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Climate Change and Critical Infrastructure in Balochistan: Assessing Vulnerabilities and Policy Preparedness

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ABSTRACT

The vulnerability of critical infrastructure and essential services to climate change is increasing worldwide, particularly in areas facing multiple threats, and a lack of resources and institutional capacity. In Balochistan, the province is subject to recurrent droughts and water scarcity, as well as a range of hazards including floods, intense precipitation, temperature extremes, and coastal hazards. This research examines the vulnerability of major critical infrastructure systems to climate and disaster risks in Balochistan and analyzes the existing policy and institutional frameworks for managing these vulnerabilities. A qualitative case-study approach was adopted, using scholarly literature, policy and government documents, planning documents and institutional reports. The data were analyzed thematically across water, urban and coastal infrastructure, health, energy, communications, and transport systems with attention to institutional responsibilities and policy responses. The findings reveal that Balochistan's multi-hazard environment leave a critical infrastructure vulnerable with vulnerability varying geographically and being intensified by existing infrastructure weaknesses, limited resources and limited institutional capacity. The water infrastructure is identified as extremely vulnerable from drought, water depletion and water scarcity while urban and coastal infrastructures is particularly exposed to flooding and extreme rainfall. The findings also highlight the interconnectedness of infrastructure systems whereby disruption in one sector can affect the continuity of essential services in others. Although climate and disaster risks are increasingly recognized in policy and planning, a persistent gap remains between policy formulation and implementation on the ground. The findings highlight the need for stronger institutional coordination, financing, implementation capacity, monitoring and climate resilient infrastructure in Balochistan.



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Introduction

Climate change poses increasing risks to the critical infrastructure on which communities depend for essential services. Infrastructure systems like water supply, healthcare systems, energy supply, transport networks and communications are vulnerable to drought, water scarcity, extreme precipitation flooding, high temperatures, and coastal hazards. However, the level of vulnerability is not determined by the hazard alone. It is also influenced by the existing condition of infrastructure the availability of financial and technical resources, institutional capacity and the ability of communities to respond to and recover from disasters. These climate-related risks are particularly relevant to Balochistan where the climatic, geographic and socio-economic conditions contribute to multiple forms of vulnerability. The province experience recurring drought and water scarcity, while urban areas such as Quetta are exposed to intense rainfall and flash flooding. Coastal areas such as Gwadar are also vulnerable to flooding and other coastal hazards. Consequently, there is comparatively less attention to how vulnerabilities across different critical infrastructure are interconnected. This is important because infrastructure systems do not operate independently. A disruption to one system can affect the functioning of others especially during climate related disasters. For Example, interruptions to electricity supply can affect water pumping and healthcare services while damage to roads and communication networks can restrict emergency response and access to essential services. A further issue concerns the policy and institutional capacity to address these interconnected vulnerabilities. Pakistan have developed policies, strategies and plans that address climate change adaptation, disaster management, water resources, agriculture and development planning. Existing research emphasizes the importance of policy coherence, institutional coordination and integration of climate considerations into development planning (Waheed et al., 2021; Javed & Nauman, 2025). The Balochistan climate change policy also provides a provincial framework for climate adaptation and resilience, including attention to water resources, disaster risk reduction, institutional coordination and climate resilient development (Government of Balochistan & United Nations Development Programme, 2024). However, the existence of policies and planning framework does not necessarily demonstrate that climate risks are consistently incorporated into infrastructure planning, investment, implementation, and maintenance. This create an important research problem that there is a need to under how climate and disaster hazards affect interconnected critical infrastructure systems in Balochistan and whether existing policy and institutional arrangements are adequately prepared to address these vulnerabilities. This study examines the vulnerability of critical infrastructure to climate and disaster risks in Balochistan and assesses the preparedness of existing policy and institutional frameworks to address these vulnerabilities. It focus on major hazards and their implications for water, urban and coastal infrastructure, health, energy, communication and transportation systems while also considering community resilience, institutional capacity and the implementation of climate related policies.

Research Question

RQ1: What major climate-related risks affect critical infrastructure in Balochistan, and how do these risks affect interconnected infrastructure systems?

RQ2: How do existing national and provincial policies and plans address climate resilience in critical infrastructure planning in Balochistan?

RQ3: What are the main gaps between climate-resilient infrastructure policies and their implementation in Balochistan?

Literature Review

Climate Change Vulnerability of Balochistan

Balochistan is considered highly vulnerable to climate change due to its semi-arid to arid climatic conditions scarce water resources, geographic diversity and its numerous economic and institutional limitations. Its diverse geography and exposure to various hazards including drought, extreme temperatures, irregular precipitation patterns, floods and coastal issues mean the province is disproportionately affected. Based on the work of Rehman and Mengal (2025), Nushki in the province of Balochistan presents complex multi hazard vulnerabilities, where exposure to multiple hazards i.e. Floods, droughts and earthquakes, is often aggravated by its socio-economic vulnerabilities, poor quality of infrastructure and low institutional capacity. Thus, this not just implies vulnerability based on climate risk exposure alone but it also on communities capacity to anticipate, adapt to, and recover from hazards. A broader assessment of climate vulnerability in Pakistan also places Balochistan among the most vulnerable regions because of its high sensitivity and relatively low adaptive capacity. The study links climate exposure with socioeconomic conditions and identifies drought and increasing temperatures as major threats in Balochistan, with possible consequences for food security, nutrition and health (Malik et al., 2012). Drought and water scarcity have already been identified as a predominant climate hazard in the region. Ashraf et al. (2021) emphasize the increasing risks to livelihoods, posing a strong case for suitable mitigation and adaptation strategies to overcome its impacts in the area. Similarly, Durrani et al. (2021) showed the relationship between drought vulnerability amongst the farmers of the region and decreased surface and ground water availability, electricity and over dependence on agricultural and livestock. The literature highlights that climate change can thus exacerbate the underlying pressures on resources thus leading to interdependent vulnerability patterns across the water, energy, food and the rural livelihoods. Concurrently, a variety of hazards including heavy and intense rainfall can also lead to flash floods especially in urban areas. Hussain (2024) documented urban flash floods in Quetta that had significant impacts on communities and urban infrastructure systems. Similar analysis was conducted of the urban flood hazards in Gwadar (Fareedi et al., 2025) with substantial impacts due to specific geophysical and socio-economic characteristics of the area. These patterns highlight that the risk of flooding is an equally significant concern as the risks arising from water scarcity and drought in Balochistan. These contrasting hazards make place based adaptation and mitigation more challenging. Moreover, the vulnerability of coastal Balochistan also deserves attention. Coastal zones are areas of unique significance and vulnerability when it comes to climate impacts, as demonstrated by Kumbhar et al. (2019) and Malik et al. (2023) who examined livelihood impacts and the socioeconomic implications of climate change in coastal Balochistan. As a prominent centre for transit and trade route, Gwadar is becoming an increasingly important area with major developments ongoing and its increasing exposure to coastal flooding risks should therefore be considered in development planning and risk adaptation. Adaptive capacity is another important aspect of climate vulnerability discussed in the literature. Javed & Nauman (2025) indicate the need for strengthened adaptive capacity through water management, implementation of climate smart agriculture practices, greater community participation and locally adapted measures. Likewise, Rehman and Mengal (2025) emphasizes the importance of enhanced institutional

capacity, robust disaster risk management for adaptation to climate change and its impacts, among other factors along with adequate infrastructure and resources. Therefore, vulnerability to climate change must be analysed in terms of climate hazard exposure, sensitivity and capacity to adapt (Hussain, 2024). The impact of climate hazards are therefore likely to be more severe in regions with low income, weak institutional and community capacity. In sum, the literature indicates that the climatic vulnerabilities in Balochistan are diverse and context specific. While drought and water scarcity are more prevalent in hinterland areas and agricultural zones, floods and associated impacts are prevalent in urban and coastal contexts (Ashraf et al., 2021; Durrani et al., 2021; Fareedi et al., 2025). Yet, few studies analyze the cascading impact of these interrelated risks for critical infrastructural systems. This provides justification to examine water, health, energy, transport, communication, and urban systems in terms of their vulnerability in the subsequent sections.

Climate Hazards and Infrastructure Vulnerability

Climate change can poses a range of threats to critical infrastructure in Balochistan, by physically damaging infrastructure, disrupting essential services and decreasing the ability of communities to respond to disasters. Existing literature suggests that the province is vulnerable to multiple climate-related hazards (floods, droughts, earthquakes, and extreme temperatures) and coastal hazards (Rehman & Mengal, 2025); therefore a multi-hazard planning approach is important for infrastructure development. Urban flash floods in Quetta are a relevant example of the potential impacts of flooding on infrastructure, such as water systems, drainage and roads (Hussain, 2024). Similarly, significant flood vulnerability is demonstrated in the Gwadar district, which may pose significant impacts on roads and infrastructure networks (Fareedi et al., 2025). However, vulnerability is also dependent on a myriad of factors other than climate change. The physical, geological, population and accessibility characteristics of the landscape influence earthquake vulnerability in Quetta and thus also the resilience of infrastructure to these event (Jamal-ud-din et al., 2023). Drought is another climatic hazards that can place significant pressure on infrastructure systems Pressures on water sources as a result of declining groundwater availability for example, can cause strain on irrigation and water-supply systems. Drought conditions in Balochistan are not uniform across the province. Analysis of drought trends has shown considerable spatial and temporal variation, highlighting the need for location-specific drought management and water planning (Ashraf et al., 2020). In addition, a lack of access to energy resources weakens people's capacity to cope with the effects of droughts (Durrani et al., 2021). Land subsidence also represents a threat to buildings, roads, utilities and infrastructure in the Quetta-Mastung area of Balochistan (Kakar et al., 2024) . Although land subsidence is not itself a climatic hazard, it represents an additional physical pressure that may be exacerbated by or interact with climate impacts.

Water Infrastructure and Climate Vulnerability

Water infrastructure faces significant climate related risks in Balochistan because Balochistan is prone to recurrent droughts, declining water availability and falling groundwater levels and increasing pressure on irrigation and water supply systems. Based on their flood and drought scenario modelling for the Porali River Basin, Ahmed et al. (2013), point to the need for improved water-resource management that considers both drought and flooding conditions, suggesting that water infrastructure must account for both water scarcity and excess water. Reliance on groundwater can further increase vulnerability. The vulnerability of water

infrastructure is also linked to limited water storage and weaknesses in water-resource management. Recent evidence from Balochistan highlights chronic water scarcity, declining groundwater levels, limited surface-water storage and deterioration of traditional irrigation systems such as karez. These pressures are further complicated by gaps in data and coordination among agencies responsible for water management (Balochistan Water Resources Development Sector Project, 2025). Based on their findings about declining groundwater and surface water availability, Durrani et al. (2021) observe that these are significant factors contributing to drought vulnerability among farmers, while Rana et al. (2020) raise concerns about the extensive use of tube-wells for agriculture purposes which contributes to groundwater depletion. This situation demonstrates the link between water and energy infrastructure where tube wells depend on electricity or based on solar power. Thus, policy and adaptation measures can play an important role in improving water resilience. Javed & Nauman (2025) suggest ways of water saving, harvesting rain water, optimum usages in irrigation and community involvement in water management. Shah et al. (2025) likewise emphasize the role of water scarcity and limited administrative support in shaping drought coping capacity in Mastung District of Balochistan.

Vulnerability to Urban and Coastal Infrastructure

The urban and coastal regions of Balochistan are increasingly vulnerable to floods, extreme rainfall, coastal hazards and rapidly developing urban centres. Hussain (2024) addresses the impact of urban flash floods in Quetta including traffic disruption, infrastructure damage and building collapse and disruption of urban services. Similarly, Fareedi et al. (2025) also found significant vulnerability in Gwadar especially in low-lying areas, built infrastructure and local populations where limited coping capacity, increases exposure to extreme rainfall and flooding. In Quetta, earthquake vulnerability also remains a concern as Jamal-ud-din et al. (2023) noted the critical role of building features, population exposure and public access to rescue services in determining urban vulnerability. Besides those already mentioned, there are additional pressure that climate induced changes create further pressures on coastal infrastructure in Balochistan. Malik et al. (2023) and Kumbhar et al. (2019) identify socio economic and livelihood impacts of climate change in coastal areas of Balochistan, highlighting the exposure of coastal communities and the infrastructure and facilities on which they depend. The risks will matter more for Gwadar given its expanding Urban, Economic, Transit and strategic features. So, climate risks need to be considered in the planning and development of urban and coastal infrastructure to reduce future vulnerability. The vulnerability of water infrastructure is also linked to limited water storage and weaknesses in water-resource management. Recent evidence from Balochistan highlights chronic water scarcity, declining groundwater levels, limited surface-water storage and deterioration of traditional irrigation systems such as karez. These pressures are further complicated by gaps in data and coordination among agencies responsible for water management (Balochistan Water Resources Development Sector Project, 2025).

Infrastructure for Health, Energy and communication

The health, energy and communication infrastructure are critical systems because their continued functionality is important during climate induced disasters. In the health sector, limited institutional and operational preparedness as well as inadequate training and disaster practice for earthquake was identified as concerns in government hospitals in Quetta (Arshad et al., 2021). Hence the health service infrastructure is vital, not only in terms of the physical condition of buildings but also the preparedness of personnel, practices and available facilities. Climate

vulnerability also has important implications for health services. Malik et al. (2012) found that Balochistan's high climate vulnerability is associated with potential health risks from drought, flooding and increasing temperatures, including malnutrition, infectious diseases and heat-related illness. This indicates that climate resilience in the health sector requires attention not only to hospital buildings but also to the continuity and capacity of health services during climate-related emergencies. Energy infrastructure is important for building resilience. Nasir et al. (2019) discuss the potential of micro grid solutions and communication networks to support more resilient infrastructure in Balochistan. Sustainable energy sources, decentralized electricity access and mobile telecommunications can help maintain essential services during disruptions. Furthermore, the use of solar power for agricultural tube wells in Balochistan can provide an alternative energy source for irrigation (Rana et al., 2020) will face issue from the rapid depletion of groundwater as found by the studies, thereby underscoring communication importance. Mobile telecommunication will become critical for warning during extreme weather/disaster because it supports early warning, emergency response, coordination, and access of people to useful services.

Community Resilience & Disaster preparedness

Community resilience is a vital component of climate & disaster preparedness because to the extent of infrastructure & emergency responses remain in part depend upon resilience at the community level. Ainuddin et al. (2024) observed the importance of disaster risk awareness & disaster preparedness at the community level in Quetta, while Nasrullah et al. (2015) examine differences in community resilience across districts prone districts of Balochistan. These studies reflect that limited awareness, resources & institutional support can increase disaster risks and reduce communities ability to respond effectively. Earlier research on earthquake-prone communities in Balochistan also emphasizes the importance of community preparedness and coordination between provincial and national institutions. Ainuddin and Routray (2012) argue that disaster preparedness at the community level is important for reducing future losses and that coordination among relevant agencies needs to be strengthened. Community capacity is also linked with local coping & adaptation strategies. Durrani et al. (2021) evaluated the coping mechanisms adopted by small farmers to manage drought but they were still constrained by water shortages, decline of natural resource & limited institutional support. Similar challenges were identified by Shah et al. (2025) among small holder farmers in Mastung where water shortages and limited institutional assistance affected their ability to cope with drought. These findings tell us that strengthening community resilience requires not only awareness and preparedness but also demand access to resources, institutional support, local participation and effective adaptation measures.

Climate Policy & Institutional Preparedness:

Transforming climate risk knowledge into institutional & Climate Policy Preparedness is essential for implementing and integrating climate risk knowledge into infrastructure development plans and building climate-resilient infrastructure. Waheed et al. (2021) looked into effective climate policy in Pakistan, and examined the importance of integrating climate considerations into policies plans and development strategies. At the provincial level, the Balochistan Climate Change Policy (2024) provides a more direct policy framework for climate adaptation. It identifies water resources, urban resilience, human health, disaster risk management and coastal areas as important adaptation priorities. The policy also calls for

integrating climate considerations into provincial sectoral policies and development plans and proposes climate screening of projects under the Provincial Public Sector Development Programme. The policy further recognizes the need for stronger institutional mechanisms, including coordination between government departments, local-level implementation, monitoring and capacity building. These provisions are particularly relevant to critical infrastructure because they indicate that climate considerations are intended to be incorporated into infrastructure and development planning rather than treated as a separate environmental issue. Particularly, for Balochistan, this aspect can be regarded as very crucial where large scale infrastructure and development projects need to consider climate risks rather than treating climate change as a separate policy issue. Among the key findings at the provincial level, Javed & Nauman (2025) identify locally appropriate adaptation measures including improved water management, promoting climate-smart agriculture, increasing community engagement, enhancing local institutions and coordinated actions. Similarly, Rehman and Mengal (2025) emphasize the importance of strengthening institutional capacity and disaster risk management to reduce Vulnerability. Moreover, policy framework like Balochistan Agriculture Policy is developed aiming to address issues related to water, agriculture, energy, natural resources and other development concerns (Rana et al., 2021). A collective observation from studies suggests that policy frameworks at the province level are in place for adaptation to Climate risk, what is really at stake is coordination, implementation, monitoring and conversion of these policies into concrete steps towards building resilient infrastructure and community resilience. This policy dimension provides an important foundation for assessing policy preparedness in the present study.

Climate Policy _ Infrastructure Implementation Gap.

Evidence shows that several existing policy and planning documents exist regarding climate adaptation, disaster management, water security and climate resilience in Balochistan. However policy of presence alone does not guaranteed effective implementation of it. Waheed et al., (2021) emphasize the importance of climate policy coherence and its integration into development plans, while Javed & Nauman (2025) highlight the need for better institutional coordination and location-specific adaptation measures in Balochistan. Similarly Rehman and Mengal (2025) highlight institutional capacity and disaster risk management is a key reducing vulnerability factor. Evidence in studies at the sectoral level demonstrates that this implementation gap has implications for infrastructure development projects. For instance the water sector continues to face problems of water scarcity and depletion of groundwater (Ahmed et al.,2013; Durrani et al., 2021), while studies concerning urban flooding and preparedness for hospitals indicate persisting weaknesses in urban and emergency facilities (Fareedi et al., 2025; Arshad et al., 2021). Hence, a potential gap may exist between goals of climate policy and practical preparedness in terms of financing, institutional capacity, coordination, implementation, monitoring and maintenance of climate resilient infrastructure. The significance of evaluating this gap is to find out whether present policies have already in place mechanisms to deal with the climate vulnerabilities identified in Balochistan. This is important because the effectiveness of climate policy depends not only on the formulation of policies but also on their translation into practical infrastructure planning and implementation.

Research Gap

The existing studies provide a good overview of climate hazards and risks in Balochistan. Previous studies have covered the issues of drought and water scarcity (Ashraf et al., 2021; Durrani et al., 2021), urban flooding (Hussain, 2024; Fareedi et al., 2025); earthquake risk (Jamal-ud-din et al., 2023), land subsidence (Kakar et al., 2024), hospital preparedness (Arshad., 2021), communication and energy infrastructure (Nasir et al., 2019) and community resilience (Ainuddin et al., 2024; Nasrullah et al. 2015). Several policy related studies have already evaluated climate adaptation and policy coherence in Pakistan and Balochistan (Waheed et al., 2021; Javed & Nauman, 2025). However there is a fragmentation in research on a topic involving specific hazards that affect specific parts of Balochistan, specific infrastructure sector and at the policy level on specific actions. In particular, a comprehensive integrated study has yet to determine whether existing infrastructure are susceptible to various combined climate hazards in Balochistan and that its institutions and plans are adequately geared towards this challenge? The links between infrastructural risks identified and policy commitment/institutions and its implementation still need to be better assessed. The present study addresses this gap by connecting two strands of research often dealt separately: (1) climate vulnerability of critical infrastructure and (2) climate policy preparedness. By examining these dimensions together the study aims to assess the extent to which climate change threatens critical infrastructure in Balochistan and whether present institutions, policies, and planning mechanisms are adequately prepared to reduce these risks. The Balochistan Climate Change Policy (2024) itself recognizes the need to mainstream climate considerations into provincial development planning and proposes climate screening of projects under the Provincial PSDP, together with stronger institutional mechanisms and monitoring. However, the existence of these provisions does not by itself demonstrate that climate considerations are consistently incorporated into infrastructure projects. This distinction between policy commitment and practical implementation is therefore important for assessing policy preparedness in Balochistan.

Methodology

Research Approach

This study uses a qualitative research approach to investigate the climate vulnerability and preparedness for climate-related disaster that affecting the critical infrastructure in Balochistan. A qualitative study is suitable for this topic because the study is concerned about understanding the nature of climate hazards, the weaknesses within infrastructure systems, the institutional capacity, and the ways in which climate related policies are implemented. These issues are explored using existing secondary materials rather than being tested through statistical comparison. This method also helps exploring the links between the physical infrastructure system and their institutional and socioeconomic contexts.

Research Philosophy

The philosophical perspective guiding this research is interpretive. Climate vulnerability and preparedness are assessed and described not only through numerical data but also through the interpretation of different types of evidence. Therefore, the study examines existing literature and policy document to identify broader patterns, relationships, inconsistencies and areas of agreement.

Research Design

Balochistan serves as a case study. The province was selected because of its diverse physical hazards and the infrastructure and institutional challenges associated with them. Balochistan faces numerous climate and disaster related risks including drought, water shortage, extreme temperatures, coastal hazards, and flooding. The critical infrastructure considered in this study includes urban services, healthcare facilities, water and energy supply systems, transportation and telecommunication networks. These infrastructure are examined within their respective geographic, social, economic and institutional contexts in Balochistan.

Data Sources and Selection

This study is based mainly on secondary sources. This include scholarly articles from peer-reviewed journals, policy and working documents produced by various governmental and non-governmental organizations, national and regional planning documents, reports, working papers from research institutions and relevant online sources. Data are selectively chosen based on : a) Balochistan as the study area , or b) climate hazards and infrastructure systems relevant to the province. The selective choice helps keep the review concise and focused.

Data Collection Method

Data were collected through a structured review of academic literature, policy documents, planning documents and relevant institutional reports. Information was extracted regarding climate risks including the type of hazards and its magnitude were reported, the specific infrastructure components affected, documented impacts and damages, adaptation and mitigation measures, responsible institutions, and relevant policy approaches and interventions. Policy and planning documents were examined to determine whether climate risks are considered in infrastructure development and planning and whether they include measures related to disaster preparedness and climate resilience.

Data Analysis

The extracted information was organized into a matrix and analyzed thematically. The data were categorized according to climate hazards, infrastructure vulnerabilities, institutional responsibilities, existing adaptation and mitigation measures as well as policy responses. The data then be cross-analyzed between sectors and geographic areas of Balochistan to reveal areas of vulnerability, difference between sectors and locations, institutional weaknesses and the potential gap between policy commitments and their implementation.

Ethical Considerations

The research relies solely on publicly available secondary sources and does not involve any form of data collection directly from or on individuals. Therefore, issues related to informed consent, participant privacy and confidentiality do not arise in the same way as they would in primary research. All sources used in the study were appropriately cited in the text and in a final bibliography.

Limitations

A major limitation of this study is its reliance on secondary data. Some infrastructure sectors and sub-regions of Balochistan are less extensively studied than others, which may result in uneven coverage of critical infrastructure or geographic areas. The availability and quality of information vary across sectors and locations. In addition, the study did not include field surveys of physical infrastructure or interviews with any infrastructure professionals, government officials, or affected communities. Therefore, the findings are based on available research, policy documents, and institutional reports. The study give an overall assessment of climate related infrastructure vulnerability and policy preparedness but it cannot provide direct field level verification of infrastructure conditions or the actual implementation of policies.

Findings

Climate hazards experienced by critical infrastructure

On document analysis, there are the main climate-related risks relevant to Balochistan including drought, water shortages, flooding, intense rainfall, extreme temperatures and coastal hazards. The evidence suggests that climate-related risks are not disturbed a common phenomenon across the province but is location specific and vary between regions. Drought and water scarcity are more common in rural and agricultural areas of the province, whereas floods may be a major problem for urban and coastal regions such as Quetta and Gwadar. Earthquakes and landslides also increased vulnerability where infrastructure is fragile and poses risk to critical infrastructure. The evidence from the documents suggest that vulnerability to climate hazards is determined not only by the occurrence of hazard but also by prevailing physical as well as socioeconomic conditions. Poor infrastructure conditions, limited financial and technical resources and communities dependence on resources can further increase vulnerability. Evidence indicates that Balochistan's critical infrastructure faces a multi-hazard environment rather than being exposed to a single climate risk.

Vulnerability of critical infrastructure systems

Evidence reveals that every sectors of infrastructure face a different combinations of climate-related and disaster risks. The Table below summaries the results based on infrastructure sector:

Infrastructure Sector	Main Vulnerabilities Identified
Water	Groundwater depletion, drought, declining water availability, pressure on irrigation.
Urban Infrastructure	Flooding, drainage problems, road disruption, building damage.
Coastal Infrastructure	Flood and climate related issues associated with coastal regions (Gwadar) in spite of low elevations and exposure of settlements to climate issues in Gwadar.
Health	Hospital preparedness, emergency capacity and continuity of services.
Energy	Electricity dependence, energy access and vulnerability of essential services.
Communication	Need for reliable communication during emergencies
Transport	Flood-related disruption and accessibility problems.

The evidence shows that risks are interconnected across different infrastructure sectors. For example reduced availability of water resources due to groundwater depletion can affect irrigation and livelihoods. Dependence of tube wells on electricity also demonstrates the interconnectedness between energy and water. This makes an inter linkage between the two services and vulnerability that can only be assessed after assessing interconnectedness among systems. The findings of analysis therefore identifies water, urban, health, energy, communication and transport infrastructure as important components of climate resilience in Balochistan.

Vulnerability of water infrastructure

Water infrastructure was identified as one of the most vulnerable sectors across the reviewed documents. In particular recurring drought, reducing ground water level, reduced surface-water availability and increasing pressure on irrigation systems were found to place greater stress on available water resources. While majority of evidence Showed increasing reliance on groundwater which places additional pressure on already limited water resources. Thus water resource problem also considered as an infrastructure issue. Several measures were identified to address these problems including water-saving technologies, rainwater harvesting, improved irrigation practices, local participation and improved water resource management. Hence majority of evidence on water infrastructure suggests a significant gap between existing water related pressures and the capacity and measure available to address them. Vulnerability within the water sector is caused by both climate related stress and existing problems such as groundwater depletion and weaknesses in resource management.

Urban and coastal infrastructure vulnerability

Evidence on urban infrastructure indicated that urban flooding in cities like Quetta is a significant threat, that affecting transportation roads, utilities and other urban services. Flash floods associated with intense rainfall have caused disruption to roads and urban services as well as damage to buildings. Similar risks are identified for coastal infrastructures in the province. Infrastructure in Gwadar is developing quickly because of its strategic and economic importance. However its coastal location and exposure to extreme rainfall and flooding create additional risks for settlements and infrastructure. Rapid urbanization and inadequate planning may further increase the vulnerability of urban and coastal infrastructure to flooding and other extreme events.

Vulnerability of health, energy and communication infrastructure

The analysis showed that infrastructure resilience depends on the continuity of essential service during disasters has become the key concern. The evidence from health infrastructure suggests that preparedness for disasters in the hospital sector remains an area for concern, including both physical and operational capacity it need careful examination and planning for improvement. The dependence of health services on reliable power highlights the linkage of the two sectors for climate resilience. Solar-power can provide an alternative source of electricity in areas where grid-based supply is less reliable but it does not solve the underlying problem of water shortages. Reliable communication infrastructure was identified as major concerns during disaster. Communication networks support hazard warnings, emergency coordination, evacuation, access

to health services and the dissemination of real time information. They also support coordination among response teams during emergencies.

Community resilience and disaster preparedness

The key factors identified in the documents were community awareness, preparedness capacity, access to local resources and institutional support. Adaptive farming and other local coping practices were identified in drought prone districts as ways of managing water shortages. These coping capacities were constrained by limited water availability, declining natural resources, and inadequate support by different institutions. Studies of disaster awareness and preparedness measures carried out in various districts of Balochistan especially in Quetta. Differences in risks and capacities between districts also indicate that community resilience varies by location. Community resilience does exist but its effectiveness depends on access to resources, information, institutional support and local participation.

Institutional and policy preparedness

The most common themes of policy related aspects from the document review are found under, Climate policy, Agricultural policy, Disaster management practices, Water resources management and development planning, where it is consistently cited that climate-related issue need to be integrated. Across these areas, the documents emphasize the need to integrate climate considerations into policies and development planning. Although, the policy framework recognizes the importance of integrating climate change into development policies but evidences show limitations in the implementation where most of the sources suggest that institutional capacity and coordination were identified as important concerns. The documents also emphasize the need for stronger local implementation capacity, institutional support and coordination between relevant departments. Other sectors like agriculture and infrastructure must work on disaster preparedness planning and implementation of existing schemes in the province.

Climate policy-infrastructure implementation gap

A significant finding from the analysis of documents was the gap between policy provisions and the current level of infrastructure preparedness. The reviewed policies, disaster management plans and development documents include provisions related to climate resilience and infrastructure planning. However, evidence from sector specific studies indicates that vulnerabilities remain at the practical level. This does not necessarily mean that existing policies are ineffective rather several factors may limit their implementation and their influence in infrastructure resilience. There needs to be particular attention to 5 factors . That is:

- Institutional coordination,
- Implementation capacities,
- Financing and availability of resources
- Monitoring and Enforcement
- Integration of climate risks into infrastructure planning.

The evidence does not support the conclusion that existing policies have completely failed. It indicates that important implementation challenges remain especially in coordination, capacity, financing, monitoring, and infrastructure planning.

Summary of findings

In general, three trends could be observed in the analysis of documents.

First, Balochistan faces multiple and interconnected hazards. Drought and water scarcity are especially important in rural and agricultural areas while flooding and coastal hazards are more prominent concerns in urban and coastal areas.

Second, vulnerabilities are interconnected across infrastructure systems. Vulnerability of the energy, water, health, transportation and communication can pose cumulative threats to each other during a climatic and disaster event. Therefore, any system that is weak can put an additional pressure on the others which are needed services during emergency.

Third, Policy preparedness appears stronger at the policy and planning level then at the implementation level. The reviewed documents recognize climate hazards and include measures related to adaption, disaster-management and resilience. However, the available evidence provides less clarity about their implementation, coordination, financing and monitoring.

These findings provide the basis for the discussion section, where they are interpreted in relation to the existing literature and used to assess the adequacy of policy and institutional preparedness for protecting critical infrastructure in Balochistan.

Discussion

Climate hazards and infrastructure vulnerability

Study findings highlight that Balochistan is a multi-hazard environment, with hazards of droughts, water scarcity, floods, intense rainfall, temperature extremes, and coastal hazards affecting different parts of the province. These findings are consistent with Rehman and Mengal (2025), who examined multi-hazard vulnerability in Nushki, as well as Ashraf et al. (2021) and Durrani et al. (2021), who highlighted water scarcity and drought as important concerns in Balochistan. Similarly, Hussain (2024) identified flood related vulnerability in Quetta, while Fareedi et al. (2025) highlighted flood vulnerability in Gwadar. The study also suggest that Infrastructure vulnerability depends not only on the occurrence of a hazard but also on the existing condition and maintenance of infrastructure, available resources and institutional capacity. This supports Malik et al. (2012), who examine vulnerability in terms of exposure, sensitivity, and adaptive capacity. This, the impacts of climate hazards cannot be understood separately from the underlying physical and institutional conditions of infrastructure systems.

Interdependence of critical infrastructure

The analysis demonstrates that critical infrastructure systems are closely interconnected. Water shortages for example affect agriculture and livelihoods, while agricultural activities depend on reliable water supply and irrigation infrastructure. Energy systems are also important because electricity is required for water abstraction and irrigation and other essential activities. Similarly, health facilities depends on reliable electricity, water, and communication systems to maintain services during emergencies. Communication systems themselves depend on supporting infrastructure and reliable power. These relationship are consistent with Durrani et al. (2021), who illustrate the connections between water resources, agriculture and livelihoods while Rana

et al. (2020) highlighted the importance of energy for agricultural water supply. Nasir et al. (2019) further emphasized the role of energy and communication systems in maintaining essential services. The findings thus suggest that infrastructure resilience cannot be addressed through isolated or sector specific approaches. Disruption in one system can create additional pressure on other systems particularly during disaster events.

Water infrastructure vulnerability

Water infrastructure emerged as one of the most consistently vulnerable sectors in the reviewed literature. Declining groundwater levels, recurring drought and water shortages identified in this study are consistent with Durrani et al. (2021) and Ahmed et al. (2013). Similarly, Rana et al. (2020) also highlighted concerns related to groundwater use through agricultural tube wells. Several studies propose measures such as water saving agricultural practices, rainwater harvesting and improved irrigation and water management techniques (Javed & Nauman, 2025). The findings suggest that these measures have not removed the underlying pressures on water availability. This indicates that water infrastructure vulnerability is influenced by both climatic stress and existing resource management challenges.

Urban and Coastal Infrastructure

The findings regarding urban infrastructure are consistent with Hussain (2024), who identified the effects of flash flooding on roads, buildings and services in Quetta. Similarly, the vulnerability identified in Gwadar is consistent with Fareedi et al. (2025), who highlighted the exposure of low lying areas and associated infrastructure to flooding. Existing research also indicates that climate related changes affect socio-economic conditions and livelihoods assets in the coastal regions of Balochistan (Kumbhar et al., 2019; Malik et al., 2023). The findings extend this discussion by highlighting the importance of considering infrastructure planning in rapidly developing coastal and urban areas such as Gwadar. Rapid urbanization combined with inadequate planning and drainage systems may increase the potential impacts of extreme rainfall and flooding.

Health, Energy and Communication Infrastructure

The findings related to health infrastructure are consistent with Arshad et al. (2021), who identified challenges in hospital preparedness in Quetta. Their findings together with the present analysis indicate that preparedness depends not only on the physical condition of health facilities but also on their operational capacity and ability to maintain services during emergencies. Energy and communication systems are important for maintaining essential services during disasters. Nasir et al. (2019) highlighted the potential role of microgrids in supporting essential services in areas like Balochistan. The findings suggest that infrastructure resilience extends beyond the physical protection of individual facilities. It also depends on the reliability of supporting systems that allow health, communication, energy, and other essential services to continue functioning during hazard events.

Community resilience and disaster preparedness

The findings support the importance of community awareness, preparedness and local coping capacity in disaster prone areas of Balochistan (Ainuddin et al., 2024; Nasrullah et al., 2015). Durrani et al. (2021) and Shah et al. (2025) identified how water shortages and resource

constraints can limit the ability of communities to cope with drought. Although evidence of community resilience exists its effectiveness is influenced by access to resources, information and institutional assistance. This is consistent with Ainuddin and Routray (2012), who emphasized the importance of strengthening both community preparedness and institutional support for disaster management. Community resilience appears to depend not only on local capacity but also on the external support available to communities during and after disasters.

Institutional and policy preparedness

The research indicates awareness and policy action on climate integration, adaptation, and disaster management reflected in policy frameworks. This is consistent with Waheed et al. (2021) who emphasized the importance of policy coherence and integrating climate considerations into development planning. Javed & Nauman (2025) highlighted the need for stronger coordination and locally relevant climate adaptation measures. It appears that institutional capacity and co-ordination remain significant challenges. This is consistent with Rehman and Mengal (2025), who identified institutional and coping limitations as factors contributing to vulnerability. The findings suggest that the presence of policies does not necessarily indicate sufficient institutional preparedness to implement them effectively.

Policy-infrastructure implementation gap

The core finding of this study is that there is a gap between policy intentions and practical infrastructure preparedness and implementation. This does not mean that there is no policy in place, but implementation can be constrained by institutional coordination, financial resources capacity of implementation agencies and the extent to which climate risks are incorporated into infrastructure planning, development and maintenance. This finding is consistent with Waheed et al. (2021), who emphasized the importance of climate considerations into development planning and Javed and Nauman (2025), who highlighted the better coordination and local implementation of climate responses. These findings point to an important distinction between policy formulation and policy implementation. Balochistan has increasingly recognized climate risks within its policy framework but translating these commitments into consistent infrastructure planning and implementation remains a challenge.

Conclusion

This study examined the vulnerability of critical infrastructure to climate change in Balochistan and evaluate the readiness of the existing policy and institutional frameworks to address these vulnerabilities. The findings highlighted that Balochistan is exposed to a range of interrelated climate and disaster hazards, including drought, water scarcity, intense rainfall, flooding, and coastal hazards. These risks affect infrastructure differently across the region, with water infrastructure particularly affected by drought, groundwater depletion, and water scarcity. Urban and coastal infrastructure is also vulnerable to flooding and extreme rainfall events. The study further demonstrates that infrastructure vulnerability is not determined by climate hazards alone. Existing infrastructure weaknesses, lack of resources, gaps in community preparedness and institutional capacity can increase the impacts of these hazards. These interacting vulnerabilities can produce cumulative impacts across interconnected water, energy, health, transportation, and communication systems. Local communities play a critical role in coping with and responding to disasters although their capacity can be constrained by limited resources and institutional

support. Turning to policy and institutional readiness, Balochistan has developed several important policies and plans related to climate adaptation, disaster management, water resource management, and development initiatives. These frameworks increasingly recognize climate change and include measures such as improved water resource management, climate smart agriculture, disaster risk reduction strategies, enhanced institutional coordination, and climate resilient development. However, a key finding is the gap between policy formulation and implementation. The existence of policy and planning documents does not necessarily ensure that climate risks are incorporated into every stage of infrastructure development, from planning and financing to implementation and maintenance. The principal contribution of this study is to connect two areas of research : critical infrastructure vulnerability and policy and institutional preparedness for climate adaptation. The findings demonstrates the importance of considering these dimensions together when assessing infrastructure resilience in Balochistan. Simply responding to individual climate and disaster risks is insufficient a more holistic approach is required, involving stronger inter-institutional coordination, mainstreaming of climate risks into development planning, adequate financial and technical resources, effective monitoring and greater community engagement. The study concludes that although Balochistan has strengthened the recognition of climate risks within policy and planning, translating these commitments into effective implementation remains a significant challenge. Therefore, any future efforts should focus on strengthening implementation processes and evaluating the effectiveness of policies in improving the resilience of critical infrastructure.

Recommendations

1. Ensure coordination between all government departments so that climate risks are integrated into critical infrastructure decision-making and planning.
2. Increase investment in water infrastructure systems and raise awareness of water conservation. This should include an emphasis on groundwater management, water conservation, and drought affected regions.
3. Consider climate risks from the early stages of planning, design, construction and maintenance of roadways, hospitals, energy and communication systems and urban environments.
4. Empower local communities with resources, including knowledge, training, early warning information and other support to help them prepare for and cope with extreme events.
5. Regular monitor the implementation of policies and action plans to ensure that policy commitments are actually translated into action at the local level.

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