Supporting China's pilot on resilient cities:

Key Recommendations for Weihai's 2035 Agenda

GLOBAL CENTER ON ADAPTATION

Ministry of Infrastructure and Water Management of the Netherlands

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Thank you to all involved for your dedication and assistance in enhancing urban resilience in Weihai, Shandong Province, as part of China's pilot 2035 Vision.

IHS
Making cities work

ABOUT THE INSTITUTE OF HOUSING AND URBAN DEVELOPMENT STUDIES (IHS), ERASMUS UNIVERISTY ROTTERDAM

The Institute for Housing and Urban Development Studies (IHS) is the international institute for urban management of the Erasmus University Rotterdam. The multidisciplinary staff of the IHS – comprised of economists, planners, engineers, architects, sociologists, geographers, governance and management specialists – are committed to tackling the complex challenges in cities and work closely together with partners to achieve integrated and holistic solutions.

GLOBAL CENTER ON ADAPTATION

ABOUT THE GLOBAL CENTER ON ADAPTATION

The Global Center on Adaptation (GCA) is an international organization, hosted by the Netherlands, which works as a solutions broker to accelerate action and support for adaptation solutions from the international to the local, in partnership with the public and private sector, to ensure we learn from each other and work together for a climate resilient future.

This document was developed with the generous support of the Ministry of Infrastructure and Water Management of the Netherlands and in partnership with the International Panel for Deltas and Coastal Areas (IPDC).

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ABBREVIATIONS

CCDMF	China Clean Development Mechanism Fund
CDM	Clean Development Mechanism
DDF	Depth-duration-frequency
DRM	Disaster risk management
DSM/DEM	Digital Surface/Elevation Model
EAD	Expected annual damage
FPMs	Full-physics process-based models
GCA	Global Center on Adaptation
GIS	Geographic Information System
IoT	Internet of things
LID	Low Impact Development
MEE	Ministry of Ecology and Environment
MOHURD	Ministry of Housing and Construction
NDRC	National Development and Reform Commission
RCPs	Representative Concentration Pathways
RP	Return period
RPMs	Reduced-physics models
SSPs	Shared Socioeconomic Pathways
NCCAS	National Climate Change Adaptation Strategy

FOREWORD

Climate change poses the greatest threat to our shared future. The risks it brings to hundreds of millions of people are magnified in our world's deltas, where nearly a tenth of the global population resides.

Rising sea levels, intensified storms, and increased flooding threaten infrastructure, agriculture, and livelihoods in these regions. Alert to these risks, China launched a ground-breaking initiative in 2017 to transform pilot cities into models of urban climate resilience.

With 39 pilot cities now part of this crucial adaptation initiative, China's network of resilient cities is in full expansion mode, fortifying their defenses against climate risk and setting a global example for urban sustainable development.

I am delighted that the Global Center on Adaptation (GCA) was able to offer technical support to the development of China's excellent National Climate Change Adaptation Strategy 2035. With a strategy in place, China is taking the necessary steps, making the investments vital to climate-proofing lives and livelihoods.

I am even happier that we are supporting Weihai City, Shandong province, to develop a city-level climate resilience roadmap to guide the city as it produces its resilient city plan. I hope this roadmap would help the other pilot cities under the national program of climate adaptation city pilot in China (气候适应型城市建设项目).

Climate adaptation is a growth agenda and a sustainable development agenda. By building resilient cities, we can pave the way for a more secure and prosperous future for all.

China's leadership will continue to be critical to success in climate adaptation globally. And, as this report demonstrates, GCA will remain a steadfast partner and supporter of China's proactive response to climate impacts on cities in coastal zones.

Patrick Verkooijen

Professor Patrick V. Verkooijen
Chief Executive Officer

EXECUTIVE SUMMARY

In 2022, China released the new and updated *National Climate Change Adaptation Strategy 2035* and in 2023, subsequently recommended the Urban Action Plan for Climate Adaptation. Provinces and cities have been encouraged to develop context-specific Action Plans for climate adaptation. Selected pilot cities are expected to serve as models for the design, planning, and implementation of climate adaptation actions. Weihai city is one of the 39 newest pilot cities in 2024.

This report offers strategic guidance for urban climate resilience planning in Weihai for the period from 2025 to 2035. As a supplementary document to the *Weihai Climate Adaptation Action Plan (2023)*, it aids in the effective implementation and support of climate adaptation efforts in Weihai.

This report highlights the importance of a climate risk assessment and outlines the steps on how to conduct it. Initially, it recommends developing climate projections that focus on critical climate factors such as extreme temperatures, sea level rise, extreme precipitation, typhoons, and snowfall. To effectively map future climate risks, establishing a climate risk database and enhancing numerical modeling skills to simulate various climate risk scenarios is advised. In addition to a hazard assessment, the report suggests that a vulnerability assessment should concentrate on properties, people, and services, as these are the most impacted in Weihai. For example, a building inventory can be created, and vulnerability curves can be formulated using historical data or global data sources, which can then be adapted with expert judgment.

Additionally, spatial planning should align with urban climate adaptation planning. Developing regulations and rules on building codes and rational land use planning for new development areas could be effective measures for spatial adaptation to climate change.

Finally, recovery planning was not highlighted in the *Weihai Climate Adaptation Action Plan (2023)*. This report recommends including disaster recovery plans for different sectors if they become dysfunctional. Financial support is a crucial component of this type of planning. For individuals and industries in high-risk areas, insurance would strengthen recovery capacity, while catastrophic insurance could alleviate the financial burden on the government during recovery efforts.

By integrating these strategic recommendations, Weihai can enhance its resilience to climate-related challenges, ensuring sustainable development and an improved quality of life for its residents. The city's proactive approach will not only safeguard its infrastructure and economy but also serve as a blueprint for other cities striving for climate resilience.

1. INTRODUCTION

1.1. Background

Climate change has become one of the greatest challenges facing humankind. Since 1880, the annual average global temperature has increased by about 0.07°C per decade. Since 1981, the rate of increase has more than tripled, to about 0.18°C per decade. Global warming has irreversibly affected the climate system due to the emission patterns inherent in our economic systems and infrastructure. In fact, over the 35-year period from 1955 to 1990, a global average of five climate-related disaster events per year resulted in losses of approximately US$1 billion. Annual economic losses associated with climate change now exceed $250 billion.

Climate change is increasingly affecting water resources, which have always been a key element underpinning human civilization and economic development. Water is both at the center of the planet's ecological cycle and the cornerstone of economic growth and human progress. It is essential for human health, food production, electricity generation, environmental preservation, and job creation. As climate change intensifies, we will face more extreme weather events, such as floods and droughts, accompanied by a series of gradual changes that will directly affect the quantity and quality of water resources.

Deltas are fertile places where rivers and oceans meet. They play an integral role in the global economy. Home to more than 500 million inhabitants, or about 8 per cent of the global population, deltas are home to many densely populated cities. These deltas are not only important population centers, but also important drivers of the global economy, contributing about 14% of global GDP. However, these specific characteristics of deltas make them highly vulnerable to the impacts of climate change.

China's deltas and coastal areas are critical to socio-economic development. Within the vast territory are key coastal and delta regions such as the Shandong Peninsula, the Yangtze River Delta, and the Pearl River Delta. These areas are home to hundreds of millions of people and make a significant contribution to China's economy. For example, the Yangtze River Delta, encompassing the cities of Shanghai, Hangzhou, and Nanjing, is an economically powerful region that accounts for approximately 20% of China's GDP. Similarly, the Pearl River Delta, with Guangzhou, Shenzhen, and Hong Kong at its core, is a globally important manufacturing and trading center.

China's coastal and delta regions are at high risk of climate change due to their rapid urbanization and economic development. Infrastructure, agriculture, and livelihoods in these areas are at great risk due to rising sea levels, extreme precipitation, and frequent flooding. To proactively address those climate challenges, China's central government launched a groundbreaking initiative aimed at developing selected pilot cities into demonstration zones for climate adaptation and resilience.

Since 2017, the Chinese government has actively promoted the pilot construction of climate-adapted cities, fostering the development of innovative approaches and best practices in the field of climate adaptation. During this period, China has continued to deepen and improve the climate adaptation models of various types of cities, significantly improving the concept and capacity of cities to adapt to climate change. By September 2023, China's Ministry of Ecology and Environment (MEE), together with seven other ministries, issued a circular encouraging more cities to actively respond to and participate in climate adaptation actions. The circular emphasizes responses to various climate risks, such as extreme weather events, sea level rise and water scarcity, and aims to develop effective solutions that can be scaled up and replicated across the country.

The project is supported by the International Panel on Deltas and Coastal Areas (IPDC), which was created by the Ministry of Infrastructure and Water Resources of the Netherlands and works with organizations such as Deltares and GCA. IPDC's core strategy is to promote climate-resilient development in deltas, coastal areas, and small islands. To this end, IPDC actively promotes international cooperation and partnership building, while also developing and sharing advanced knowledge and technology on climate risk and resilience building. Further, IPDC provides scientific advice and expert guidance to policymakers, sharing best practices, investment opportunities, and guidance on financing strategies.

1.2. China's experiences on climate adaptation

China puts equal emphasis on adaptation and mitigation to climate change. It has placed great importance on climate change adaptation efforts and proposed an active national strategy to address climate change since 2007. For example, China incorporated climate change adaptation into its national economic and social development plans in the 12th Five-Year Plan (2011–-2015). In addition, China published the *National Climate Change Adaptation Strategy (2020)* and *Adaptation Strategy (2035)*, aiming to promote the strengthening of adaptation actions in key areas and regions, and continuously enhance its ability to adapt to climate change.

The *Adaptation Strategy 2035* is based on an in-depth assessment of the risks posed by climate change and the foundations, challenges, and opportunities of climate change adaptation efforts. It clearly defines the basic principles for climate change adaptation, which are "proactive adaptation, prevention first; scientific adaptation, conforming to nature; systematic adaptation, focusing on key areas; and coordinated adaptation, joint governance." The strategy proposes key tasks such as enhancing climate change monitoring, early warning systems, and risk management; improving the ability of natural ecosystems to adapt to climate change; strengthening the adaptive capacity of economic and social systems; and establishing a regional framework for climate change adaptation. It outlines a comprehensive plan for climate change adaptation from now until 2035 in three stages (2025, 2030, and 2035), providing a strategic basis and guidance for future climate change adaptation efforts.

The *Adaptation Strategy 2035* includes four new key points: 1) Enhance early warning and monitoring systems, and risk management; 2) An "urban and human settlements" dimension added within the economic and social systems; 3) Integrate climate change adaptation with national spatial planning; and 4) Promote mechanism development and cross-department collaboration. A summary report on the achievements of China's climate change endeavor (UNFCCC, 2022) points out that China intends to take proactive actions to adapt to climate change, which includes taking action in key areas (namely, cities, coastal erosion areas, the Qinghai-Tibet Plateau, and other ecological areas) and key fields (namely, agriculture, forest and grasslands, water resources, infrastructure, and public health).

To specify and implement the *National Climate Adaptation Strategy 2020*, China issued the *Urban Action Plan for Climate Adapation* in 2016 and published 28 pilot cities on climate adaptation in 2017. However, challenges remain, such as insufficient awareness of climate risks, incomplete working mechanisms, the necessity of increased resource investment and action efforts, and the urgent need to enhance adaptive capacity. It is imperative to further deepen pilot projects for climate-adaptive city construction to explore and summarize pathways and models for building climate-adaptive cities. This will improve urban climate change adaptation and contribute Chinese solutions to actively advancing the global climate change adaptation process.

In 2024, MEE together with other Chinese ministries published another 39 pilot cities and districts, aiming to strengthen climate risk assessment, improve implementation action plans, and refine key tasks and responsibilities. Weihai city was selected as one of the pilots because of its representative coastal geographic location and great achievements on climate adaptation in the past.

1.3. Characteristics of Weihai City

This section offers an overview of Weihai's characteristics and natural conditions in response to climate change, covering geographic, climatic, environmental, and hydrological conditions, as well as economic factors. Additionally, the climate adaptation planning in Weihai will be presented.

1.3.1. Geography

Weihai, positioned at the easternmost tip of the Shandong Peninsula, is enclosed by the Yellow Sea on its northern, eastern, and southern borders, spanning a total area of 5,797 square kilometers and holding a population of 2.9 million (Weihai Statistics Bureau, 2023). The urban center covers 777 square kilometers and is home to a registered population of 656,000. It shares its western boundary with Yantai and is bordered by the sea to the east, separating it from the Korean Peninsula and Japanese chain islands.

With a coastline stretching 986 kilometers, Weihai is a pivotal center for diverse industries, including manufacturing fishing gear, tires, carpets, medical polymer products, printers, and new materials. Additionally, it holds strategic importance as a bustling port city, facilitating trade and maritime activities. Economically, the administrative district of Weihai thrives with its high population and building density. The city comprises a municipal administrative district and three county-level cities: Huancui, Wendeng, Rongcheng, and Rushan (see Figure 1) (Weihai Statistics Bureau, 2023).

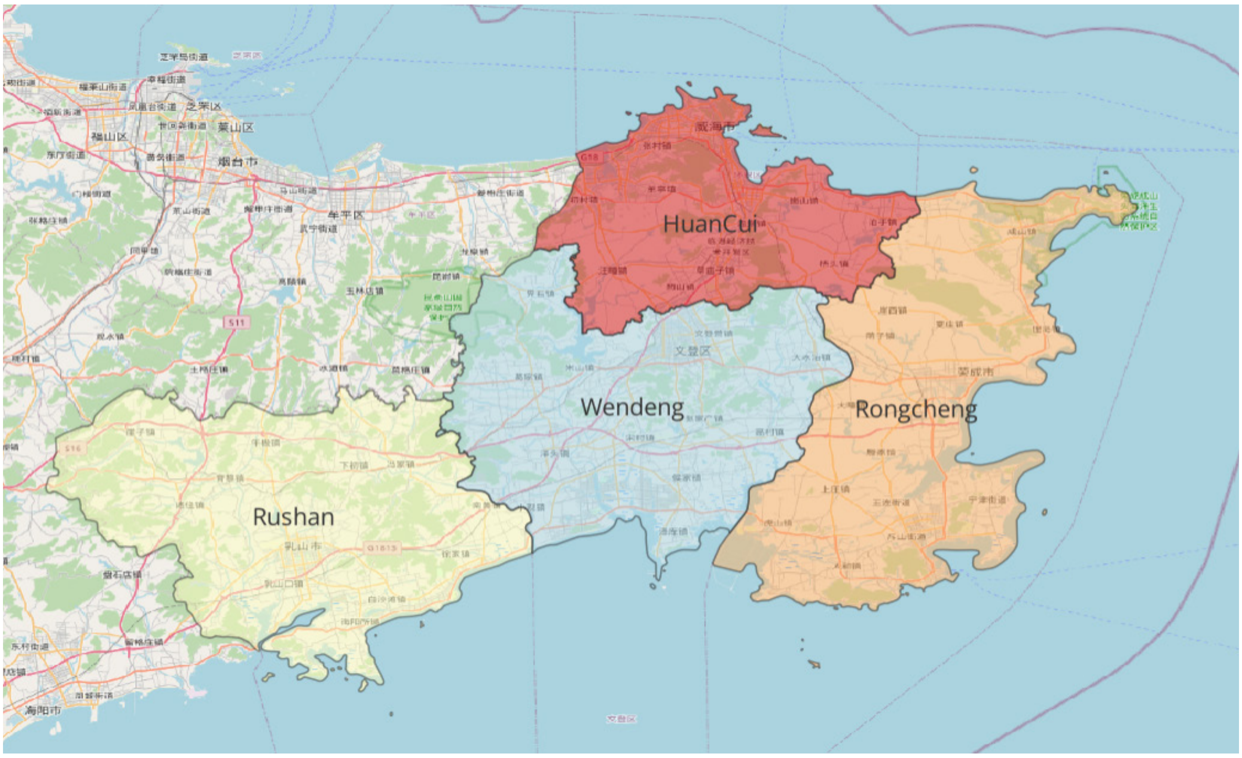

Figure 1: Administrative boundaries of Huancui, Wendeng, Rongcheng, and Rushan in Weihai Municipality

In terms of topography, the elevation of Weihai city ranges from 1.58~912m (See Figure 2). The coastal area within two kilometers from the shore is predominantly flat, with an average elevation of 10–15 meters. Moving inland, the terrain transitions to mountainous regions, with elevations reaching 200 meters. Notably, the flat two-kilometer belt-zone inland from the coast is particularly susceptible to the impact of typhoon storm surges due to its low-lying nature.

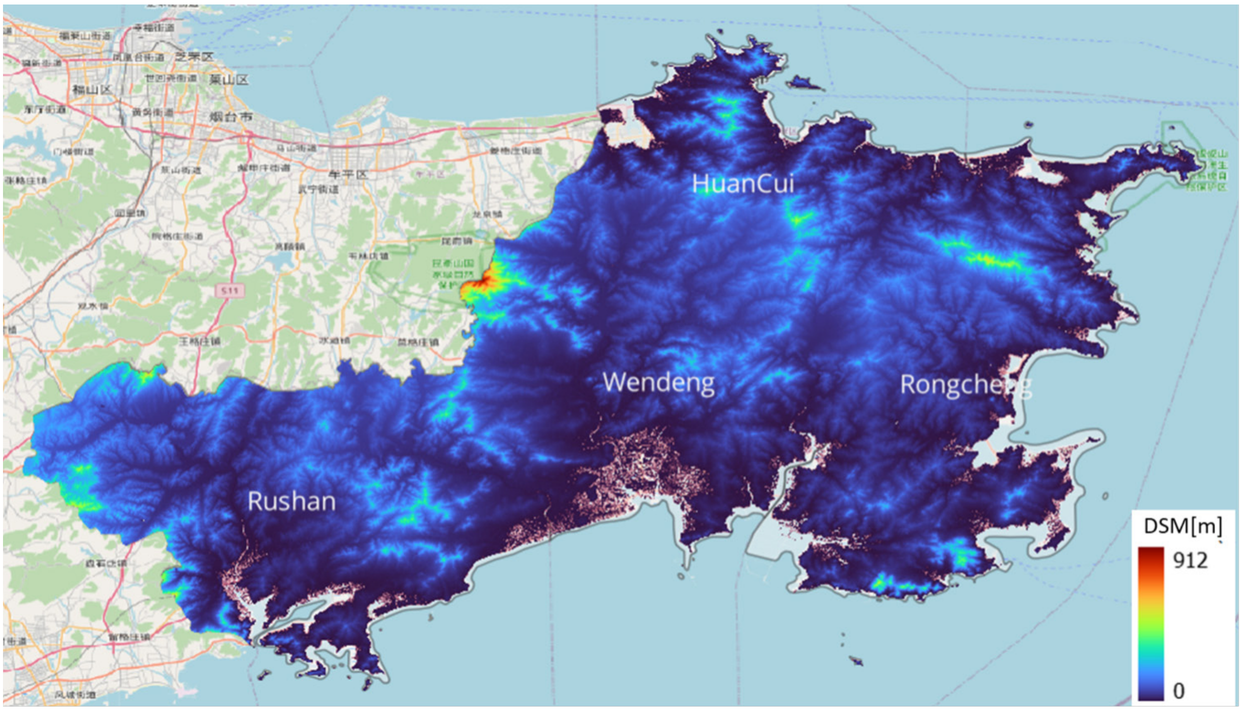

Figure 2: Topography (Digital Surface Model) in Weihai.
Data source: ALOS World 3D - 30m (AW3D30) v. 3.5

1.3.2. Climate Patterns and Environmental Risks

Weihai experiences a temperate monsoon continental climate within the mid-latitude zone, characterized by four distinct seasons and seasonal winds. The city benefits from abundant rainfall compared to other cities at similar latitudes. Influenced by its coastal location, spring brings cold temperatures, while summer remains relatively cool due to the moderating effects of the ocean. Autumn sees a transition with increased activity of cold air masses from the north, leading to variable precipitation patterns (See Figure 3), sometimes affected by typhoons. In the winter, the city experiences dry and cold conditions under the influence of the Mongolian high-pressure system, with prevailing north winds.

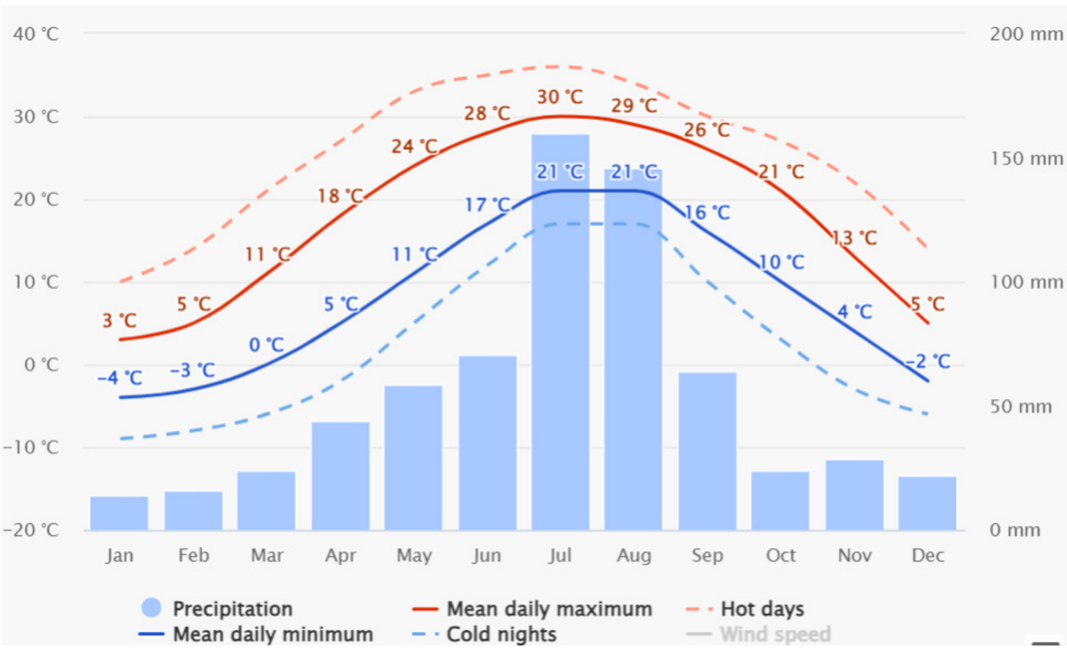

Figure 3: Average temperature and precipitation during the period of 1993 - 2023 in Weihai (datasource: meteoblue)

Weihai has witnessed a notable increase in temperature since the 1970s, with the annual average temperature rising at a rate of 0.26°C per decade. The decade from 2011 to 2020 marked the warmest period on record, accompanied by a trend of decreasing precipitation. Projections suggest that this warming trend will persist into the mid-21st century, escalating risks associated with climate change for economic and social development, as well as people's livelihoods.

A significant event on 26th June 2023, highlighted the vulnerability of Weihai to extreme weather events. Intense precipitation led to widespread flooding, with the entire city experiencing an average precipitation of 77 millimeters over a span of 24 hours. This precipitation exceeded historical records, with the city accumulating 185.7 millimeters of rainfall since the beginning of the flood season—significantly higher than the same period in previous years. Despite a slight decrease in cumulative precipitation compared to the previous year, the city still faced challenges such as waterlogging in low-lying areas, emphasizing the need for robust climate resilience measures to mitigate future risks.

1.3.3. Hydrogeological Profile

According to the hydrogeological zoning of Shandong Province, the Weihai area falls within the hydrogeological region characterized by loose rocks, clastic rocks, and metamorphic rocks in the Lüdong Low Hills. Further division is based on differences in hydrogeological conditions, resulting in sub-regions: the northern slope of the Jiaobei Uplift and the southern slopes of the Jiaonan and Jiaobei Uplifts. Each sub-region encompasses a specific hydrogeological zone, namely the Weihai Low Hills Fracture Aquifer Zone and the Rongcheng-Rushan Low Hills Fracture Aquifer Zone.

Based on hydrogeological conditions such as groundwater conditions, aquifer lithology, and hydraulic characteristics within the area, the aquifer lithology is categorized by porous aquifers in loose rocks and fractured aquifers in bedrock (Liu, 2021). Porous aquifers are predominantly located in foothills and valley edges, composed of gravelly clayey sand with an approximate thickness of 5 meters and groundwater depths ranging from 1 to 3 meters. Typically, individual well yields are below 100 m^3/d. Groundwater quality is generally favorable, characterized by a bicarbonate-chloride-calcium-sodium type, with a mineralization degree of less than 1 g/L.

1.3.4. Natural and Economic Resources

- **Marine Resources:** Weihai is a coastal city with a significant coastline of 985.9 kilometers, making it a vital fishery production base in China. It also serves as a national ship export base with substantial shipbuilding and port handling capacities.

- **Tourism Resources:** The city boasts abundant tourist attractions, including scenic spots like Liugongdao Island and Chengshantou Cape. These attractions attract over 28 million visitors annually, contributing to Weihai's tourism industry.

- **Land Resources:** Weihai has a total land area of 582,200 hectares, predominantly allocated for agriculture (~78%) and construction purposes (~22%). The city has an actual cultivated land area of 162,700 hectares, with the same area designated as permanent basic farmland.

- **Water Resources:** Weihai primarily relies on atmospheric precipitation for its water supply, with surface water resources amounting to 1.068 billion cubic meters and groundwater resources estimated at 629 million cubic meters. However, the city lacks major rivers, relying heavily on rainfall.

- **Mineral Resources:** Weihai is endowed with diverse mineral resources, including energy minerals, metallic minerals, non-metallic minerals, and aqueous and gaseous minerals. These resources contribute to the city's economic development and industrial activities.

- **Biological Resources:** The city possesses abundant marine biological resources, particularly in shallow sea and intertidal zones, with a wide variety of species and significant resource quantities.

- **Natural Protected Areas:** Weihai has optimized its natural protected areas, reducing them to 19, including nature reserves, geological parks, wetland parks, and marine parks, aiming to preserve its biodiversity and ecological balance.

- **Agricultural Economy:** Weihai's agriculture sector plays a vital role in its economy, with a total arable land area of 1638 km2 (Weihai Statistics Bureau, 2023) and numerous agricultural households engaged in farming. The city has implemented various policies and insurance schemes to support agricultural development and ensure farmers' income stability.

1.3.5. Climate adapation planning

In recent years, climate change has emerged as one of the greatest challenges, impacting water-related disasters, economic growth, and urbanization in Weihai. To address these challenges, Weihai has undergone five rounds of urban planning since its founding, focusing on incremental space and urban safety resilience.

The 14th Five-Year Plan for Addressing Climate Change (Weihai Municipal People's Government, 2022), issued on 29th August 2022, serves as a guide for enhancing the city's natural ecological system and economic and social adaptability to climate change. This plan emphasizes optimizing water resource management, enhancing agricultural and health department adaptability, improving urban climate protection capabilities, and strengthening climate forecasting, warning, and emergency capabilities.

Additionally, the Weihai City Territorial Spatial Master Plan (2021–2035) emphasizes water security and infrastructure construction to achieve sustainable development and social stability in the face of climate change. Despite achievements in disaster management and meteorological observation, challenges remain, including unclear division of responsibilities, inefficient working mechanisms, and inadequate accuracy in forecasting and early warning systems. Weihai continues to address these challenges to effectively adapt to climate change, mitigate its impacts on the city's development, and strengthen resilience.

In 2023, Weihai Municipality published its *Climate Adapation Action Plan (2023)*, which clearly stated 20 indicators to meet the overall climate adapation objective in 2025. These indicators are mainly reflected in three aspects: 1) governance system; 2) climate monitoring and early warning, risk assessment, and disaster emergency institutional management; 3) Key actions in climate-risk awareness education, climate-risk reduction (including climate-disaster preparedness and prevention), emergency management, and ecological restoration.

1.4. Objective of this report

The overall objective of the project is to actively support the development of climate-resilient cities in China and to assist in facilitating the effective implementation of China's *National Adaptation Strategy 203*5. Specifically, the project aims to provide technical support to Weihai city to strengthen its resilience in the face of climate change. Through this endeavor, the project aims to catalyze the city to go a step further in planning, designing, and implementing policies and projects that are climate resilient, ensuring that the city can be more resilient, adaptive, and responsive to future climate challenges.

Additionally, this report complements the *Weihai Climate Adaptation Action Plan (2023)* by providing strategic guidance for Weihai's climate adaptation efforts from 2025 to 2035. It focuses on offering guidelines for climate risk assessment and urban resilience planning. Over the next ten years, the key actions outlined in the *Action Plan (2023)* will be progressively refined and detailed.

2. URBAN CLIMATE-RESILIENCE ROADMAP

An urban climate-resilience roadmap is a type of strategic plan that outlines objectives, desired outcomes, and activities to be taken over at specified time frameworks to increase resilience capacity within a region or a system. A roadmap should outline the proposed tasks and priorities for action and allow progress to be monitored and evaluated.

This roadmap report will provide operational guidance on how to plan and prioritize climate adaptation actions and clarify the responsibilities of different departments in Weihai Municipality within a timeframe of 2025–2035. In addition, it also provides recommendations for other Chinese cities faced with similar climate risks.

Climate adaptation guidelines and action plans should be based on an assessment of climate risks, leading to the formulation of a comprehensive, city-wide, and multi-hazard adaptation strategy. Although the *National Strategy (2023)* strongly recommends climate risk assessments for climate adaptation, detailed implementation instructions are lacking, especially since this task requires cross-department collaboration. The following section will outline the steps for conducting a climate risk assessment.

2.1. Climate-risk Assessment

It should be noted that this report will not assess climate risk; instead, it will provide guidance on how to conduct climate risk assessment when data is available. The required data checklist for climate risk assessment is outlined in the Appendix.

First, it is essential to understand the concept of risk, which is often described as a combination of three elements: hazard, exposure, and vulnerability (Bründl et al., 2009; OECD, 2021). According to the Intergovernmental Panel on Climate Change (IPCC),

- **Hazard** refers to the potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources (IPCC, 2021).

- **Exposure** refers to the presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected (IPCC, 2021).

- **Vulnerability** refers to the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC, 2021).

By considering these three elements together, we can better understand and manage risks, develop effective strategies to reduce their likelihood or impact, and improve the overall resilience of systems and communities.

Another concept is climate risk, which refers to the potential for social, economic, or environmental damage due to internally and externally forced climate variability. It covers a variety of hazards, from severe weather events to gradual shifts in climate patterns. These risks can manifest in numerous ways, interrupting businesses, supply chains, infrastructure, and the broader economy. Climate risks serve as a crucial starting point for analyzing potential losses and damages. This report adopts the IPCC's definition of climate risk, which considers it as a function of climate-related hazards, the exposure of people and assets, and their vulnerability to these hazards (IPCC, 2022) (see Figure 4). Where hazards, exposure, and vulnerability intersect, the consequences of climate risks become apparent, affecting lives, livelihoods, health, well-being, ecosystems, social and cultural assets, services (including ecosystem services), and infrastructure (IPCC, 2018). While these impacts can be both negative and positive, this report primarily focuses on the negative impacts.

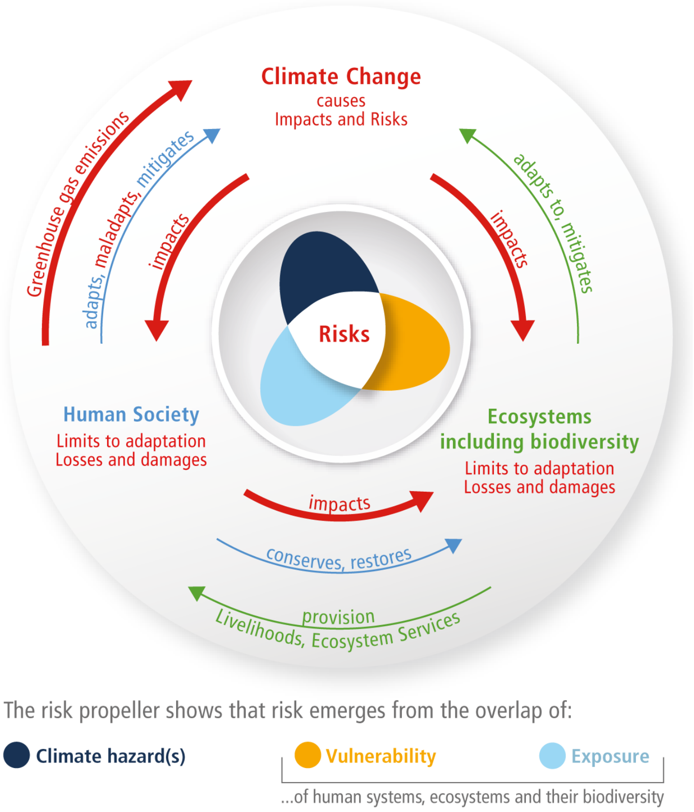

Figure 4: Illustration of intersection and trends from climate risk to climate resilient development (IPCC,2022)

Furthermore, besides precisely understanding climate risk, carrying out a multi-hazard risk assessment is a crucial step in preparing climate adaptation and urban resilience strategy. The assessment process includes two main steps: 1) hazard identification and assessment, and 2) impact assessment. Hazard identification and assessment involves identifying all the potential hazards that can affect the location or system being assessed. Impact assessment involves analyzing the potential adverse consequences, by integrating vulnerabilities and exposures, to those hazards. In addition, climate-risk assessment also involves developing scenarios since the uncertainties of the changing climate, technology advancement, policy changes, and socio-economic development over time are inherent and unforeseen in the future, which will be discussed in the following section.

2.1.1. Climate Projection

This section discusses the necessity of developing a climate projection for Weihai city. At the time of writing, no official report on climate projections for Weihai was found. It was only found that the temperature was observed at the rising rate of 0.26°C per decade, and sea level was rising at the rate of 2.9 millimeter per year over the past 50 years in Weihai city. In the future, it is anticipated that the temperature in Shandong province will continue to rise at the rate of 0.3°C per decade until 2050.

Climate change is a dynamic and uncertain process, as are socio-economic development and humanity's response to climate change. When we anticipate future climate risk, it is essential to consider these dynamic factors and to what extent these changes can affect the risk results. Scenarios can be developed and utilized to help us to understand the plausible future environment. The IPCC proposed different Representative Concentration Pathways (RCPs) and Shared Socioeconomic Pathways (SSPs) scenarios, which account for rising temperature and socio-economic development, respectively. Since technology advancement, policy changes, and socio-economic development over time are inherent and unforeseen in the future, it is difficult to estimate the changing patterns of future climate risk in Weihai. In particular, there remain large uncertainties on how the climate risk will transfer, re-distribute, and evolve. Therefore, future scenario analysis should focus on the integration of local data with global forecasts to tailor responses that are both effective and contextually relevant.

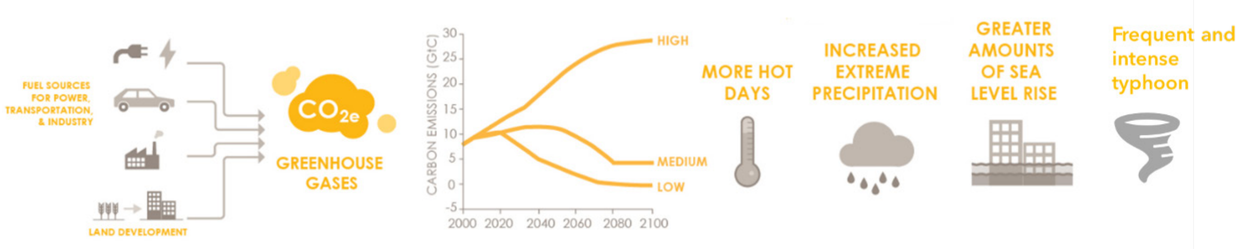

Figure 5: Key climate factors in the future in Weihai: temperature, precipitation, sea level rise and typhoon

With temperatures rising at a rate of 2.6°C between 2011 and 2020, it is projected that this warming trend will continue into the mid-21st century in Weihai. Changes in typhoon climatology are expected to intensify wind speeds and cause higher storm surges and wave setup, posing significant risks to sea dikes and other coastal infrastructures.

On a global scale, Knutson et al. (2010) indicated that precipitation intensity near storm centers is projected to increase by approximately 20% within 100 kilometers due to climate change. Furthermore, studies have shown that the translation speed of tropical cyclones has decreased by 10% globally since 1949, potentially leading to increased rain intensity (Hall and Kossin 2019; Kossin 2018). Consequently, an increasing trend in rainfall volume during typhoon periods in Weihai city is anticipated.

Although a warming trend may not result in more snowfall, the humid amphoteric environment increases the atmosphere's moisture-holding capacity, leading to additional precipitation that may come as snow. Quante et al. (2021) noted that extreme snowfall events are likely to become a more significant impact of climate change in the coming decades. While these events may become rarer, they could remain intense in the latter half of the century.

Therefore, to better understand local climate change impacts, it is urgent to develop a consensus on climate projections for Weihai. This consensus should focus on key climate factors: extreme temperatures, relative sea-level rise, extreme precipitation, typhoons, and snowfall. These factors drive major climate hazards in Weihai, including pluvial flooding, typhoon-induced coastal flooding, hail, and snowstorms.

2.1.2. Climate Hazard Assessment

A climate hazard assessment identifies the probability, intensity, and timescale of the key hazards and their spatial distribution within it, considering the city's historical trends and current situation, as well as future projected scenarios. In this report, we mainly focus on the hazards of pluvial flooding, typhoon-induced compound flooding, hails, and snowstorms in Weihai, which are anticipated to pose potentially severe risks in the future (Weihai Municipality, 2023).

2.1.2.1. Rapid assessment

Due to the limited data and resources available for a comprehensive quantitative climate risk assessment, a rapid method on the estimation of the occurrence probability and intensity of a particular climate hazard is recommended.

The following steps could be considered:

1. **Determine relevant climate hazards**

   Important climate hazards that are potentially relevant for Weihai city are **pluvial flooding, Typhoon-induced compound flooding, hails, and snowstorms**. Other climate hazards such as droughts, heatwaves, thunderstorms, and landslides are regarded as secondary in importance for Weihai.

It should be noted that,

- **Pluvial flooding** refers to flooding caused by high rainfall intensity combined with insufficient drainage capacity in urban areas.

- **Typhoon-induced compound flooding** is caused by the high water level in the ocean due to the co-occurrence of storm surge, high astronomic tide, high wave set-up, and torrential rainfall, which somehow undermine the drainage capacity in the river channel due to the high water level at the estuary.

- **Hails** refer to precipitation in the form of balls or irregular lumps of ice, typically ranging in size from small pellets to larger stones. They are formed during thunderstorms with strong updrafts that carry raindrops upward into extremely cold areas of the atmosphere, causing them to freeze and accumulate additional layers of ice before falling to the ground.

- **Snowstorms** refers to heavy precipitation falling as snow. In December 2023, Weihai experienced an unprecedented blizzard event with a record accumulated snow depth of 74 centimeters in Wendeng district.

2. Estimate the occurrence frequency and intensity

Probability is a term to measure the occurrence of hazard events in a mathematical way, which is calculated based on long-term series of data with the estimated probability distributions to fit in the pattern and by extrapolating the exceedance probability of a given value. Frequency per year can be regarded as the invert value of probability, which shows the likelihood of occurrence of a specific hazard every year. It can be based on scientific datasets, historical, or governmental records supporting this assessment. Annualized frequency can be calculated as the number of historical occurrences of a climate-related hazard within a known period of record (e.g. per year) per geographic area (e.g. in Weihai city) using the following equation (FEMA, 2023):

Annualized Frequency = Number of Recorded Hazard Events / Period of Record

Intensity indicates the severity of the hazard when it occurs. This is usually estimated based on the exposure map of elements-at-risk (population, buildings, infrastructures, land use types, etc.) It can also be estimated based on scientific datasets, historical, or governmental records. For example, the coastal flood in Weihai can be caused by a typhoon-induced storm surge and wave set-up overtopping. The severity due to overtopping and the failure of the flood defense system would be massive to society and the agricultural system. The pluvial flooding caused by torrential rainfall in a short period of time could cause inconvenience to social life and potentially interrupt business and transportation, which can also be regarded as significant.

It is recommended to map the spatial distribution of the frequency and intensity of each climate hazard at district levels. Additionally, to identify hazardous areas more precisely, these spatial maps can be downscaled to a finer scale, such as at the neighborhood level. Figure 6 illustrates the spatial distribution of areas frequently affected by lightning in Weihai. The red areas indicate regions with high lightning frequency, while orange represents medium frequency, yellow signifies low frequency, and green denotes extremely low frequency. Ideally, maps should depict areas with varying lightning intensity. The intensity of lightning can be measured using indicators such as flash density or flash rate. Lightning data serves as a proxy for hail and windshear and is also utilized for derived products such as precipitation estimates or thunderstorm nowcasting (Meteorage, 2015).

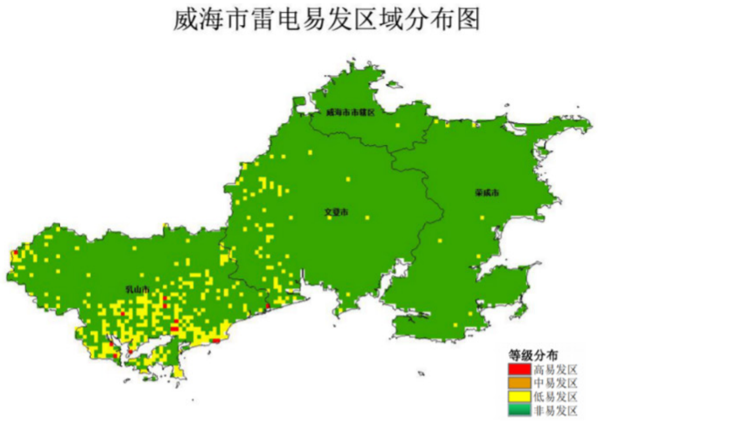

Figure 6: Spatial distribution of areas frequently affected by lightning in Weihai (Weihai Meteorological Bureau, 2024)

Maps depicting the frequency and intensity of climate-related events, particularly pluvial flooding, typhoon-induced compound flooding, hail, and snowstorms, should be developed in Weihai.

2.1.2.2. Advanced assessment

For the **pluvial flooding**, advanced hydraulic models (such as SOBEK1D2D, HEC-RAS, MIKE1D2D, Inforworks) can be considered as the tools to simulate the flow, water level, and velocity and generate flood area in and around Weihai city. The combined 1D-2D and/or Fully 2D will be developed, which depends on available digital elevation model (DEM) and river cross-section. The main input data for the hydraulic model are: 1) Digital elevation model or digital surface model (DEM/DSM) and geometry of river cross-section (if DEM does not include riverbed), 2) Hydraulic structures in the modeled area such as bridges, levees, gates, and culverts will be included in model, if any, 3) Roughness information for the river bed, and 4) Upper boundaries (inflow) will be derived from hydrological models. The model will be calibrated with the observed water level that is available in the river network.

For the simulation of pluvial flooding, the 1D flow model can be coupled with the 2D overland flow model. The 1D drainage pipeline system can be modelled based on the Geographic Information System (GIS) information of drainage systems in Weihai, if it exists. Setting up the model includes data collection on the location and depth of manholes, and the layout, diameter, and materials of pipelines. The 1D drainage model can also be coupled with 2D overland flow model by incorporating surface DEM/DSM. The input data will be the intensity of precipitation as a function of return period (RP) in the study area. For the simulation of the rainfall process, the hydrograph model in the report Planning of Rainwater Drainage in Weihai (2013-2035) can be used. Based on this model the rainfall depth-duration-frequency (DDF) curves can be produced. The RP of rainfall event will be set as 2, 5, 10, 25, 50, 100 to 200 years, for a duration of rainfall of 3 hours, for instance.

For **typhoon-induced compound flooding**, the simulation of coastal inundation is a final consequence of high water levels from extreme or combined hazards such as precipitation, run-off, storm surge, high spring tide, and wave run-up. Leijnse et al. (2021) identified three approaches to simulate coastal flooding: simple models, reduced-physics models (RPMs), and full-physics process-based models (FPMs). A typical way to execute simple flood modeling is through the combination of large-scale hydrodynamic models (e.g., global models; Verlaan et al., 2016; Kirezci et al., 2020) and the static bathtub approach, also regarded as a GIS-based approach. This approach calculates the water depth and flood extent based on the overlaying of inland elevation with extreme water levels (e.g., tide, wind-driven surge, and wave-driven setup). This approach demands low computational cost while coming at the expense of very low accuracy due to omission of dynamic hydrodynamic processes. Conversely, FPMs and RPMs can capture (all) relevant hydrodynamic processes, resulting in a more accurate flood characterization, at the expense of requiring detailed datasets and experienced modelers to set-up and calibration, which largely increases computation cost (Van Dongeren A. et al., 2013; Giardino A. et al, 2018).

Utilizing the above-mentioned advanced models requires sophisticated data. A checklist of detailed data requirement on climate risk assessment is shown in the Appendix. This table has been modified according to the C40 Data Checklist for a Climate Risk Assessment, adapting it specifically for the Weihai context.

Figure 5 shows the spatial distribution of risk levels based on the topographic information in Weihai (J. Liu et al, 2016). Areas shaded in blue, indicating the highest risk level, are those most susceptible to typhoon-induced flooding. These zones are primarily situated in low-lying coastal regions.

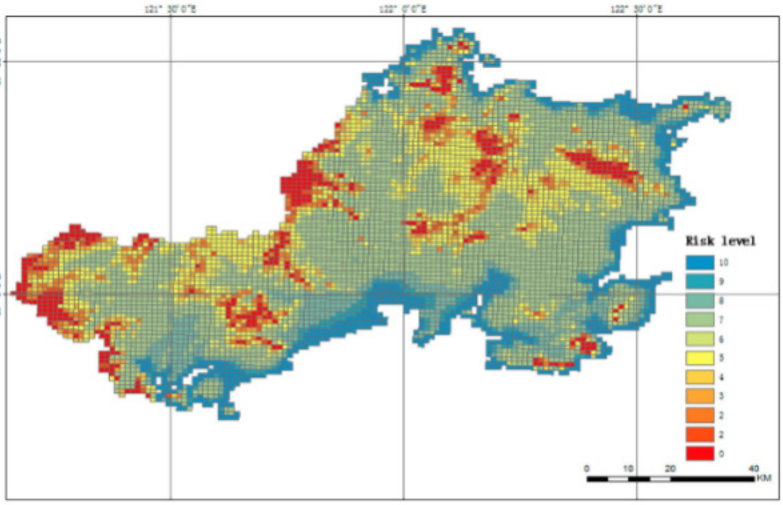

Figure 7: Spatial distribution of risk level based on elevations in Weihai (0 indicate high elevation with low risk, 10 indicates low elevation with high risk) (J. Liu et al, 2016)

Level	10	9	8	7	6	5	4	3	2	1	0
Height/m	1.58–7	7–16	16–35	35–60	60–81	81–100	100–116	116–135	135–157	157–180	>180

2.1.3. Climate Impact Assessment

A climate impact assessment examines the potential impacts of those climate-related hazard events on **properties, people, and services**. Table 1 shows a proposed list of impact categories which should be considered in a climate risk assessment. The impact assessment should identify: 1) tangible and economic loss on different properties (e.g. buildings, infrastructures, and agriculture), 2) the potential impact on the people, and 3) the indirect impact on social convenience and the economy. It is proposed to assess the impact, in terms of the loss of the elements-at-risk, by combining their exposed assets and vulnerability curves. The impact can be evaluated using Equation 1.

$$Impact = \sum_{i=1}^{n}(E \times V)$$

Equation 1

where Iimpact is the loss of the elements-at-risk; E is refers to the exposed assets; V is the loss rate of the elements-at-risk at different severity levels of hazard, (for instance, the inundation depth intervals or velocity intervals for flood events); and i is the grid cell number in the raster format of the exposure map. The cumulative loss of elements-at-risk then will be estimated by this equation.

In the end, risk can be represented as a curve plotting all scenarios with their RP or probabilities and associated losses, which can be used to calculate the expected annual damage (EAD).

Table 1: Proposed impact categories in climate risk assessment

Climate impact category	Sub-category	Item	Description
Properties	Buildings	Structural damage	Direct physical damages include the destruction and degradation of buildings and infrastructure as a result of coastal flooding, strong wind, and hails, and are quantifiable as monetary losses
		Content damage	
	Infrastructure	Structural damage	
	Agriculture	Crop land Fruit land	
People	Fatalities and injuries	Number of loss of lives	People who have lost lives and been injured during climate-related disasters, such as a storm surge event
		Number of injuries	
Services	Business service interruption	Loss of employment	Associated income lost as a result of an event that disrupts the operations of the business or the removal of a piece of real estate, both rental and sale properties, from the market as a result of disaster impacts
		Output loss	
	Social service interruption	Social inconvenience	Qualitative description on the cost of displacement, disrupted daily routines, health risks, and impaired access to essential services, impacting overall community well-being

2.1.3.1. Properties

Physical damage on properties is an important component caused by flooding and other climate-related disasters, such as strong wind and hails. It is very common to classify elements-at-risk by land use categories or by different types of buildings (Klijn, Baan et al. 2007) in which the structural and content damage were commonly considered as impact assessment (Kok, Huizinga et al.2004; Ke, 2014).

In Weihai, the vulnerability index under a typhoon-induced storm surge was developed (Liu et al, 2016). The vulnerability score is divided into 10 different levels where the value for areas that never flood is denoted as 0. From the calculation results of the risk level in Weihai, it can be observed that both the urban area of Weihai and the downtown area of Rongcheng (See Figure 8) are the main urban areas located along the coastal line. These areas have high spatial value density and relatively low average elevation; therefore, they are susceptible to storm surge disasters. Consequently, the risk level for both these areas is high. The area where Wendeng county adjoins Rongchen county (See Figure 8) is also extensively affected, but the hazard level is not as high despite the fact that typhoons make landfall frequently in this area and a river flows into the sea here, therefore typhoon storm surges can affect the area relatively far inland along the river. However, because this area is known to be susceptible to typhoon disasters, urban planning specifies that this area should remain as mainly marine culture and coastal wetland; therefore, its spatial value density is quite low.

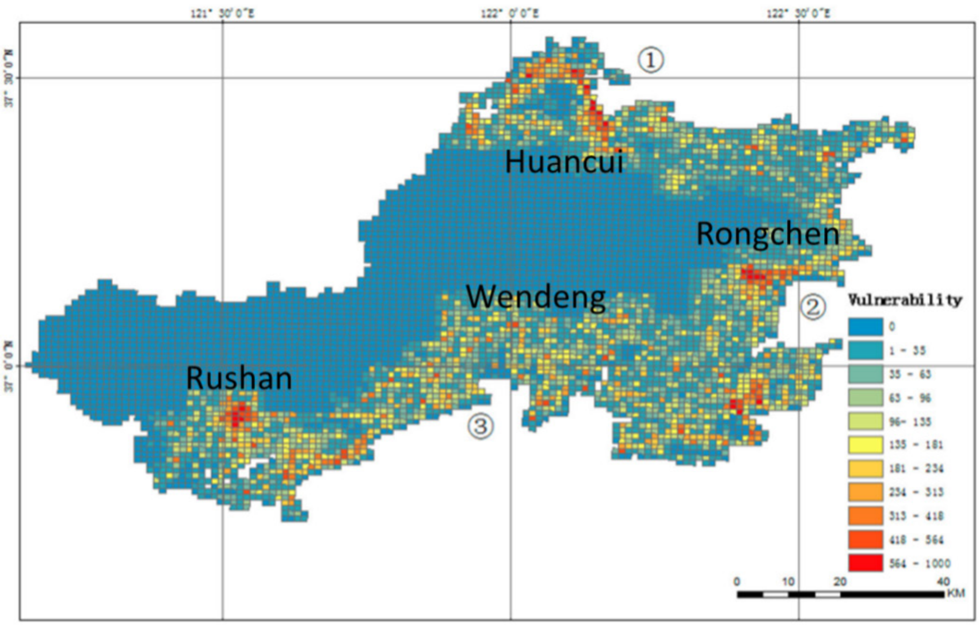

Figure 8: Vulnerability results during storm surge events (adapted from (Liu et al, 2016)

- **Buildings**

  The previously mentioned vulnerability assessments did not incorporate detailed information on the different types of buildings. This means that while the high spatial density of buildings suggests significant potential damage, the resistance characteristics of these buildings were not considered, which can greatly influence the vulnerability results. For example, houses or buildings in informal settlements are more susceptible to flooding than high-rise or elevated buildings. Therefore, it is recommended to compile a comprehensive building block inventory in Weihai. This inventory should include detailed information such as the structure's location, footprint, usage, number of stories, and real estate market value. Based on these characteristics, analysts can develop estimates for building construction and replacement costs, one-time disruption costs, expected contents and inventory, rental rates, and other assumptions needed to understand the potential economic consequences in the climate-related event, such as a flood event. Flood depths at each structure should be cross-referenced with depth-damage functions that provide expected damage ratios and expected displacement times (the number of days the structure is expected to be uninhabitable).

- **Infrastructure**

  Infrastructure refers to facilities and assets that provide a public service to the city and its population. Infrastructure may be publicly or privately owned and operated and include the following (Boston City, 2016), for example:

  - Critical facilities, such as water treatment facilities and generating plants
  - Transportation infrastructure, such as roads, bridges, and public transportation
  - Essential facilities, such as hospitals and emergency operations centers
  - Public facilities, such as schools and civic structures

A vulnerability assessment of infrastructure is also essential. Factors such as age, design, maintenance, location, and existing protective measures against climate-related events should be considered. Besides structural damage, the cascading effects resulting from the failure of critical infrastructure can include widespread service disruptions, economic losses, compromised public safety, and reduced resilience of interconnected systems. Assessing these vulnerabilities helps identify weaknesses and develop strategies to enhance the overall resilience and reliability of critical infrastructure.

- **Agriculture**

  A vulnerability assessment of farmland in Weihai should be conducted due to the potential of intensified hazards of flooding, hails, and snowstorm. Flooding poses a major threat, with heavy rainfall and storm surge, leading to crop submersion, soil erosion, and long-term fertility loss. Hailstorms cause direct physical damage to crops, puncturing leaves and stems, which can result in decreased agricultural productivity and increased susceptibility to diseases. Snowstorms also present serious risks by burying crops under heavy snow, potentially causing physical breakage and impeding growth. Water-resistant and cold-tolerant crops can be identified and promoted to adapt to climate change. By understanding which areas are most vulnerable, targeted climate adapation strategies can be developed, such as implementing protective measures for crops and selecting crop varieties that are more resilient to extreme weather conditions. These will help safeguard agricultural productivity and ensure the long-term sustainability of farming in Weihai.

2.1.3.2. People

Beyond property damage, the population will also be vulnerable to flooding and other climate-related events, which are considered difficult to measure in monetary terms and thus regarded as intangible losses. The most vulnerable groups include seniors over 65, children under 12, and disabled individuals, especially those with mobility challenges. Additionally, people living in coastal areas or working in the fishery industry in Weihai are considered at risk. Flooding from high storm surges during typhoons or dike breaches poses significant threats to their safety. These threats are exacerbated by high inundation levels (e.g., above 1.5 meters) for extended periods or high flow rates in breach areas if there is a dike breach. Safety can also be compromised by electrical shocks during floods or being struck by falling trees during typhoons. Moreover, hailstorms and snowstorms create hazardous driving conditions, leading to transportation accidents due to slippery roads and reduced visibility.

2.1.3.3 Services

Business interruption would be a main aspect of indirect economic damage. Basically, there are two sources of business interruptions due to climate-related disasters, such as flooding and snowstorm. One source is the industries themselves, which causes the production sector to be out of order and unable to meet the requirements of suppliers and customers. Another source is the suppliers, or the customers who cannot easily access the industries due to traffic network interruptions, which affect the production capacity of the industries indirectly. If a producer is affected during a flood, then both those who supply that producer and those who consume the products from that producer will be affected. The cascading effects lead to huge losses in a region if the economic boundary is limited within an area. Because there are other strategies for suppliers and customers to seek equilibrium on their production, they may quit or defer the original choice and divert resources from other users. A case of flooding in Thailand in 2011 demonstrates how business interruption plays a crucial role in flood losses. Owing to the long period of flooding in the area, business interruption was larger than the property damage, with the former accounting for ~125% of the latter.

Another significant effect of indirect damage is the disruption of services caused by the breakdown of bus, subway, and railway stations or the suspension of airport operations. In recent years, numerous reports have highlighted incidents of subway flooding due to heavy rainfall. This underscores the vulnerability of underground spaces and infrastructure to flooding.

In 2017, Weihai Municipality approved a transportation connection system construction plan for the period of 2018–2035, aimed at enhancing the transportation network with links to Qingdao, Yantai, and other cities in Shandong Province. This plan includes the development of subway lines and other railways. Given the susceptibility of these infrastructures to climate-related events, it is crucial to incorporate these vulnerabilities into future urban planning.

By proactively addressing these risks, Weihai can build a more resilient transportation network capable of withstanding the challenges posed by climate change. This will not only safeguard infrastructure but also ensure the continuity of essential services during extreme weather events.

2.2. Strategic Development, Planning and Prioritization

This section elaborates how climate adaptation strategies for Weihai could be developed based on the principle of disaster risk management and resilience planning. It should be noted that these strategies are in line with the proposed strategies in the Weihai Climate Adaptation Action Plan (2023). All the strategies contribute to reaching the main climate adaptation objectives. In addition, in order to provide rational information for decision-makers on strategy prioritization, several criteria have been selected. In the end, the proposed strategies will be sequenced in terms of long-term efficiency.

2.2.1. Guideline and Principles

2.2.1.1. Disaster risk management

According to United Nations Office for Disaster Risk Reduction (UNDRR), disaster risk management (DRM) is the systematic process of using administrative directives, organizations, and operational skills or capacities to implement strategies, policies, and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster. When successful, DRM efforts reduce the effects of hazards, through activities and measures related to **Preparedness, Prevention, Response, and Recovery**.

Using DRM as a guideline for the strategic development of climate adaptation in Weihai is advantageous for several reasons, particularly in enhancing the city's resilience and comprehensive response to climate-related events.

- **Comprehensive framework:** DRM provides a structured framework that both focuses on proactive measures like preparedness and prevention and strongly emphasizes the importance of effective response and efficient recovery strategies. This comprehensive approach is essential because it ensures that all aspects of disaster management, including recovery, are integrated into the planning process.

- **Consider recovery as a planning component:** Although Weihai has taken proactive steps towards adaptation and resilience, the lack of emphasis on recovery planning in existing plans is noted. Recovery is a crucial phase in DRM as it involves not just the immediate restoration of services and infrastructure but also the long-term sustainability of the community and environment. Implementing DRM allows Weihai to develop systematic recovery plans that include reconstruction, redevelopment, and resettlement strategies, ensuring that the city not only survives a climate event but also thrives afterward.

- **Adaptability in uncertainty:** Climate change introduces a significant level of uncertainty in terms of future risks and impacts. DRM guidelines are designed to be flexible, allowing for adjustments as new information becomes available or as circumstances change. This adaptability is crucial for Weihai, enabling the city to adjust its strategies in response to evolving climate conditions and socio-economic dynamics.

- **Enhancing community resilience:** Effective DRM involves the community at every stage of the disaster management cycle. This includes preparing communities for potential disasters, involving them in the response efforts, and supporting them through the recovery process. By using DRM as a guideline, Weihai can ensure that its climate adaptation strategies are not only about protecting physical infrastructure but also about strengthening the resilience of the people within the community.

- **Alignment with global best practices:** By adopting DRM guidelines, Weihai aligns itself with international best practices and standards in disaster management and climate adaptation. This alignment can improve the city's access to global support networks, funding opportunities, and partnerships, which are beneficial for implementing effective climate adaptation measures.

In summary, applying DRM in Weihai's strategic development for climate adaptation ensures a balanced approach that covers all critical aspects of disaster management. It highlights the necessity of recovery plans, enhances adaptability to changing conditions, and fosters a resilient community, thereby creating a robust framework for dealing with the impacts of climate change.

2.2.1.2. Resilience planning

There are many considerations for developing resilience strategies. Communities are shaped by their natural and engineered environments, and many factors influence long-term resilience. Determining what those drivers may be, where there are existing plans that support resilience, and where opportunities exist to improve resilience will be important when establishing a strategy and prioritizing solutions. Common characteristics (Hotchkiss and Done, 2019) used to establish resilient systems include:

- **Avoidance:** This means either taking proactive or implementing reactive measures to reduce the likelihood or impact of threats on a system.

- **Diversity:** This denotes avoiding a single point of failure or reliance on a single solution.

- **Redundancy:** This means including extra components in case of system failure (e.g., backup generators, spare parts for equipment, two electricity lines feeding a site or building).

- **Decentralization:** For energy systems, this means introducing a greater number of small-capacity units that are all connected to the larger energy network or grid to generate energy at a local level, often utilizing onsite renewable energy technologies.

- **Transparency:** This refers to the effective communication of problems or challenges. Transparency makes it easier to determine where a problem may lie; therefore, sharing plans and preparations lets others help find potential gaps in resilience.

- **Collaboration:** This translates to the process of working together to produce or create something effective or useful. In the resilience space, collaboration can help with sharing resources and incorporating creative solutions.

- **Flexibility:** By not anticipating stability, a city can be ready to change when one of the system or critical infrastructure is not working.

- **Foresight:** This involves anticipating change, monitoring conditions to account for change when it occurs, analyzing trends, and identifying emerging vulnerabilities.

2.2.2. Strategies Development

2.2.2.1. Objectives and strategies

In the report Climate Adaptation Action Plan (2023) (Weihai Municipality, 2023), Weihai clearly defined its primary short-term objectives for adapting to climate change. These objectives focus on minimizing direct economic losses and reducing fatalities. When developing new objectives for climate adaptation until 2035, it is important to ensure that these objectives are specific, measurable, acceptable, and aligned with a relevant timeframe. These should also correspond with the strategic directions indicated in Weihai Municipality's fifteenth five-year plan (2026–2030) and the sixteenth five-year plan (2031–2035). The report Shandong Province Climate Adaptation Strategy (2035) clearly states short-term (by 2025), mid-term (by 2030), and long-term (by 2035) objectives in a qualitative way, specifically in the aspects of climate change monitoring and early warning, climate risk management and prevention, and the establishment of a climate-resilient society. They are shown in the below box.

In this report, it is recommended to formulate the objectives focused on minimizing direct economic losses and reducing fatalities, such as:

- To control the annual average mortality rate due to climate disasters to within 0.5 persons per million people by 2025

- To restrict the annual direct economic losses caused by climate disasters to within 1% of Weihai's GDP by 2025

- To maintain the number of deaths caused by climate disasters annually within 0.5 persons per million people by 2035
- To restrict the annual direct economic losses from climate disasters at within 0,8% of Weihai's GDP[1] by 2035

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Shandong Province Climate Change Adaptation Action Plan 2035

By 2025, a policy system and institutional mechanism for climate change adaptation will be basically established. The capabilities for monitoring and early warning of climate change and extreme weather events will continue to improve. The level of impact and risk assessment of climate change will be effectively enhanced. Significant progress will be made in modernizing the prevention and control systems and capabilities for climate-related disasters. Effective climate change adaptation actions will be carried out in key sectors and regions. The regional pattern for climate change adaptation will be basically established. Significant progress will be achieved in pilot projects for climate-adaptive city construction. Advanced adaptation technologies will be applied and promoted, and a social atmosphere where the whole society actively participates in climate change adaptation actions will begin to form.

By 2030, the policy system and institutional mechanism for climate change adaptation will be fully established. A comprehensive system for climate change observation, prediction, impact assessment, and risk management will be in place. The capability to prevent major climate-related risks and disasters will be significantly enhanced. Climate change adaptation actions will be carried out comprehensively across all sectors and regions, significantly reducing the climate vulnerability of natural ecosystems and socio-economic systems. The concept of climate change adaptation will be widely understood and accepted by society. A technical and standard system for climate change adaptation will be basically formed, achieving phased results in building a climate-resilient society.

By 2035, the capabilities for monitoring and early warning of climate change will reach the advanced international level of the time. The system for climate risk management and prevention will be essentially mature, effectively controlling the risks of major climate-related disasters. The technical and standard systems for climate change adaptation will be further improved. The overall ability of society to adapt to climate change will be significantly enhanced, and a climate-resilient society will be basically established.

Table 2 presents the proposed strategies following the principle of DRM to achieve the objectives. Under **Preparedness**, strategies include implementing the Internet of Things (IoT) for data collection and monitoring, employing high-resolution mapping for risk identification including climate projection development, improving forecasting accuracy, establishing early-warning systems, conducting district-wide drill simulations, and implementing risk awareness education initiatives.

In terms of **Prevention**, the focus is on both engineering and non-engineering solutions. Engineering solutions involve increasing drainage capacity, reinforcing sea dikes, and adopting nature-based approaches like sponge city measures. Non-engineering measures include enforcing building codes to mitigate risks. It should be noted that a single solution is not recommended; a combination of engineering and non-engineering solutions should be employed.

1 This is based on formulated objective in 'Weihai City Major Emergency Response System Construction Plan (2021-2030)': http://www.shandong.gov.cn/jpaas-jpolicy-web-server/front/info/detail?iid=ed01241819ec4a5286e49ede3727b7e3

For **Response**, the emphasis is on effective emergency management, including formulating evacuation plans and routes, enhancing the capacity of rescue teams, and ensuring the availability of adequate emergency resources.

For **Recovery**, proposed strategies encompass establishing financial schemes such as individual and collective insurance to facilitate recovery efforts, along with building capacity for post-disaster recovery endeavors.

Table 2: Proposed strategies for climate adaptation in Weihai

Climate adaptation	Proposed strategies
Preparedness	• Internet of things (IoT) – data collection and monitoring • Risk mapping and identification (climate projection, identify risky area with high-resolution maps) • Forecasting (improve efficiency and effectiveness of prediction and forecasting) • Early-warning system (related to forecasting system) • Simulation of drills • Education to raise risk awareness

Prevention	• Engineering (infrastructure and ecosystem-based approach)
	  ○ Increase drainage capacity
	  ○ Strengthen sea dikes
	  ○ Nature-based solutions (sponge city measures)
	• Non-engineering
	  ○ Building code
	  ○ Spatial planning

Response	• Emergency management
	  ○ Evacuation plan and routes on map
	  ○ Capacity building of rescue team
	  ○ Ensure sufficient emergency resources

Recovery	• Financial scheme (e.g. individual and collective insurance) • Recovery capacity building

2.2.2.2. Stakeholder engagement and collaboration

Collaborative efforts among stakeholders are one of the crucial elements of effective DRM and resilience planning. Engaging authorities, communities, NGOs, and other key actors in a concerted effort fosters inclusive decision-making, enhances resource mobilization, and promotes sustainable solutions. To ensure that authorities collaboratively work together, several strategies can be employed, including clear communication channels, trust-building measures, and capacity-building initiatives. By embracing these approaches, stakeholders can collectively develop strategies that mitigate risks, build resilience, and safeguard communities against the impacts of disasters.

- **Identify key stakeholders to grasp their interests, concerns, and priorities**

  Recognize and enlist stakeholders from various sectors, including government agencies (e.g., MEE), Weihai municipalities (e.g., mayor), district heads, community representatives, local emergency response committees, NGOs, academic institutions, and the private sector.

  Generally, alongside international partners such as organizations and prominent programs, there is provision for technical support, knowledge exchange, and funding for climate adaptation initiatives. The National Development and Reform Commission) functions as the central authority overseeing national climate change strategies, with the Ministry of Housing and Construction and MEE assuming crucial roles in policy implementation. Concurrently, the Weihai Municipality, in collaboration with the Environmental

Protection Bureau and Urban Planning authorities, spearheads local endeavors in environmental monitoring and management, while also integrating climate adaptation into local development plans. Moreover, businesses, industries, and research institutions contribute their expertise, technology, and funding to climate resilience projects within Weihai City.

Stakeholders include, but are not limited to:

- **National-level governmental organizations**
  - **National Development and Reform Commission (NDRC):** As the central economic planning agency in China, the NDRC is responsible for formulating and implementing national strategies, policies, and plans for climate change adaptation.
  - **Ministry of Housing and Construction (MOHURD):** Works alongside the NDRC to develop and implement policies related to urban development, construction standards, and infrastructure resilience to climate change.
  - **Ministry of Ecology and Environment (MEE)**: Responsible for environmental protection, including climate change mitigation and adaptation strategies, as well as coordinating efforts with other ministries and agencies.

- **City-level governmental organizations**
  - **Municipality of Weihai City:** Plays a crucial role in implementing national policies and developing local strategies and action plans for climate resilience, adaptation, and disaster prevention.
  - **Environmental Protection Authority:** Responsible for monitoring and managing environmental resources, including water resources, ecosystems, and air quality, to enhance resilience to climate change impacts.
  - **Urban Planning and Development Authorities:** Involved in integrating climate adaptation considerations into urban planning, infrastructure development, and land use policies, such as the Weihai Planning and Design Institute and the Weihai Municipal Natural Resources and Planning Bureau.
  - **District head:** Overseeing the implementation of climate resilience projects and ensuring coordination between various departments at the district level.
  - **Community representatives:** Engaging local communities in the planning process to ensure their needs and perspectives are considered and facilitating grassroots participation in resilience initiatives.
  - **Local emergency response committees:** coordinating disaster preparedness and response efforts, ensuring timely and effective action during climate-related emergencies, and enhancing community resilience.

- **Research institutes and experts:** NGOs, research institutions, and industry experts play a role in raising awareness, conducting research, and mobilizing knowledge input in climate adaptation efforts.

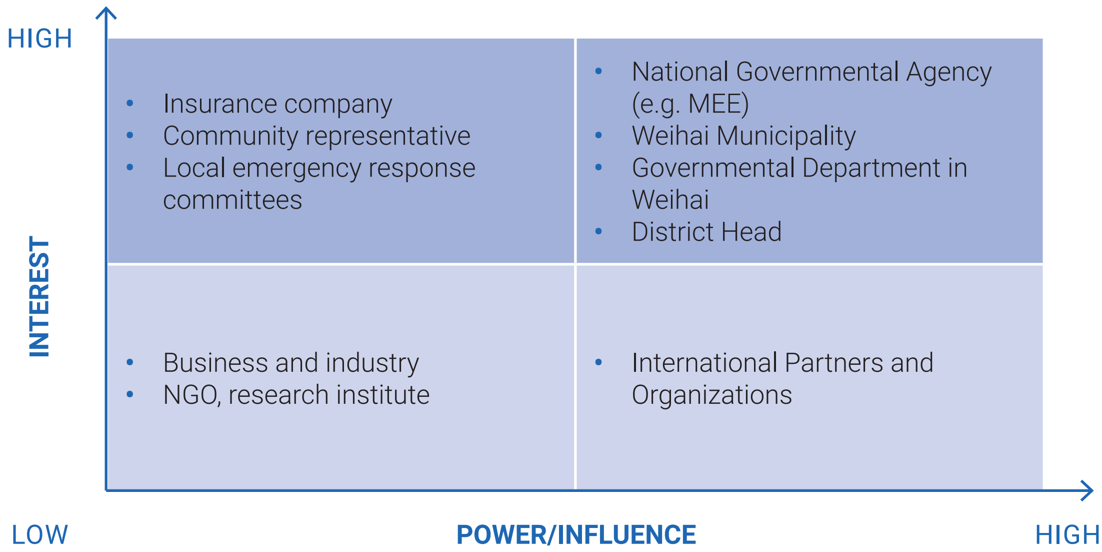
- **Businesses and Industries:** Companies operating in Weihai City, particularly those in sectors vulnerable to climate risks, such as agriculture, fisheries, tourism, and manufacturing, are stakeholders in climate resilience and adaptation actions.

- **International Partners and Organizations:** Foreign governments, international development agencies, and investors may support Weihai City's climate adaptation initiatives through funding, technology transfer, and knowledge sharing. Organizations such as the Global Center on Adaptation (GCA) and the Asian Development Bank (ADB) provide technical support, knowledge exchange, and funding for climate adaptation projects in Weihai City.

- **Map Out Engagement Group:**

  Group stakeholders based on their preferences, availability, and level of involvement. Establish clear communication channels and mechanisms for ongoing interaction and feedback exchange. For instance, email loops, group chats, or online meetings can be set up to meet the needs of different level of involvement.

Figure 9: Stakeholder power-interest grid



- **Develop tailored engagement plan:**
  - **Engagement with national government:**
    - Organizing high-level forums and roundtable discussions to facilitate knowledge exchange and capacity-building workshops on climate adaptation and resilience strategies, and inviting key stakeholders from relevant ministries and agencies
    - Providing technical assistance in the form of policy briefs, expert consultations, and training programs to support the national government in formulating robust policy frameworks and regulatory mechanisms for climate resilience
    - Supporting the establishment of national-level funding mechanisms, including climate finance facilities and risk-sharing mechanisms, to mobilize resources for climate adaptation projects and initiatives
    - Collaborating on joint research projects and data-sharing initiatives to enhance the scientific understanding of climate change impacts and adaptation strategies, aligning with international standards and commitments such as the Paris Agreement
  - **Engagement with local government stakeholders:**
    - Conducting comprehensive assessments of Weihai City's climate vulnerabilities and risks through participatory workshops, stakeholder consultations, and climate impact assessments, in collaboration with local government agencies and academic institutions (all the relevant department sectors)
    - Co-designing and co-creating tailored climate resilience action plans and strategies for Weihai City, based on the outcomes of vulnerability assessments and stakeholder consultations, ensuring alignment with national and provincial adaptation priorities (all the relevant department sectors)
    - Providing capacity-building support to local government officials through training programs, technical workshops, and knowledge-sharing platforms, focusing on topics such as climate risk management, ecosystem-based adaptation, and climate-resilient infrastructure planning (municipality departments, district head, community representatives, and emergency responsecommittee)
    - Facilitating multi-stakeholder partnerships and knowledge exchange initiatives with other cities

and regions facing similar climate challenges, leveraging platforms such as city-to-city learning networks and peer-to-peer exchanges to share best practices and lessons learned in climate adaptation planning and implementation

- **Engagement with private sector and research bodies**
    - Establishing public-private partnerships and innovation hubs to foster collaboration between international businesses, local industries, research institutions, and startups in Weihai City, focusing on developing and scaling innovative climate adaptation solutions and technologies
    - Exploring the potential in joint research projects and technology transfer initiatives to address key climate resilience challenges in priority sectors such as agriculture, tourism, coastal infrastructure, and water resource management, leveraging funding from public and private sources
    - Supporting the development of market-based instruments and financing mechanisms, such as climate insurance schemes and green bonds, to incentivize private sector investment in climate adaptation projects and initiatives in Weihai City
    - Establishing knowledge-sharing platforms and communities of practice to facilitate collaboration on research, innovation, and capacity-building activities, including webinars, workshops, and online forums, to exchange information and expertise on climate resilience best practices and lessons learned

2.2.3. Strategies Selection and Prioritization

Based on the proposed adaptation strategies, a selection and prioritization should be performed. Most often a Cost-Benefit Analysis, Cost-effectiveness Analysis, and Multi-Criteria Analysis can prove useful for ranking and selecting preferred strategies to be developed into concrete actions. The selection criteria often include effectiveness, efficiency, acceptance, equity, flexibility, and urgency (F. Giordano et al., 2022) (see Table 3). Ideally, stakeholders should be involved in assessments in order to include different values and criteria in the assessment. The preferred adaptation strategies should be agreed with stakeholders.

Table 3: Criteria on strategies selection and prioritization

Criteria	Description
Effectiveness	The risk minimization potential, with respect to reducing the probability of occurrence and severity of the hazard, minimizing the negative impact
Efficiency	The (economic and non-economic) benefits gained from the strategy exceed the (economic and non-economic) costs
Equity	The benefits of adaptation strategy equally across society It helps allocate risks in a fair manner in social terms
Flexibility	The strategy can be adapted, revised or upscaled at a low cost
Acceptance	It is culturally, socially, environmentally, and politically acceptable
Urgency	It is needed in case of a high danger of significant impacts in the near future

To further refine the prioritization and management of strategies related to climate adaptation in Table 4, the criterion of efficiency is selected to trade off Resilience Capacity and Resource Intensity. Table 4 shows the results of the prioritization of strategies based on their potential to minimize risk and the intensity of resources required. This allows decision-makers to quickly identify which initiatives and/or strategies should be prioritized, and which can be regarded as strategic investments and routine maintenance, which can be considered as of secondary importance.

Table 4: Prioritization of strategies, based on resilience capacity and resource intensity

Resilience Capacity / Resource Intensity	Relatively Limited Resource Intensity	High Resource Intensity
High Resilience Capacity	**Cost-effective Priorities**	**Strategic Investments**
	Regulations and rules on land use planning and building codes	Internet of things (IoT)
	Early warning and forecasting	Climate risk mapping (including climate projection consensus)
	Emergency management	Engineering construction and maintenance
	Education to raise risk awareness	Environment and ecological restoration
	Simulation of drills	
Relatively Limited Resilience Capacity	**Routine Maintenance**	**Secondary Importance**
		Recovery plan and capacity building on recovery
		Financial scheme on recovery

- **Priority 1:** Strategies that can be implemented in the current adaptation process. This can be considered as a **cost-effective priority**;

- **Priority 2:** Strategies that require additional information, knowledge, and resources before being implemented, such as engineering construction and maintenance, environmental and ecological restoration, and the construction of a monitoring system via meteorological/hydrological observational infrastructures. However, the city may want to explore them as part of the current planning activity. This can be a **strategic investment**.

- **Priority 3:** Strategies that required relatively limited resources while having limited resilience capacity. This can be seen as **routine maintenance**.

- **Priority 4:** Strategies that have implicit impact in a worst-case scenario (for example, an extreme event occurred with massive damage). This can be considered as **secondary importance**.

It should be noted that strategies with multiple benefits can also facilitate the funding of related strategies by pooling resources and putting emphasis on shared benefits that outweigh the investments. In practice, each adaptation strategy performs differently, with multiple conflicting criteria that need to be evaluated and integrated in decision-making.

Ensuring inclusivity and equity in stakeholder engagement efforts is critical to building a resilient and sustainable future for all residents of Weihai City. Prioritizing inclusivity means actively seeking representation from marginalized or vulnerable communities in decision-making processes related to climate resilience. By fostering an inclusive environment that values diverse perspectives and experiences, we can ensure that the needs and concerns of all community members are heard and addressed. This approach not only promotes social equity but also strengthens the legitimacy and effectiveness of resilience initiatives by enhancing community buy-in and ownership.

2.3. Implementation, Monitoring and Funding

2.3.1 Development of action plan

2.3.1.1 Developing potential actions

Twenty-five proposed actions are listed in accordance with the strategies in Table 4. Table 5 presents a comprehensive list of proposed actions associated with climate adaptation strategies and identifies the corresponding stakeholders responsible for leading or supporting these initiatives. The table is structured into several sections, each representing different categories of strategies (e.g., Internet of Things (IoT), risk mapping and identification, forecasting improvements, early-warning systems, etc.). Each strategy includes specific actions, such as updating meteorological observation systems, improving drainage capacity, and enhancing early-warning systems. The potential climate-related disasters that each action addresses are also listed.

It should be noted that Low-Impact Development (LID) actions are not viewed as standalone measures to reduce flood risk. LID encompasses sponge-city measures and nature-based solutions designed to mitigate flooding. However, research indicates that the effectiveness of sponge-city measures is limited during intense, short-duration rainfall events. In extreme events, engineering solutions such as drainage systems and flood defense mechanisms are essential and should primarily mitigate flooding. Despite this, LID measures offer multiple benefits beyond flood mitigation, including water purification, water resource regulation, and enhanced social well-being.

In addition, Table 5 also specifies the departmental authorities responsible for leading and supporting the implementation of each action. For example, the Meteorological and Maritime Bureaus (MMB and MOB) are often listed as leading stakeholders, while other departments like the Water Authority (MWAB) and various management bureaus support these efforts. Furthermore, this table provides the status of each action, indicating whether it is existing or new. This layout allows decision-makers and stakeholders to clearly understand their roles and responsibilities in implementing the climate adaptation strategies and assess the progress of these initiatives.

2.3.1.2 Responsibilities of stakeholders

In order to show an effective and clear roadmap on climate adaptation, it is very important to be clear on the next four points:

1. **What has to be done (actions)**

2. **By whom (city-level authorities)**
   - Municipal Meteorological Bureau (MMB)
   - Municipal Emergency Management Bureau (MEMB)
   - Municipal Science and Technology Bureau (MSTB)
   - Weihai Big Data Center (WBDC)
   - Municipal Natural Resources and Planning Bureau (MNRPB)
   - Municipal Ecological Environment Bureau (MEEB)
   - Municipal Education Bureau (MEB)
   - Municipal Housing and Urban-Rural Development Bureau (MHURDB)
   - Municipal Natural Resources and Planning Bureau (MNRPB)
   - Municipal Water Affairs Bureau (MWAB)
   - Municipal Civil Affairs Bureau (MCAB)
   - Municipal Development and Reform Commission (MDRC)
   - Municipal Bureau of Industry and Information Technology (MBIIT)
   - Municipal Finance Bureau (MFB)
   - Municipal Water Affairs Bureau (MWAB)

- Municipal Agriculture and Rural Affairs Bureau (MARAB)
- Municipal Oceanographic Bureau (MOB)
- Weihai Local Financial Supervision and Administration Bureau (WLFSAB)

3. **When (short-term, mid-term or long-term)**

4. **With what resources (who else is involved, dependent on what strategy finishes)**

Table 5: Proposed actions linked to climate adaptation strategies, along with the corresponding stakeholders designated for leading or supporting roles

Strategies	Actions	Climate-related disaster	Department authorities		Status
			Leading	Supporting	
A. Internet of things (IoT)	A.1 Update meteorological observation and monitoring stations, networks and systems	lightening/ heatwave/ rainstorm/strong wind	MMB	WBDC	Existing
	A.2 Marine meteorological stations	storm surge/ waves	MOB	WBDC	Existing
B. Risk mapping and identification	B.1 Develop database on climate risk assessment	flooding/strong wind	MMB	WEMB, WBDC	New
	B.2 Calculate climate risk and risk mapping (including climate projection)		MEMB	MMB, MWAB, MNRPB, MHURDB	New
C. Improve forecasting	C.1 Improve data quality/ sharing and modelling techniques	flooding/ landslide/ snowstorm/ strong wind/hails	MMB	MWAB, MNRPB, MHURDB, WBDC	New
D. Early-warning system	D.1 Construct Weihai Meteorological early warning and release Center	flooding/ landslide/ snowstorm/ strong wind/hails	MMB	WBDC, MWAB	Existing
E. Simulation of drills	E.1 Frequently simulate drills for public and rescue team	coastal flooding/ typhoon-induced strong wind	MEMB		Existing
F. Education to raise risk awareness	F.1 Educate the public, school students, and professionals on climate risk and climate adaptation	all climate-related disaster type	MEMB	MEB	Existing
G. drainage capacity	G.1 Improve the drainage capacity of natural rivers and the pipeline system in the urban area	pluvial and fluvial flooding	MWAB, MHURDB		Existing
H. Strengthen sea dikes	H.1 Liudao town tidal dike project. Ningjin street east coast tidal dike project. Rushan city seawall project.	coastal flooding/ storm surge	MOB		Existing

Strategies	Actions	Climate-related disaster	Department authorities		Status
			Leading	Supporting	
I. River and reservoir management	I.1 Reservoir reinforcement project	fluvial flooding	MWAB		Existing
	I.2 Ecological protection and restoration project		MEEB		Existing
	I.3 Water diversion and transfer project		MWAB		Existing
J. LID development	J.1 Transform sponge city and construct drainage channels	pluvial flooding/ heatwave	MHURDB		Existing
K. Ecological restoration	K.1 Restore and protect damaged mountains	wildfire	MEEB, MMB		Existing
	K.2 Restore marine habitats	coastal flooding	MOB		Existing
L. Building code	L.1 Develop regulation and rules on building codes	flooding/ snowstorm/ strong wind/hails	MHURDB		New
M. Spatial planning	M.1 Rational land use planning for new development area	flooding/ snowstorm/ strong wind/hails	MNRPB	MHURDB, MMB	New
N. Evacuation plan and routes on map	N.1 Develop evacuation plan including evacuation routes for public in coastal area	flooding	MEMB		New
O. Capacity building of rescue team	O.1 Training for rescue professionals	all climate-related disaster type	MEMB		Existing
P. Ensure sufficient emergency resources	P.1 Construct mobile emergency command platform	all climate-related disaster type	MEMB		Existing
	P.2 Upgrade, renovate, and maintain emergency equipment		MEMB		Existing
	P.3 Ensure availability of local emergency materials		MEMB		Existing
Q. Financial scheme	Q.1 Consider insurance and re-insurance scheme, and PPP scheme	all climate-related disaster type	MFB		New
R. Recovery capacity building	R.1 Develop disaster plan and recovery plan in different sectors (water, transport, energy, waste, etc.)	all climate-related disaster type	MEMB		New

Each action is assigned a leading authority and supporting authorities who are responsible for ensuring collaboration and cooperation among different departments in Weihai.

- **Update meteorological observation and monitoring stations, networks, and systems**
  This action will be mainly led by MMB with support from MSTB and WBDC. Upgrading existing observation and monitoring stations both on land and offshore is crucial for improving data collection relevant to climate risk assessment. Additionally, the implementation of monitoring stations to measure inundation depth during flood events in low-lying areas, such as tunnels, is essential for precise and timely data.

- **Update marine meteorological stations**
  This action is supported by MOB with support from WBDC, focusing on enhancing the capabilities of marine meteorological stations to better monitor storm surges and waves. This initiative is vital for coastal areas prone to these specific climate-related threats.

- **Develop database on climate risk assessment**
  MMB leads this initiative with support from WBDC, MSTB, and WEMB. It involves developing and maintaining a comprehensive database for climate risk assessment targeting flooding, snowstorms, hail, and typhoons. The database includes meteorological, geophysical, hydrological, and morphological data, as well as land-use, building, and socioeconomic data for vulnerability assessments. Climate projections are also incorporated for use in climate risk assessments. This database is fundamental in mapping risk areas and enhancing predictive capabilities.

- **Calculate climate risks for various flooding types, snowstorms, and other climate-related disaster**
  Led by MEMB, and supported by MMB, MWAB, MNRPB, and MHURDB, this action focuses on detailed assessments and calculations of risks associated with pluvial, coastal, and river flooding, as well as snowstorms. These assessments are key to developing targeted mitigation strategies.

- **Improve data quality, data sharing, and modeling techniques**
  Led by MMB, with the support of WBDC, MWAB, MNRPB, and MHURDB, this new initiative aims to enhance the quality and accessibility of climate data through improved sharing protocols and advanced modeling techniques. This will significantly benefit forecasting and planning for flooding, landslides, hails, strong wind and snowstorms.

- **Construct Weihai Meteorological Early Warning and Release Center**
  This existing project, led by MMB with support of MWAB, WBDC, MSTB, focuses on building a dedicated center for early warnings, particularly for flooding and landslides. Such a center is pivotal in disseminating timely information to prevent or mitigate disaster impacts.

- **Frequently simulate drills for public and professionals**
  Led by MEMB, this action involves regular simulation drills to prepare public and rescue teams for efficient response during emergencies caused by coastal flooding and strong winds induced by typhoons.

- **Educate the public, school students, and professionals on climate risk and adaptation**
  MEMB leads this ongoing effort to raise awareness and educate various groups about climate risks and effective adaptation strategies across all climate-related disaster types. MEB supports this action to ensure school students are properly educated.

- **Improve the drainage capacity of natural rivers and the pipeline system**
  This initiative, led by MWAB and MHURDB, focuses on enhancing the drainage systems of natural drainage channel of rivers and the pipeline system in the urban area to manage pluvial and fluvial flooding more effectively.

- **Strengthen sea dikes**
  Led by MOB, this action includes major projects like the Liudao town tidal dike, Ningjin street east coast tidal dike, and Rushan city seawall. These projects are critical in preventing the failure of sea dikes (e.g. overtopping and structural collapse) during typhoon-induced flooding.

- **Reservoir reinforcement project**
  This action is led by MWAB to enhance the structural integrity of reservoirs to prevent fluvial flooding. Strengthening reservoirs is vital for reducing the risk of overflow and ensuring the safety of downstream communities.

- **Ecological protection and restoration project**
  Supported by MEEB, this project aims to protect and restore ecological areas that naturally mitigate flooding and enhance biodiversity. Such efforts are crucial for maintaining the ecological balance and enhancing natural resilience to climate impacts.

- **Water diversion and transfer project**
  Also supported by MWAB, this action involves creating infrastructure to divert and transfer water efficiently during peak flow periods. This helps manage river levels and reduces the risk of flooding in vulnerable areas.

- **Increase the area of green spaces, sponge transformation of old residential areas, and construction of drainage channels**
  Led by MHURDB, this action focuses on LID strategies that enhance urban resilience. The creation of park green spaces, transformation of old residential areas into 'sponge cities', and construction of drainage channels are essential to managing pluvial flooding and heat waves.

- **Restore and protect damaged mountains**
  MNRPB and MMB lead the effort to restore and protect mountain areas that have been damaged by wildfire or other environmental factors. Restoring these areas is critical for preventing flooding and maintaining natural water catchment areas.

- **Restore marine habitats**

  Supported by MOB, this action aims to restore marine habitats that are essential for biodiversity and can also provide natural barriers against storm surges and coastal erosion.

- **Develop regulation and rules on building codes**

  Led by MHURDB, this new action involves developing stringent building codes to ensure that structures are capable of withstanding flooding, hails, strong winds, and snowstorms, thereby reducing the risk to life and property.

- **Rational land use planning for new development area**

This initiative, led by MNRPB, and supported by MHURDB and MMB, focuses on rational land use planning in new development areas to minimize potential damage to agricultural land, critical infrastructures, and human life caused by flooding, hails, and snowstorm hazards.

- **Develop evacuation plans, including evacuation routes for public**

  This new initiative, led by MEMB, involves developing effective evacuation plans with clearly defined routes to ensure the safety of the public in coastal areas prone to typhoon.

- **Training rescue professionals**

  MEMB leads this existing action, which focuses on training rescue professionals on the advanced skills and techniques needed to effectively respond to all types of climate-related disasters.

- **Construct mobile emergency command platform**

  Led by MEMB, this existing action intends to construct a mobile command platform that enables flexible and rapid coordination of emergency responses across different districts and communities among different disaster types.

- **Upgrade, renovate, and maintain emergency equipment**

  Led by MEMB, this project ensures that all emergency equipment is state-of-the-art, well-maintained, and ready for immediate deployment in any climate-related disaster scenarios.

- **Ensure availability of local emergency materials**

  Led by MEMB, this action ensures that a sufficient supply of emergency materials (e.g. food, water, and rescue toolkits) are available locally to quickly address needs arising during any climate-related disaster.

- **Consider insurance and re-insurance scheme, and PPP scheme**

  Led by MFB, the proposed financial strategy involves exploring options for insurance, re-insurance, and public-private partnerships (PPP) to provide financial resilience against the economic impacts of climate-related disasters.

- **Develop disaster plan and recovery plan in different sectors**

  Led by MEMB, this new initiative focuses on developing comprehensive disaster and recovery plans tailored to critical sectors such as water, transport, energy, and waste management, ensuring a swift and effective recovery from climate-related disaster events. For water management, the plans will protect water infrastructure, prevent contamination, and restore supply systems post-disaster. In transport, strategies will maintain routes and services during emergencies and expedite repairs afterwards. Energy plans will safeguard infrastructure and restore power swiftly. Waste management plans will handle increased debris and hazardous materials and rehabilitate facilities. The initiative also includes integrated communication systems for coordination, regular training and drills, community engagement for preparedness, and resource allocation to support the implementation of these plans.

2.3.1.3. Scheduling actions

The comprehensive array of actions outlined for climate adaptation and urban resilience in Weihai use a strategic approach spanning short, mid, and long-term horizons, each addressing distinct aspects crucial for bolstering resilience to climate change impacts. Short-term endeavors (which aim to be completed before 2025, the end of the 14th Five-Year Plan), lay the foundation for immediate preparedness and risk reduction. These include updating meteorological infrastructure and conducting emergency response drills,. Meanwhile, mid-term actions (targeted at the period before 2030, the end of the 15th Five-Year Plan), focus on building adaptive capacity and enhancing resilience over the coming decade. These include climate-risk database development, infrastructure projects, and community education initiatives,. Looking further ahead, long-term (before 2035, the end of the 16th Five-Year Plan), commitments to ecosystem restoration, infrastructure upgrades, and policy development are poised to fortify Weihai against future climate challenges. The interconnectedness of these actions is evident in their dependencies, with initiatives like data quality improvement (C.1) serving as prerequisites for subsequent steps such as risk assessment (B.2) and infrastructure development (D.1). Through this holistic approach, Weihai endeavors to foster sustainable urban environments capable of withstanding the complexities of a changing climate, ensuring the well-being and prosperity of its citizens for generations to come.

Table 6: Scheduling of actions in short-term, mid-term, and long-term timeframes

Actions	Timing	Dependency
A.1 Update meteorological observation and monitoring stations, networks and systems This action is critical for enhancing the accuracy and reliability of meteorological data, providing the foundation for effective climate risk assessment and early warning systems.	short-term	
A.2 Marine meteorological stations This action focuses on expanding meteorological monitoring capabilities to coastal regions, where climate impacts such as sea-level rise and extreme weather events are particularly pronounced.	short-term	

Actions	Timing	Dependency
B.1 Database on climate risk assessment This mid-term action lays the groundwork for understanding and quantifying climate risks, serving as a foundation for informed decision-making in adaptation planning.	mid-term	C.1
B.2 Calculate climate risk and risk mapping (including climate projection) Another mid-term action, this step involves analyzing climate data from B.1 to assess vulnerabilities and identify high-risk areas, informing targeted adaptation strategies.	mid-term	B.1
C.1 Improve data quality/sharing and modelling techniques This short-term action is essential for enhancing the accuracy and reliability of climate data, facilitating more robust risk assessments and adaptation planning.	short-term	
D.1 Construct Weihai Meteorological early warning and release Center This long-term action builds upon the updates to meteorological monitoring infrastructure (A.1), providing a centralized hub for issuing early warnings and disseminating critical information during extreme weather events.	long-term	A.1, A.2
E.1 Simulate drills on emergency management for public and rescue team This action aims to enhance preparedness and response capabilities, ensuring effective coordination and communication during climate-related emergencies.	mid-term	O.1
F.1 Educate the public, school students, and professionals on climate risk and climate adaptation This mid-term action focuses on raising awareness and building capacity among various stakeholders to foster a culture of resilience and proactive adaptation.	mid-term	
G.1 Improve the drainage capacity of natural rivers and the pipeline system in urban areas This long-term action addresses flood risk mitigation, enhancing the resilience of communities to climate-related hazards.	long-term	
H.1 Liudao town tidal dike project. Ningjin street east coast tidal dike project. Rushan city seawall project. These actions involve infrastructure projects to protect coastal areas from sea-level rise and storm surges, reducing vulnerability to climate impacts.	mid-term	
I.1 Reservoir reinforcement project This action enhances reservoir capacity, ensuring reliable water supply amidst changing precipitation patterns.	mid-term	
I.2 Ecological protection and restoration project This long-term action aims to restore natural ecosystems, enhancing biodiversity and ecosystem services to support climate resilience.	long-term	

Actions	Timing	Dependency
I.3 Water diversion and transfer project Another long-term action, this involves infrastructure projects to address water scarcity and distribution challenges exacerbated by climate change.	long-term	
J.1 Park green space, sponge transformation of old residential areas, and construction of drainage channels This mid-term action focuses on enhancing urban resilience through green infrastructure and improved drainage systems.	mid-term	B.2
K.1 Restore and protect damaged mountains This mid-term action addresses soil erosion and landslide risks from damaged mountains, enhancing ecosystem stability and resilience to climate impacts.	mid-term	
K.2 Restore marine habitats A long-term action, this involves conservation efforts to protect and restore coastal ecosystems, supporting biodiversity and mitigating coastal erosion.	long-term	
L.1 Develop regulation and rules on building codes This long-term action ensures that infrastructure and buildings are aligned and designed to withstand climate-related hazards, reducing vulnerability to extreme weather events.	long-term	B.2
M.1 Rational land use planning for new development areas This long-term action ensures sustainable development practices that minimize exposure to climate risks and promote resilience.	long-term	B.2
N.1 Develop evacuation plans, including evacuation routes for public in coastal area Based on the calculation from B.2, this mid-term action involves identifying evacuation routes and protocols to ensure the safety of coastal communities during climate-related emergencies.	mid-term	B.2
O.1 Training for rescue professionals This short-term action enhances the capacity of emergency responders to effectively manage and coordinate response efforts during climate-related disasters.	short-term	
P.1 Mobile emergency command platform This long-term action provides a centralized platform for coordinating emergency response efforts, enhancing communication and coordination during crises.	long-term	
P.2 Upgrade, renovate, and maintain emergency equipment This mid-term action ensures that emergency response infrastructure is reliable and functional, supporting effective response efforts during climate-related emergencies.	mid-term	

Actions	Timing	Dependency
P.3 Ensure the availability of local emergency materials This mid-term action involves stockpiling essential supplies and resources to support emergency response efforts at the local level.	mid-term	
Q.1 Consider insurance and re-insurance scheme, and PPP scheme This mid-term action aims to enhance financial resilience by exploring innovative financing mechanisms and partnerships to support adaptation and recovery efforts.	long-term	B.2
R.1 Develop disaster plan and recovery plan in different sectors (water, transport, energy, waste, etc.) This mid-term action involves sector-specific planning to ensure resilience and continuity of critical services such as water, transportation, energy, and waste management during and after climate-related disasters.	long-term	B.2

Note: Short-term: by 2025; mid-term: by 2030; long-term: by 2035

2.3.2. Monitoring and Evaluation

2.3.2.1. Stakeholder engagement

Monitoring and evaluating engagement outcomes are essential for assessing the impact and effectiveness of stakeholder engagement activities in Weihai City. Regularly monitoring and evaluating outcomes allows us to measure progress towards engagement goals and identify areas for improvement. Key Performance Indicators, such as the number of stakeholders engaged, levels of participation, satisfaction levels, and quality of feedback received, can help quantify the success of engagement efforts. Soliciting feedback from stakeholders on the engagement process itself enables us to gain insights into their experiences and perspectives, which can inform the refinement of future engagement strategies. By adopting a systematic approach to monitoring and evaluation, we can ensure that stakeholder engagement activities are responsive, adaptive, and ultimately contribute to building a more resilient and inclusive community in Weihai City.

2.3.2.2. Actions outcome

Evaluation and monitoring are different, but they must go hand-in hand and are aimed at assuring a continuous feedback-correction cycle that can help cities and communities to adjust their adaptation strategies and plans and make them increasingly effective. A list of adaptation indicators (see Table 7) are used for the adaptive actions to measure the achievement of objectives.

The indicators proposed for evaluating climate adaptation actions are intricately aligned with the overarching objectives outlined in 2.2.2.1 Objectives and strategies. With a keen focus on addressing the immediate challenges, the indicators are designed to track progress towards specific and measurable objectives aimed at minimizing both economic losses and human fatalities resulting from climate-related disasters. These objectives serve as crucial benchmarks for gauging the effectiveness of adaptation efforts, ensuring that actions are tailored to achieving tangible outcomes within a defined timeframe. Moreover, the alignment of actions with the objectives of the roadmap underscores a strategic approach to climate adaptation, wherein each activity is purposefully selected to contribute towards the overall objective of enhancing resilience and minimizing vulnerability to climate risks in Weihai. By utilizing these indicators, decision-makers can precisely target actions that align with the roadmap's objectives, thereby maximizing the effectiveness and impact of climate adaptation efforts in Weihai and even beyond.

Table 7: Adaptation indicators for actions in accordance with the timeline

Actions	Indicators
A.1& A.2	**Number of newly installed stations** **Number of updated stations** These indicators assess the progress of actions aimed at updating meteorological observation and monitoring infrastructure (A.1 and A.2), providing insights into the expansion and modernization of meteorological networks to enhance data collection and accuracy.
B.1	**Creation of the database** This indicator evaluates the establishment of a comprehensive database on climate risk assessment, reflecting the advancement of efforts to systematically analyze and quantify climate risks (B.1).
B.2	**Results of risk maps in different climate-related risks, especially coastal flooding and pluvial flooding** This indicator evaluates climate risk mapping results, particularly focusing on coastal flooding and pluvial flooding, providing critical insights into vulnerable areas and informing targeted adaptation strategies (B.2).
C.1	**Number of data-sharing activities** This indicator tracks the implementation of measures to improve data quality, sharing, and modeling techniques, reflecting efforts to enhance the availability and accessibility of climate data for informed decision-making (C.1).
D.1	**Creation of the platform** This indicator assesses the establishment of the Weihai Meteorological Early Warning and Release Center, indicating progress in centralizing early warning systems and dissemination of critical information during extreme weather events (D.1).
E.1	**Number of drills** This indicator evaluates the implementation of simulation drills on emergency management for the public and rescue teams, reflecting efforts to enhance preparedness and response capabilities (E.1).
F.1	**Number of days of training for school students** **Number of students involved** These indicators measure the extent of educational efforts aimed at raising awareness and building capacity among school students regarding climate risks and adaptation strategies (F.1).
G.1	**Magnitude of drainage capacity [m^3/s] or return periods** This indicator assesses the effectiveness of actions to improve drainage capacity of rivers, providing insights into the enhanced resilience of communities to flood risks (G.1).
H.1	**Length of sea dike on enhancement** This indicator tracks progress in implementing tidal dike projects to protect coastal areas from sea-level rise and storm surges, indicating advances in coastal resilience (H.1).
I.1	**Number of reservoirs being reinforced** This indicator tracks the number and progress specifically in reinforcing potentially risky reservoirs

Actions	Indicators
I.2	**Size of ecological protection and restoration [km^2]** This indicator measures the coverage and extent of efforts focused on ecological protection and restoration, indicating progress in restoring natural ecosystems to support biodiversity and ecosystem services for climate resilience.
I.3	**Number of water diversion and transfer projects** This indicator evaluates the number of projects and progress in implementing water diversion and transfer projects aimed at addressing water scarcity and distribution challenges exacerbated by climate change.
J.1	**Number of 'Sponge City' projects** **Size of green roof [km^2]** **Size of impervious pavement [km^2]** These indicators evaluate the implementation of green infrastructure projects and sponge city initiatives, indicating progress in enhancing urban resilience to climate-related hazards such as flooding and heat stress (J.1).
K.1	**Size of restored mountains [km^2]** This indicator assesses the coverage and efforts specifically focused on restoring damaged mountains to address soil erosion and landslide risks, enhancing ecosystem stability and resilience to climate impacts.
K.2	**Size of restored marine habitat [km^2]** This indicator evaluates the covering areas and progress in restoring marine habitats, focusing on conservation efforts to protect and restore coastal ecosystems, supporting biodiversity, and mitigating coastal erosion.
L.1	**Approval of regulations and rules on building codes** This indicator measures progress in developing regulations and standards to ensure that infrastructure and buildings are resilient to climate-related hazards.
M.1	**Approval of land use planning on climate adaptation** This indicator evaluates progress in integrating climate adaptation considerations into land use planning, ensuring sustainable development practices that minimize exposure to climate risks.
N.1	**Creation of evacuation plan** This indicator tracks the development of evacuation plans for coastal areas, indicating progress in enhancing community resilience and preparedness for climate-related emergencies.
O.1	**Number of participants** This indicator evaluates the participation in training programs for rescue professionals, reflecting efforts to enhance the capacity of emergency responders to effectively manage climate-related disasters.
P.1	Creation of platform This indicator evaluates progress specifically in establishing an emergency command platform, providing a centralized hub for coordinating emergency response efforts during climate-related emergencies.

Actions	Indicators
P.2	**Number of emergency equipment** This indicator measures the increase and the extension of efforts to upgrade, renovate, and maintain emergency equipment, ensuring that emergency response infrastructure is reliable and functional to support effective response efforts.
P.3	**Number of emergency materials (food, water bottles, etc.)** This indicator tracks progress in improvement of equipping essential emergency materials such as food and water bottles, stockpiling critical supplies to support emergency response efforts at the local level.
Q.1	**Implementation of insurance and re-insurance scheme** This indicator evaluates progress in exploring innovative financing mechanisms to support climate adaptation and recovery efforts, enhancing financial resilience.
R.1	**Creation and approval of disaster plan for water supply chain interruption** This indicator tracks progress in developing sector-specific disaster plans, ensuring resilience and continuity of critical services during and after climate-related disasters.

2.3.3. Funding Opportunities

Climate adaptation requires substantial financial resources to implement effectively. Various funding opportunities exist to support these initiatives, including:

2.3.3.1. Public-private partnerships (PPPs)

Public-private partnerships are crucial in mobilizing resources and expertise from both the public and private sectors. These partnerships can leverage government funding with private sector investments to finance climate adaptation projects. PPPs facilitate collaboration between governments, businesses, and non-profit organizations, allowing for innovative solutions and shared risk management. For example, Weihai could partner with private investors to develop climate-resilient infrastructure projects such as flood protection systems or renewable energy installations.

2.3.3.2. Insurance and re-insurance consideration

Insurance and re-insurance mechanisms are crucial components of climate adaptation strategies, providing essential financial support for recovery in the aftermath of climate-related disasters. For individuals and industries located in high-risk areas, insurance policies can significantly enhance their capacity to recover by offering compensation for damages and losses, thereby enabling quicker rebuilding and restoration. Catastrophic insurance plays a pivotal role in mitigating the economic impact of large-scale disasters. By spreading the financial risk associated with severe events, catastrophic insurance can substantially reduce the fiscal burden on the government, allowing public funds to be allocated more effectively across various recovery and resilience-building efforts. Additionally, these mechanisms can incentivize the adoption of risk-reduction practices, such as improved construction standards and proactive disaster preparedness, ultimately contributing to more resilient communities.

2.3.3.3. Other sources

In addition to PPPs and insurance mechanisms, other sources of funding for climate adaptation include:

- **National Government Grants:** The Chinese government often provides funding for climate adaptation projects through various grants and subsidies. For example, the China Clean Development Mechanism Fund (CCDMF) is a national climate fund that supports low-carbon growth and climate resilience in China.

It is a revolving fund that receives regular capital injections from levies collected by the government on Clean Development Mechanism (CDM) projects in China. (https://www.cdmfund.org/jjgk.html)

- **International Climate Funds and Initiatives:** Weihai could access funding from international climate funds such as the Green Climate Fund (GCF) or the Global Environmental Facility (GEF). For example, the GCF has provided funding to China. (https://www.greenclimate.fund/countries/china)

- **Multilateral Development Banks (MDBs):** MDBs like the Asian Development Bank (ADB) or the World Bank provide financial assistance for climate adaptation projects.

- **Climate Finance Instruments:** Exploring climate finance instruments such as green bonds or climate insurance can provide alternative sources of funding for adaptation efforts. For example, Qingdao City in Shandong Province issued a green bond to finance projects related to environmental protection and climate change mitigation, demonstrating the potential for local governments in the region to access climate finance through innovative mechanisms.

- **Bilateral Cooperation and Donor Agencies:** Bilateral cooperation agreements with other countries or partnerships with donor agencies can offer financial support for climate adaptation. For example, the Chinese and British governments, financial regulators, and various financial institutions established the UK-China Green Finance Center (UKCGFC). The agency mainly conducts communication and dialogue around six aspects: green Belt and Road Initiative, green capital market, green banking and supervision, environmental, social, and governance (ESG) and sustainable investment, data and disclosure, and green technology and innovation.

3. RECOMMENDATIONS AND CONCLUSION

In response to the release of the National Climate Adaptation Strategy (2023) and the subsequent recommendation of the Urban Action Plan for Climate Adaptation in China, the pilot city Weihai has a unique opportunity to serve as a model for the design, planning, and implementation of climate adaptation actions for other cities facing similar climate risks in the future.

This report aims to provide strategic guidance for urban climate resilience planning in Weihai for the period from 2025 to 2035. It emphasizes the critical importance of conducting climate risk assessments to adapt to the dynamic changes in climate and anthropogenic development. It outlines the necessity of developing climate projections focusing on extreme temperatures, sea level rise, extreme precipitation, typhoons, and snowfall. To effectively map future climate risks, the establishment of a comprehensive climate risk database and the enhancement of numerical modeling skills are essential.

In addition to hazard assessments, the report suggests that vulnerability assessments should focus on properties, people, and services, as these are the most impacted in Weihai. Creating a detailed building inventory and formulating vulnerability curves using historical data and expert judgment are recommended steps.

Furthermore, spatial planning should align with urban climate adaptation efforts. Based on the results of climate risk assessment, developing regulations and building codes, as well as rational land use planning for new development areas, are effective measures for spatial adaptation to climate change.

The report also recommends the inclusion of disaster recovery plans for various sectors to ensure post-disaster functionality. Financial support mechanisms, such as insurance and catastrophic insurance, are crucial to strengthening recovery capacity for individuals and industries in high-risk areas and alleviating the financial burden on the government during recovery efforts.

In conclusion, by integrating these strategic recommendations, Weihai can enhance its resilience to climate-related challenges, ensuring sustainable development and improved quality of life for its residents. The city's proactive approach will not only safeguard its infrastructure and economy but also serve as a blueprint for other cities striving for climate resilience.

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APPENDIX

Data Requirement of Climate Risk Assessment

Weihai Municipality can require data sharing agreements in different departments before data is shared. It is advisable to validate the legal arrangements required early on to enable data to be exchanged between government agencies and with external parties.

It is important to recognize that data can be sensitive and confidential. Such datasets should be flagged early on, so that the appropriate level of security measures can be put in place to facilitate access to essential datasets.

Category / Hazard Indicator	**Preferred data examples**	**Data type**	**Data Provider**
		☒ check if available 3 categories: • GIS data on city level • climate change projection data • other publications (such as reports) containing maps or climate change projections Please note: Not all categories will apply to each hazard. Only check the available categories.	Identify: • the agency housing the data • an individual contact person Take note of steps required to access the data, and note any data that is sensitive or confidential.
Flooding			
(Extreme) precipitation	e.g. (extreme) rainfall statistics, total yearly rainfall, extreme precipitation intensities (XX mm per hour / day) Preferably over 30+ year period and including future climate projections.	☐ GIS data format (e.g. shapefile / raster) ☐ Climate change projections (preferred: reference period/ RCP8.5/2050) ☐ Other publications	Meteorological Bureau
Monsoon	e.g. Monsoon onset date, monsoon offset date, total monsoon rainfall, rainfall distribution: share of total rainfall during monsoon period	☐ GIS data format (e.g. shapefile / raster) ☐ Climate change projections (preferred: reference period/ RCP8.5/2050) ☐ Publications	Meteorological Bureau
Typhoons	e.g. historical typhoon trajectories, frequency / intensity data on typhoon. Preferably including trend / future projections.	☐ GIS data format (e.g. shapefile / raster) ☐ Climate change projections (preferred: reference period/ RCP8.5/2050) ☐ Publications	Meteorological Bureau
Lightning	e.g. lightning frequency, for example strikes / km^2 / year.	☐ GIS data format (e.g. shapefile / raster) ☐ Climate change projections (preferred: reference period/ RCP8.5/2050) ☐ Publications	Meteorological Bureau

Pluvial flooding	e.g. Pluvial flood modelling maps showing areas vulnerable for inundation caused by extreme precipitation. If not available alternatives are indicative risk areas based on expert judgement.	☐ GIS data format (e.g. shapefile / raster) ☐ Climate change projections (preferred: reference period/ RCP8.5/2050) ☐ Publications	Meteorological Bureau Water Affair Authority
Fluvial flooding	e.g. River flood modelling maps showing areas vulnerable for inundation (for example due to failure of river embankment). If not available alternatives are indicative risk areas based on expert judgement.	☐ GIS data format (e.g. shapefile / raster) ☐ Climate change projections (preferred: reference period/ RCP8.5/2050) ☐ Publications	Water Affair Authority
Landslides	e.g. unstable soils, steep slopes, map of erosion prone areas	☐ GIS data format (e.g. shapefile / raster) ☐ Climate change projections (preferred: reference period/ RCP8.5/2050) ☐ Publications	Geological Bureau
Sea level rise and storm surge			
Coastal flooding	e.g. data on storm surges (frequency/intensity), High Water Marks maps (e.g. 1:10 year), sea level rise records / projections	☐ GIS data format (e.g. shapefile / raster) ☐ Climate change projections (preferred: reference period/ RCP8.5/2050) ☐ Publications	Ocean And Fishery Bureau
Coastal erosion	e.g. subsidence rates, map of subsidence-prone areas	☐ GIS data format (e.g. shapefile / raster) ☐ Climate change projections (preferred: reference period/ RCP8.5/2050) ☐ Publications	Ocean And Fishery Bureau
Salt water intrusion	e.g. Groundwater and river salinization maps. Recorded/projected frequencies of high salinization levels.	☐ GIS data format (e.g. shapefile / raster) ☐ Climate change projections (preferred: reference period/ RCP8.5/2050) ☐ Publications	Ocean And Fishery Bureau
Heat			
Heat waves	e.g. heat wave days, monthly / yearly average heatwave severity.	☐ GIS data format (e.g. shapefile / raster) ☐ Climate change projections (preferred: reference period/ RCP8.5/2050) ☐ Publications	Meteorological Bureau

(Extreme) hot days / nights	e.g. extreme heat days, maximum temperatures, number of nights above 30 °C per year, map showing the urban heat island effect (UHI), average climate surface temperature, water temperatures.	☐ GIS data format (e.g. shapefile / raster) ☐ Climate change projections (preferred: reference period/ RCP8.5/2050) ☐ Publications	Meteorological Bureau
Drought			
Drought	e.g. number of dry years, length/number of dry spells, aridity (ratio between actual evapotranspiration and precipitation), soil moisture / deficit. Reservoir dam levels.	☐ GIS data format (e.g. shapefile / raster) ☐ Climate change projections (preferred: reference period/ RCP8.5/2050) ☐ Publications	Meteorological Bureau Water Affair Authority
Wildfires	e.g. active fire detections, fire risk map	☐ GIS data format (e.g. shapefile / raster) ☐ Climate change projections (preferred: reference period/ RCP8.5/2050) ☐ Publications	Forest Bureau

Other data

- Infrastructures
  - Flood defense system (sea dikes, flood gates, barriers, etc.)
    - GIS information
    - Geometry of hydraulic structures
  - Drainage system
    - Layout of pipeline and manholes
    - Pipeline material
  - Transportation networks
  - Schools and hospitals
- Others
  - Land use map (raster)
  - Soil map (raster)
  - Future projection on sea level rise, storm surge or typhoon intensification (wind speed, air- pressure, and landfall location, etc.)

TERMINOLOGY

Climate hazards are threatening climate events that have the potential to cause damage or harm to humans, assets and natural systems.

Climate risk is linked to the probability of adverse impacts from climate change. It is caused by harmful climate events that have negative effects on cities worldwide. Risk is determined by an interplay of hazards, exposure and vulnerability. Climate risks affect every city differently, depending on geography, socioeconomic and demographic context.

Climate impact refers to the effect of extreme weather and climatic events on natural and human systems. The impact may affect lives, health, the economy, infrastructure and ecosystems.

Hazard refers to the potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.

Exposure refers to the presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected.

Vulnerability refers to the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Adaptive capacity is the ability and willingness of systems to adjust to potential damage, to take advantage of opportunities or to respond to the consequences of climate change. Systems can be natural systems, individuals, or institutions, such as governments.

Adaptation refers to actions that people take in response to, or in anticipation of, projected or actual changes in climate, to reduce adverse impacts or take advantage of opportunities posed by climate change.

Mitigation refers to actions taken to prevent, reduce or slow climate change, through slowing or stopping the build-up of greenhouse gases in the atmosphere.

Resilience The resilience of a natural system is its capacity to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes. A resilient system can withstand shocks such as extreme events and rebuild itself. When a system loses resilience, it becomes vulnerable to changes that previously could have been absorbed. In a vulnerable system, even small changes may be devastating. Even in the absence of disturbance, gradually changing conditions such as climate, land use and policies can surpass threshold levels, triggering an abrupt system response.

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