GLOBAL STUDY ON DISASTER RESILIENCE OF AIRPORTS
PHASE 1
UNDERSTANDING THE CURRENT STATE OF PRACTICE OF DISASTER RISK MANAGEMENT AND RESILIENCE
Launched by Indian Prime Minister Narendra Modi at the 2019 UN Climate Change Summit, the Coalition for Disaster Resilient Infrastructure (CDRI) is a global multi-stakeholder partnership of national governments, UN agencies, programmes, multilateral development banks financing mechanisms, private sector, academic and knowledge institutions. CDRI is committed to working with various stakeholders to promote the resilience of infrastructure globally. CDRI aims to address the challenges of incorporating resilience into infrastructure systems and the development that comes with it. To date, CDRI’s members and partners include 31 countries and 8 organizations worldwide.

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GLOBAL STUDY ON DISASTER RESILIENCE OF AIRPORTS PHASE 1

UNDERSTANDING THE CURRENT STATE OF PRACTICE OF DISASTER RISK MANAGEMENT AND RESILIENCE
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Transport infrastructure is a lifeline for global economies. The aviation sector, in particular, is a critical infrastructure system, essential for sustainable development and wellbeing of societies. The sector significantly contributes to and influences 15 of the 17 Sustainable Development Goals. As the recent pandemic and disaster events across the globe have illustrated, aviation provides critical services during disasters and other humanitarian crises.

The aviation sector attracts large scale capital investments in airport infrastructure. Governments are presenting industry-friendly policies and frameworks towards challenges like decarbonization, sustainable aviation fuels and improved ESG to sustain and attract massive investments to build/improve airport infrastructure. The complex, interconnected system-of-systems nature of the aviation sector lends itself to both opportunities and challenges in ensuring resilient infrastructure.

The massive disruption to services and operations of airports due to the COVID pandemic is redefining the sector in terms of revisiting operating models, reassessing de-risking strategies, and re-examining sustainable aviation financing among others. Challenges posed by climate uncertainty, extreme weather events and anthropogenic activities compound the risks faced by the sector. To reduce the impact of these factors, airport operators and other stakeholders need to invest in research and data-driven decision systems to build resilient infrastructure and provide optimal services. Digitization and access to real-time data will enable simulation of potential risk scenarios to be better prepared in case of a disaster event. There is a clear need to strengthen the capacity of manufacturing and service facilities, and skilled professionals to cater to the exponential growth in the aviation industry.

We must leverage the huge investments in aviation to be better prepared for an uncertain future and the challenges and disruptions it might hold, refine insurance mechanisms to safeguard assets and investments from climate and disaster events, and reform strategies and policies to ensure climate financing towards resilience, beyond mitigation or adaptation initiatives.

This report reflects the Coalition for Disaster Resilient Infrastructure’s efforts to provide an incisive look at the current state of practice of disaster risk management and resilience in airports. This report will inform airport operators and owners on the risks to their infrastructure assets, services, and investments. It brings to focus the key challenges and opportunities in terms of the preparedness of airports across the world in the face of an uncertain future marked by global transitions.

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Director General
Coalition for Disaster Resilient Infrastructure

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GLOSSARY

Disaster
The impact of a hazard or a sudden calamitous event bringing great damage, loss, or destruction. (United Nations Office for Disaster Risk Reduction)

Disaster Preparedness
A set of measures undertaken by governments, organizations, communities, or individuals to better respond and cope with the immediate aftermath of a disaster, whether it be human-made or caused by natural hazards. The objective is to reduce loss of life and livelihoods. (European Civil Protection and Humanitarian Aid Operations)

Hazard
A potential source of harm (event or circumstance) which can cause damage to health, life, property, or operations. (United Nations Office for Disaster Risk Reduction)

Impact
The total effect, including negative effects (e.g., economic losses) and positive effects (e.g., economic gains), of a hazardous event or a disaster. The term includes economic, human and environmental impacts, and may include death, injuries, disease and other negative effects on human physical, mental and social well-being. (United Nations Office for Disaster Risk Reduction)

Resilience
Resilience is the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions. (United Nations Office for Disaster Risk Reduction)

Risk
The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity. (United Nations Office for Disaster Risk Reduction)

Vulnerability
Vulnerability refers to the inability of a system to withstand the effects of a hostile environment or situation. (United Nations Office for Disaster Risk Reduction)
## ACRONYMS

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<tr>
<td>A-CDM</td>
<td>Airport Collaborative Decision Making</td>
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<tr>
<td>ACI</td>
<td>Airports Council International</td>
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<td>ACROS</td>
<td>Airport Climate Risk Operational Screening</td>
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<td>ACRP</td>
<td>Airport Cooperative Research Program</td>
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<tr>
<td>AERP</td>
<td>Airport Emergency Response Plan</td>
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<tr>
<td>BCP</td>
<td>Business Continuity Plan</td>
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<tr>
<td>CAPEX</td>
<td>Capital Expenditure</td>
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<tr>
<td>CAR</td>
<td>Civil Aviation Regulation</td>
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<tr>
<td>CAT 9</td>
<td>Category 9 Level of Service</td>
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<tr>
<td>COOP</td>
<td>Continuity of Operations Plan</td>
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<tr>
<td>ERP</td>
<td>Emergency Response plan</td>
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<td>FGD</td>
<td>Focus Group Discussion</td>
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<tr>
<td>GSE</td>
<td>Ground Service Equipment</td>
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<tr>
<td>IATA</td>
<td>International Air Transport Association</td>
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<tr>
<td>ICAO</td>
<td>International Civil Aviation Organization</td>
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<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
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<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
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<tr>
<td>MAP</td>
<td>Million annual passengers</td>
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<tr>
<td>NACO</td>
<td>Netherlands Airport Consultants, a company of Royal HaskoningDHV</td>
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<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
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<tr>
<td>RFF</td>
<td>Rescue and Firefighting</td>
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<td>RHDHV</td>
<td>Royal HaskoningDHV</td>
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<tr>
<td>SMS</td>
<td>Safety Management System</td>
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<tr>
<td>T100</td>
<td>Once Per 100 Years</td>
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<td>TCFD</td>
<td>Task Force on Climate-Related Financial Disclosures</td>
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EXECUTIVE SUMMARY
The world is experiencing an increasing frequency of extreme weather events due to climate change, continued exposure to other natural and human-induced hazards, and increasing system interdependency and integration. Modern socio-economic and infrastructural systems have become more complex due to rapid urbanization and economic growth, adding pressure on critical nodes. Airports are arguably one of such nodes providing multi-scale connectivity, stimulating economic and business environment activity, and serving society.

Building disaster resilience capacity can be critical in protecting airport assets and their continued operability and business continuity today and in the future. Currently, the field of research concerned with systematically measuring airport resilience is less established, vis-a-vis other forms of major infrastructure.

To address the impacts of natural hazards and human-induced disasters on airports, as well as the associated direct losses and cascading economic impacts affecting the lives and livelihoods of millions of people, the Coalition for Disaster Resilient Infrastructure (CDRI) initiated the Global Study on Disaster Resilience of Airports. This report is the result of a year-long research by the Netherlands Airports Consultants, a company of Royal HaskoningDHV (NACO) on behalf of CDRI.

Study sets out to define the current state of practice on disaster risk management and resilience at airports globally by gathering information around three questions:

1. What is the current perception of hazard and disaster exposure at airports?
2. How do airports perceive their resilience to climate, environmental and natural hazards?
3. What are the current practices in airport resilience?

Herein, the collective perspective from the various departments and responsibilities within an airport organization inform an understanding of the risks and impact of extreme events and disasters on airports, the practices in place, challenges to resilience and the actions moving forward for the industry.

As a result of the outreach efforts described in the document, this section presents the findings resulting from the analysis of disaster resilience practices in place at 81 airports.
A representative sample set was achieved through a multi-pronged outreach approach. The sample set represents all the major regions of the world and provides a comprehensive overview of all the natural hazards identified in the study.
Findings

This study answers the three primary research questions by investigating the perception of the airports on the following:

- **Baseline and Hazard Exposure**
  Understanding historic and anticipated natural hazards and their impact. Capturing risk vs resilience practices.

- **Infrastructural Adaptive Capacity**
  Understanding the awareness on critical assets and response plans in action.

- **Operational Adaptive Capacity**
  Understanding operational preparedness and post-disaster planning measures in place.

- **Organizational Adaptive Capacity**
  Gauging capacity, and financial preparedness.

What is the current perception of hazard and disaster exposure at airports?

**Disaster Impact Context**

Across regions, airports expect extreme storms and winds, extreme precipitation, and third-party systems failures to result in partial infrastructural restrictions, flight delays, and indirect economic loss to airport partners.

Each region displays a different ability to recover from climate and natural hazards. Notably, North America displays a slower ability to fully recover from extreme icing conditions, extreme storms and winds and geological hazards compared to Asia/Pacific and Europe. Similarly, although airports in Africa tend to resume operations at similar rates than their counterparts, full recovery appears to take longer in the region.

Airports report a faster ability to resume and recover operations from disruptions of incremental intensity and predictable occurrence like flooding, drought, and extreme heat than from volcanic activity, geological hazards (earthquakes, landslide and others) and third-party systems failures.

Larger airports (50MAP+) anticipate potential closure for restrictive conditions of operations, reduced efficiency, and potential direct economic loss to airport partners. Smaller airports expect limited severity of impact on their assets, with severity levels limited to partial infrastructural restrictions.
Airports which conduct periodic vulnerability assessments are anticipating lower impact on their organization as compared to airports without a periodic assessment practice. For these vulnerability assessments, the three most important elements are:

1. Personnel and Passenger Infrastructure
2. Civil Structure and Installations
3. Reliability of Operations

Runways, terminals, and communication systems are given the highest priority among the critical assets, with the majority of participating airports having mitigation or recovery measures in place for these assets. Though airport access links are considered one of the most vulnerable assets, participating airports highlight that developing mitigation or recovery measures for these assets is often challenging, as they may not be a part of airport jurisdiction and require extensive collaboration with multiple stakeholders in the region.

To ensure operational continuity, several airports rely on Memorandum of Understandings with external stakeholders and designated in-house staff for emergency maintenance or repair, as well as partnerships with other airports in the vicinity for emergency assistance. Currently most natural hazards are currently not addressed by insurance policies.

Existing airport risk and resilience practices include a limited number of operational and financial measures. Measures employed to increase resilience and protect critical assets focus predominantly on organizational and infrastructural measures. These measures include:

1. Procedural methods and trainings like recurring drills and risk management focused meetings.
2. Asset management systems, maintenance manuals and pre-defined response processes to protect critical assets.
3. New infrastructure and redundant installations for storm water drainage and power supply. However, although recognised as crucial, redundancy of infrastructure and utilities is often difficult to address because of financial constraints.

How do airports perceive their resilience to climate, environmental and natural hazards?
Risk Assessment Practices
What are the current practices in airport resilience?
Adaptive Capacity

At organizations with effective practices, the drivers of an airport’s risk and resilience practice are:

1. Executive Board/Management
2. Results of a Risk Assessment
3. Government Policies

To complement their in-house capacity and expertise, airports collaborate with airlines, ground handlers, government agencies and utility providers to define, implement and monitor their Airport Emergency Response Plan and Disaster Recovery Plan. This early involvement of all stakeholders contributes to effective response and recovery. Even though the pandemic improved dynamics between stakeholders, respondents emphasize that collaboration processes with internal and external stakeholders can be boosted further, especially through closer work with national government for improving resiliency of airports.

Human safety, government policies, and risk assessment results are the three biggest drivers of airport resilience practices. Increasing responsibility and accountability of authorities and governments, for active resilience planning, funding and mandating resilience practices are key to improving the resilience of airports.

Airports, irrespective of the income level of the country where they are located, rely predominantly on internal datasets and open-source government and public datasets to predict future hazards, and improve adaptation. However, larger economies and bigger airports are able to complement these data sources with scientific studies, industry groups data, and subcontracted studies.

Airports that have been able to consider the risks identified as part of their planning and design process, and employ additional measures typically have access to scientific studies and knowledge through industry groups. Industry organizations like ICAO, ACI and government authorities are urged to support knowledge sharing practices, facilitate trainings, and actively conduct research.

Way Forward

Based on the findings, the study shares recommendations for the way forward. These are supported by expert opinions, examples and possible further steps for implementation.

The recommendations are spread across three broad themes:
<table>
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<th>Research &amp; Knowledge Sharing</th>
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<tr>
<td>Recommendations suggest methods to bridge the current gap in knowledge and data available.</td>
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<tr>
<td>• Conduct in-depth studies of risk and resilience practices at airports to understand differences in ability to resume operations and recover across regions.</td>
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<td>• Establish a broader understanding of risk appetite of airports.</td>
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<td>• Encourage cross-industry knowledge sharing and learnings from industries and environments with similar complexities, such as cities.</td>
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<td>Recommendations present possible regulations or mandates which can facilitate improvement in resilience practices and address the identified challenges.</td>
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<tr>
<td>• Integrate the Task Force on Climate-related Financial Disclosures (TCFD) framework as standard practice to improve airport understanding of their current practices, including physical and transition risks.</td>
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<td>• Airport and government bodies should continue to work together to build integrated disaster resilience.</td>
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<td>• Mandate government authorities and institutions to conduct region-focused scientific studies and address the scarcity of scientific studies related to airport's natural and climate hazard exposure.</td>
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<td>• Mandate quick scans to assess hazard exposure and resilience planning as part of all greenfield and brownfield developments.</td>
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<td>Recommendations present common practices captured during the study.</td>
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<td>• Airports should engage local and regional stakeholders for increasing airport resilience practices and support the acceleration of resilience in the catchment area.</td>
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<tr>
<td>• Airports should conduct periodic vulnerability assessments and develop a resilience strategy.</td>
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<tr>
<td>• Airports should move towards a more proactive approach rather than reactive towards hazard management and resilience planning.</td>
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<tr>
<td>• Airports and insurers should collaborate to mitigate climate risk, this will be mutual beneficial.</td>
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Note: Each dot represents the relevant actor per recommendation.

- Government/Politician
- Airports
- International Knowledge Institutions
1

INTRODUCTION
The world is experiencing an increasing frequency of extreme weather events due to climate change, continued exposure to other natural and human-induced hazards, and increasing system interdependency and integration. Modern socio-economic and infrastructural systems have become more complex and together with urban growth, the aviation infrastructure has also expanded, both in number of airports and flights as well as size of airport infrastructure. Airports are arguably one of such nodes, providing multi-scale connectivity, stimulating economic and business environment activity, and serving society.

Disruption of airport operations and services can have a cascading effect through dependent infrastructure and socio-economic systems. The probability of such disruptions is elevated by the location of various airports (and their surroundings) resulting in increased exposure to natural hazards and human-induced disasters. Further, there is significant dependence on external factors like surface access and utilities, which if disrupted at source, is beyond their control. Finally, airports are naturally prone to adverse effects of hazards due to their design creating concentrations of people combined in large open spaces/structures (human-induced hazards). Additionally, airports could play a key role in disaster relief which doubles down on the impact of disaster events when the airport experiences operational disruptions.

Building disaster resilience capacity is argued to be one of the core components for protecting airport assets, continuous operability, and business continuity today and in the future. Problematically, in contrast with other forms of major infrastructure, the field of research concerned with systematically measuring airport resilience is less established. This prompted the initiation of this global study that seeks to critically understand the disaster resilience of airports across the globe.

**CASE STUDY 1**

**Closure due to floods - Don Muang Airport (Bangkok)**

In October 2011, the city of Bangkok was flooded, including Bangkok’s Don Muang Domestic Airport. Around 90 percentage of the airport was flooded, including the road towards the airport, the runways, aprons, and other facilities, resulting in grounding operations for several days. The main international airport Suvarnabhumi continued to function operational and was not impacted by the flood event, due to the applied polder systems during the design. After the event, Don Mueang Airport has implemented a flood wall and upgrades the water system with pumps to mitigate a flood event in the future.

*Source: Daily mail news article dated 31 Oct 2011 (https://tinyurl.com/3j3b9344)*
To address the impact of natural hazards and human-induced disasters on airports, and the associated direct losses and cascading economic impacts that affect millions of people’s lives and livelihood, Coalition for Disaster Resilient Infrastructure (CDRI) initiated the development of a Global Study on Disaster Resilience of Airports in four phases as shown in Figure 1.

This report is limited to Phase 1 of this study and the result of the one-year-long research conducted by Netherlands Airports Consultants, a company of Royal HaskoningDHV (NACO) on behalf of CDRI.

The main objective of Phase 1 of the study is to define the current state of practice of disaster risk management and resilience at airports. It is based on an online survey and focus group discussions of airport representatives’ perceptions on airport resilience. The collective perspective from various departments and responsibilities within an airport organization provide insights on the risks and impact of extreme events and disasters on airports, existing practices in place for risk management, perceived threats to resilience and the actions needed to move the industry forward.

CASE STUDY 2
Typhoon Jebi’s storm: Kansai International Airport

On September 4, 2018, Japan’s third busiest airport, Kansai International Airport in Osaka Bay, was inundated by the Category 2 Typhoon Jebi’s storm surge. The deluge and rain flooded one runway, closing it for 10 days, and damaged electrical facilities in one of the airport’s two terminals, forcing its closure for 17 days. The economic impact on the region was estimated to be around USD 500 Million. With extreme climate events becoming more frequent in the country, the airport needed to mitigate future impacts and reduce downtime. NACO has advised KIX how to reduce climate-related downtime from two weeks to two days and increase the protection of critical assets and priority areas.

First, it presents the research methodology used for the study: this includes the research questions and the key dimensions addressed including but not limited to airport operational and organizational adaptive capacity (Section 2).

Second, it introduces the online survey (Section 3) and focus group discussions (Section 4) design and outreach approach and the associated detailed analysis results.

Lastly, the findings from the survey and focus group discussions are integrated to inform the key findings, limitations of the study (Section 5) and further recommendations (Section 6).

Figure-1 Phase 1 of the Global Study on Disaster Resilience of Airports in the context of the overall study
2

RESEARCH METHODOLOGY

2.1. State of Disaster Resilience Practice
2.2. Gap Analysis
2.3. Research Questions and Dimensions
2.1 State of Disaster Resilience Practice

Critical infrastructure, which include airports, are systems on which society relies to protect communities from hazards, provide essential services, or connect communities. As critical pieces of regional or national infrastructure, ensuring continued airport performance in the face of disruptions is essential. Nevertheless, the inherent complexity of airports makes it challenging for airport management to respond to threats and disruptions. This section presents current practices in airport risk management.
2.1.1 Pre-existing practice in airport risk management

Most of the airports have risk management processes. Risk management is the process of identifying risks, analysing their impact on system performance, and implementing measures to either prevent or mitigate/absorb negative consequences (ISO 31000, 2018). For example, the “Bow tie” Model shown in Figure 3 is commonly used in the aviation industry and includes a risk assessment component.

Figure-3 An overview of the “Bow tie” model, commonly used in the aviation industry
(adapted from ICAO, 2018)

However, risk assessments have important limitations including assessing risks for complex systems in dynamic conditions. Firstly, risk assessment deal with static hazards, which are easy to quantify in terms of both frequency and impact (ISO 31000, 2018). Hence, it is challenging for risk assessments to accurately capture hazards that are constantly changing in terms of frequency of occurrence, such as changing weather patterns due to climate change. Secondly, assessing the impacts of hazards on highly complex systems with strong internal and external interdependencies is extremely challenging. This is complicated even further when human-decision making plays an important role (Gössling-Reisemann, Hellige and Thier, 2018), as is typical in socio-technical systems. The aforementioned factors accentuate the need to complement risk assessment with risk resilience for airports, in the context of natural hazards.

2.1.2 Pre-existing practice in airport climate resilience

In the context of climate change, two types of risks can be identified, physical climate risks and transition risks.

1. Physical climate risks are the direct risks from climate-related events. For example, floods can damage infrastructure and create life-threatening conditions (NOAA, 2021).

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1 ISO 31000:2018 Risk management – Guidelines provides principles, a framework and a process for managing risk that can be used by organizations of any size, activity and sector
2. On the other hand, transition risks relate to transitioning to a lower-carbon economy. While transition risks will not directly impact physical assets, they can have important implications for organizations. These include policy, legal, technology, and market risks related to the capacity of an organization to address climate mitigation and adaptation requirements (TCFD, 2017).

Coping with these risks is also referred to as climate adaptation and climate mitigation respectively. Minimizing risks (e.g., loss and damage) is an important component of resilience, but not the only one. The next sections show why resilience assessment is also indispensable to airports.

The International Civil Aviation Organization (ICAO) defines a climate-resilient airport as one that "has taken steps to prepare for the challenges that climate change and severe weather bring" (ICAO, 2021). However, the resilience of a system can also depend on its capacity to absorb and recover from acute disruptions, as well as adapt to changing conditions (Linkov and Trump, 2019). Furthermore, it is important to highlight that climate change can also impact airports through transition risks, which are not explicitly addressed by the ICAO definition, nor addressed in this study.

In 2019, ICAO proposed a resilience framework to help airports adapt to climate change. As shown in Figure 4, the framework includes several steps such as forming a project team, setting climate resilience goals, and developing and reviewing resilience strategies. ICAO also includes the use of climate risk assessment as part of airport resilience planning, highlighting the Airport Climate Risk Operational Screening (ACROS) tool.

![Figure-4 Components of resilience planning as proposed by ICAO (ICAO, 2019)](image-url)
2.2 Gap Analysis

The following section gives an overview of current airport industry gaps and highlights the need for airport climate resilience assessment.

2.2.1 Resilience Capacities

To improve climate resilience and reduce vulnerability to climatic extremes, research shows various approaches based on “resilience capacities” that need to be strengthened. Francis and Bekera (2014) conducted a systematic review of the resilience developments across multiple domains and identified three resilience capacities: absorptive capacity, restorative capacity, and adaptive capacity. Based on these three resilience capacities Verdijk (2020) has drawn up a custom definition of a climate-resilient airport: an airport that can absorb impacts of extreme weather events, recover from disruptions and adapt to the changing conditions.

These three capacities have been identified for engineered and infrastructure systems which fit in perfectly with single logistics system (transportation) and utility infrastructure. However, airports are far more complex and more like cities. The definition of a climate-resilient airport is capability of an airport’s infrastructure including operations, businesses, passengers, and systems to adapt, and grow despite of acute and chronic climatic extremes. Additionally, two more resilience capacities must be considered: “threshold capacity” at the front and “transformative capacity” at the end of a series of five incremental or constructive capacities (De Graaf-Van Dinther and Ovink, 2021):

1. Threshold capacity: the capability to prevent damage by constructing a threshold against environmental variation.
2. Coping capacity: the capability to deal with extreme weather conditions and reduce damage during such conditions. Similar to “absorptive capacity” as identified by Francis and Bekera (2014).
3. Recovery capacity: the capability to bounce back to a state equal to, or even better than, before the extreme event. Similar to “restorative capacity” as identified by Francis and Bekera (2014).
4. Adaptive capacity: the capability to anticipate uncertain future developments. Similar to “adaptive capacity” as identified by Francis and Bekera (2014);
5. Transformative capacity: the capability to create an enabling environment, strengthen stakeholder capacities, and identify and implement catalysing interventions to transition proactively to a climate-resilient society.

Each of these capacities are influenced by their unique economic considerations, funding availability, risk appetite and stakeholder dynamics, as shown in Figure 5.
2.2.2 Risk Assessment vs. Resilience Assessment

There is a lack of understanding on the fundamental differences between risk assessment and resilience. Risk assessment approaches put a strong emphasis on preventing and mitigating the most consequential and probable risks. On the other hand, resilience assessment focuses on the ability of the system to recover from disruptions and adapt to changing conditions (Linkov and Trump 2019). Uncertainties about future stresses and state of the system makes it imperative to adopt the resilience assessment approach. Climate change makes it necessary to complement risk assessment with resilience assessment across airports. The list of factors for choosing resilience assessment as a complementary approach to risk assessment (adapted from Gössling-Reisemann, Hellige and Thier, 2018) is given in Figure 6.
2.2.3 Lack of clarity on indicators and characteristics of airport resilience

Although awareness of climate resilience is growing, the development of climate resilience strategies are currently limited due to lack of information and guidance on how to improve climate resilience (Burbidge, 2018). Resilience assessments can be pivotal in building resilience of airports to climate change. Most of the research on climate change and airports has focused either on climate change mitigation (Dolman et al., 2021) or on the impacts of climate change on airport operations and infrastructure (e.g., Burbridge, 2018). There are limited assessment scans providing insights on factors affecting airport resilience due to climate change. It can be concluded that there is a lack of knowledge on key climate resilience indicators and how they can be measured and operationalised at the airport level.

Since airports are complex systems akin to large cities, it is prudent to delve deeper into studies of resilience of cities. This can help identify some guidelines to close gaps and using the same for airports.

This study addresses the gap in knowledge on the existing risk and resilience practices of airports. It focusses primarily on natural hazards and the related physical risks.

Out of the gaps presented above for resilience capacities, the study focuses primarily on:

1. Understanding natural hazards and the related physical risks
2. Mapping existing risks and resilience assessment practices at airports, considering the factors mentioned in Figure 6.
3. Assessing existing infrastructural, organizational, and operational adaptive capacities

Figure 6 Factors for choosing resilience assessment as a complementary approach to risk assessment
2.3 Research Questions and Dimensions

As a result of the literature review and the gap analysis presented above, the Phase 1 study is articulated around six key research dimensions. These research dimensions and the corresponding research objectives are presented in Table 1.

The secondary questions are then translated in tertiary questions to yield the first online survey draft.

The next section presents the survey design methodology, associated analysis, and results.

Table 1 Key dimensions, associated objectives, and secondary questions

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Research Objective</th>
<th>Secondary Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Historical Disaster Impact</td>
<td>Understanding the prevalent disasters and their severity</td>
<td>What hazards has the airport been exposed to in the past? How much time did the recovery take?</td>
</tr>
<tr>
<td><strong>Risk Assessment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relevant Hazards</td>
<td>Shortlisting the relevant hazards and understanding their severity</td>
<td>Which hazards is the airport exposed to?</td>
</tr>
<tr>
<td>Hazard Exposure Mapping</td>
<td>Gauging the practice of risk vs resilience assessment and ranking hazards as per perceived future impact</td>
<td>Does the airport conduct risk and resilience assessments?</td>
</tr>
<tr>
<td><strong>Adaptive Capacity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infrastructural Adaptive Capacity</td>
<td>Understanding the awareness on critical assets and response plans in action</td>
<td>Has the airport identified its critical assets and charted plans for protection, maintenance, and repair in response to the hazard?</td>
</tr>
<tr>
<td>Operational Adaptive Capacity</td>
<td>Understanding operational preparedness and post-disaster planning measures in place</td>
<td>Can the airport maintain operations during a disaster? How much time will it take to resume operations after hazard impact?</td>
</tr>
<tr>
<td>Organizational Adaptive Capacity</td>
<td>Gauging capacity and financial preparedness</td>
<td>Is the management/organization prepared for a hazard impact?</td>
</tr>
</tbody>
</table>
3

ONLINE SURVEY

3.1. Methodology
3.2. Data Collection
3.3. Respondent profile
3.4. Data Analysis
3.5. Results
3.6. Mitigation and Protection Measures
3.1 Methodology

The survey questions were derived from the primary and secondary questions identified in Section 2. Questions for each dimension were selected based on the following criteria:

1. Relevance of the question
2. Possible depth of knowledge of the respondent
3. Balance of perception analysis and objective questions
4. Time taken to respond
5. Possible analytical output
6. Capturing each research dimensions

The online survey design approach described above yields an extensive list of more than 50 questions. In collaboration with CDRI, a list of questions and format is refined to focus on original research and address elements not covered by existing surveys and results, notably the ICAO Climate Change Adaptation Survey Synthesis report and the ACI Climate Change Adaptation Survey. As a result, the comprehensive list of questions is then condensed to 35 questions under the sections: General Information, Hazard Mapping, Risk and Resilience Assessment, Emergency Response Planning, and Organization. The final survey can be found in Annexure-A.

The survey is built using the Survey Monkey online platform. The platform allows the user to manoeuvre through the questions with ease, edit their responses after completion, and save partial survey responses.

As time to complete the survey and complexity of the question is highly correlated with the response rate, the survey includes a limited number of open-ended questions. The answering method mix maximises survey effectiveness by making sure that the answers provide the information required in line with the scope, and the time required to answer each question is in line with the relevance to the study objectives. Each of the question’s answering method as well as the estimated completion time is as presented in Table 2. The 35-question survey is expected to be completed in 40 to 45 minutes.
3.2 Data Collection

NACO partnered with ACI World to disseminate the survey. With immense support from ACI World, the survey was broadcasted to over 2,000 ACI Airport members. The low response rate may be attributed to most invitations being received by different departments within an airport. To increase the response rate, a targeted outreach was conducted using the consultant’s network, especially focusing on Asia, Africa, and Latin America. Furthermore, CDRI’s intervention helped in increasing the response rate from Indian airports. (Figure 7)

Out of the 60 partial responses, 26 respondents had another member of their organization fully complete the survey.

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**Table 2** Question type and estimated completion time.

<table>
<thead>
<tr>
<th>Question type</th>
<th>Number of questions</th>
<th>Estimated completion time per question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Checkboxes</td>
<td>5</td>
<td>1 min</td>
</tr>
<tr>
<td>Demographic and general information</td>
<td>6</td>
<td>&lt; 1 min</td>
</tr>
<tr>
<td>Dropdown</td>
<td>1</td>
<td>&lt; 1 min</td>
</tr>
<tr>
<td>Dichotomous</td>
<td>5</td>
<td>&lt; 1 min</td>
</tr>
<tr>
<td>Multiple choice</td>
<td>6</td>
<td>&lt; 1 min</td>
</tr>
<tr>
<td>Open-ended</td>
<td>3</td>
<td>2 – 3 min</td>
</tr>
<tr>
<td>Rating matrix</td>
<td>5</td>
<td>4 min</td>
</tr>
<tr>
<td>Semantic differential scale</td>
<td>3</td>
<td>&lt; 1 min</td>
</tr>
<tr>
<td>Slider scale</td>
<td>1</td>
<td>&lt; 1 min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>35</td>
</tr>
</tbody>
</table>

**Figure - 7** Survey outreach timeline
3.2.1 Leakage Analysis

Each section of the survey was designed to provide the information required in line with the scope of this study. The time needed for answering each question was in line with the relevance to the study objectives, and the complexity of this aspect of disaster resilience practices. However, the response rate was heavily influenced by the time required to complete the survey and complexity of the questions.

Although the survey included some open-ended questions across all sections, complexity of the subject and the time required for completing each additional section resulted in:

(1) An average completion time of 61 minutes, as compared to 35-40 minutes estimated as part of the survey design and validation.

(2) Figure 8 provides an overview of leakage between survey sections. From the leakage assessment, it is evident that most of the airports faced challenges to fill in future hazard mapping, resulting in drop-out of 24 survey respondents.

![Figure - 8 Leakage between survey sections (Source: NACO analysis from survey results)]

3.3 Respondent profile

To contextualize the results of this analysis, this section presents an overview of survey respondent profiles. Each respondent’s profile is informed through the following six lenses:

(1) Region
(2) Airport size
(3) Economic background
(4) Airport hazard exposure
(5) Ownership structure
(6) Respondent role

The six-lenses approach of respondent profiles ensured comprehensiveness of the surveyed airports, identifying common challenges faced by airports, by region, airport size, etc. as part of the data analysis exercise.
This is because profiling the airports solely based on risk exposure limits regional coverage and representativeness of the distribution of airport sizes. Additionally, inclusion of different economic profiles and passenger activity levels across regions ensured holistic regional representation, to capture adequate data and a balanced overview.

The profile information uses a combination of proprietary and publicly available data sources relating to airport region, size, hazard exposure, and economic context. Table 3 provides an overview of the data sources used for each categorization.

Table 3 Overview of data sources

<table>
<thead>
<tr>
<th>Profile Component</th>
<th>Variable</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region</td>
<td>Based on airport code</td>
<td>Based on airport code</td>
</tr>
<tr>
<td>Airport size</td>
<td>Total number of passengers in 2019</td>
<td>ACI 2019 Traffic Database</td>
</tr>
<tr>
<td>Economic background</td>
<td>Gross Domestic Product (GDP per capita) 2021 World Bank Economy Classification</td>
<td>Oxford Economics World Bank</td>
</tr>
<tr>
<td>Airport hazard exposure</td>
<td>0-100 exposure index score</td>
<td>RHDHV's Multi hazard risk platform</td>
</tr>
<tr>
<td>Ownership structure</td>
<td>Survey results</td>
<td>Survey results</td>
</tr>
<tr>
<td>Respondent role</td>
<td>Survey results</td>
<td>Survey results</td>
</tr>
</tbody>
</table>

The following sections includes an assessment of survey results representativeness and detailed information regarding region, size, economic background, hazard exposure, ownership structure of participating airports, and roles of survey respondents.

3.3.1 Sample representativeness

The completed responses represent a subset of the group of interest for this study, airports. As a result, one of the key activities prior to inferring survey findings was to confirm the representativeness of the sample space.

For a sample size of 2,500 airports (number of airports represented in the ACI traffic database) and a 95 percentage confidence level, the margin of error associated with the survey results is:

- 11 percentage considering complete responses from 81 airports
- 9 percentage considering partial responses from 111 airports

Figure 9 presents a qualitative representation of sample representativeness:

- Each participating airport with complete responses represents an individual red dot
- Each participating airport with partial responses represents an individual grey dot
- Other airports in the ACI database and countries in the Oxford database are represented in a lighter grey

The more prevalent the coverage of the red dots is, the more representative the results with respect to regional coverage, risk exposure, airport size and the economic position.

For purpose of this study, and in line with survey analysis, best practices, the survey findings are based on the only 91 complete responses.
Figure - 9 Sample representativeness of respondents over regions, hazards and GDP per capita

(Source: NACO analysis from survey results, ACI database, Oxford database)
3.3.2 Region

As shown in Figure 10 and Table 4, the survey results represents most of the regions equally. However, the number of participating airports are limited in the Middle East, with only two complete responses.

![Survey responses by region](image)

**Figure - 10** Survey responses by region (Source: NACO analysis from survey results, ACI database)

**Table 4 Number of participants per region**

<table>
<thead>
<tr>
<th>Region</th>
<th>Complete Responses</th>
<th>Partial Responses</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>6</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Asia-Pacific</td>
<td>30</td>
<td>8</td>
<td>38</td>
</tr>
<tr>
<td>Europe</td>
<td>26</td>
<td>7</td>
<td>33</td>
</tr>
<tr>
<td>Latin America &amp; Caribbean</td>
<td>5</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>Middle East</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>North America</td>
<td>12</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>81</strong></td>
<td><strong>30</strong></td>
<td><strong>111</strong></td>
</tr>
</tbody>
</table>

As shown, the participating airports are a representative sample in terms of distribution of risk exposure, airport size, and Gross Domestic Product (GDP) per capita. However, for regional representativeness specifically, coverage is limited for the Middle East.
3.3.3 Airport size

Figure - 11 Survey responses by airport size (Source: NACO analysis from survey results, ACI database)

Note. The size of the dots on the map is proportional to 2019 annual passengers for airport included in the ACI traffic data.

Table 5 Number of participants by airport size

<table>
<thead>
<tr>
<th>Airport size</th>
<th>Complete Responses</th>
<th>Partial Responses</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5M</td>
<td>29</td>
<td>12</td>
<td>41</td>
</tr>
<tr>
<td>5-15M</td>
<td>21</td>
<td>7</td>
<td>28</td>
</tr>
<tr>
<td>15-30M</td>
<td>9</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>30-50M</td>
<td>13</td>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>50-70M</td>
<td>7</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>&gt;70M</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>81</td>
<td>30</td>
<td>111</td>
</tr>
</tbody>
</table>
3.3.4 Airport hazard exposure

Airport hazard exposure is calculated using RHDHV’s multi-hazard risk platform. The platform uses data analysis to provide insights in hazard exposure of airport assets. Using a set of historic hazard data, it gives insight on locations exposed to different hazards. The hazard components included for purpose of the risk exposure calculations are presented in Table 6.

**Table 6 Multi Hazard Platform risk exposure calculation factors**

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Exposure calculations based on:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme precipitation</td>
<td><strong>Floods</strong> Combination of all fluvial World Research Institute (WRI) indices</td>
</tr>
<tr>
<td></td>
<td><strong>Rain</strong> Average annual number of days the daily rainfall is more than 30mm</td>
</tr>
<tr>
<td></td>
<td><strong>Pluvial floods</strong> Index based on rain intensity</td>
</tr>
<tr>
<td>Extreme icing conditions</td>
<td><strong>Cold</strong> Average annual number of days the temperature is below zero degrees</td>
</tr>
<tr>
<td></td>
<td><strong>Snow</strong> Average annual number of days that the snow cover is more than 10 cm</td>
</tr>
<tr>
<td>Extreme storms and wind</td>
<td><strong>Tropical Cyclone</strong> Combination of indices related to the occurrences of cyclones</td>
</tr>
<tr>
<td></td>
<td><strong>Storms</strong> Average annual number of days the windspeed is at least 9 Beaufort</td>
</tr>
<tr>
<td>Extreme heat</td>
<td><strong>Drought</strong> Cumulative number of days with deficit higher than 300 mm</td>
</tr>
<tr>
<td></td>
<td><strong>Heat</strong> Average annual number of days the temperature is above 30 degrees</td>
</tr>
<tr>
<td></td>
<td><strong>Wildfires</strong> Count of wildfire occurrence</td>
</tr>
<tr>
<td>Sea level</td>
<td><strong>Coastal floods</strong> Combination of all coastal WRI indices</td>
</tr>
<tr>
<td>Other natural hazards</td>
<td><strong>Landslide</strong> 1-5 landslide susceptibility map and landscape characteristics</td>
</tr>
<tr>
<td></td>
<td><strong>Earthquake</strong> Acceleration of the ground due to earthquakes</td>
</tr>
<tr>
<td>Public Health</td>
<td><strong>Air Pollution</strong> Air quality index</td>
</tr>
</tbody>
</table>

The resulting exposure score associated with each hazard is an index between zero to one hundred. An overview of the hazard exposure of participating airports for the hazard groups is presented in figure 12.

The list of hazards includes extreme - heat, icing conditions, and precipitation, intensity of storms and winds, landslides and earthquakes, low air quality and flooding at participating airports, are indicated in black.
**Figure - 12** Hazard exposure of participating airports (Source: NACO analysis from survey results, RHDHV Multi Hazard Risk Platform)

**Figure - 13** Overall hazard exposure of participating airports (Source: NACO analysis from survey results, RHDHV Multi Hazard Risk Platform)

Note. The intensity of the colour associated with each location is based on the 0-100 risk exposure
Figure 13 shows that the sample set is qualitatively representative of the various hazards listed in the RHDHV Multi Hazard Risk Platform. It can be noted that the complete responses sufficiently cover the spectrum of hazards when compared to the ACI database. Further, the survey responses are also fairly representative of the geographical expanse of the ACI airport database. India and Europe saw the highest number of respondents while the Middle East and Australia saw two responses each.

3.3.5 Economic background of participating countries

As shown in Table 7, the number of participating respondents is limited for low-income countries, with only one complete response.

Table 7 Number of participants by their country’s income group

<table>
<thead>
<tr>
<th>Income group</th>
<th>Complete Responses</th>
<th>Partial Responses</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>High income</td>
<td>21</td>
<td>4</td>
<td>25</td>
</tr>
<tr>
<td>Upper middle income</td>
<td>6</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>Lower middle income</td>
<td>9</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>Low income</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>37</strong></td>
<td><strong>17</strong></td>
<td><strong>54</strong></td>
</tr>
</tbody>
</table>

P.S: Out of 54 countries that participated in the online survey, responses from 17 countries were only partial and remaining 37 countries include both complete as well as complete+partial responses.

3.3.6 Ownership structure

This indicator provides an insight into the ownership model of the participating airports.

As per Figure 14 and Table 8, there was more representation from airports with the ownership model government-owned, managed and government-owned and privately-operated airports. However, about 1/3rd of these respondents provided a partial response, while less leakage was noted with the government-owned organizations and privately-owned and operated airports.

Figure - 14 Survey respondents by ownership model (Source: NACO analysis from survey results)
Table 8 Ownership model of participating airports

<table>
<thead>
<tr>
<th>Ownership Model</th>
<th>Complete Responses</th>
<th>Partial Responses</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government-owned and managed</td>
<td>30</td>
<td>11</td>
<td>41</td>
</tr>
<tr>
<td>Government-owned and privately-operated</td>
<td>10</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>Government-owned with private sector participation</td>
<td>26</td>
<td>11</td>
<td>37</td>
</tr>
<tr>
<td>Privately-owned and operated</td>
<td>14</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>Information not available</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Number of airports</strong></td>
<td><strong>81</strong></td>
<td><strong>30</strong></td>
<td><strong>111</strong></td>
</tr>
</tbody>
</table>

3.3.7 Respondent role

The survey was completed predominantly by respondents with airport operational roles. There was also considerable representation from safety, security and compliance management and planning, strategy and airport development departments.

Figure 15 shows most respondents had considerable knowledge on the topic. All the respondents who completed the survey, from airport operations, safety and security, general management, emergency response, environmental affairs and sustainability and risk management, were either aware or well-versed with the subject.

Table 9 Respondent profile by their designated departments

<table>
<thead>
<tr>
<th>Department Category</th>
<th>Complete Responses</th>
<th>Partial Responses</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airport Operations</td>
<td>33</td>
<td>12</td>
<td>45</td>
</tr>
<tr>
<td>Safety, Security and Compliance Management</td>
<td>14</td>
<td>7</td>
<td>21</td>
</tr>
<tr>
<td>Planning, Strategy and Airport Development</td>
<td>10</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>General Management</td>
<td>8</td>
<td>13</td>
<td>21</td>
</tr>
<tr>
<td>Asset Management and Technical Services</td>
<td>6</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Emergency Response (including firefighting services)</td>
<td>5</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Environmental affairs and sustainability</td>
<td>8</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>Quality, Health Safety &amp; Environment</td>
<td>4</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Risk management and corporate resilience &amp; Compliance</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>91</strong></td>
<td><strong>60</strong></td>
<td><strong>151</strong></td>
</tr>
<tr>
<td>Department Category</td>
<td>Survey Completion</td>
<td>Unaware</td>
<td>Not unaware nor aware</td>
</tr>
<tr>
<td>----------------------------------------------------------</td>
<td>-------------------</td>
<td>---------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>Airport Operations</td>
<td>Complete</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Partial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety, Security and Compliance Management</td>
<td>Complete</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Partial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planning, Strategy and Airport Development</td>
<td>Complete</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Partial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>General Management</td>
<td>Complete</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Partial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asset Management and Technical Services</td>
<td>Complete</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Partial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emergency Response (including firefighting services)</td>
<td>Complete</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Partial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental affairs and sustainability</td>
<td>Complete</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Partial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality, Health Safety &amp; Environment</td>
<td>Complete</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Partial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk management and corporate resilience &amp; Compliance</td>
<td>Complete</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Partial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>Complete</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Partial</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure - 15** Airports’ response on awareness to hazardous events and disasters
(Source: NACO analysis of Survey results)
3.4 Data Analysis

3.4.1 Approach

In order to gauge the current state of practice of disaster risk management and resilience at airports, the survey responses were analyzed using quantitative and semi-quantitative methods. Factors such as research dimension, cluster and airport characteristics were considered. The goal was to understand the perception of airport operators and managers about climate and disasters, and the resilience of airports to them. The data analysis framework includes four approaches:

Comparative Analysis
The first analysis uses the airport profile characteristics to develop a comparative analysis of disaster resilience practices between regions, economic context, different ownership models, and disaster sensitivity.

Crosstab Analysis
The crosstab analysis is a follow up to the comparative and cluster analysis. It attempts to understand the relationship between the different dimensions.

Factor Analysis
Factor analysis is used to understand the value drivers that constitute the airport’s risk and resilience practice. This framework aims to correlate multiple conditions and draw inferences or establish prevalent theories from the collected data.

Open-ended Response Analysis
Analysis of open-ended responses contributed to building a holistic understanding of mitigation and protection measures currently in place at airports, as well as how governments, international organizations, and industry working groups can support airports in becoming more resilient.

The data analysis components and associated findings are presented by key research dimensions. When shown, percentages relate to the share of respondents.

Figure - 16 Research Methodology (Source: NACO analysis of Survey results)
3.5 Results

3.5.1 Historical and Future Hazard Mapping

For purpose of this study, the hazard severity rating system defined as part of the survey is as follows.

This rating system is based on a combination of RHDHV internal risk matrix, the ICAO Risk Matrix Doc 9859, 4th edition, and coordination with CDRI. Given this definition, respondents prompted to select a given rating if the hazard caused/is anticipated to cause at least one of the conditions listed in the associated row in the table below. The historical and anticipated severity of impact by region are shown on the figure 17.

Table 10 Hazard Severity rating system

<table>
<thead>
<tr>
<th>Severity</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety &amp; Health</td>
<td>No impact</td>
<td>Impact not likely to cause damages</td>
<td>Injuries requiring first aid only</td>
<td>Injury requiring medical treatment (lacerations, burns, fractures)</td>
<td>Reduced efficiency of operations due to increased workload</td>
<td>Serious injuries or life-threatening occupational medical conditions</td>
</tr>
<tr>
<td>Infrastructure &amp; Operational Disruption</td>
<td>No impact</td>
<td>Flight delays of 15 minutes maximum</td>
<td>Partial restrictions and flights delay lower than 2 hours</td>
<td>Restrictions in operations</td>
<td>• Flight delays lower than 8 hours</td>
<td>• Closure for more than 8 hours</td>
</tr>
<tr>
<td>Economic Loss</td>
<td>No impact</td>
<td>Insignificant costs</td>
<td>Indirect economic loss to airport partners</td>
<td>Indirect economic loss to the airport</td>
<td>Direct economic loss to airport partners</td>
<td>Direct economic loss to the airport</td>
</tr>
<tr>
<td>Image</td>
<td>No impact</td>
<td>Insignificant impact</td>
<td>Local negative PR</td>
<td>• Regional media coverage</td>
<td>• National media coverage</td>
<td>• International media coverage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Negative publicity</td>
<td>• Impact on brand image</td>
<td>• Impact on brand image</td>
</tr>
</tbody>
</table>

Image

No impact

Insignificant impact

Local negative PR

• Regional media coverage

• Negative publicity

• National media coverage

• Impact on brand image

• International media coverage

• Impact on brand image
Table 11 Understanding hazard terminologies

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme precipitation</td>
<td>Rain: Average annual number of days the daily rainfall is more than 30mm</td>
</tr>
<tr>
<td></td>
<td>Pluvial floods Index based on rainfall intensity</td>
</tr>
<tr>
<td>Geological hazards</td>
<td>A geological hazard is an extreme natural events in the crust of the earth</td>
</tr>
<tr>
<td></td>
<td>that pose a threat to life and property, for example, earthquakes, and landslides.</td>
</tr>
<tr>
<td>Third-party equipment/system</td>
<td>Operational disruptions caused due to third-party failures, outside the</td>
</tr>
<tr>
<td>failures</td>
<td>direct control of the airport operator</td>
</tr>
<tr>
<td>Extreme icing conditions</td>
<td>Cold: Average annual number of days the temperature is below zero degrees</td>
</tr>
<tr>
<td></td>
<td>Snow: Average annual number of days that the snow cover is more than 10 cm</td>
</tr>
<tr>
<td>Wildlife invasion</td>
<td>Increase in number of operational disruptions due to wildlife at the airport</td>
</tr>
<tr>
<td>Drought</td>
<td>Cumulative number of days with water deficit higher than 300 mm</td>
</tr>
<tr>
<td>Extremely poor air quality</td>
<td>Disruptions in operations due to poor air quality</td>
</tr>
<tr>
<td>Extreme heat</td>
<td>Heat: Average annual number of days the temperature is above 30 degrees</td>
</tr>
<tr>
<td></td>
<td>Wildfires: Count of wildfire occurrence</td>
</tr>
<tr>
<td>Flooding</td>
<td>Combination of all fluvial World Research Institute (WRI) indices</td>
</tr>
<tr>
<td>Extreme storms and wind</td>
<td>Tropical Cyclone: Combination of indices related to the occurrences of</td>
</tr>
<tr>
<td></td>
<td>cyclones</td>
</tr>
<tr>
<td></td>
<td>Storms: Average annual number of days the windspeed is at least 9 Beaufort</td>
</tr>
<tr>
<td>Volcanic activity</td>
<td>Operational and infrastructural disruptions caused due to Volcanic activity</td>
</tr>
</tbody>
</table>
Figure - 17 Historical and future severity of impact across regions
(Source: NACO analysis of Survey results)
Historical and future severity of impact across regions

As highlighted in the Figure 17, each region has a distinct hazard profile, with Africa, Asia-Pacific, and Europe anticipating that severity of impact will be higher over the next 20 years.

**Africa:** Historically, the leading hazards for Africa, with severity impact of more than 1, include extreme precipitation, poor air quality, third-party equipment failure, extreme heat, wildlife invasion and extreme storms and winds. Most hazards are anticipated to have a higher impact in future with the highest increase in flooding and geological hazards.

**Asia Pacific:** Currently, the leading hazards for Asia-Pacific include extreme precipitation, and extreme storms and winds. These are anticipated to have a relatively similar impact in the future. Severity of impacts of hazards such as extreme heat and drought are expected to increase significantly in the coming years. Other hazards anticipated to result in more severe impact include flooding, geological hazards, and third-party equipment/systems failures.

**Europe:** Existing leading hazards for Europe are third-party equipment/systems failures, extreme-precipitation, storms and wind, and icing conditions. These hazards are anticipated to have a similar or increased impact in the future, with extreme heat and droughts having the highest anticipated increase.

**Latin America:** Third-party system failures, extreme storms and winds, extreme precipitation, flooding and geological hazards have had the most severe historical impact in Latin America. Extreme storms and wind and wildlife invasion are expected to result in a higher severity of impact on airports in the future.

**North America:** Third-party systems failures, extreme- storms and winds, precipitation, and icing conditions, are the leading hazards for the region. Severity of impact of each of these hazards are expected to decrease the coming years, except for extreme storms and winds. Extreme storms and winds, extreme heat and third-party systems failures are expected to be more severe, with the maximum increase expected in extreme heat.

**Please note:** Only two respondents from the Middle East completed the survey; thus, the associated results do not inform the findings.

Across regions, airports expect level 2 severity of impact for extreme storms and winds, extreme precipitation, and third-party systems failures. These results suggest that these hazards are associated with partial infrastructural restrictions, flight delays, and indirect economic loss to airport partners.
3.5.2. Anticipated severity of impact on different asset groups across airport size

As highlighted in Figure 18, different asset groups are anticipated to be subject to different impact severity, with key differences across airports having different million annual passengers (MAP) levels.

Overall, larger airports anticipate higher severity of impact on their infrastructure over the next 20 years, with the airfield, personnel/passenger infrastructure, utility systems and equipment being the most severely impacted.

For each airport size category, Figure 18 presents an overview of the anticipated severity of impact on different asset groups.

With severity levels of 3 to 4, larger airports (50MAP+) envision potential closure for restrictive conditions of operations, reduced efficiency, and potential direct economic loss to airport partners.

Contrastingly, smaller airports expect limited severity of impact on their assets, with severity levels below 2.
Figure - 18 Anticipated severity of impact on different asset groups
(Source: NACO analysis of Survey results)
3.5.3 Resuming operations and recovering from a disaster overview per hazard

Resilience of an airport can be represented as the performance curve of its system, before, during, and after a climate/natural hazard-related disruption. For the purpose of analysis, two key performance metrics are used in determining how resilient airports are relative to a given hazard:

- The time required to resume operations after the hazard
- The time required for the airport to fully recover after the hazard, with full recovery, defined as resumption of all regular operations and normal airport functioning.

For each hazard group relevant to this study, figure 19 presents the following:

- The historical severity of impact of a given hazard across all respondents
- The distribution of airport recovery time

The hazards scores can be organized in two severity categories:

- Low severity of impact (0-1 range)
- Mid-Low severity of impact (1-2 range)

---

**Figure - 19** Time taken to resume operations by hazard type
(Source: NACO analysis from survey results)
A majority of respondents noted that their airports fully recover from the hazards listed within 0-6 hours of impact. However, some respondents also indicated that their airports take relatively longer to fully recover from geological hazards and volcanic activities.

Overall, it is seen that airports recover faster from hazards like wildlife invasion, drought and extreme heat. It takes them longer to recover from extreme storms, precipitation, extreme icing and third-party equipment failures.

Figure - 20 Time taken to fully recover operations by hazard type
(Source : NACO analysis of Survey results)
Airports display a higher ability to resume and recover operations sooner for disruptions of incremental intensity and predictable occurrence like flooding, drought, and extreme heat, than from volcanic activity, geological hazards (earthquakes, landslide and others) and third-party systems failures, which are harder to predict.
3.5.4 Resuming operations and recovering from a disaster: Differences across regions

This sub-section provides an overview of time taken to resume operations and recovery across regions for different hazards addressed as part of this study.

In addition to differences in hazard exposure context and risk appetite across regions, the time taken to resume operations and fully recover is linked to:

- Integration with alerting authorities (including weather services)
- Hazard event duration
- Ability to conduct a comprehensive inspection of the runway and taxiways, and removing debris
- Impact on utilities and time taken to restore power
- Inspection of infrastructural damage and ability to conduct immediate repairs
- Communication systems (air and ground systems) readiness and site accessibility (access roads, public transit, etc.)

For majority of these elements, airports are dependent on the authorities and external service providers to move forward, re-emphasizing the importance of integrated disaster risk and resilience practices.

Each region displays a different ability to recover from climate and natural hazards. Notably, although airports in Africa tend to resume operations at similar rates than their counterparts, full recovery appears to take longer in the region. Similarly, North America displays a slower ability to fully recover from extreme icing conditions, extreme storms and winds and geological hazards compared to Asia/Pacific and Europe.
Drought

All regions display a similar ability to resume and recover from droughts. The African region however takes longer to resume and recover, while Europe and North America take longer times to fully recover.

**Figure - 22** Comparison of time taken to resume and recover from Drought
(Source: NACO analysis of Survey results)
Extreme icing conditions

Although Latin America appears to resume operations sooner than its counterpart, full recovery takes longer than other regions.

Figure - 23 Comparison of time taken to resume and recover from icing
(Source : NACO analysis of Survey results)
Extreme precipitation

All regions display similar ability to resume operations after extreme precipitation, however, Latin America and North America require more time to recover completely.

![Figure - 24 Comparison of time taken to resume and recover from precipitation](Source: NACO analysis of Survey results)
Flooding

Africa appears to require more time to resume operations and recover from flooding than its Asia-Pacific, Europe, and Latin America counterparts.

<table>
<thead>
<tr>
<th>Region</th>
<th>Resume</th>
<th>Recover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>Asia-Pacific</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Europe</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Latin America and Caribbean</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>North America</td>
<td>1.3</td>
<td></td>
</tr>
</tbody>
</table>

**Figure - 25** Comparison of time taken to resume and recover from flooding
(Source: NACO analysis of Survey results)
Geological Hazards

Africa appears to require more time to resume operations and recover from geological hazards than its Asia-Pacific, Europe, and Latin America counterparts.

Figure - 26 Comparison of time taken to resume and recover from geo hazards
(Source: NACO analysis of Survey results)
**Extremely poor air quality**

Europe and North America seem to require more time to recover from poor air quality when compared to their counterparts - Africa, Asia-Pacific and Latin America.

![Figure - 27 Comparison of time taken to resume and recover from air quality](Source: NACO analysis of Survey results)
Extreme Storm and Winds

For similar overall historical impact of extreme storms and winds, Latin America and North America seem to require more time to resume and recover relative to their European counterparts.

<table>
<thead>
<tr>
<th>Region</th>
<th>Resume</th>
<th>Recover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>Asia-Pacific</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>Europe</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>Latin America and Caribbean</td>
<td>2.1</td>
<td></td>
</tr>
<tr>
<td>North America</td>
<td>2.1</td>
<td></td>
</tr>
</tbody>
</table>

Figure - 28 Comparison of time taken to resume and recover from storms
(Source: NACO analysis of Survey results)
Wildlife Invasion

For similar overall historical impact of wildlife invasion, Africa seems to require more time to resume and recover.

[Figure - 29 Comparison of time taken to resume and recover from wildlife invasion]

(Source : NACO analysis of Survey results)
Third-Party equipment / systems failure

On an average, Africa takes longer to fully recover from third-party failures. North America takes relatively longer to resume operations.

![Comparison of time taken to resume and recover from third-party equipment failure](Figure-30.png)

(Source: NACO analysis of Survey results)
Extreme heat

African airports take longer to resume operations when impacted by extreme heat conditions.

<table>
<thead>
<tr>
<th>Region</th>
<th>Resume</th>
<th>Recover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Asia-Pacific</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>Europe</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Latin America and Caribbean</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>North America</td>
<td>1.7</td>
<td></td>
</tr>
</tbody>
</table>

**Figure - 31** Comparison of time taken to resume and recover from extreme heat

(Source : NACO analysis of Survey results)
Volcanic Activity

Airports in Asia Pacific and Europe are more severely impacted by volcanic activity and take longer to resume and recover from the impact.

Figure - 32 Comparison of time taken to resume and recover from volcanic activity
(Source : NACO analysis of Survey results)
3.5.5 Risk and Resilience Practice

Risk is defined as an event or impact that can negatively affect the operations, infrastructure, or finances of an airport. To assess the risk and resilience practices followed by airports, the data analysis focused on identifying the practices in place, the extent disaster impacts are considered, as well as the key measures employed, stakeholders driving the resilience agenda and the availability of resources.

Overview per region

A **Vulnerability Assessment** is the process of identifying, quantifying, and prioritizing/ranking the possible vulnerabilities in a system. For this study, the systems of interest include airport infrastructure and operations.

**Resilience Assessments** measure the ability of assets to recover from or adapt to changing conditions. Critical assets are designated infrastructure that, if disrupted, would prevent the airport from operating.

An **Airport Emergency Response Plan (AERP)** is a set of actions and resources required at the time of or immediately after the hazard in order to minimize damage or safeguard key assets, operations, and people. The AERP might include provisions to continue operations during hazardous events.

A **Disaster Recovery Plan** are actions, resources, and roadmap to consider relating to how to restore airport processes within a certain amount of time— the recovery time objective — during/after hazardous events.

A **Business Continuity plan** includes key steps to ensure that critical assets and operations can continue working with minimal downtime in the event of an interruption.

**Mitigation costs** relate to costs employed to reduce or prevent the impact of a specific hazard/risk.
Overall, different regions have similar risk and resilience practices. Most airports have critical assets identification, Airport Emergency Response Plan, Disaster Recovery Plan and Business Continuity plan in place.

However, Vulnerability Assessments and Resilience Assessments appear to be comparatively less frequent in Africa, Asia/Pacific and Latin America.

### Figure - 33 Comparison of risk and resilience practices by region.

(Source: NACO analysis of Survey results)

<table>
<thead>
<tr>
<th></th>
<th>Africa</th>
<th>Asia Pacific</th>
<th>Europe</th>
<th>Latin America</th>
<th>Middle East</th>
<th>North America</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vulnerability Assessment</td>
<td>72%</td>
<td>60%</td>
<td>76%</td>
<td>60%</td>
<td>100%</td>
<td>92%</td>
</tr>
<tr>
<td>Resilience Assessment</td>
<td>86%</td>
<td>57%</td>
<td>69%</td>
<td>80%</td>
<td>100%</td>
<td>85%</td>
</tr>
<tr>
<td>Identification of critical assets</td>
<td>72%</td>
<td>80%</td>
<td>90%</td>
<td>80%</td>
<td>50%</td>
<td>69%</td>
</tr>
<tr>
<td>Provisions to continue operations during hazardous events</td>
<td>88%</td>
<td>89%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Disaster Recovery Plan</td>
<td>75%</td>
<td>86%</td>
<td>84%</td>
<td>80%</td>
<td>100%</td>
<td>79%</td>
</tr>
<tr>
<td>Disaster impacts reflected in Business Continuity Plan</td>
<td>86%</td>
<td>91%</td>
<td>97%</td>
<td>80%</td>
<td>67%</td>
<td>100%</td>
</tr>
<tr>
<td>Availability of funds to cover mitigation costs</td>
<td>71%</td>
<td>94%</td>
<td>86%</td>
<td>80%</td>
<td>100%</td>
<td>92%</td>
</tr>
</tbody>
</table>
### 3.5.6 Vulnerability Assessment Practice

#### Airport Vulnerability Assessment Practice

<table>
<thead>
<tr>
<th></th>
<th>Yes, the airport conducts vulnerability assessments periodically 58.0%</th>
<th>Yes, the airport has conducted a vulnerability assessment once 13.6%</th>
<th>No, the airport has not been able to conduct a vulnerability assessment 11.1%</th>
<th>Information not available 17.3%</th>
</tr>
</thead>
</table>

#### Vulnerability Assessment Frequency

- **Yearly**: 52.2%
- **Monthly**: 8.7%
- **Every 2 years**: 8.7%
- **Every 2 to 5 years**: 28.3%
- **Every 5 to 10 years**: 2.2%

#### Inclusion of assets controlled by third parties in Vulnerability Assessment

- **Yes**: 61.5%
- **No**: 16.9%
- **Not applicable**: 4.6%
- **Information not available**: 16.9%

#### Vulnerability Assessment components

<table>
<thead>
<tr>
<th>Component</th>
<th>Africa</th>
<th>Asia-Pacific</th>
<th>Europe</th>
<th>Latin America and Middle East Caribbean</th>
<th>North America</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel and passenger infrastructure</td>
<td>2nd</td>
<td>1st</td>
<td>1st</td>
<td>6th</td>
<td>2nd</td>
<td>1st</td>
</tr>
<tr>
<td>Civil structure / installations (eg: terminal building installation safety)</td>
<td>1st</td>
<td>3rd</td>
<td>2nd</td>
<td>2nd</td>
<td>6th</td>
<td>3rd</td>
</tr>
<tr>
<td>Reliability of operations (eg: closure, flight delays, recovery time)</td>
<td>3rd</td>
<td>2nd</td>
<td>3rd</td>
<td>3rd</td>
<td>5th</td>
<td>4th</td>
</tr>
<tr>
<td>Emergency service operations</td>
<td>3rd</td>
<td>3rd</td>
<td>5th</td>
<td>3rd</td>
<td>8th</td>
<td>2nd</td>
</tr>
<tr>
<td>Reliability of utility services (eg: water, electricity, sewage)</td>
<td>3rd</td>
<td>5th</td>
<td>4th</td>
<td>1st</td>
<td>4th</td>
<td>5th</td>
</tr>
<tr>
<td>Financial impact</td>
<td>6th</td>
<td>7th</td>
<td>6th</td>
<td>5th</td>
<td>3rd</td>
<td>6th</td>
</tr>
<tr>
<td>Availability of supply chain</td>
<td>7th</td>
<td>6th</td>
<td>8th</td>
<td>8th</td>
<td>1st</td>
<td>7th</td>
</tr>
<tr>
<td>Impact on image</td>
<td>8th</td>
<td>8th</td>
<td>7th</td>
<td>6th</td>
<td>7th</td>
<td>8th</td>
</tr>
</tbody>
</table>

*Figure - 34 Overview of Vulnerability Assessment Practices
(Source: NACO analysis of Survey results)*
The relative importance of elements included in Vulnerability Assessments are similar across all regions except for Latin America.

Out of the participating airports, 71.6 percentage of airports have conducted a vulnerability assessment for their infrastructure at least once. Of the airports conducting Vulnerability Assessments periodically, 55.3 percentage conduct Vulnerability Assessments yearly and 27.7 percentage conduct one every 2 to 5 years.

The three most important elements of Vulnerability Assessments for airports are
1. Personnel and passenger infrastructure
2. Civil structure and installations
3. Reliability of operations

Future hazard exposure against vulnerability assessment

In the figure below, the size of the box is proportional to the anticipated impact of a given hazard for different vulnerability assessment practices.

<table>
<thead>
<tr>
<th>Anticipated impact of a given hazard</th>
<th>Hazard exposure score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, the airport conducts vulnerability assessments periodically</td>
<td>1.4</td>
</tr>
<tr>
<td>Yes, the airport has conducted a vulnerability assessment once</td>
<td>1.8</td>
</tr>
<tr>
<td>No, the airport has not been able to conduct a vulnerability assessment</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Figure - 35 Future hazard exposure vs vulnerability assessment practices
(Source: NACO analysis of Survey results)

Overall, airports conducting vulnerability assessment periodically anticipate slightly lower impact than their counterparts. There is no significant difference between airports that conduct it once and those which have not conducted any assessments. This finding is a motivation for airports and authorities to encourage the practice of conducting regular vulnerability assessments.
3.5.7 Emergency Response Planning Overview

As shown on the Figure 36, across all regions:

- All respondent airports have provisions in their Airport Emergency Response Plan to continue operations during hazardous events, except for some airports from Africa (14.3%) and Asia-Pacific (11.4%).
- At least 75% of respondent airports from all regions, except Africa, have a Disaster Recovery Plan.

**Figure - 36** Overview of Airport Emergency Response Planning and Disaster Recovery Planning practices.
(Source: NACO analysis of Survey results)
3.5.8 Airport Emergency Response Plan and Disaster Recovery Plan Practices

To reduce the risk on people’s life and equipment damage, supporting operations recovery, Airport Emergency Response Plans (AERP) focused on collaboration with external and internal stakeholders and reliability of operations. These practices are elaborated below based on responses from participating airports.

1. Collaboration with external stakeholders:
   - Collaborate with stakeholders through monthly AERP meetings
   - Emergency planning and exercises, multi-agency steering and working groups, e.g., defining aircraft diversion plans with local hospitals, governmental firefighting agencies and nearby airports
   - Increased collaboration with the government when the airport is considered of critical national importance, must be included in the national recovery plans.
   - Manage media response

2. Collaboration with internal stakeholders:
   - Staff training and preparedness assessment by conducting one partial exercise per year and a full-scale drill every two years
   - Assign limited staff to critical assets and capacity management during an emergency.

3. Reliability of operations
   - Define check list to guarantee the continuity of the operations in a safe manner.
   - Define different activation levels and estimate operational disruption for each kind of natural hazard that could occur in the airport.
   - Define associated protocols and response actions backed to maintain business continuity and resumption of operations.
   - Deploying multi-agency operations room to implement pre-defined protocols and restart operations

Overall, participants integrate their Airport Emergency Response Plans, Disaster Response Plan, Continuity of Operations Plan and Business Continuity Plans (BCP) into one practice, with additional independent recovery plans defined for independent systems like aircraft and IT systems.

Airports collaborate with airlines, ground handlers, government agencies and utility providers to define, implement and monitor their Airport Emergency Response Plan and Disaster Recovery Plan.
## 3.5.9 Organizational Adaptive Capacity Overview

### Airport resilience practice elements

<table>
<thead>
<tr>
<th></th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure upgrade</td>
<td>83.9%</td>
</tr>
<tr>
<td>Business continuity planning</td>
<td>75.9%</td>
</tr>
<tr>
<td>Design guidelines / regulations</td>
<td>75.9%</td>
</tr>
<tr>
<td>Simulation exercise</td>
<td>71.3%</td>
</tr>
<tr>
<td>Assessment strategy</td>
<td>67.8%</td>
</tr>
<tr>
<td>Inclusion as part of Masterplan</td>
<td>66.7%</td>
</tr>
<tr>
<td>Progress review</td>
<td>57.5%</td>
</tr>
<tr>
<td>None of the above</td>
<td>2.3%</td>
</tr>
</tbody>
</table>

### Organization efficiency in mitigating risks for the airports

<table>
<thead>
<tr>
<th></th>
<th>Ineffective</th>
<th>Neither ineffective, nor effective</th>
<th>Effective</th>
<th>Very effective</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.2%</td>
<td>18.0%</td>
<td>46.1%</td>
<td>33.7%</td>
</tr>
</tbody>
</table>

### In-house capacity/expertise sufficiency

<table>
<thead>
<tr>
<th></th>
<th>Insufficient in-house capacity</th>
<th>Potential to grow in-house capacity</th>
<th>Sufficient in-house capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9.0%</td>
<td>59.0%</td>
<td>32.1%</td>
</tr>
</tbody>
</table>

### Airport risk and resilience drivers

1. Human safety
2. Government policies
3. Results of a Risk Assessment
4. Executive board / Management
5. Insurance of assets
6. Shareholder interests
7. Inclusion as part of Masterplan
8. Investors
9. Market trends

### Figure - 37 Overview of Airport Resilience practices.
(Source: NACO analysis of Survey results)
A total of 83.9 percentage of respondents indicate addressing resilience as part of their infrastructure upgrade, and 75.9 percentage of respondents indicate that they are able to integrate business continuity planning to their resilience practice. Their resilience practice is also informed by design guidelines and simulation exercise, thus reinforcing the criticality of knowledge sharing and key policies.

Design guidelines to mitigate impact and pre-emptive simulation exercises to test the design were also mentioned as commonly used measures.

- Human safety, government policies, and risk assessment results are the three biggest drivers of airport resilience practices.
- 59 percentage of respondents see potential to grow their in-house capacity/expertise to support their resilience practice.
- 80 percentage of respondents believe their organization is effective in mitigating risks for their airport.
Lesson learned practices

- Yes, the airport documented the lessons learned and acted on them: 78.4%
- Yes, the airport documented the lessons learned but was unable to act on them: 6.8%
- No, the airport was not able to document the lessons learned: 3.4%
- Information not available: 11.4%

Resilience Assessment and associated resilience measures

- Yes, the airport has conducted at least one resilience assessment and actions have been taken to improve the resilience of its assets: 64.8%
- Yes, the airport has conducted at least one resilience assessment but has not been able to take additional actions to improve the resilience of its assets: 4.4%
- No, the airport has not been able to conduct a resilience assessment: 13.2%
- Information not available: 17.6%

Identification of critical assets and how they might be impacted by future hazards

- The airport has identified its critical assets and has identified additional adaptive/protective measures against future hazards: 69.2%
- The airport has identified its critical assets but has not been able to identify additional adaptive/protective measures against future hazards: 11.0%
- The airport has not been able to identify its critical assets: 8.8%
- Information not available: 11.0%

Figure - 38 Overview of Airport Resilience Practices (Lessons learned and resilience measures)

(Source: NACO analysis of Survey results)
Most respondent airports document their lessons learned and act on them by mapping responses and incorporating measures. It is seen that 64.8% of the airports have conducted a resilience assessment at least once and have consequently taken action to improve the resilience of its assets. Further, 69.2% of the airports have identified their critical assets and adaptive/protective measures required.

While this indicates that most airports are actively addressing resilience, there is still a gap in action for 3-13% of airports.

3.5.10 Resilience drivers

Relative importance of the top three resilience practice drivers (risk assessment results, executive board/management and government policies) is similar across airports with different ownership and operating models.

Furthermore, additional analysis shows government-owned airports with private sector participation and government-owned and privately-operated airports assign more importance to shareholder interests.

Please note: Only one respondent from privately-owned and government operated airports participated, thus the associated results do not inform the findings.

<table>
<thead>
<tr>
<th>Resilience drivers</th>
<th>Government-owned and managed</th>
<th>Government-owned with private sector participation</th>
<th>Government-owned and privately-operated</th>
<th>Privately-owned and operated</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Results of a Risk Assessment</td>
<td>1st</td>
<td>3rd</td>
<td>2nd</td>
<td>1st</td>
<td>1st</td>
</tr>
<tr>
<td>Executive board / Management</td>
<td>2nd</td>
<td>1st</td>
<td>1st</td>
<td>2nd</td>
<td>2nd</td>
</tr>
<tr>
<td>Government policies</td>
<td>3rd</td>
<td>2nd</td>
<td>2nd</td>
<td>3rd</td>
<td>3rd</td>
</tr>
<tr>
<td>Human safety</td>
<td>4th</td>
<td>5th</td>
<td>4th</td>
<td>5th</td>
<td>4th</td>
</tr>
<tr>
<td>Inclusion as part of Masterplan</td>
<td>5th</td>
<td>8th</td>
<td>6th</td>
<td>7th</td>
<td>5th</td>
</tr>
<tr>
<td>Insurance of assets</td>
<td>6th</td>
<td>4th</td>
<td>7th</td>
<td>6th</td>
<td>6th</td>
</tr>
<tr>
<td>Shareholder interests</td>
<td>7th</td>
<td>5th</td>
<td>5th</td>
<td>9th</td>
<td>7th</td>
</tr>
<tr>
<td>Investors</td>
<td>8th</td>
<td>7th</td>
<td>8th</td>
<td>4th</td>
<td>8th</td>
</tr>
<tr>
<td>Market trends</td>
<td>9th</td>
<td>9th</td>
<td>9th</td>
<td>8th</td>
<td>9th</td>
</tr>
</tbody>
</table>

(Source: NACO analysis of Survey results)

Figure - 39 Ranking resilience drivers by Ownership model.
Resilience drivers across different regions

Similar to the analysis across ownership and operating models, the relative importance of the top two resilience practice drivers results of risk assessment and executive board/management is consistent across regions.

However, it is worth noting that Latin America give more importance to investors and shareholder interest.

*Please note: Only two respondents from the Middle East participated, thus the associated results do not inform the findings.*

<table>
<thead>
<tr>
<th>Resilience Drivers</th>
<th>Region</th>
<th>Africa</th>
<th>Asia-Pacific</th>
<th>Europe</th>
<th>Latin America</th>
<th>Middle East</th>
<th>North America</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Results of a Risk Assessment</td>
<td>4th</td>
<td>3rd</td>
<td>1st</td>
<td>2nd</td>
<td>3rd</td>
<td>1st</td>
<td>1st</td>
<td>1st</td>
</tr>
<tr>
<td>Executive board / Management</td>
<td>2nd</td>
<td>1st</td>
<td>2nd</td>
<td>3rd</td>
<td>1st</td>
<td>6th</td>
<td>2nd</td>
<td></td>
</tr>
<tr>
<td>Government policies</td>
<td>7th</td>
<td>2nd</td>
<td>3rd</td>
<td>1st</td>
<td>1st</td>
<td>2nd</td>
<td>3rd</td>
<td></td>
</tr>
<tr>
<td>Human safety</td>
<td>1st</td>
<td>4th</td>
<td>4th</td>
<td>4th</td>
<td>4th</td>
<td>3rd</td>
<td>4th</td>
<td></td>
</tr>
<tr>
<td>Inclusion as part of Masterplan</td>
<td>3rd</td>
<td>5th</td>
<td>9th</td>
<td>8th</td>
<td></td>
<td>4th</td>
<td>5th</td>
<td></td>
</tr>
<tr>
<td>Insurance of assets</td>
<td>5th</td>
<td>8th</td>
<td>5th</td>
<td></td>
<td></td>
<td>5th</td>
<td>6th</td>
<td></td>
</tr>
<tr>
<td>Shareholder interests</td>
<td>6th</td>
<td>7th</td>
<td>7th</td>
<td>5th</td>
<td>4th</td>
<td>6th</td>
<td>7th</td>
<td></td>
</tr>
<tr>
<td>Investors</td>
<td>7th</td>
<td>6th</td>
<td>6th</td>
<td>7th</td>
<td></td>
<td>8th</td>
<td>8th</td>
<td></td>
</tr>
<tr>
<td>Market trends</td>
<td>9th</td>
<td>8th</td>
<td>6th</td>
<td></td>
<td></td>
<td>9th</td>
<td>9th</td>
<td></td>
</tr>
</tbody>
</table>

*Figure - 40 Ranking resilience drivers by Region.*

(Source: NACO analysis of Survey results)

*Note: Blank cells indicates that no respondents selected those drivers.*
Resilience drivers and Risk and Resilience practice efficiency

Figure 41 presents an overview of resilience drivers sorted in order of importance. The darker the colour, the higher the importance given by respondents to the resilient driver. The data indicates that airports with actively involved executive boards / management are effective in mitigating risks as an organization. Further, effective mitigation is also seen when risk assessment results and government policies motivate the organization to act.

Figure - 41 Ranking resilience drivers by effectiveness of organization in mitigating risk for the airport.
(Source : NACO analysis of Survey results)
3.5.11 In-house capacity and expertise

Figure 42 shows a five-by-five matrix comparing how sufficient is the in-house capacity and how effective the organization of the respondent is in mitigating risks for the airport. Please note, each dot represents a respondent.

- Respondents reporting potential to grow in-house capacity tend to report that their organization is neither effective nor ineffective.
- Respondents reporting sufficient in-house capacity tend to report that their organization is effective to very effective.

The results suggest that the availability of in-house capacity and expertise drive the perceived effectiveness of risk and resilience practices.

Figure - 42 Effectiveness of organization in mitigating risks for the airport vs the availability of in-house capacity.

(Source: NACO analysis of Survey results)
3.5.12 Data availability and Risk and Resilience Assessment practices

Figure 43 provides an overview of data source types for different risk and resilience practices.

*Please note the size of the dot is proportional to the number of respondents.*

Analysis suggests that airports with access to scientific studies and knowledge through industry groups are more likely to consider their identified risks in the planning and design process as well as employ additional measures.

**Figure - 43 Overview of data availability for airports vs their risk mitigation practices**

(Source: NACO analysis of Survey results)
Data availability across income levels

Figure 44 provides an overview of data source types for different income level economies (at the country level).

Please note, each dot represents a respondent.

Organizational Adaptive Capacity

Airports rely predominantly on their internal datasets and on open-source government and public datasets to predict future hazards and improve adaptation, irrespective of the income level of their home country.

However, larger income economies have access to more data sources, including scientific studies and industry groups: they are able to complement their data sources with contracted studies or additional subscription-based datasets.

Figure - 44 Access to datasets vs economic profile of the airport’s country
(Source: NACO analysis of Survey results)
Data availability across passenger size

Figure 45 provides an overview of data source types for different airport sizes.

Please note, each dot represents a respondent.

Small airports (less than 5MAP) have access to less data sources vis-a-vis their larger counterparts and typically rely on public datasets, open-source data sets, and their internal data to predict future hazards and improve adaptation.

**Figure - 45 Access to datasets vs airport size**
(Source: NACO analysis of Survey results)

**Organizational Adaptive Capacity**
3.5.13 Business Continuity Plan-Key considerations

Respondents indicate an overlap between AERP’s and BCP’s. The use of simulations and business impact analysis to generate the plan was mentioned.

One respondent also highlighted collaboration with 65 independent departments, Annexes outlining MEF’s, Succession, and Critical Records Management as good practices. Annexes updated annually and refresher training across all departments bi-annually.

3.5.14 Risk and resilience funding practices

Common funding practices specified by respondents include:

• Using insurances to make funds available for specific emergency scenarios
• Leveraging federal funds or government funds where accessible
• Including funding provisions in budget and planned capital expenditures and operational expenditures

More than 89 percentage of airports irrespective of their size are able to consider disaster impacts as part of their Business Continuity Plan, with the BCP addressing a timeframe up to 2025

Similarly, 90 percentage of the airports have funds available to cover mitigation costs.
**Figure - 46** Overview of Business Continuity Plans and the inclusion of resilience practices.
(Source: NACO analysis of Survey results)
3.6 Mitigation and Protection Measures

Mitigation Measures

The mitigation measures reported by airports can be categorised in three distinct areas of focus:

1. Infrastructure
2. Operations
3. Organization

Details of responses submitted by participants are included below and can be considered a ‘menu’ of best practices.

a) Infrastructure

**Drainage**

- Procurement of dewatering pumps to remove excess water
- Procurement of heavy water pump or mobile water pump
- Clean the drainage system, e.g. by clearing vegetation in and around drain system
- Rain water harvesting
- Increased storage capacity of fluid from deicing activities
- Raise level of sea walls
- Improved city drainage system connected to the airport’s storm water drainage

**Power Supply**

- Build backup power station
- Construction of independent power supply
- Physical separation of power supply substations
- Relocate electric installations above ground

**Others**

- Creation of rest areas for passengers for disrupted periods
- Strengthen seismic stability of infrastructure
- Improve perimeter fence
- Acquire modern snow plowing equipment
- Upgrade communication systems
- Improve vegetation control

In addition to, developing hazard-specific and infrastructure-specific recovery plans, infrastructure-focused measures reported by the respondents relate primarily to two measures:

1. Improving drainage
2. Safeguarding the power supply
b) Operations

**Operational measures focus predominantly on developing hazard and infrastructure specific response plans, and ensuring redundancy of systems through:**

1. Backup arrangements with airports in the vicinity or airports managed by the same organization
2. Setting up redundant emergency operations centre at a different location
3. Developing and evaluating alternative control measures
4. Implementing off-site back up arrangements
5. Developing contingency plans with third-party service providers

---

**Redundancies**

- Backup arrangements with airports of the same group/airports in the vicinity
- Redundant Emergency Operation Center at a different location
- Evaluation of control measures, incase existing ones are inappropriate
- Implement off-site back up arrangements for salient data
- Develop contingency with security contractor
- Stand-by Pump

**Response Plans**

- Prepare recovery plan and update Master Plan accordingly
- Develop and regularly review contingency plans, the Airport Emergency Response Plan to ensure
- Develop and evaluate Continuity of Operations Plan (COOP)
- Develop and practice recovery plans for extreme precipitations, extreme icing conditions, and extreme storms and winds
- Develop resilience plans for each building
c) Organization

Existing airports organisational measures are articulated around four objectives:

1. Define procedures and train staff appropriately
2. Set up communication plans and collaborative practices with third parties
3. Set up information systems and tools and application to manage disaster-related information
4. Assign hazard-specific responsibilities to personnel

For all respondents, achieving these objectives is enabled by periodical risk assessments, infrastructure inspection, and budget allocation for regular maintenance.
Protective Measures for Critical Assets

As with the mitigation measures, protective and adaptive measures currently in place at airports can be organized around three themes:

Details of responses submitted by participants are included below and can be considered a ‘menu’ of best practices.

a) Infrastructure

- Improve drainage system and safeguard critical assets against flooding, (e.g., by building a wall to prevent flooding)
- Purchase flood control barriers and create accompanying plans
- Initiate infrastructure upgrade, e.g., seismic upgrades and integrate disaster resilience to future designs
- Runway cleaning machines, friction testing machines and hot mix plant available at the airport for restoring operations on the runway in case there is any damage to the runway
- Ensure the different infrastructure follow the same standard to simplify asset management protocols
- Ensure power supply autonomy and redundancy for critical assets
- Adjustment of the de-icing quantity products to reflect increase exposure to extreme icing conditions
- Investing in spare fire fighting vehicle to maintain CAT 9

Protective measures relating to infrastructure are predominantly:

1. Standardisation of assets
2. Independent power supply for critical infrastructure
3. Investing in emergency response equipment, such as fire-fighting vehicles and de-icing materials.
b) Operations

**Redundancies**

- Keep additional spare parts for critical equipment
- Implement back up arrangements with alternate airports in the vicinity
- Set up data backup procedures and ensure redundancy of IT systems
- Redundancy arrangements of critical electrical systems
- Redundancy in security systems and networks
- Alternative runway operations in case of disruption events

**Response Plans**

- Recurring maintenance Program and Air Mobility Command
- Update Airport Emergency Plan periodically
- Include off airport incidents in Disaster Management Authority’s plan for specialised rescue services
- Contingency Plan for all critical assets
- Fire evacuation planning in case of fire emergency
- Adopt asset management system and asset lifecycle plan
- Enhanced response/recovery capabilities, including ransomware insurance
- Undertake projects as part of a comprehensive airport resilience plan focused on safety and compliance

**Assessments & Studies**

- Conducting risk or criticality assessments for operational procedures and existing infrastructure
- Impact assessment on airport physical assets and operation
- Evaluation of control measures, in case existing ones are inappropriate
- Implement off-site back up arrangements for salient data
- Safety assessments and implementation of mitigation measures
- Risk assessments to clarify scenarios for reduced runway length etc.

**Protective measures relating to operations follow three rationales:**

1. Operational continuity by embedding redundancy of critical systems, especially utility supply systems, distribution networks, and IT systems
2. Pre-disaster plans and protocols
3. Periodic review and updating of emergency response plans and resources
c) Organization

### Organizational Adaptive Capacity

**Procedures and Trainings**
- Continuously monitor and staff critical assets
- Asset management system in place ISO 55001 (risk assessment, proactive maintenance, quality control, etc.)
- Conduct regular emergency exercises and test emergency response scenarios
- Establish Safety Management System (SMS) manual
- Enhance Plan Do Check Act cycle on asset management
- Provide training for all personnel required to drive on airport. A permit is issued to all successful participants
- Prioritize innovation and sustainability
- Set up non-contractual civil liability policy
- Conduct inspections of all vehicles accessing the airport
- Contract Insurance coverage for critical assets

**Third Party Collaboration**
- Coordinate with local emergency and fire fighting entities
- Improve preparedness with government entities
- Set up emergency response contracts for privately-owned assets
- Schedule periodic interaction with local authorities for early warning systems
- Implement mutual aid and assistance agreements with relevant agencies
- Engage environmental authority for the control of wildlife
- Coordinate with airlines and auxiliary personnel
- Memorandum of Understanding (MoUs) with critical stakeholders

**Information Systems**
- Document simulation exercises
- Implementing world class cybersecurity systems
- Define MoU and Service Level Agreements with third-party service providers
- Airport Collaborative Decision Making (A-CDM) tool for collaborative decision making

**Personnel**
- Hire designated staff for Emergency Response Planning
- Trained manpower for operations and maintenance of critical assets
- Back up emergency man power
- Create multidisciplinary teams to support passengers on days of emergencies
- Hire Climate Mitigation & Resiliency Program Manager
- Create contingency Aerodrome Operations Unit
- Subject matter experts for expert guidance

Organizational protective measures are articulated around one objective: plan and develop effective communication channels with airport staff, and aviation stakeholders.

To achieve this objective airports rely on cyclical trainings and protocols collaboration with third-parties, internal information sharing and storing protocols, and designated roles for key in-house experts.
### Key policies or efforts that can be undertaken by the industry and government authorities, to improve the resilience of airports

<table>
<thead>
<tr>
<th><strong>Authorities and Regulatory Bodies</strong></th>
<th>Appoint national level expert group or task force for knowledge sharing and advisory for existing policies and updating the civil aviation regulation (CAR)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mandatory dedicated department for emergency and resilience management</td>
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<tr>
<td></td>
<td>Resilience planning costs should be calculated under aeronautical expense</td>
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<tr>
<td></td>
<td>Standardisation of policies for resilience of airports, local guidelines / regulations for resilience</td>
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<tr>
<td></td>
<td>Improvement of land-use planning around airports</td>
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<tr>
<td></td>
<td>Financial support from government / federal transport or infrastructure grants</td>
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<tr>
<td></td>
<td>Government to provide response infrastructure e.g.: early warning system, evacuation guidance</td>
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<tr>
<td></td>
<td>Update design standards as per IPCC global climate scenarios</td>
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<td></td>
<td>Show flexibility in regulations and implementation of new policies at the time of a disaster event</td>
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<tr>
<td></td>
<td>Address cyber crime</td>
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<td></td>
<td>Improve definitions and more precise regulatory roles and responsibilities for various stakeholders</td>
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<table>
<thead>
<tr>
<th><strong>Organization</strong></th>
<th>Ensure airport staff, tenants and stakeholders have necessary resources for safety management and response, including training</th>
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<tbody>
<tr>
<td></td>
<td>Conduct regular drill exercises and inspections</td>
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<td>Emphasize scenario-planning as part of disaster mitigation plans, include previous lessons learned in the designs and plans</td>
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<td></td>
<td>Process automation and adaptation to new technologies to reduce downtime of services</td>
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<tr>
<td></td>
<td>Conduct periodic assessment and identify risks</td>
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<td></td>
<td>Collaborate with external stakeholders during the development phase</td>
</tr>
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<td></td>
<td>Improvement of facilities, disaster-related fund releases, and risk assessment matrices</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Industry and Institutions</strong></th>
<th>Conduct research on impact of climate change on major international airports</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Develop a resilience action plan and adaptation plan for airports with defined timelines and monitoring methodologies for the next 10 to 20 years</td>
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<tr>
<td></td>
<td>Joint forums and planning activities</td>
</tr>
<tr>
<td></td>
<td>Create standards and models</td>
</tr>
<tr>
<td></td>
<td>ACI and ICAO to engage more actively to share best practices and knowledge</td>
</tr>
<tr>
<td></td>
<td>Mandatory resilience training</td>
</tr>
<tr>
<td></td>
<td>Shared database of lessons learned after disaster impact</td>
</tr>
</tbody>
</table>

**Respondents recommend increasing responsibility and accountability of authorities and governments for active resilience planning, funding, and mandating resilience practices. Institutions and industry practice groups are urged to support knowledge sharing practices, facilitate trainings, set disaster goals, and actively conduct research.**
FOCUS GROUP

DISCUSSION

4.1. Methodology
4.2. Data Collection
4.3. Data Analysis and Results
As highlighted in Section 1 Introduction, survey results were complemented by Focus Group Discussions (FGD). The preliminary data collected from the survey was used to refine and enrich the scope of the FGD.

This section presents results and learnings from the Focus Group Discussion (FGD). A brief methodology and approach for outreach is outlined, followed by data analysis and results.

### 4.1 Methodology

The Focus Group Discussions were designed to engage participants and collect information to form a deeper understanding of airport risk and resilience practices. The workshops were designed to enable in-depth follow-up discussions with selected airports and relevant stakeholders.

The content of each workshop is informed by the following considerations:

- **Capture key expectations and challenges per airport**
- **Validate preliminary survey results for each region**
- **Address gaps in preliminary survey results, notably discuss existing adaptive capacity practices**
- **Balance of perception analysis and objective questions**
- **Time required to address a given subject**
This content was then tailored to capture participants expectations for each workshop.

**The workshop was organized as follows:**

1. **Contextualize the workshop and set the premises by introducing key definitions and survey results relating to the first three research dimensions:**
   - (1) Historical Disaster Impact,
   - (2) Relevant Hazards and
   - (3) Hazard Exposure Mapping by region

2. **Discuss and validate the related preliminary findings with the participants from the relevant regions and facilitate a discussion around the underlying drivers that might explain the difference across regions.**

3. **Introduce the remaining three dimensions relating to Adaptive Capacity:**
   - (4) Infrastructural Adaptive Capacity,
   - (5) Operational Adaptive Capacity and
   - (6) Organizational Adaptive Capacity.

Sub-themes for these dimensions are highlighted to clearly indicate the scope for the discussion (Figure 47). The resulting framework to address Adaptive Capacity is as follows:

**Adaptive Capacity**

1. Key expectations & challenges
2. Measures undertaken by asset type
3. Internal and external stakeholder involvement
4. Financial preparedness

The format and content were evaluated and validated by internal experts with resilience expertise and an understanding of regional knowledge sharing practices and capabilities.
Infrastructural Adaptive Capacity

- Adaptable risk mitigation measures
- New resilient infrastructure
- Robust and redundant access links
- Resilient Energy & Water supply

Financial: Airport finances, financial planning, Business strategy

Operations: Aircraft operation, wildlife management, environment, emergency response, etc.

Interdependencies beyond airport boundaries

Figure - 47 Overview of themes discussed in the focus group discussion (NACO)
4.2 Data Collection

Broadcast outreach to survey participants who provided their contact details for further engagement with the study

April 25 2022

Participants grouped by region to ensure optimal participation and discussion

Targeted outreach through CDRI and NACO’s networks

April 25 - May 16 2022

Outreach to underrepresented regions to ensure equitable representation

Conduct FGD

May 20th, 24th and 25th 2022

Four workshops are held based on the participant’s availability, for a total participation of 23 airport stakeholders from Africa, Asia/Pacific, Europe, Middle East, Latin America and North America

Tools used

Miro Board and Mentimeter were used to capture inputs from participants and improve the meeting minutes. These web-based tools enabled participants to respond while discussing and documenting their current practices.

The FGDs were conducted over Microsoft teams with one moderator, one technical support personnel and a transcriber. Data sheets were prepared to synthesize the minutes, Mentimeter results and Miro board outcomes. A thematic analysis yielded the results presented in the following section.
4.3 Data Analysis and Results

4.3.1 Expectations

Participant expectations from the workshop centred around knowledge sharing and community practice. Expectations from the session included:

- Learning from other airports
- Gauging best practices
- Learning how to prepare for and manage a disaster as well as coordinate between management and operations.

Participants expressed a collective determination for drafting a strategy and roadmap to address airport. Some common questions mentioned are:

1. How to include resilience across the lifecycle of an airport?
2. How to prepare for incoming regulations?
3. What are the implications on business continuity plans?
4. How have airports integrated stakeholders?
5. What actions need to be taken for a strategic approach?

4.3.2 Historical Disaster Impact, Relevant Hazards, and Hazard Exposure Mapping by Region

Consistent with the survey, the most mentioned disruptions are increased extreme precipitation events and third-party equipment failures. Natural hazards like windstorms and earthquakes are also noted to become more frequent and increasingly intense.

Third-party failures were primarily linked to the lack of redundancies in the system and equipment. Small airports typically have one handling agent at the airport. Failure of any equipment causes disruption, considering that there are no redundancies in the system.

A lack of strong external stakeholder engagement leads to limited integration between the airport development and regional or national plans. Communication with third parties is essential to ensure timely and effective response.

The overall experience of FGD participants’ was consistent with the preliminary survey results presented for their region. Respondents also mentioned additional challenges faced by their airports and suggested the study team to focus on contextualization and airport-specific policies for subsequent phases.
4.3.3 Adaptive Capacity

Thematic analysis is a method of analysing qualitative data by searching, identifying, and reporting repetitive patterns. A thematic analysis is conducted for the FGDs based on the three Adaptive Capacity dimensions: Infrastructural Adaptive Capacity, Operational Adaptive Capacity and Organizational Adaptive Capacity. The findings have been categorised to reflect the participants’ perception of the airport’s infrastructural, operational and organizational adaptive capacities.

a) Infrastructure Adaptive Capacity

For purpose of the discussions, infrastructure adaptive capacity is structured as follows:

- Resilient design and proper maintenance of infrastructure
- Effective emergency strategies
- New resilient infrastructure

With an overall score of 2.8 – 4.5 out of 5, all participants agree that there is room for improvement for the maintenance plans for their key assets. Participants acknowledge the importance of identifying the different events which can disrupt operations as well as their economic consequences. Small airports emphasized how crucial runway maintenance is, especially for single runway airports.

It was highlighted that some airports consider hazard impact in their design and maintenance plans. They plan for response and redundancies in maintenance plans with third party agencies.
Measures in place to safeguard critical assets against disasters

Table 12 Number of measures per asset group

<table>
<thead>
<tr>
<th>Asset Group</th>
<th>Number of measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runway</td>
<td>23</td>
</tr>
<tr>
<td>Terminal</td>
<td>22</td>
</tr>
<tr>
<td>Communication systems</td>
<td>17</td>
</tr>
<tr>
<td>Utilities</td>
<td>15</td>
</tr>
<tr>
<td>Machinery and Equipment</td>
<td>13</td>
</tr>
<tr>
<td>Access links</td>
<td>12</td>
</tr>
<tr>
<td>Airfield</td>
<td>11</td>
</tr>
<tr>
<td>Land</td>
<td>6</td>
</tr>
<tr>
<td>Multiple Assets</td>
<td>2</td>
</tr>
</tbody>
</table>

Runways, Terminal, and Communication Systems are given the highest priority among the critical assets. Most participating airports have mitigation or recovery measures in place for these assets. Whereas access links to the airport are considered to be one of the most vulnerable assets, the respondents emphasize that protecting them requires extensive collaboration with multiple stakeholders and is often not a part of their jurisdiction. In addition, although redundancies in infrastructure and utilities is crucial but some respondents expressed that it is often financially difficult for them to factor in redundancy.
Runways

Effective drainage plans and maintenance plans are the most common pre-disaster measures taken for safeguarding runways and ensure reliability of critical operation processes (take-off, landing, etc). Overflow water storage tanks, designing the system for a 100-year storm and upgrading the infrastructure to maintain a proper drainage system are some of the measures mentioned to mitigate flooding and extreme precipitation. Proper maintenance and inspections including two-diary revisions of runways by marshalls, updated contingency plans, and stand-by teams for emergency response are also in place.

At the time of disaster, airports mention having emergency response plans and business continuity plans in place, as well as agreement with suppliers.

Post-disaster measures for recovery include inspection of the damage, prioritized maintenance, and flight plans.

Terminals

Terminals are considered the second most important critical infrastructural assets. Considering potential hazards in the design stage, periodical revisions of emergency systems, effective drainage pumps and a maintenance plan are mitigation measures in place at the design stage. Additional measures include providing multiple access and egress roads on the landside for redundancy.

During a disaster, the airports have emergency response teams to respond to the crisis. Protocols are in place to integrate the airport’s response and the third parties and authorities. MoUs and framework contracts are drawn up with maintenance and repair suppliers. Some airports also use satellite phones and set up crisis centres for coordination at the time of the disaster.

Communication Systems and Utilities

Building redundancies in communication systems and utilities to ensure continued operations during a disaster and quick recovery was considered as an essential measure. Key measures mentioned include independent power supply for their communication systems, back-up technologies for the time of disaster, periodic testing, and in-house staff for maintenance.

b) Operational Adaptive Capacity

Efficiency of existing early warning systems for covering key assets and operations

Respondents also emphasize the importance of proper implementation of early warning systems. The warnings need to be specific, clearly defined and communicated.
Respondents from the Asia and Middle Eastern regions perceive their early warning systems to be very effective. While respondents from Europe, Africa, North America and Latin America (LATAM) perceive their systems are effective but have some scope for improvement, in particular as it relates to how the warnings are communicated.

**Emergency Response Planning**

Some respondents mention working closely with national disaster management centres. This allows for collaborative efforts between airports of the same region or country for issuing travel guidelines, protocols, and information.

Overall, the pandemic pushed the organizations to adopt technologies in a short period of time. Further, it was a good test for all the internal stakeholders to work collaboratively.

"Emergency response has seen considerable developments due to the COVID-19 pandemic. Virtual crisis centres were instituted at airports which allowed effective decision making, data storage and situation analysis."

**c) Organizational Adaptive Capacity**

Although the pandemic improved dynamics between internal stakeholders, respondents are of the opinion that collaboration with internal and external stakeholders in mitigating financial disruption can be improved. Early involvement of stakeholders is beneficial in orchestrating effective response and recovery.

**Collaboration with stakeholders to implement adaptive capacity measures**

Governments are noted to have integrated relationships with airports of national importance or when the airport is the only point of entry-exit to the country or island-state. This allows the airport to have a personal relationship with the authorities and facilitates access to the funding and grant opportunities.

**Preventive collaboration practices**

Government or regulating agencies, airport operators, airline, service providers, ground handlers and developers are the key stakeholders for the pre-disaster phase.
Coping collaboration practices

Rescue and firefighting (RFF) teams are noted to be the first responders during an emergency. The RFF then hand over the disaster management and recovery operations to government agencies, contracted maintenance agencies, or appointed internal tactical teams.

Effective communication with the stakeholders during a disaster is indispensable for a smooth response. For small airports and airports of national importance, city and national governments are a key part of their disaster response procedures. Where available, the immediate response is given by city or national agencies like firefighting departments, military, and national disaster forces.

Recovery collaboration practices

Post disaster recovery is seen as a collective responsibility of the airport operator, government agencies and maintenance service providers with local authorities spearheading the definition of recovery milestones.

Primary sources of funding for adaptive capacity measures

Private investors and government entities are the primary funders in the pre-disaster (prevention) and during disaster stage (coping). International agencies also play a key role in financing infrastructure in collaboration with national governments and are relied upon for monetarised risk evaluation.

Post-disaster recovery (as well as adaptive and transformative capacity) could be additionally funded by airport operators, maintenance agencies, insurances, and international aid. This suggestion is in line with the approach advocated by United Nations Office for Disaster Risk Reduction in 2015 as part of the Sendai Framework.

“Financial security enables our ability to fund unforeseen recovery activities. Developing non-aeronautical revenues not dependent on passenger activity is a key contributor to our airport’s financial independence.”
FINDINGS
As indicated at the outset, the world is experiencing an increasing frequency of extreme weather events due to climate change, continued exposure to other natural hazards, and increasing system interdependency and integration. Today’s socio-economic and infrastructural systems have become more complex and together with urban growth, the aviation industry is expanding, both in terms of traffic activity and airport infrastructure. Airports are providing multi-scale connectivity, stimulating economic growth and business activity.

The results of this study indicate that airports are increasingly facing disruptions due to natural and human-induced hazards. Disruption of airport operations can have a cascading effect through dependent infrastructure and socio-economic systems. Therefore, airports could play a key role in building disaster resilience capacity.

Against this backdrop, building disaster resilience capacity is argued to be one of the core components for protecting airport assets, continuous operability, and business continuity today and in the future. To understand the disaster resilience of airports across the globe, the study is articulated around three questions:

1. What is the current perception of hazard and disaster exposure at airports?
2. How do airports perceive their resilience to climate, environmental and natural hazards?
3. What are the current practices in airport resilience?

As a result of the outreach efforts described in this document, this section presents the findings resulting from the analysis of disaster resilience practices in place at 81 airports.

### 5.1 What is the current perception of hazard and disaster exposure at airports?

**Disaster Impact Context**

Across regions, airports expect extreme storms and winds, extreme precipitation, and third-party systems failures to result in partial infrastructural restrictions, flight delays, and indirect economic loss to airport partners.

Each region displays a different ability to recover from climate and natural hazards. Notably, North America displays a slower ability to fully recover from extreme icing conditions, extreme storms and winds and geological hazards compared to Asia-Pacific and Europe. Similarly, although airports in Africa tend to resume operations at similar rates than their counterparts, full recovery appears to take longer in the region.

Airports display a higher ability to resume and recover operations for disruptions of incremental intensity and predictable occurrence like flooding, drought, and extreme heat than from volcanic activity, geological hazards (earthquakes, landslide and others) and third-party systems failures. These hazards are harder to predict. Larger airports (50MAP+) anticipate potential closure for restrictive conditions of operations, reduced efficiency, and potential direct economic loss to airport partners. Contrastingly, smaller airports expect limited severity of impact on their assets, with severity levels limited to partial infrastructural restrictions.
5.2 How do airports perceive their resilience to climate, environmental and natural hazards? Risk Assessment Practices

Airports which conduct periodic vulnerability assessments anticipate lower impact on their organization than airports without a periodic assessment practice. About 71.6 percentage of airports have conducted a vulnerability assessment for their infrastructure at least once. Of the airports conducting vulnerability assessments periodically, 55.3 percentage conduct vulnerability assessments yearly and 27.7 percentage conducting one every 2 to 5 years. For these vulnerability assessments, the three most important elements are (1) personnel and passenger infrastructure, (2) civil structure and installations, and (3) reliability of operations.

Runways, terminals, and communication systems are given the highest priority among the critical assets, with the majority of participating airports having mitigation or recovery measures in place for these assets. Whereas, airport access links are considered one of the most vulnerable assets. Participating airports highlight that developing mitigation or recovery measures for these assets is often challenging as airport access links are often not a part of airport jurisdiction and require extensive collaboration with multiple stakeholders in the region.

To ensure operational continuity, several airports rely on Memorandum of Understandings (MoUs) with external stakeholders and designated in-house staff for emergency maintenance or repair, as well as partnerships with other airports in the vicinity for emergency assistance. However, most natural hazards are currently not addressed by insurance policies.

Existing airport risk and resilience practices include a limited number of operational and financial measures. Measures employed to increase resilience and protect critical assets focus predominantly on organizational and infrastructural measures. These measures include:

- **Procedural methods and trainings like recurring drills and risk management focused meetings**
- **Asset management systems, maintenance manuals and pre-defined response processes to protect critical assets**
- **New infrastructure and redundant installations for storm water drainage and power supply**

However, although recognised as crucial, redundancy of infrastructure and utilities is often difficult to address because of financial constraints.
5.3 What are the current practices in airport resilience?  
Adaptive Capacity

At organizations with effective practices, (1) executive board/management, (2) results of a risk assessment, and (3) government policies drive the airport’s risk and resilience practice, with 90% of respondents reporting availability of funds to cover mitigation costs, and 80% of respondents report that their organization is effective in mitigating risks for the airport.

More than 89% of airports irrespective of their size are able to consider disaster impacts as part of their Business Continuity Plan. However, the results suggest availability of in-house capacity and expertise drive the effectiveness of airport risk and resilience practices, with more than half of respondents seeing potential to grow their in-house capacity and expertise to support their resilience practice, in particular by employing new and specialised personnel and deploying adequate IT systems.

To complement their in-house capacity and expertise, airports collaborate with airlines, ground handlers, government agencies and utility providers to define, implement and monitor their Airport Emergency Response Plan and Disaster Recovery Plan. This early involvement of all stakeholders contributes to effective response and recovery. Nevertheless, although the pandemic improved dynamics between internal stakeholders, respondents emphasize that collaboration processes with internal and external stakeholders can still be improved, with good relations with the national government indispensable to improving airports’ resilience.

Human safety, government policies, and risk assessment results are the three biggest drivers of airport resilience practices. Increasing responsibility and accountability of authorities and governments, for active resilience planning, funding and mandating resilience practices is key to improving the resilience of airports.

Airports, irrespective of the income level of the country where they are located, rely predominantly on internal datasets and open-source government and public datasets to predict future hazards, and improve adaptation. However, larger income economies and larger airports are able to complement these data sources with scientific studies, industry groups data, and subcontracted studies.

Airports that have been able to consider the risks identified as part of their planning and design process, and employ additional measures typically have access to scientific studies and knowledge through industry groups. Industry organizations like ICAO, ACI and government authorities are urged to support knowledge sharing practices, facilitate trainings, and actively conduct research.

Limitations

The research methodology described in this document and findings presented are subject to certain limitations associated with a survey and perception analysis study.
1. While the different outreach efforts and sampling methodology has been designed to collect information from a representative number of airports, key differences in resource and expertise availability by region and economic context, limited participation is from the Middle East and low-income countries. In-depth studies focused on Africa, Latin America and the Caribbean, as well as the Middle East are needed in future phases.

2. Achieving the balance between a comprehensive questionnaire, reasonable survey completion time, administering the survey online, and the need for statistical representation is a common challenge for survey-based studies. As a result, and as highlighted by FGD participants, the survey did not always further investigate airport specific practices. Developing case studies and complementing these surveys with the field visits in Phase 2 should address these limitations.

3. Given the perception analysis nature of the study, the results presented in this report are based on a self-assessment by the online survey respondents and FGD participants. Information provided as part of this study would need to be corroborated by a review of internal documents and proprietary airport information.

4. This study is restricted to four capacities out of the five airport resilience capacities that is, threshold capacity, coping capacity, recovery capacity, and adaptive capacity. Transformative capacity, i.e., the capability to create an enabling environment, strengthen stakeholder capacities, and identify and implement catalysing interventions is, yet to be addressed.
WAY FORWARD
Key recommendations to action the findings of this research are presented below. Each recommendation is contextualized by a combination of NACO expert opinion, an illustrative example, and action items for airport, government, and other stakeholders.

<table>
<thead>
<tr>
<th>Conduct in-depth studies of risk and resilience practices at airports to understand differences in ability to resume operations and recover across regions</th>
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</thead>
<tbody>
<tr>
<td><strong>Expert Opinion</strong></td>
</tr>
<tr>
<td><strong>Illustrative Example / Case Study</strong></td>
</tr>
</tbody>
</table>
| **Proposed Action Plan** | 1. In line with the Phase 2 scope, map current practices on the capacity of airport system to manage uncertainties (disaster risk management and resilience)  
2. Develop a public register of existing recovery practices to allow airports to learn from each other’s experiences  
3. Develop framework and indicators for disaster resilient airports  
4. Organize dissemination workshops with airport and government agency participation to bring awareness to the risks that airports face and the support airports require |

**Research & Knowledge Sharing**
Establish a broader understanding of risk appetite of airports

Expert Opinion
Risk appetite, at the organizational level, is the amount of risk exposure, or potential adverse impact from an event, that the organization is willing to accept. Resilience and adaptation measures should be developed based on each airport organization’s risk appetite. Indeed, these measures require a trade-off between cost efficiency and future-proofing. Therefore, the airport should take a risk-based approach to understanding their critical needs and impact prioritisation. This involves assessing which risks are acceptable or not acceptable for the airport organization. For example, a certain extreme event or impact can be considered acceptable because there is limited operational disruption or damage. The implementation of certain measures depends on the return period of the extreme event and the related costs of disruption, damage, and maintenance. Certain measures require a relatively high investment that the airport is not able to mobilize despite the cost effectiveness on the long term. For some airports, partial closure of the airport for a short period of time after a disaster event is considered acceptable.

Illustrative Example / Case Study
Amsterdam Airport Schiphol
Amsterdam Airport Schiphol is a low-lying airport built on reclaimed land below sea level, which faces water challenges daily. Making Schiphol airport less vulnerable to (pluvial) flood risk means additional investment. At the same time Schiphol will benefit from avoided damages and disruption of operation. Based on a comprehensive pluvial flood stress test (2017) and the judgement of Schiphol’s airside experts, a flood impact assessment was adapted. The flood impact assessment illustrates the frequency and the extent to which pluvial flood risk is expected to cause damages and disrupt operations. This translated to direct and indirect cost. The figure shows a “risk appetite” or optimal risk tolerance of an extreme rainfall event occurring close to once per 100 years (T100). This risk tolerance implies stricter requirements than current design standards.
An example of an airport dealing with disasters is Rockhampton Airport in Australia (QLD). Every year the regional river is flooding the region including the airport. When this is expected all aircrafts will be evacuated, the terminal is closed and protected by local retaining barriers. After the water levels have resided the sediment is being washed from the runways and aprons.

### Proposed Action Plan

For airports: Foster ‘Risk dialogue’ with relevant stakeholders in order to decide what is the organization's risk appetite. Key considerations might include:

1. Study hazard context, in particular frequency (e.g., return period), intensity and duration of relevant hazards
2. Select relevant impact scenario for a given climate and natural hazards
3. Identify critical airport infrastructure (assets) and operation (processes)
4. Consider effects of acute (e.g., extreme flooding, earthquakes, major storm event etc.) and chronic events (e.g., sea level rise, change in precipitation, increase in temperature etc)
5. Integrate all relevant airport assets in climate stress test or risk assessment
6. Determine potential cascade effects
7. Perform economic impact analysis
8. Assess willingness and financial capacity to invest in mitigation measures

### Expert Opinion

Airports, local and regional government authorities depend on each other for adaptation planning. Therefore, to have an effective resilience plan, engagement from regional and local authorities is critical. In this way, it allows for assessing the overall risk and assures a shared responsibility.
Illustrative Example / Case Study

The World Bank Resilience Projects

The majority of the World Bank-funded resilience projects include critical and vital assets such as airports as part of the assessment. This systemic approach accounts for the responsibility of various regional departments e.g., building authority, road authority, water management board, municipalities, and commercial entities e.g., airport, cargo supply chain, transport etc. in ensuring resilience to hazards. For instance, although protection from sea level rise is the responsibility of the water authority, the airport is a key stakeholder in the adaptation planning. At the same time, protection from extreme rainfall is the responsibility of the airport, but it also affects the surrounding areas. Hence, partnerships with all the governing authorities is essential for cohesive action.

Singapore PUB Coastal Protection Study

The National Water Agency PUB of Singapore is currently conducting a coastal protection study. This study looks at the potential impact of floods on critical assets in three areas, the East-Coast Marina stretch, part of the Greater Southern Waterfront district and Changi, Changi airport included.

Proposed Action Plan

Delineate scope of responsibilities for the airport, local and regional authorities, as well as other relevant stakeholders groups for the different hazards the airport is exposed to.

Airports should conduct periodic Vulnerability Assessments and develop a resilience strategy

Expert Opinion

Vulnerability Assessments are influenced by the following,

1. Climate and natural hazard exposure projections
2. Changes in the airport organization’s operations
3. The risk assessments framework and models developed internally
4. Asset replacement and changes in airport operations
5. Availability of data on historical impact and infrastructure damages

As these evolve over time, reviewing the Vulnerability Assessment will enable appropriate prioritisation and resource allocation, as well as analysis of how impacts and costs evolve over time.

Planning cycle for climate adaptation (source: EU Interreg CATCH project, 2019, based on Climate-ADAPT and consistent with ISO 14090 ‘Adaptation to climate change-Principles, requirements and guidelines’)
**Articles/Reference:**
According to the ISO 14090 adaptation cycle, this could be every six years or as part of development plans.

<table>
<thead>
<tr>
<th><strong>Mandate government authorities and institutions to conduct region-focused scientific studies and address the scarcity of scientific studies related to airport natural and climate hazard exposure.</strong></th>
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</thead>
</table>

**Expert Opinion**
Responsible authorities should facilitate research and data collection for region or airport specific hazard exposure. This data should then be disseminated to the airport and their stakeholders to enable them to act. The data will enable airports to integrate risk and resilience planning in their BCP’s and development plans as well as mitigation processes and measures.

The ready availability of data will enable airports to integrate risk assessments in their pre-feasibility, feasibility, and masterplan phases, without having to conduct independent studies for each phase.

**Illustrative Example / Case Study**
Many national and regional governments stepped up to assist airports in the time of the COVID-19 pandemic. Effective communication channels were established to transfer existing knowledge on the situation, evolving guidelines and the possible impact on the airport. This is a good example of airport-government cooperation enabling increased preparedness.

The OECD framework for governance of infrastructure mentions data support as one of the key actions to be taken in infrastructure governance. (IATA, 2020)

- Develop a long-term strategic vision for infrastructure
- Manage integrity and corruption threats throughout the project
- Choose how to deliver the infrastructure
- Ensure good regulatory design
- Integrate a consultation process
- Co-ordinate infrastructure policy across levels of government
- Guard affordability and value for money
- Generate, analyse and disclose useful data
- Make sure the asset performs throughout its life
- Public infrastructure needs to be resilient
| Proposed Action Plan | For multilateral institutions (ACI, ICAO, CDRI, IATA):
• Mandate / advocate with governments / Civil Aviation authorities to undertake the research and dissemination exercise.
• Provide guidance / technical support on integrating the exercise as a sustainable practice in their way of working.

For governments and local authorities
• Introduce policy shift to focus on research and knowledge dissemination on hazard exposure in their region.
• Collaborate with Airports to understand the current hazard related challenges faced by them and map the gaps in the data available.

For airports
• Lobby with governments to highlight the scarcity of data and actively participate in the research process. |

| Mandate quick scans to assess hazard exposure and resilience planning as part of all greenfield and brownfield developments |
| Expert Opinion | The civil aviation authority could make quick scans mandatory as part of airport development plans. This would increase adoption of resilience practices and ensure integration of resilience and adaptation planning into the existing master planning process. |
| Proposed Action Plan | NACO proposes quick scans as part of the Master Plan process |

| Encourage cross industry knowledge sharing and learning from industries and environments where there are similarities in complexity such as cities |
| Expert Opinion | The airports and the aviation industry in general can learn from data about resilient cities. Airports and cities are similar in complexity. They are also layered complex systems with interdependencies. Airports are similar to urban dense areas, represent complex economic systems with multiple stakeholders, and function as multimodal interconnected hubs. |
| Illustrative Example / Case Study | The Rockefeller Foundation developed a city resilience framework that presents seven qualities of resilient cities
• Reflective: referring to having a mechanism to continuously evolve and systematically learn from their past.
• Robust: refers to limit spread of failure. A robust system includes well-conceived, constructed, and managed physical asset, so that they can withstand the impact of hazard events without significant loss of function
• Resourceful: refers to having spare capacity in the system and easily repurposes resources efficiently.
• Flexible: refers to a system that can change, evolve, and adapt in response to changing circumstances. Meaning it can effectively implement alternative strategies or incorporated traditional knowledge and experience in an innovative way.
• Redundant: refer to having a spare or backup capacity within a system to be able to accommodate disruption or other impact of hazard event |
• Inclusive: refers to the inclusion of broad consultation, engagement, and communication, including all the relevant stakeholders creates a sense of ownership to together develop build on the resilience.
• Integrated: refers to all the integration and alignment of all systems, to be able to work together to increase resilience across the systems. This includes sharing information between the systems to collectively take decisions for the long term and having short lines to collectively take rapid decisions and actions in case of a hazard event.

Rotterdam City:
The Rotterdam resilience strategy provides inspiration for airports about the challenges of these cities. Furthermore, how they adjust to the changing circumstances and implement resilience within their layered complex systems with interdependencies. The city built dedicated area for flooding with a dual function. These areas act as reservoirs during flooding, and otherwise serve a recreational use.

| Proposed Action Plan | Cross-industry learning by organization of conference and resilience related topic specific symposium

Industry organizations like CDRI, ICAO, ACI and government authorities are urged to support knowledge sharing practices, facilitate trainings, and actively conduct research. This would improve cross-industry and cross-regional collaboration.

• Create resilience index for airports based on city framework, ISO of resilient city indicator.

Reference to ISO, that has developed an international standard in Indicators for Resilient Cities: https://www.iso.org/standard/70428.html

Airports and government bodies should continue to work together to build integrated disaster resilience

Expert Opinion
Based on the survey results and focus group discussions, most airports have an Emergency Response Plan in place. This plan contains one or more protocols to act on calamities, like a power outage or water nuisance. In most cases these plans do not yet address the financial consequences of disasters. When disasters happen, this has an effect not only on the airport, but often on an entire region. Therefore, airport and government bodies should work together in case of a disaster or hazard.

Illustrative Example / Case Study
Netherlands – Integrated National Approach
The Netherlands is divided into 25 security regions, which are all committed to the safety of the inhabitants and visitors of that area. This commitment comes with a responsibility and several tasks in the domain of fire service, medical assistance, public order, safety, and disaster- and crisis management. Among the main responsibilities of the security region, is their responsibility to prevent and fight fires and it therefore has to ensure the presence of fire brigades. In addition, they prepare for risks, disasters, and crises by setting up an approach and risk profile for each region.

Proposed Action Plan
For airports
• Check and assess emergency plan and protocols

• Coordinate with the governmental bodies in the region to define which agreements can be made about disaster management and/or a regional or national disaster recovery fund

• If necessary, invest in protocol or strategic plan for disaster management
For governments:
- Provide financial support to facilitate disaster preparedness and recovery
- Develop forecasting model and local measures to estimate and address the impact on regional and airport infrastructure

**Airports should move towards a more proactive approach rather than reactive towards hazard management and resilience planning.**

**Expert Opinion**

The reactive approach relates to employing measures and finances after disaster impact. The measures are implemented in reaction to a disaster and rely on the resources available at the time. These measures are typically identified as part of the Airport Emergency Response Plans.

The proactive approach to resilience is based on pre-identified actions and financing alternatives in anticipation of a disaster. Disaster resilience and adaptation are embedded in the airport’s masterplan and periodic practice. The airport reserves resources as part of their capital development plan and operating expenditures budget process. These resources are readily available at the time of disaster. The planning should also incorporate flexibility for future changes. However, although this approach improves the airports preparedness and resilience, it requires additional investment and redundancies.

**Illustrative Example / Case Study**

Key examples and framework for pro-active resilience planning include:

**Boston Logan International Airport – Resiliency Strategy**

Flood barriers help protect from storm surge at Boston Logan International Airport (Progress report infographic, 2018 BOS Annual Sustainability & Resiliency Report)

<table>
<thead>
<tr>
<th>KPI</th>
<th>Target</th>
<th>Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of capital projects that address resiliency of Massport facilities at Boston Logan International Airport</td>
<td>25 percentage of critical assets and/or key resources enhanced by 2020; 100 percentage of critical assets and key resources enhanced with resiliency measures by 2025.</td>
<td>60 percentage of critical assets enhanced with resiliency measures.</td>
</tr>
</tbody>
</table>

Note: Critical assets include electrical power, diesel fuel pumping stations, telecommunication systems and public safety including police and fire.

**Build Back Better**

This framework defined as part of the Sendai framework, provides the opportunity to integrate resilience planning into communities and address recurring vulnerabilities through the components represented in the figure below.

**LaGuardia Airport Design**

As part of the redesign of the airport, the airport elevated essential elements out of the flood zone and integrated seismic design on liquefiable soils.
**Integrate the Task Force on Climate-related Financial Disclosures (TCFD) framework as standard practice to improve airport understanding of their current practices, including physical and transition risks**

<table>
<thead>
<tr>
<th>Expert Opinion</th>
<th>To support different industries in tackling climate-change related hazards, the Financial Stability Board (FSB) created the TCFD, Task Force on Climate-related Financial Disclosures, to develop recommendations on the types of information that companies should disclose to support investors, lenders, and insurance underwriters in appropriately assessing and pricing risks related to climate change.</th>
</tr>
</thead>
</table>
| Illustrative Example / Case Study | TCFD provides a comprehensive understanding of the risks and opportunities they face from climate change in disclosures that are uniform, consistent, and comparable between organizations. It increases awareness and understanding of climate-related risks and opportunities within the company resulting in better risk management and more informed strategic planning.  
Hong Kong Airport 2021 - TCFD Statement |
| Proposed Action Plan | Airports are advised to use the TCFD framework for their current and new developments |
## Expert Opinion

Insurers are evolving and started understanding the areas of risk and re-evaluating their insurance coverage and premium for a different type of assets. So it is expected from any vital infrastructure operator or owner such as an airport to show the level of climate risk or preparedness towards a disastrous event. In this way, an airport can avail a reasonable premium from insurers.

## Illustrative Example / Case Study

More frequent and catastrophic events can make insuring some risk unaffordable for customers or unfeasible for insurers. Therefore, it is likely that insurance solutions go beyond traditional risk transfer to explicitly address risk mitigation (McKinsey’s Insurance and Sustainability Practices, Nov 2020). Insurance companies are considering conducting stress-test for their new and current portfolio to understand the exposure to natural hazards and climate risks. In addition, insurers could use their knowledge of risks and support organizations, including airports, to mitigate these risks and adapt. Following is an example for changing the approach from transactional risk transfer to risk mitigation, by incentives or even direct partnerships in development and funding of mitigation measures.

### National Flood Insurance Reform Act

This act led to the creation of the US National Flood Insurance Program (NFIP) and created a framework to provide flood insurance for assets in communities where certain floodplain management processes are in place. The reasons advanced by the US Congress for the creation of NFIP include:

1. The economic burden of unforeseeable disaster relief measures
2. Create a reasonable method of sharing the risk of flood losses through a program of flood insurance which can complement and encourage preventive and protective measures.

The program is expanded as knowledge is gained and experience is appraised, thus eventually making flood insurance coverage available on reasonable terms and conditions to persons who have need for such protection.

## Proposed Action Plan

Airports and insurers should collaborate to define risk levels and figuring out mutual agreements allowing to protect both parties. For example, insurers could provide funding for measures to increase airport resilience and provide reduction in insurance premium when certain measures are implemented. The TCFD framework described earlier could support this cooperation.
ANNEXURES
ANNEXURE-A

Online Survey

Assessment of Airport Disaster Resilience

Global Study on Disaster Resilience of Airports

Airports are key building blocks of aviation infrastructure, and play a critical role in national, regional, and global connectivity. Damage to airports from natural or man-made hazards lead to not only direct losses, but also knock-on economic effects impacting millions of lives and livelihoods. With the onset of COVID-19, resiliency has taken a new dimension. Airports must now build greater flexibility in their operations and maintenance to meet challenges posed by disasters, much like that of a pandemic. Moreover, long-term investments in airports must address the current and future risks, including those emanating from climate and disaster-related hazards.

The survey will analyze varied segments of an airport’s functions - taking stock of airport practices, risk management across regions and hazards- to eventually derive a set of recommendations that can be adopted by existing and future airport stakeholders viz. airport authorities, governments, airport operators, investors, designers, engineers, etc.

To that end, the survey goals are:

1. Understanding your current perception of disaster events;
2. Mapping out the organizational, infrastructure and operating elements influencing your airport’s resilience;
3. Gaining insight into your expectations for over the next 20 to 50 years.

This survey is being conducted on behalf of the Coalition for Disaster Resilient Infrastructure (CDRI), by NACO subsidiary of Royal HaskoningDHV.

All data gathered through this survey will be kept confidential and only be used in aggregate form. The results of this study will be made available to participating airports.

Thank you for participating in this survey!

**CDRI** is a partnership of national governments, UN agencies and programmes, multilateral development banks and financing mechanisms, the private sector, and knowledge institutions that aims to promote the resilience of new and existing infrastructure systems to climate and disaster risks in support of sustainable development. The Coalition provides a forum for countries at all stages of development — to access knowledge and resources from other members, to make their infrastructure resilient and thus, contribute to each other’s economic growth and progress.

**Royal HaskoningDHV** is an engineering consultancy that delivers services in the fields of strategy design, policy development and city programming. Its subsidiary, NACO provide specialist know-how and services in the development of airports and all associated facilities within, as well as outside the premises of the airport. The companies work at the forefront of developments for a sustainable and resilient airport and aviation industry. This involvement and innovation includes airport strategy, planning and design practises, research, definition of standards, and client projects.
Assessment of Airport Disaster Resilience

SECTION 1: GENERAL INFORMATION

1. Please provide your full name: 

* 2. Please provide your official title at the airport:  

* 3. Please provide your department name:  

* 4. Please provide the 3-letter ICAO code for your airport:  

5. Please provide the airport location (country):  

* 6. What is the ownership structure of your airport?  
   • Government-owned and managed  
   • Government-owned with private sector participation  
   • Government-owned and privately-operated  
   • Privately-owned and operated  
   • Privately-owned and government-operated  
   • Information not available  

7. How aware are you of your airport’s response to hazardous events and disasters?  

   Very unaware  

   Not unaware, nor aware  

   Very aware
**SECTION 2A: HISTORICAL HAZARD MAPPING**

The following table describes the hazard severity rating system for purpose of this study.

<table>
<thead>
<tr>
<th>Severity</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Safety &amp; Health</strong></td>
<td>No impact</td>
<td>Impact not likely to cause damages</td>
<td>Injuries requiring first aid only</td>
<td>Injury requiring medical treatment (lacerations, burns, fractures) Reduced efficiency of operations due to increased workload</td>
<td>Serious injuries or life-threatening occupational medical conditions</td>
<td>Multiple deaths and injury</td>
</tr>
<tr>
<td><strong>Infrastructure &amp; Operational Disruption</strong></td>
<td>No impact</td>
<td>Flight delays of 15 minutes maximum</td>
<td>Partial restrictions and flights delay lower than 2 hours</td>
<td>Restrictions in operations Flight delays lower than 8 hours</td>
<td>Closure for more than 8 hours Major damage to equipment</td>
<td>Closure for multiple days Destruction of equipment or infrastructure</td>
</tr>
<tr>
<td><strong>Economic Loss</strong></td>
<td>No impact</td>
<td>Insignificant costs</td>
<td>Indirect economic loss to airport partners</td>
<td>Indirect economic loss to the airport</td>
<td>Direct economic loss to airport partners</td>
<td>Direct economic loss to the airport</td>
</tr>
<tr>
<td><strong>Image</strong></td>
<td>No impact</td>
<td>Insignificant impact</td>
<td>Local negative PR</td>
<td>Regional media coverage Negative publicity</td>
<td>National media coverage Impact on brand image</td>
<td>International media coverage Impact on brand image</td>
</tr>
</tbody>
</table>

For the following question: To qualify for a rating, the hazard should **have caused at least one of the conditions listed in the associated row** in the table above. If your airport has not experienced a specific hazard, please mark N/A.
8. On a scale of 0 (no impact) to 5 (severe impact), please rate the following hazards based on severity of the impact in the past.

<table>
<thead>
<tr>
<th>Hazard</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>N/A</th>
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<tr>
<td>Drought</td>
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<td>Extreme precipitation (rain, pluvial floods...)</td>
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<td>Geological hazards (permafrost thawing, landslide, earthquake...)</td>
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<td>Extreme heat (high temperature, wildfires...)</td>
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<tr>
<td>Third-party equipment/systems failures</td>
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<td>Wildlife invasion (sudden increase of wildlife on airport site...)</td>
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<td>Flooding (fluvial floods ...)</td>
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<td>Extreme icing conditions (cold, snow...)</td>
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<td>Extremely poor air quality</td>
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<tr>
<td>Extreme storms and winds (tropical cyclones ...)</td>
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<td>Volcanic activity</td>
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</table>

Other: Please specify the nature of the hazards, impact on the airport, including how long it took to recover.

9. How long did it take to resume operations?

<table>
<thead>
<tr>
<th>Hazard</th>
<th>0 - 2 hours</th>
<th>2 - 5 hours</th>
<th>5 - 10 hours</th>
<th>10 - 24 hours</th>
<th>More than 24 hours</th>
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<tbody>
<tr>
<td>Extreme heat (high temperature, wildfires...)</td>
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<tr>
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<tr>
<td>Drought</td>
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<td>Volcanic activity</td>
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</tbody>
</table>
10. How long did it take to fully recover?

Full recovery is defined as the airport functioning normally and resuming all regular operations.

<table>
<thead>
<tr>
<th>Hazard</th>
<th>0 - 6 hours</th>
<th>6 - 12 hours</th>
<th>12 - 24 hours</th>
<th>1 - 3 days</th>
<th>More than 3 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme heat (high temperature, wildfires...)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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<td>Extreme icing conditions (cold, snow...)</td>
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<tr>
<td>Third-party equipment/systems failures</td>
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</tbody>
</table>

The following questions in this section relate to the five most impactful hazards experienced by your airport.

11. Did the airport document the lessons learned (impact of the hazard(s) and associated response) and act on them post impact?

- ☐ Yes, the airport documented the lessons learned and acted on them by mapping responses and incorporating measures
- ☐ Yes, the airport documented the lessons learned but was unable to act on them
- ☐ No, the airport was not able to document the lessons learned
- ☐ Information not available
12. What are some of the five most relevant measures taken post impact? Answers should be limited to one sentence (50 characters) or less. Examples include:

- Improve drainage network
- Develop recovery plan
- Conduct risk and resilience assessment every 5 years
- Implement back up arrangements with other airports in the vicinity

Key measure 1:

Key measure 2:

Key measure 3:

Key measure 4:

Key measure 5:

SECTION 2B: FUTURE HAZARD MAPPING

The following table describes the hazard severity rating system for purpose of this study.

<table>
<thead>
<tr>
<th>Severity</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<tbody>
<tr>
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<td>Infrastructure &amp; Operational Disruption</td>
<td>No impact</td>
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<td>Direct economic loss to the airport</td>
</tr>
<tr>
<td>Image</td>
<td>No impact</td>
<td>Insignificant impact</td>
<td>Local negative PR</td>
<td>Regional media coverage Negative publicity</td>
<td>National media coverage impact on brand image</td>
<td>International media coverage Impact on brand image</td>
</tr>
</tbody>
</table>

For the following question: To qualify for a rating, the hazard should be expected to cause at least one of the conditions in the associated row in the table above. If the airport is not expected to experience specific hazards, mark ‘N/A’
13. On a scale of 0 (no impact) to 5 (severe impact), please rate the following hazards based on anticipated severity of the impact in the next 20 years, in the absence of additional mitigation measures. Improve drainage network

<table>
<thead>
<tr>
<th>Hazard</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>N/A</th>
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</thead>
<tbody>
<tr>
<td>Extreme precipitation (rain, pluvial floods…)</td>
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<td>Volcanic activity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Other: Please specify the nature of the hazards and the anticipated impact on the airport

* 14. On a scale of 0 (no impact) to 5 (severe impact), rate the anticipated impact on the following element categories in the next 20 years.

Please, mark "N/A" the elements that are not relevant.

<table>
<thead>
<tr>
<th>Element Category</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aircraft</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational buildings (passenger and cargo terminal, etc)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Airfield (Runway, Taxiway, Aprons)</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Utility Systems (Electrical, Drainage, Fuel)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communication systems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machinery / Vehicles / Equipment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personnel and Passengers Infrastructure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landslide Infrastructure (airport access roads, parking facilities, …)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Buildings</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Other: Please specify the nature of the hazards and the anticipated impact on the airport
SECTION 3: RISK AND RESILIENCE ASSESSMENT

A Vulnerability Assessment is the process of identifying, quantifying, and prioritizing/ranking the possible vulnerabilities in a system.

* 15. Has the airport conducted a Vulnerability Assessment for its infrastructure and operations?

<table>
<thead>
<tr>
<th>Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, the airport conducts vulnerability assessments periodically</td>
</tr>
<tr>
<td>Yes, the airport has conducted a vulnerability assessment once</td>
</tr>
<tr>
<td>No, the airport has not been able to conduct a vulnerability assessment</td>
</tr>
<tr>
<td>Information not available</td>
</tr>
</tbody>
</table>

16. How frequently is the Vulnerability Assessment conducted?
   Please, specify the closest frequency.

17. Rank the elements included in the Vulnerability Assessment in order of importance.
   Rank elements 1-8
   Please, mark as “N/A” the elements that are not included in the Vulnerability Assessment.

   Personnel and passenger infrastructure

   Civil structure / installations (eg: terminal building equipment safety)

   Reliability of operations (eg. closure, flight delays, recovery time)

   Reliability of utility services (eg. water, electricity, sewage)

   Availability of supply chain
Emergency service operations

Financial impact

Impact on image

18. Are assets controlled by third-parties also assessed as part of the Vulnerability Assessment?

- [ ] Yes
- [ ] No
- [ ] Not applicable
- [ ] Information not available

**Risk** can be defined as an event or impact that can negatively affect the operations, infrastructure or finances of the airport. **Mitigation measures** are measures employed to reduce or prevent the impact from the risk.

* 19. Has the airport considered the risks identified in the planning and design process?

- [ ] Yes, the airport has considered the risks identified in its planning and has employed additional measures
- [ ] Yes, the airport has considered the risks identified in its planning but has not been able to employ additional measures
- [ ] No, the airport has not been able to identify risks as part of the planning and design process
- [ ] Information not available

**Resilience** is the ability of the asset to recover from or adapt to changing conditions. Resilience Assessments measure this ability.

* 20. Has the airport conducted any Resilience Assessment?

- [ ] Yes, the airport has conducted at least one resilience assessment and actions have been taken to improve the resilience of its assets
- [ ] Yes, the airport has conducted at least one resilience assessment but has not been able to take additional actions to improve the resilience of its assets
- [ ] No, the airport has not been able to conduct a resilience assessment
- [ ] Information not available
21. What type of data do you have access to predict future hazards and improve adaptation?
Please, select all that apply.

<table>
<thead>
<tr>
<th>Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐ Open-source government / public datasets</td>
</tr>
<tr>
<td>☐ Subscription-based datasets</td>
</tr>
<tr>
<td>☐ Internal datasets (e.g. airport-specific modelling)</td>
</tr>
<tr>
<td>☐ Other (please specify)</td>
</tr>
<tr>
<td>☐ None of the above</td>
</tr>
</tbody>
</table>

**Critical assets** are designated infrastructure that, if disrupted, would prevent the airport from operating. For example, if a runway is fully flooded, then aircraft cannot land or take-off. But, if grassland in-between runway and taxiway strip are flooded, it will not hamper the airport operations. In this case, the runway is considered a critical asset, but the grassland in-between runway and taxiway are not considered critical assets.

* 22. Has the airport identified its critical assets and how these assets might be impacted by future hazards?

<table>
<thead>
<tr>
<th>Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐ The airport has not been able to identify its critical assets</td>
</tr>
<tr>
<td>☐ The airport has identified its critical assets but has not been able to identify additional adaptive/protective measures against future hazards</td>
</tr>
<tr>
<td>☐ The airport has identified its critical assets and has identified additional adaptive/protective measures against future hazards</td>
</tr>
<tr>
<td>☐ Information not available</td>
</tr>
</tbody>
</table>

23. What additional protective and/or adaptive measures has your airport employed for its critical assets?
Please, specify the five most important measures.

**Answers should be limited to one sentence (50 characters) or less.** Examples include:

- Hire designated staff for Emergency Response Planning
- Insurance of critical assets
- Implement back up arrangements with other airports in the vicinity

Protection Measure 1

Protection Measure 2

Protection Measure 3

Protection Measure 4

Protection Measure 5
SECTION 4: EMERGENCY RESPONSE PLANNING

An Airport Emergency Response Plan is a set of actions and resources required at the time of or immediately after the hazard in order to minimize damage or safeguard key assets, operations and people.

* 24. Does your Airport Emergency Response Plan have provisions to continue operations during hazardous events?

- [ ] Yes
- [ ] No
- [ ] Information not available

A Disaster Recovery Plan are actions, resources and roadmap to consider relating to how to restore airport processes within a certain amount of time— the recovery time objective – during/after hazardous events.

* 25. Do you have a Disaster Recovery Plan?

- [ ] Yes
- [ ] No
- [ ] Information not available

If able, please provide additional information.

26. Do you collaborate with third parties (airlines, ground handlers, government agencies, utility providers, etc.) to define, monitor and/or implement your Airport Emergency Response Plan and your Disaster Recovery Plan?

For each plan, please select all that apply. If you do not collaborate with third parties for the given plan, please leave it blank.

<table>
<thead>
<tr>
<th></th>
<th>Define</th>
<th>Implement</th>
<th>Monitor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airport Emergency Plan</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Disaster Recovery Plan</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

A Business Continuity plan includes key steps to ensure that critical assets and operations can continue working with minimal downtime in the event of an interruption.

* 27. Are you able to consider disaster impacts as part of your Business Continuity Plan?

- [ ] Yes
- [ ] No
- [ ] Information not available
If able, please provide more details below.

* 28. To your knowledge, are there funds available to cover mitigation costs?
   - Yes
   - No
   - Information not available

If able, please provide more details below.

29 What timeframe does your Business Continuity Plan address?

- 5 Years (2025)
- 15 Years (2035)
- 25 Years (2045)

SECTION 5: ORGANIZATION

30. How sufficient is in-house capacity/experts to assess, manage, and respond to the different hazards your airport is exposed to?

- Insufficient in-house capacity
- Potential to grow in-house capacity
- Sufficient in-house capacity

* 31. What is driving your airport risk and resilience planning process?

Please, rank these items in order of importance, and mark as "N/A" when not applicable.

Government Policies

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>N/A</th>
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</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Human Safety

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
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<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>
## Results of a Risk Assessment

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Executive Board/ Management</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>Investors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>Shareholder Interests</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>Market Trends</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>Insurance of Assets</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>Inclusion as part of Masterplan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>N/A</td>
</tr>
</tbody>
</table>

32. Which of the following are being included in the airport’s resilience practice? Please, select all that apply.

- [ ] Assessment strategy
- [ ] Infrastructure upgrade
- [ ] Inclusion as part of Masterplan
- [ ] Progress review
- [ ] Design guidelines / regulations
- [ ] Business continuity planning
- [ ] Simulation exercise
- [ ] Other (please specify) [ ]
- [ ] None of the above
33. In your opinion, how effective is your organization in mitigating risks for the airport?

<table>
<thead>
<tr>
<th>Very ineffective</th>
<th>Neither ineffective, nor effective</th>
<th>Very effective</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

34. In your opinion, what are the key policies or efforts that can be undertaken by the industry and government authorities, to improve the resilience of airports?

Please, elaborate in less than 300 words.

35. Please, specify your information below if you would like to be notified when the results of this study are available.

Name

Email Address
ANNEXURE-B

FOCUS GROUP DISCUSSIONS RESULTS

To what extent are future hazards considered for the maintenance of key assets?

![Mentimeter results overview – Asset Maintenance and Early Warning Systems](image)

How effective are your existing early warning systems in covering key assets and operations?

![Mentimeter results overview](image)

Figure a: Mentimeter results overview – Asset Maintenance and Early Warning Systems

How effective is the collaboration with internal stakeholders in mitigating financial disruption?

![Mentimeter results overview](image)

How effective is the collaboration with external stakeholders in mitigating financial disruption?

![Mentimeter results overview](image)

Figure b: Mentimeter results overview – Collaboration with stakeholders
Figure c: What measures does your airport take to safeguard its critical assets against disaster?

Table a: Focus Group Discussion Output

<table>
<thead>
<tr>
<th>ASSET</th>
<th>PRE-DISASTER / MITIGATION</th>
<th>DURING THE DISASTER / EMERGENCY RESPONSE</th>
<th>POST-DISASTER / RECOVERY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runways</td>
<td>• Ensuring proper drainage system for large rainfall events</td>
<td>• Emergency Response Plan</td>
<td>• Disaster recovery plan</td>
</tr>
<tr>
<td></td>
<td>• Effective Maintenance and inspection plans, Update runway contingency (diary revision by marshalls)</td>
<td>• Stand-by team / Multi Asset environmental team for response</td>
<td>• Airport Personnel to assess and clean the runways</td>
</tr>
<tr>
<td></td>
<td>• Runway redundancy</td>
<td>• Diversion and continuity plans</td>
<td>• Ops inspection and maintenance</td>
</tr>
<tr>
<td></td>
<td>• Overflow Water Storage Tank</td>
<td>• Agreement with Suppliers</td>
<td>• Prioritized flight plans</td>
</tr>
<tr>
<td>Terminals</td>
<td>• Proper design to include potential hazards</td>
<td>• Stand-by contracts with maintenance and repair suppliers</td>
<td>• Disaster Recovery Plan</td>
</tr>
<tr>
<td></td>
<td>• Periodical revisions of emergency systems and exits</td>
<td>• Emergency response plan includes fire evacuation and security events</td>
<td>• Engineers are onsite to assess damage and immediately access our maintenance team.</td>
</tr>
<tr>
<td></td>
<td>• Improved cooling designs and wind resistance</td>
<td>• Emergency Plan integrated with response of third parties and authorities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Effective drainage design, use of pump</td>
<td>• Stand-by team for disaster (ARFF)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Maintenance plan and team to ensure structure is ready</td>
<td>• Crisis centre for coordination</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Regular inspections</td>
<td>• Alternate modes of communication – Satellite phones</td>
<td></td>
</tr>
<tr>
<td>ASSET</td>
<td>PRE-DISASTER / MITIGATION</td>
<td>DURING THE DISASTER / EMERGENCY RESPONSE</td>
<td>POST-DISASTER / RECOVERY</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Utilities</td>
<td>• Include redundancies in design – supplies coming from different stakeholders</td>
<td>• Emergency response plans for all utilities</td>
<td>• Making utilities available within 2-12 hours after disaster</td>
</tr>
<tr>
<td></td>
<td>• Back up for power supply – Separate systems for Runway and Terminal</td>
<td>• Stand-by contracts with maintenance and repair suppliers</td>
<td>• Revert to grid if off-grid</td>
</tr>
<tr>
<td></td>
<td>• Independent from national / local grid (e.g.: for water and power)</td>
<td>• Contingency plans</td>
<td></td>
</tr>
<tr>
<td>Access links</td>
<td>• Multiple egress and access roads</td>
<td>• Standard Protocols</td>
<td>• Quick clean up of debris</td>
</tr>
<tr>
<td></td>
<td>• Weakest point due to limited collaboration and communication with municipality</td>
<td>• Often not an issue for airports with multiple access roads</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Teams staged for multiple scenarios</td>
<td>• Efficient public transport connectivity</td>
<td></td>
</tr>
<tr>
<td>Communication Systems</td>
<td>• Redundancies in the form of hotlines</td>
<td>• Use of cloud systems</td>
<td>• Fixed on priority</td>
</tr>
<tr>
<td></td>
<td>• DR site and cloud systems</td>
<td>• Alternate communication methods like satellite phones</td>
<td>• Contract with local suppliers</td>
</tr>
<tr>
<td></td>
<td>• Backup Communication systems</td>
<td>• Communications access checked every 30 minutes during an event to ensure emergency services can assist</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Control tower and airport communication protocols</td>
<td>• Virtual Crisis Centre is setup for direct communication</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Wireless communications are checked to ensure viability</td>
<td>• Independent physical centre set up to manage response</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Contingency sites for data centres</td>
<td>• Emergency response plans for IT and telecom disruptions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Alternate communication rooms</td>
<td>• In house staff for maintenance and repair</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Pre-established MOU's for response</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Strong cyber security</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machinery</td>
<td>• Redundancies in procedures and equipment to ensure business continuity</td>
<td>• Equipment stored in areas which are deemed safe (separate buildings)</td>
<td>• Post event shakedown and assessed for damage</td>
</tr>
<tr>
<td></td>
<td>• All machinery is staged for known events</td>
<td>• Stand-by contracts with maintenance and repair supplier</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Financial commitment from top management for investment in latest equipment</td>
<td>• Own staff trained for maintenance and repair of critical infrastructure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Dedicated machinery for specific event (e.g. for flooding)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Review of ground handling equipment twice a day, maintenance of equipment on the Apron</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Airfield</td>
<td>• Drainage control</td>
<td>• Storm drainage management</td>
<td>• Master plan adequacy</td>
</tr>
<tr>
<td></td>
<td>• Proper design considering potential hazards</td>
<td>• Closed to all traffic and inspected during safe periods</td>
<td>• Checked by engineers for structural and physical damages and immediately scheduled for repairs</td>
</tr>
<tr>
<td></td>
<td>• Preventive maintenance</td>
<td>• Emergency Response plans</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Own staff trained for maintenance and repair</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Stand-by contracts with other suppliers</td>
<td></td>
</tr>
</tbody>
</table>
GLOBAL STUDY ON DISASTER RESILIENCE OF AIRPORTS

<table>
<thead>
<tr>
<th>ASSET</th>
<th>PRE-DISASTER / MITIGATION</th>
<th>DURING THE DISASTER / EMERGENCY RESPONSE</th>
<th>POST-DISASTER / RECOVERY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>• Proper design and construction</td>
<td>• Protocols in cooperation with authorities • Access to property is restricted until deemed safe</td>
<td>• Assessment to check for damage</td>
</tr>
<tr>
<td>Other</td>
<td>• Protection of non-critical assets is at the same level during the design and construction stages</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pre-disaster/mitigation measures

- Airport operator <Name>
- 2. Government Agency <Name>
- 3. Maintenance <Name>
- Investors (Important but not part of the operations)
- Service Providers <Name>

During disaster/emergency response

- 1. Airport Operator <Name>
- 2. Government Agency <Name>
- 3. Maintenance <Name>
- Airliness
- Service Providers <Name>

Post-disaster/Recovery plan

- Investors <Name>
- Government Agency <Name>
- Airport Operator <Name>
- Maintenance <Name>

Figure d: Which stakeholders do you collaborate with to implement the measures mentioned?

Pre-disaster/mitigation measures

- Private investors <Name>
- Private investors <Name>
- Government Entity <Name>

During disaster/emergency response

- Private investors <Name>
- Government Entity Indirect funding

Post-disaster/Recovery plan

- Government Entity <Name>
- Government Entity <Name>
- Government Entity <Name>

Investment in non-aviation side -business center, construction of a new business center, a hotel -airport campus (Business Plan)

Figure e: What are your primary sources of funding for the measures mentioned?
ANNEXURE-C

Case Study: Analysis of Airports at the Country level

An online survey was conducted under this Global Study on Disaster Resilience of Airports: Phase-1 (refer to Chapter-3 for details), and the highest number of respondent airports were from the Indian subcontinent. Considering the available strong dataset, it was an opportunity to analyze and understand the current state of practice of disaster risk management and resilience at the country level. 25 airport stakeholders from Indian airports participated in this study. This section will provide insights at the country level, while the report in total will cover the state of practice at a global level.

Respondent Profile

Airports with various ownership models were part of the survey. Even so, airports that are owned and managed by the government were the major respondents.

Respondents from the airport operations department were more aware of hazardous events and disasters.

<table>
<thead>
<tr>
<th>Ownership structure of participating Indian airports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government-owned and managed</td>
</tr>
<tr>
<td>Government-owned with private sector participation</td>
</tr>
<tr>
<td>Government-owned and privately-operated</td>
</tr>
<tr>
<td>Privately-owned and operated</td>
</tr>
</tbody>
</table>

Figure i Ownership structure of participating Indian airports

Awareness of airport response to hazardous events and disasters

<table>
<thead>
<tr>
<th>Awareness of airport response to hazardous events and disasters</th>
<th>52.38%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airport Operations</td>
<td>19.05%</td>
</tr>
<tr>
<td>Safety, Security, Risk and Compliance Management</td>
<td>14.29%</td>
</tr>
<tr>
<td>General Management</td>
<td>9.52%</td>
</tr>
<tr>
<td>Environmental affairs and sustainability</td>
<td>4.76%</td>
</tr>
<tr>
<td>Emergency Response (including firefighting services)</td>
<td></td>
</tr>
</tbody>
</table>

Figure ii Airport’s response on awareness to hazardous events and disasters
Airport size and hazard exposure

Figure iii Hazard exposure of participating airports (Source: NACO analysis from survey results, RHDV Multi-Hazard Risk Platform)

Note. The size of the dots on the map is proportional to 2019 annual passengers for airports included in the ACI traffic database.

Based on the proprietary Royal HaskoningDHV’s multihazard platform, participating Indian airports exhibit a higher Airport Exposure Index in comparison to other participating airports. In particular, participating Indian airports are more exposed to extreme heat and precipitation than their counterparts, and less exposed to extreme storms and winds.

Figure iv Historical and future severity of impact (Source: NACO analysis of survey results)
However, this exposure does not directly correlate to the historical impact of these different hazards on the airports. Indeed, based on the survey results as shown in figure iv, participating Indian airports are currently most impacted by extreme storms and winds and extreme precipitation. In the future, the impact of the various hazards is expected to become more severe, in particular for flooding and third-party equipment/systems failures.

Further investigation is required to understand which airport practices drive the difference between exposure and impact of different hazards.

About 76 percent of participating Indian airports have identified their critical assets and adaptive measures against future hazards compared to 67 percent in the rest of the world. Overall, Indian airports anticipate aircraft, communication systems and utility systems to be their most impacted assets, although with a lower severity than the rest of the world.

**Vulnerability Assessment Practice**

<table>
<thead>
<tr>
<th>Airport Vulnerability Assessment Practice</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, the airport conducts vulnerability assessments periodically</td>
<td>42.86%</td>
</tr>
<tr>
<td>Yes, the airport has conducted a vulnerability assessment once</td>
<td>14.28%</td>
</tr>
<tr>
<td>Information not available</td>
<td>42.86%</td>
</tr>
</tbody>
</table>

Figure v Airport vulnerability assessment practice
The periodical assessment of vulnerability is relatively low for the Indian participants in comparison to the other participating airports, with 43 percent compared to 63 percent. Of the airports conducting vulnerability assessments periodically, the majority conduct them once every 2 to 5 years.

Indian airports with an existing Vulnerability Assessment practice give higher importance to emergency service operations and reliability of operations.

71 percent of Indian participants include assets controlled by third parties in the Vulnerability assessment, compared to 59 percent of other airports in the world. Including the assets controlled by third parties provide a more comprehensive overview and reduces the risk of cascading effect due to the failure of third parties’ assets.

This will continue to be relevant as Indian airports anticipate higher severity of impact on their organizations for disruptions related to third-party systems failures.

Airports are moving towards a more proactive approach rather than reactive towards hazard management and resilience planning. Conducting periodic Vulnerability Assessments that address both operational and infrastructural aspects and developing a resilience strategy are key components of a proactive approach.

<table>
<thead>
<tr>
<th>Vulnerability Assessment Frequency</th>
<th>Monthly</th>
<th>Yearly</th>
<th>Every 2 years</th>
<th>Every 2 to 5 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>33.33%</td>
<td>11.11%</td>
<td>11.11%</td>
<td>44.44%</td>
</tr>
</tbody>
</table>

**Figure vi Vulnerability assessment frequency**

<table>
<thead>
<tr>
<th>Risk and Resilience Practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel and passenger infrastructure</td>
</tr>
<tr>
<td>Civil structure / installations (e.g. terminal building equipment safety)</td>
</tr>
<tr>
<td>Reliability of operations (e.g. closure, flight delays, recovery time)</td>
</tr>
<tr>
<td>Emergency service operations</td>
</tr>
<tr>
<td>Reliability of utility services (e.g. water, electricity, sewage)</td>
</tr>
<tr>
<td>Financial impact</td>
</tr>
<tr>
<td>Availability of supply chain</td>
</tr>
<tr>
<td>Impact on image</td>
</tr>
</tbody>
</table>

**Figure vii Vulnerability assessment components**
The airport risk and resilience drivers of the Indian participants do not significantly differ from the other participating airports. In comparison to other airports worldwide, the Indian airport participants score high on organizational efficiency in mitigating risks for airports. Half of participating Indian airports see the potential to grow their in-house capacity.

Risk and Resilience Practices

52 percentage of participating Indian airports have conducted at least one resilience assessment and taken actions to improve the resilience of their assets, compared to 70 percentage in the rest of the world.

The airport risk and resilience drivers of the Indian participants do not significantly differ from the other participating airports. In comparison to other airports worldwide, the Indian airport participants score high on organizational efficiency in mitigating risks for airports. Half of participating Indian airports see the potential to grow their in-house capacity.

### Figure viii Inclusion of assets controlled by third parties in vulnerability assessment

- **India**: 71.4%
- **Other**: 58.3%

### Table: Airport risk and resilience drivers

<table>
<thead>
<tr>
<th></th>
<th>India</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Results of a Risk Assessment</td>
<td>2nd</td>
<td>1st</td>
</tr>
<tr>
<td>Executive board/Management</td>
<td>1st</td>
<td>2nd</td>
</tr>
<tr>
<td>Government policies</td>
<td>3rd</td>
<td>3rd</td>
</tr>
<tr>
<td>Human safety</td>
<td>4th</td>
<td>4th</td>
</tr>
<tr>
<td>Inclusion as part of Masterplan</td>
<td>5th</td>
<td>6th</td>
</tr>
<tr>
<td>Insurance of assets</td>
<td>5th</td>
<td>5th</td>
</tr>
<tr>
<td>Shareholder interests</td>
<td>7th</td>
<td>7th</td>
</tr>
<tr>
<td>Investors</td>
<td>6th</td>
<td>8th</td>
</tr>
<tr>
<td>Market trends</td>
<td>8th</td>
<td>9th</td>
</tr>
</tbody>
</table>

### Figure ix Overview of airport resilience practice

- **India**
  - Ineffective: 9.1%
  - Neither ineffective, nor effective: 54.5%
  - Effective: 36.4%

- **Other**
  - Ineffective: 8.9%
  - Neither ineffective, nor effective: 60.7%
  - Effective: 30.4%
Based on survey results, resilience is embedded within existing practices. This is relatively high in comparison to the other participating airports’ reported practices.

<table>
<thead>
<tr>
<th>Practice</th>
<th>India</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure upgrade</td>
<td>91.7%</td>
<td>81.0%</td>
</tr>
<tr>
<td>Design guidelines/regulations</td>
<td>87.5%</td>
<td>71.4%</td>
</tr>
<tr>
<td>Inclusion as part of Masterplan</td>
<td>87.5%</td>
<td>58.7%</td>
</tr>
<tr>
<td>Simulation exercise</td>
<td>79.2%</td>
<td>68.3%</td>
</tr>
<tr>
<td>Assessment strategy</td>
<td>79.2%</td>
<td>63.5%</td>
</tr>
<tr>
<td>Business continuity planning</td>
<td>70.8%</td>
<td>77.8%</td>
</tr>
<tr>
<td>Progress review</td>
<td>70.8%</td>
<td>52.4%</td>
</tr>
<tr>
<td>None of the above</td>
<td>3.2%</td>
<td></td>
</tr>
</tbody>
</table>

**Figure x Resilience practice elements at Indian airports**

Identification of critical assets and how they might be impacted by future hazards

- The airport has identified its critical assets and has identified additional adaptive/protective measures against future hazards: 76.19%
- The airport has identified its critical assets but has not been able to identify additional adaptive/protective measures against future hazards: 4.76%
- Information not available: 19.05%

**Figure xi Identification of critical assets and how they might be impacted by future hazards**

More than 80 percent of Indian airports indicate addressing resilience as part of their infrastructure upgrade, design guidelines/regulations, and inclusion as part of Masterplan development. Addressing resilience as part of these three practices contributes to the building of infrastructural resilience.
Airport Emergency Response Plan and Disaster Recovery Plan Practices

Figure xi Overview of airport emergency response planning and disaster recovery planning practices

Most (>90%) Indian participating airports indicated having an Airport Emergency response Plan to continue operations during hazardous events, as well as a Disaster Recovery Plan.

Approximately 70 to 80 percent of the participating Indian airports collaborate with third parties in the three different stages of Airport Emergency Response Planning and Disaster Recovery Planning: define, monitor, and implement. The involvement of third parties in these stages can increase overall resilience and reduce response time during an emergency or disaster.
All participating Indian airports indicate they have funds available to cover mitigation costs and the ability to consider disaster impact as part of the Business Continuity Plan. The participating Indian airports mainly consider the 5-, 15- and 25-year timelines for their business continuity plan.

A Business Continuity plan includes key steps to ensure that critical assets and operations can continue working with minimal downtime in the event of an interruption.

Mitigation costs relate to costs employed for reducing or preventing the impact of a specific hazard/risk.

In India, these airports rely predominantly on open-source government datasets to predict future hazards.