Humidity changes are greater in the summer months, about 10% greater over the Arabian Gulf, with higher humidity across most of the UAE. [D]
Sea level rise	**2046–2065 [A]** • RCP 2.6: 0.17–0.32 m • RCP 4.5: 0.19–0.33 m • RCP 6.0: 0.18–0.32 m • RCP 8.5: 0.22–0.38 m **2081–2100 [A]** • RCP 2.6: 0.26–0.55 m • RCP 4.5: 0.32–0.63 m • RCP 6.0: 0.33–0.63 m • RCP 8.5: 0.45–0.82 m	**Predicted sea level rise scenarios for the Southern Arabian Gulf by 2099:** • Low scenario: 0.21 m [H] • Medium scenario: 0.59 m [A] • High scenario: 0.81 m [I] • Extreme scenario: 2.0 m [J]	**According to different sources, all coastal cities in the UAE will experience progressively increasing inundation:** • Sea levels increasing by 20–30 cm in the coastal shallows of the UAE. [K] • Sea level rise may advance landward flooding at a rate of 23–58 m per year and result in flooding 2.26–3.81 km from the shoreline by 2100. [L] • In the worst-case sea level rise scenario, inundation may extend to 25–30 km in Abu Dhabi by 2100. [M]
Rainfall	Changes in precipitation will not be uniform. [F] It is likely that the frequency or proportion of heavy rainfalls in total precipitation will increase. [N]	By the end of the 21st century, there is a reduction of the average monthly precipitation reaching 8–10 mm in the coastal areas of the Arab Domain. Some areas, however, show increasing precipitation trends. [C]	Rainfall in the UAE will likely increase, especially in the summer (50–100% in the Northern Emirates and Dubai, and 25% in surrounding regions). [D]
Extreme events	Models project substantial warming in temperature extremes by the end of the 21st century. It is likely that the frequency or proportion of heavy rainfalls in total precipitation will increase. [K]	Being in the domain of the monsoon system, the southern part of the Arabian Peninsula is expected to receive more precipitation in the form of extreme events, such as when Cyclone Gonu hit Oman in 2007. [N]	An increasing risk for "grey swan" (high-impact) cyclones to hit the UAE is predicted. Albeit a low likelihood, this will have a high impact. [O]

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