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Climate Resilience in Airport Infrastructure

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Abstract—Airports are increasingly exposed to climate-related risks such as sea-level rise, flooding, extreme heat, storms and heavy rainfall. These hazards can disrupt airport infrastructure, flight operations and supporting transport networks. This review examines the climate resilience of airport infrastructure, focusing on major climate risks, assessment methods, adaptation strategies and international case studies. Particular attention is given to the Climate Resilience Assessment of Airports Tool (CRAAT), which helps identify climate-related risks and evaluate suitable control measures. Studies of coastal airports, Soekarno-Hatta International Airport and LaGuardia Airport highlight the importance of location-specific climate data and effective adaptation planning. The review emphasizes that airport resilience requires continuous improvements in infrastructure, maintenance, emergency preparedness and stakeholder coordination. Integrating climate projections into airport planning and operations is essential for ensuring long-term safety and operational continuity.

Keywords—Adaptation, Airport infrastructure, Climate hazards, Climate resilience, Coastal airports, CRAAT, Risk assessment

I. INTRODUCTION

Airports are vital infrastructure that support passenger travel, freight transport, business activities, and regional connectivity. They rely on road and rail networks, utilities, emergency services, air navigation systems, and nearby communities. Therefore, disruptions at airports can affect not only airport operations but also the surrounding regions.

Climate change poses growing challenges to airport infrastructure and operations. Major risks include sea-level rise, flooding, heavy rainfall, extreme temperatures, storms, drought, and changing wind and icing conditions. Climate-resilient airports must be able to withstand these challenges, maintain essential services, and recover quickly from disruptions [1].

Since airport infrastructure has a long service life, future climate conditions must be considered in planning and maintenance. Identifying climate risks at an early stage can help airport authorities develop effective adaptation strategies, improve emergency preparedness, and ensure long-term operational continuity.

II. OBJECTIVES

- To understand the importance of climate resilience in airport infrastructure.
- To identify the major climate hazards that affect airport facilities and operations.
- To examine the effects of climate change on runways, terminals, utilities, navigation systems, aircraft operations, and ground access.
- To review the methods used to assess climate risks and evaluate airport resilience.
- To study suitable adaptation measures and selected international case studies.
- To identify future needs for developing climate-resilient airports through continuous monitoring, effective planning, and improved infrastructure.

III. METHODOLOGY

This study is based on a review of the submitted seminar report and relevant academic and institutional publications. The review was carried out in four stages: identifying major climate hazards and airport systems, examining risk and resilience assessment methods, reviewing adaptation strategies, and comparing selected case studies and research findings.

The main sources include the ICAO Eco Airport Toolkit on Climate Resilient Airports, the ACI policy brief on airport resilience and adaptation, the 2018 ISOCARP paper by Flanagan et al., the ICAS paper on CRAAT, the 2024 study by Chen et al. on coastal airports, and other airport-climate studies cited in the seminar report [1–7]. This paper focuses on existing research and does not introduce new airport-specific risk scores or engineering design calculations.

IV. CLIMATE HAZARDS AFFECTING AIRPORT INFRASTRUCTURE

Climate change can affect different parts of an airport, from runways and terminals to navigation systems and access roads.

TABLE I
CLIMATE HAZARDS AFFECTING AIRPORT INFRASTRUCTURE

Climate hazard	Main systems affected	Typical impacts
Sea-level rise and storm surges	Runways, terminals, utilities, access roads	Flooding, infrastructure damage, and airport closures
Extreme heat	Pavements, aircraft operations, terminals, workers	Pavement deterioration, reduced aircraft performance, increased cooling demand, and heat stress
Heavy rainfall	Drainage systems, airfields, buildings, roads	Flash flooding, drainage overflow, and access disruptions
Storms and high winds	Aircraft, buildings, and airport equipment	Structural damage, flight delays, and cancellations
Drought	Water supply systems and airport operations	Water shortages and difficulties maintaining normal operations
Changing icing conditions	Runways and aircraft	Increased de-icing requirements and possible reductions in airport capacity
Biodiversity changes	Wildlife hazard management systems	Changes in wildlife movement and increased bird-strike risks
Lightning and extreme weather	Navigation, communication, and operational systems	Equipment failures, communication problems, and operational disruptions

The ACI policy brief highlights the effects of climate hazards on airfields, terminals, ground facilities, navigation systems, aircraft operations, communications, and emergency services [2]. Similarly, the ICAO toolkit explains that disruptions can extend beyond individual airports because aviation networks depend on interconnected infrastructure and services [1].

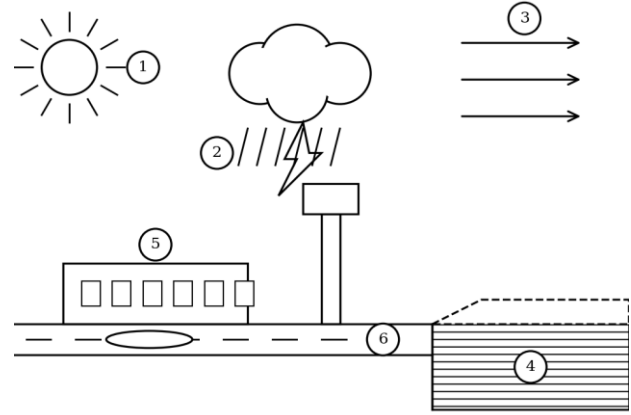


Fig. 1. Schematic of an airport exposed to climate hazards: (1) extreme heat, (2) heavy rainfall and lightning, (3) storms and high winds, (4) sea-level rise and storm surge, (5) terminal and landside flooding, (6) runway and pavement stress.

V. IMPACTS ON AIRPORT SYSTEMS

A. Airfield and Pavement Systems

High temperatures and changes in rainfall can affect runway surfaces and increase maintenance needs. Heavy rain may overwhelm drainage systems and leave water on runways. Extreme heat can also reduce aircraft performance during take-off, sometimes requiring longer runways or operational restrictions [1,2].

B. Terminal and Landside Infrastructure

Floods and storms can damage terminal buildings, parking areas, loading zones, and access roads. High temperatures increase the need for air conditioning and may cause equipment to overheat. Even when runways remain usable, damaged access roads or flooded terminal areas can prevent passengers and staff from reaching the airport.

C. Navigation, Communication and Utilities

Climate-related events can disrupt navigation equipment, communication networks, electricity supplies, and satellite-based services. For example, a storm-related power failure may affect several airport systems at the same time. Backup power, protected equipment, and clear emergency procedures are therefore important for maintaining airport operations.

D. Aircraft Operations

High temperatures reduce air density, which can affect aircraft lift and engine performance. As a result, aircraft may require longer take-off distances, experience reduced climb performance, or face restrictions on certain flights. Changes in wind, visibility, turbulence, rainfall, and icing conditions can also affect flight safety and efficiency [1,2].

E. People, Access and Business

Climate-related disruptions can affect passengers, airport staff, airlines, and other businesses. Flight delays, cancellations, limited road access, and higher maintenance costs can lead to financial losses and reduced passenger satisfaction. Since airports are connected through wider transport networks, disruption at one airport may also affect other airports and the surrounding regional economy [2,3].

VI. CLIMATE RISK AND RESILIENCE ASSESSMENT

Climate risk assessment helps identify how climate hazards can affect airport infrastructure and operations. It considers the hazards themselves, the airport's exposure and vulnerability, and the possible consequences. The approach recommended in ICAO-related guidance involves forming a project team, consulting relevant stakeholders, studying climate projections, prioritising risks, planning adaptation measures, and monitoring their implementation [1,5].

A. CRAAT Approach

The Climate Resilience Assessment of Airports Tool (CRAAT) provides a structured method for assessing climate risks at airports. It uses airport-specific climate projections to identify potential hazards and evaluate the risks that may remain after protective measures are introduced. The process includes identifying future climate conditions, estimating the likelihood of events, assessing their consequences, selecting control measures, and reviewing the remaining risks [5].

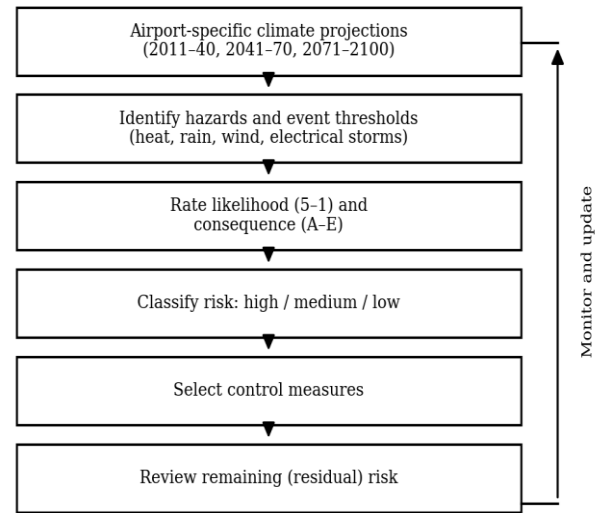


Fig. 2. Stages of the CRAAT climate risk assessment process.

CRAAT considers three future climate periods: 2011–2040, 2041–2070, and 2071–2100. Hazards assessed may include heatwaves, heavy rainfall, strong winds, and electrical storms. The likelihood of an event is rated from 5 (highly probable) to 1 (improbable), while its consequences are graded from A (catastrophic) to E (minimal). These ratings are used to classify risks as high, medium, or low according to the tool's guidance [5].

Likelihood	5 Highly probable	Med	Med	High	High	High
	4 Probable	Med	Med	Med	High	High
	3 Possible	Low	Med	Med	Med	High
	2 Remote	Low	Low	Med	Med	Med
	1 Improbable	Low	Low	Low	Med	Med
		E Minimal	D Minor	C Moderate	B Major	A Catastr.
		Consequence				

Fig. 3. Illustrative likelihood–consequence risk matrix (likelihood 5–1, consequence A–E). Hatching indicates risk class (plain: low; dotted: medium; diagonal: high); boundaries are indicative only.

B. Quantitative Resilience Index

Chen et al. developed a quantitative framework to evaluate the climate resilience of coastal airports. Their study used coupling-coordination and obstacle-degree models and considered four main aspects: the natural environment, socioeconomic conditions, governance capacity, and climate-change risk [6].

A resilience index provides a numerical way to assess and compare resilience using selected indicators, assigned weights, and a defined evaluation method. However, the index does not represent a physical measurement like metres or kilograms. Its results must be interpreted according to the methods and indicators used in the particular study.

VII. ADAPTATION AND RESILIENCE STRATEGIES

A. Infrastructure Adaptation

Airport infrastructure should be designed and maintained to withstand future climate conditions. Improving drainage, protecting facilities from flooding and storm surges, and using climate-appropriate materials for runways and buildings can help reduce damage. Critical electrical, communication, and navigation systems also need proper protection.

B. Operational Adaptation

Airports can reduce climate-related disruptions through weather monitoring, suitable operating procedures, and well-planned emergency responses. Maintenance schedules and contingency plans should also be adjusted to prepare for extreme heat, heavy rainfall, strong winds, and other severe weather events.

C. Building and Terminal Adaptation

Terminal buildings need adequate flood protection, effective drainage, and improved energy efficiency. As temperatures rise, better cooling systems and protection for sensitive equipment can help maintain a comfortable and safe environment for passengers and staff.

D. Energy and Utility Resilience

A reliable energy supply is essential for continuous airport operations. Protecting power distribution systems, providing backup power, improving cooling efficiency, and using renewable energy where practical can help airports manage climate-related disruptions.

E. Emergency and Business Continuity

Airports should have clear plans for protecting staff and passengers during extreme weather.

These plans should cover communication, passenger movement, transport access, utility failures, and coordination with emergency services. Such preparation helps essential operations continue or resume quickly after a disruption.

F. Master Planning and Maintenance

Climate risks should be considered during airport planning, construction, and routine maintenance. Including adaptation measures in master plans, infrastructure design, maintenance schedules, and emergency procedures helps airports prepare for future climate challenges more effectively.

VIII. RESEARCH FINDINGS AND CASE STUDIES

A. Soekarno-Hatta International Airport

Rahutomo et al. studied daily average air temperatures at Soekarno-Hatta International Airport over a period of 30 months. The data were analysed in six-month intervals. The findings showed generally warm and relatively stable temperatures, although statistically significant differences were observed between several periods. The study highlights the importance of combining temperature data with other weather conditions and flight information to improve future forecasting. It also discusses the potential use of solar energy in warm airport environments [4].

B. LaGuardia Airport and Hurricane Sandy

Flanagan et al. examined the effects of Hurricane Sandy on LaGuardia Airport in 2012. Severe flooding forced the airport to close for almost two days. This event demonstrates how vulnerable coastal airports can be to extreme weather. Improved flood protection, drainage systems, and reliable backup power are important measures for reducing similar disruptions in the future [3].

C. Coastal Airport Quantitative Assessment

Chen et al. developed a quantitative method to assess climate resilience at coastal airports and applied it to Hong Kong International Airport. Their study reported an overall increase in the climate resilience index. The natural environment and governance capacity showed improving trends, while the climate-change-risk index declined. The researchers also used coupling-coordination and obstacle-degree models to examine relationships between resilience factors and identify areas that required improvement [6].

D. Global Airport Assessment Using CRAAT

Ösund-Ireland et al. applied the Climate Resilience Assessment of Airports Tool (CRAAT) to eight representative airports.

The method uses climate projections from the IPCC and defined event thresholds to assess potential climate hazards and their consequences. It offers airport managers a consistent way to identify risks and consider the financial effects of climate-related disruptions, including possible revenue losses [5].

E. European Airport Climate Considerations

The reviewed seminar literature also examined the effects of rising temperatures at European airports. The research considered historical and projected temperatures, heatwaves, thermal comfort, and changes in heating and cooling requirements. It also discussed temperature-related fuel considerations and the need to account for future climate conditions when planning airport infrastructure [7].

IX. STAKEHOLDER COORDINATION AND RESILIENCE PLANNING

Preparing airports for climate-related challenges requires cooperation between different organisations. Key stakeholders include airport owners and managers, airlines, air navigation service providers, utility companies, transport agencies, emergency services, government authorities, airport staff, nearby communities, and technical experts. According to ACI, climate risks should be considered in airport master plans and risk assessments, with early adaptation measures and clear communication between stakeholders [2].

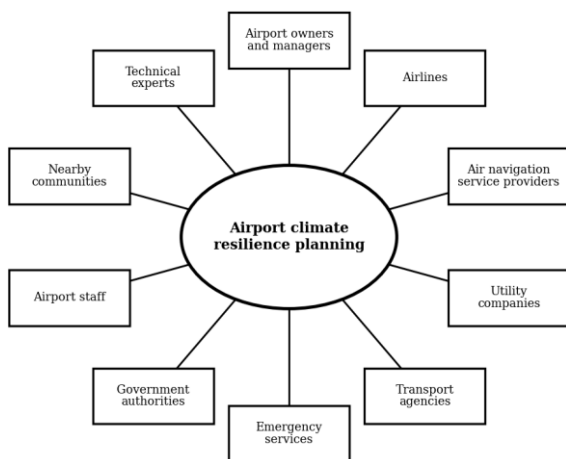


Fig. 4. Key stakeholders in airport climate resilience planning.

Cooperation is essential because airport operations depend on reliable roads, railways, electricity, water supplies, and communication networks.

If any of these services are disrupted, airport activities may also be affected. Furthermore, problems at one airport can spread to other airports and affect the wider aviation network. Therefore, joint planning and effective communication are important for maintaining airport operations and improving long-term climate resilience.

X. ADVANTAGES, CHALLENGES AND FUTURE SCOPE

A. Advantages

Climate resilience offers several benefits for airport infrastructure and operations:

- Helps maintain essential airport services during extreme weather.
- Reduces the effects of climate change on airport facilities.
- Improves the safety and reliability of aircraft and ground operations.
- Helps airport authorities plan maintenance and allocate funds effectively.
- Minimises avoidable delays, disruptions, and recovery expenses.
- Encourages better coordination between airport authorities and external agencies.
- Supports sustainable infrastructure development over the long term.

B. Challenges

Despite these benefits, improving airport climate resilience involves several challenges:

- Future climate conditions are difficult to predict accurately.
- Climate hazards and their effects vary from one airport to another.
- Airports depend on external transport links and utility services.
- Detailed, airport-specific climate data may not always be available.
- Adaptation projects can require significant financial investment.
- Effective planning requires cooperation among many organisations.
- Converting climate projections into practical operating limits can be difficult.

C. Future Scope

Future research can explore the use of temperature, rainfall, wind, humidity, and flight data to predict delays and climate-related infrastructure problems. Statistical and machine-learning techniques could help identify patterns and improve forecasting.



Combining local climate projections with airport asset records and operational limits could also support better decision-making.

Further studies can develop resilience assessment methods that consider infrastructure conditions, socioeconomic factors, governance, and climate risks together. Continuous monitoring would allow airport authorities to update their plans as weather conditions change and new information becomes available. These improvements could help airports prepare more effectively for future climate challenges.

XI. RELEVANCE TO CIVIL ENGINEERING

Climate resilience is an important aspect of civil engineering, particularly in the planning, design, and maintenance of airport infrastructure. Civil engineers play a key role in designing durable runways, improving drainage systems, protecting buildings and foundations from flooding, and managing water resources. They are also involved in construction planning, regular maintenance, and assessing the condition of existing infrastructure.

The reviewed studies highlight the need to consider future climate conditions when designing and maintaining airport facilities. These engineering measures should be planned alongside airport operations, emergency preparedness, and external transport and utility networks. This approach helps improve infrastructure safety, reliability, and long-term performance.

XII. CONCLUSION

Climate resilience is essential for airport infrastructure because airports depend on many connected systems to operate safely and efficiently. Climate hazards such as sea-level rise, flooding, extreme heat, heavy rainfall, storms, drought, and changing icing conditions can affect runways, terminals, aircraft operations, utilities, and transport access. These disruptions can also affect passengers, employees, and airport businesses.

The reviewed studies show that airports need to identify climate risks and take suitable measures to reduce their impacts. Climate projections should be considered in airport planning, infrastructure design, maintenance, emergency preparedness, and business continuity. Cooperation between airport authorities, airlines, government agencies, utility providers, and surrounding communities is also important.

The case studies highlight different ways to assess and manage climate risks, including temperature analysis, flood protection, quantitative resilience assessment, and the use of CRAAT. Overall, climate resilience is an ongoing process that requires regular assessment, effective planning, adaptation, and monitoring. By adopting these measures, airports can improve their ability to withstand climate-related challenges and maintain essential services under changing environmental conditions.

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