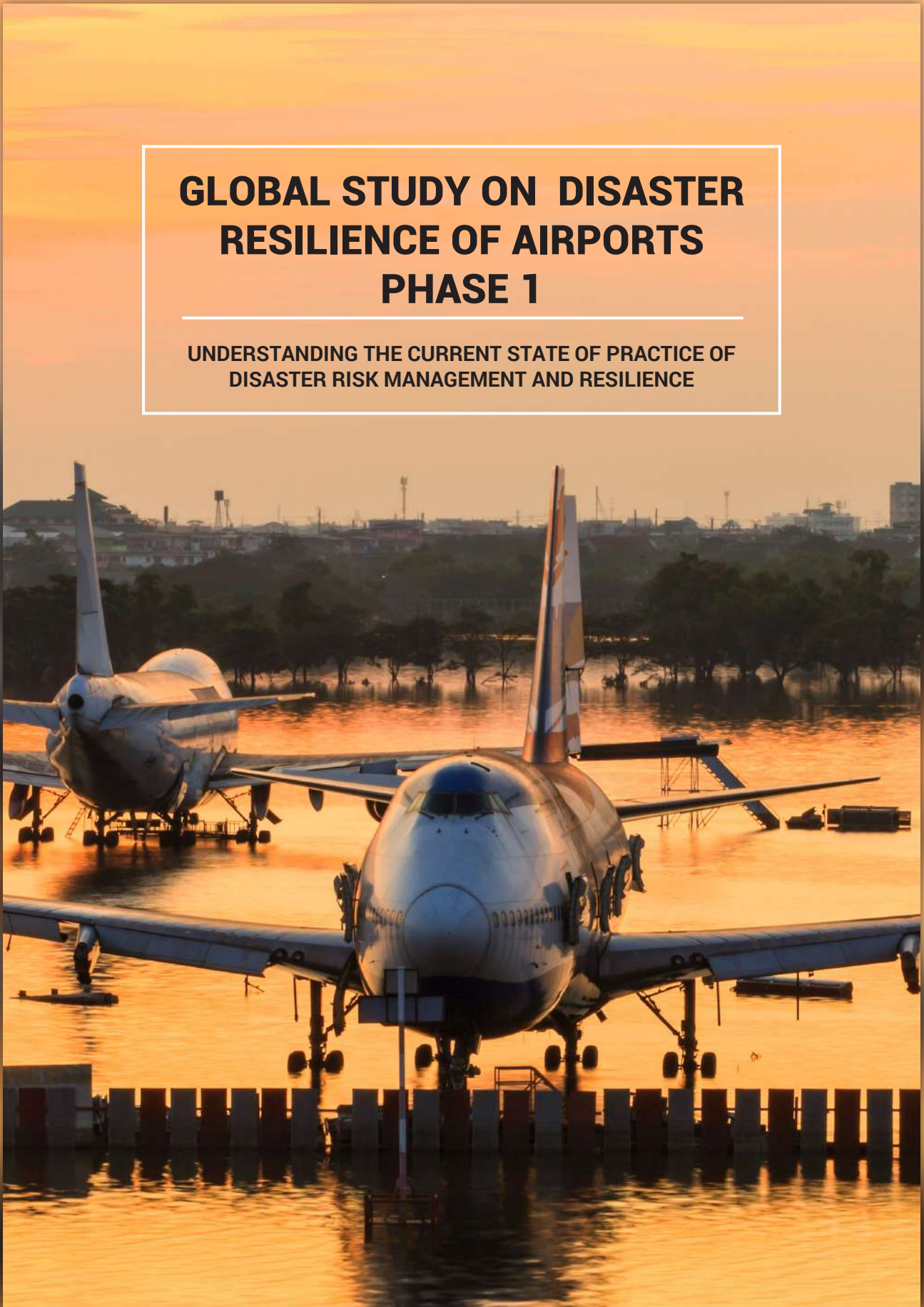


GLOBAL STUDY ON DISASTER RESILIENCE OF AIRPORTS PHASE 1

**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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**UNDERSTANDING THE CURRENT STATE OF PRACTICE OF DISASTER RISK
MANAGEMENT AND RESILIENCE**

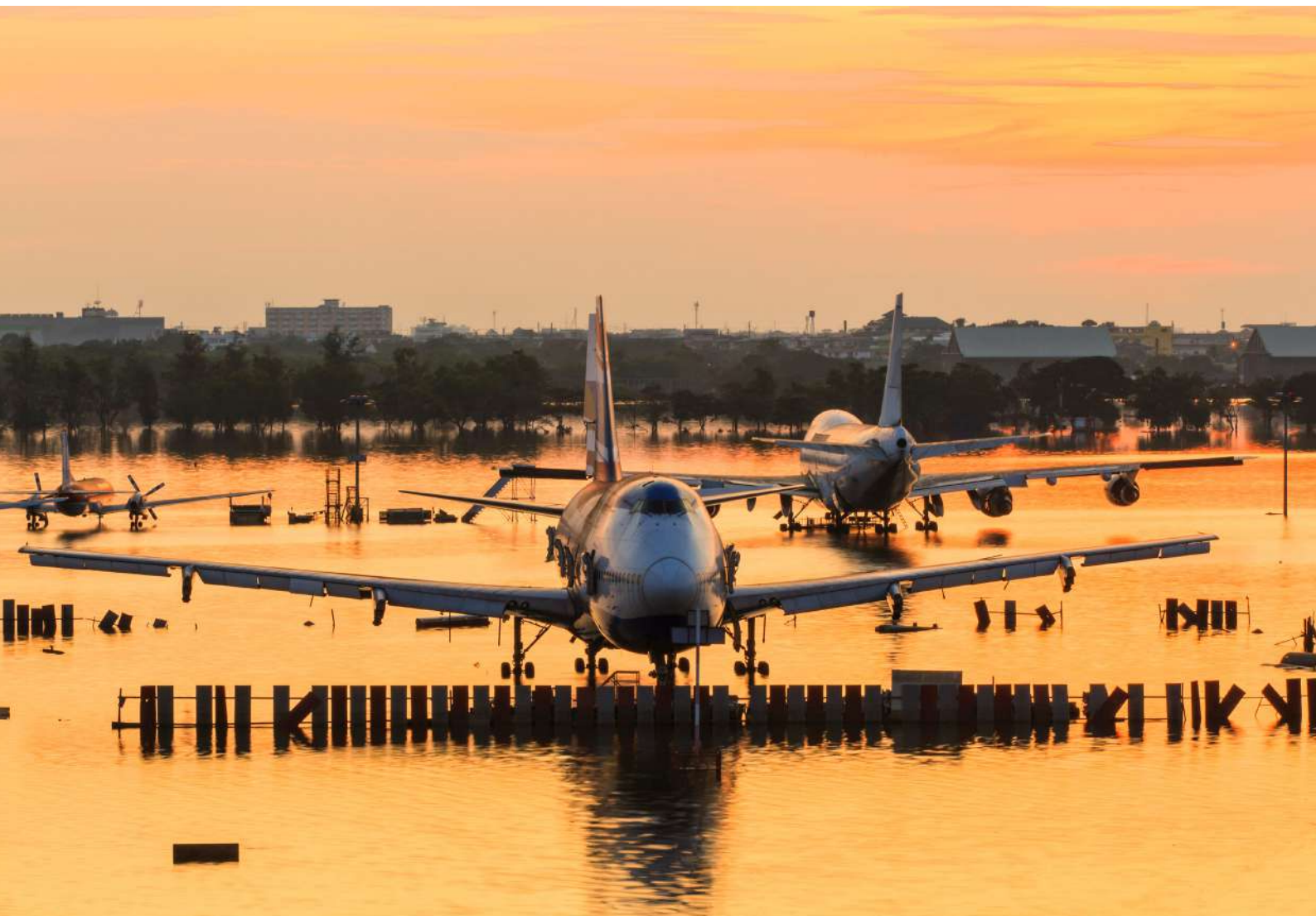




TABLE OF CONTENTS

Acknowledgement	vi
Foreword	vii
List of Figures	ix
List of Tables	xi
Glossary	xii
Acronyms	1
Executive Summary	2
1. Introduction	9
2. Research Methodology	13
2.1. State of Disaster Resilience Practice	14
2.2. Gap Analysis	17
2.3. Research Questions and Dimensions	20
3. Online Survey	21
3.1. Methodology	22
3.2. Data Collection	23
3.3. Respondent Profile	24
3.4. Data Analysis	34
3.5. Results	35
3.6. Mitigation and Protection Measures	74
4. Focus Group Discussion	81
4.1. Methodology	82
4.2. Data Collection	85
4.3. Data Analysis and Results	86
5. Findings	92
5.1 What is the current perception of hazard and disaster exposure at airports? Disaster Impact Context	93
5.2 How do airports perceive their resilience to climate, environmental and natural hazards? Risk Assessment Practices	94
5.3 What are the current practices in airport resilience? Adaptive Capacity	95
6. Way Forward	97
7. Annexures	108
Annexure A - Online Survey Questionnaire	109
Annexure B - Focus Group Discussion	123
Annexure C - Case Study: Analysis of Airports at the Country level	127



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FOREWORD

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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LIST OF FIGURES

Figure 1.	Phase 1 of the global study on disaster resilience of airports in the context of the overall study.	12
Figure 2.	The research methodology used in mapping perceptions and practices of airport managers and operators	14
Figure 3.	An overview of the “Bow tie” model, commonly used in the aviation industry	15
Figure 4.	Components of resilience planning as proposed by ICAO (ICAO, 2019)	16
Figure 5.	Internal and external factors which impact resilience capacities of an organization	18
Figure 6.	Factors for choosing resilience assessment as a complementary approach to risk assessment	19
Figure 7.	Survey outreach timeline	23
Figure 8.	Leakage between survey sections	24
Figure 9.	Sample representativeness of respondents over regions, hazards and GDP per capita	26
Figure 10.	Survey responses by region	27
Figure 11.	Survey responses by airport size	28
Figure 12.	Hazard exposure of participating airports	30
Figure 13.	Overall hazard exposure of participating airports	30
Figure 14.	Survey respondents by ownership model	31
Figure 15.	Airports' response on awareness to hazardous events and disasters	33
Figure 16.	Research methodology	34
Figure 17.	Historical and future severity of impact across regions	37
Figure 18.	Anticipated severity of impact on different asset groups	40
Figure 19.	Time taken to resume operations by hazard type	41
Figure 20.	Time taken to fully recover operations by hazard type	42
Figure 21.	Comparison of time taken to resume and recover by hazard type	43
Figure 22.	Comparison of time taken to resume and recover from Drought	45
Figure 23.	Comparison of time taken to resume and recover from icing	46
Figure 24.	Comparison of time taken to resume and recover from precipitation	47
Figure 25.	Comparison of time taken to resume and recover from flooding	48
Figure 26.	Comparison of time taken to resume and recover from geo hazards	49
Figure 27.	Comparison of time taken to resume and recover from air quality	50



Figure 28. Comparison of time taken to resume and recover from storms	51
Figure 29. Comparison of time taken to resume and recover from wildlife invasion	52
Figure 30. Comparison of time taken to resume and recover from third-party equipment failure	53
Figure 31. Comparison of time taken to resume and recover from extreme heat	54
Figure 32. Comparison of time taken to resume and recover from volcanic activity	55
Figure 33. Comparison of risk and resilience practices by region.	57
Figure 34. Overview of vulnerability assessment practices.	58
Figure 35. Future hazard exposure vs vulnerability assessment practices	59
Figure 36. Overview of airport emergency response planning and disaster recovery planning practices	60
Figure 37. Overview of airport resilience practices	62
Figure 38. Overview of airport resilience practices (lessons learned and resilience measures)	64
Figure 39. Ranking resilience drivers by ownership model	65
Figure 40. Ranking resilience drivers by region	66
Figure 41. Ranking resilience drivers by effectiveness of organization in mitigating risk for the airport	67
Figure 42. Effectiveness of organization in mitigating risks for the airport vs the availability of in-house capacity.	68
Figure 43. Overview of data availability for airports vs their risk mitigation practices	69
Figure 44. Access to datasets vs economic profile of the airport's country	70
Figure 45. Access to datasets vs airport size	71
Figure 46. Overview of business continuity plans and the inclusion of resilience practices.	73
Figure 47. Overview of themes discussed in the focus group discussion (NACO)	84



LIST OF TABLES

Table 1.	Key dimensions, associated objectives, and secondary questions	20
Table 2.	Question type and estimated completion time	23
Table 3.	Overview of data sources	25
Table 4.	Number of participants per region	27
Table 5.	Number of participants by airport size	28
Table 6.	Multi hazard platform risk exposure calculation factors	29
Table 7.	Number of participants by their country's income group	31
Table 8.	Ownership model of participating airports	32
Table 9.	Respondent profile by their designated departments	32
Table 10.	Hazard severity rating system	35
Table 11.	Understanding hazard terminologies	36
Table 12.	Number of measures per asset group	88



GLOSSARY

Disaster	The impact of a hazard or a sudden calamitous event bringing great damage, loss, or destruction. <i>(United Nations Office for Disaster Risk Reduction)</i>
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. <i>(European Civil Protection and Humanitarian Aid Operations)</i>
Hazard	A potential source of harm (event or circumstance) which can cause damage to health, life, property, or operations. <i>(United Nations Office for Disaster Risk Reduction)</i>
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. <i>(United Nations Office for Disaster Risk Reduction)</i>
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. <i>(United Nations Office for Disaster Risk Reduction)</i>
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. <i>(United Nations Office for Disaster Risk Reduction)</i>
Vulnerability	Vulnerability refers to the inability of a system to withstand the effects of a hostile environment or situation. <i>(United Nations Office for Disaster Risk Reduction)</i>



ACRONYMS

A-CDM	Airport Collaborative Decision Making
ACI	Airports Council International
ACROS	Airport Climate Risk Operational Screening
ACRP	Airport Cooperative Research Program
AERP	Airport Emergency Response Plan
BCP	Business Continuity Plan
CAPEX	Capital Expenditure
CAR	Civil Aviation Regulation
CAT 9	Category 9 Level of Service
COOP	Continuity of Operations Plan
ERP	Emergency Response plan
FGD	Focus Group Discussion
GSE	Ground Service Equipment
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
MAP	Million annual passengers
NACO	Netherlands Airport Consultants, a company of Royal HaskoningDHV
NOAA	National Oceanic and Atmospheric Administration
RFF	Rescue and Firefighting
RHDHV	Royal HaskoningDHV
SMS	Safety Management System
T100	Once Per 100 Years
TCFD	Task Force on Climate-Related Financial Disclosures



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.

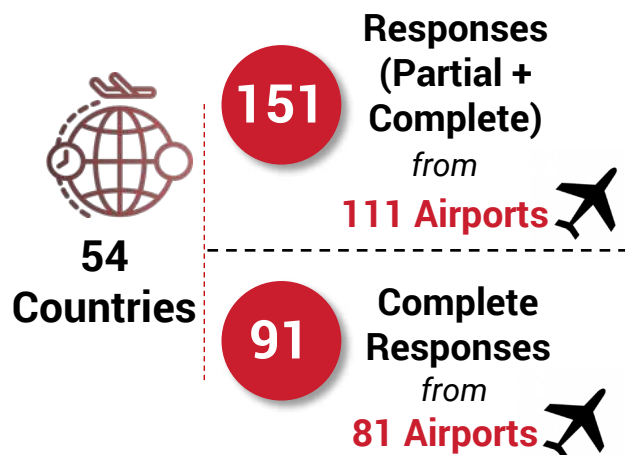
To address the impacts of natural hazards and human-induced disasters on airports, as well as the associated direct losses and cascading economic impacts affecting the lives and livelihoods of millions of people, the Coalition for Disaster Resilient Infrastructure (CDRI) initiated the Global Study on 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:



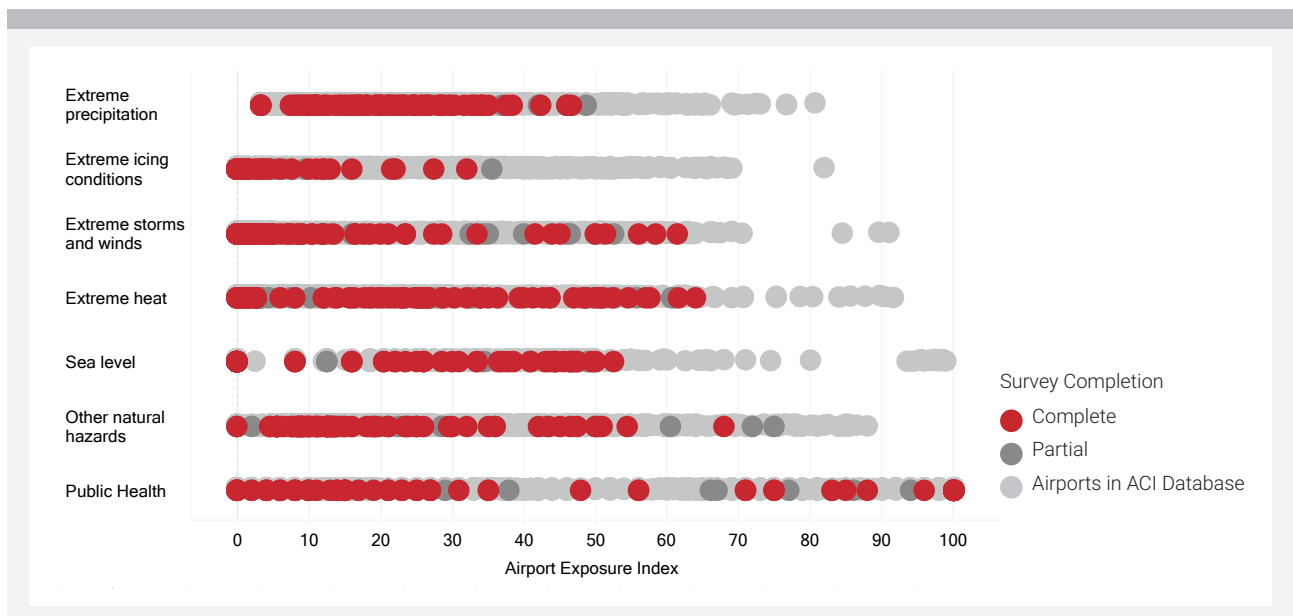
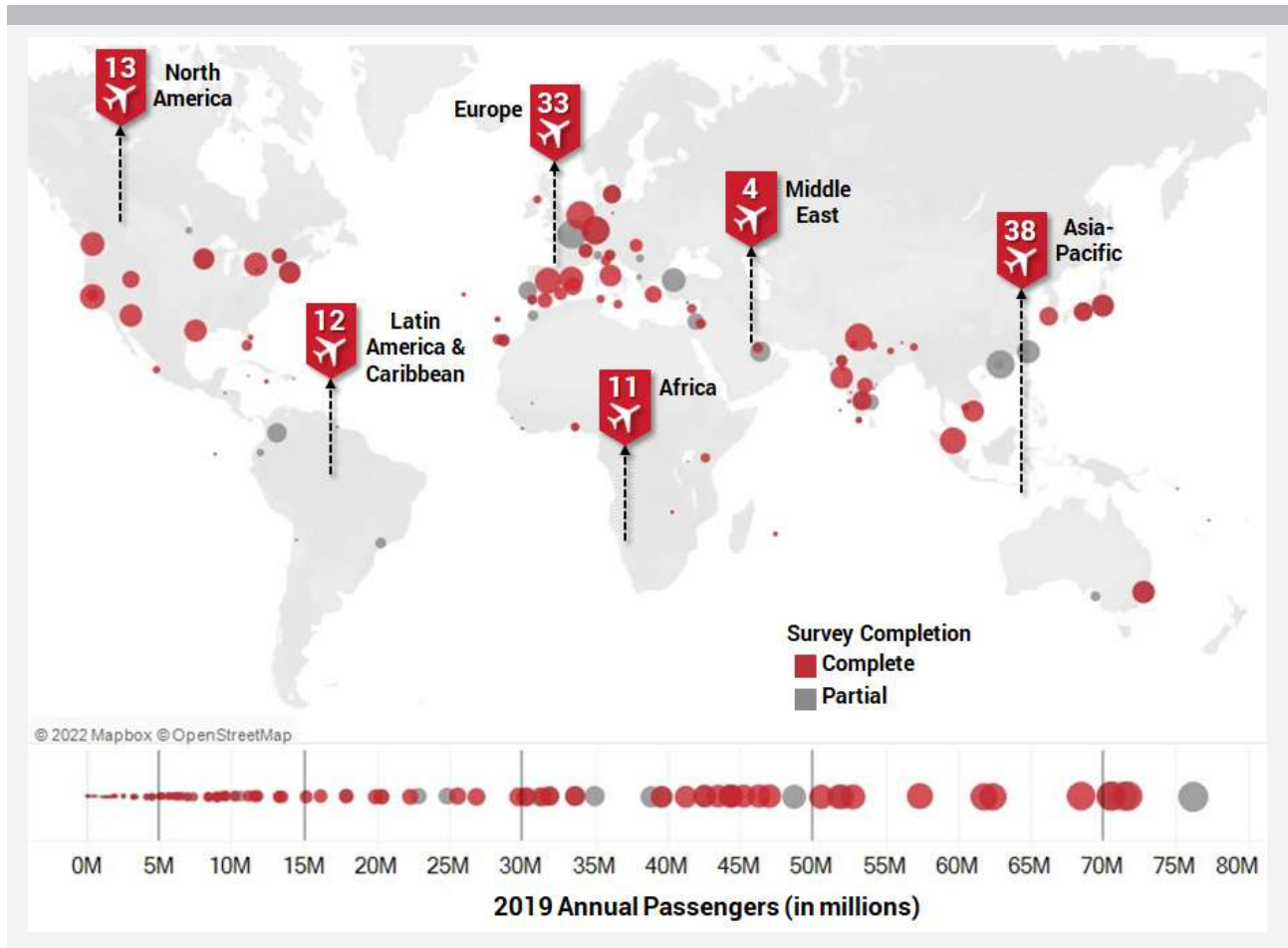
Herein, the collective perspective from the various departments and responsibilities within an airport organization inform an understanding of the risks and impact of extreme events and disasters on airports, the practices in place, challenges to resilience and the actions moving forward for the industry.

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.





Respondent Profile

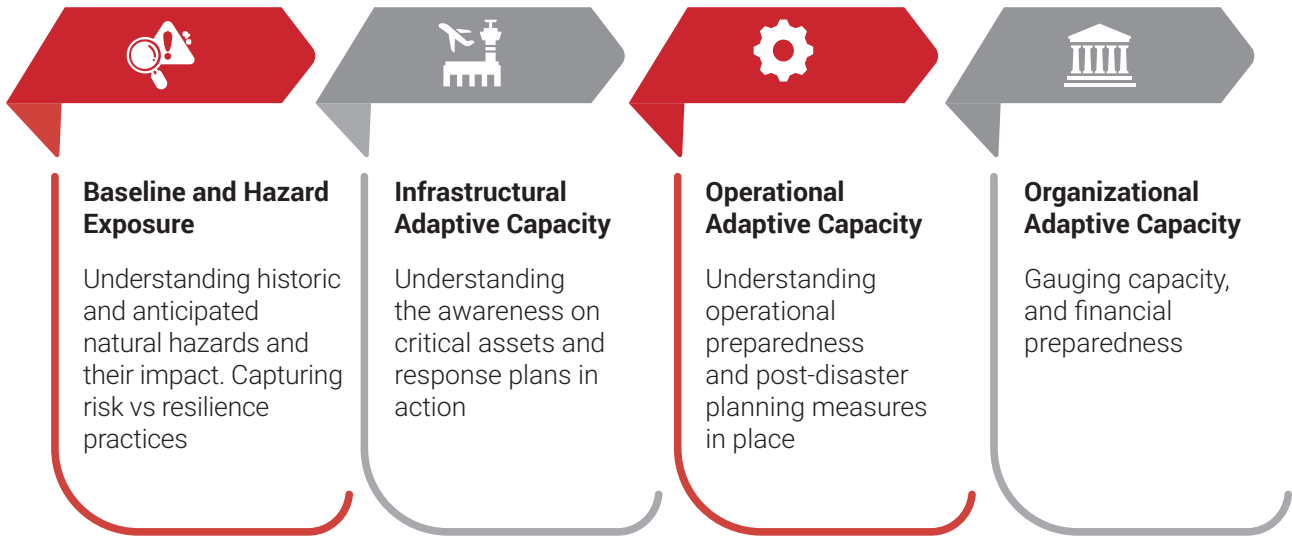


A representative sample set was achieved through a multi-pronged outreach approach. The sample set represents all the major regions of the world and provides a comprehensive overview of all the natural hazards identified in the study.



Findings

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



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.



How do airports perceive their resilience to climate, environmental and natural hazards? Risk Assessment Practices

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.



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:




 **Research & Knowledge Sharing**
 Recommendations suggest methods to bridge the current gap in knowledge and data available.

- Conduct in-depth studies of risk and resilience practices at airports to understand differences in ability to resume operations and recover across regions. ●
- Establish a broader understanding of risk appetite of airports. ●
- Encourage cross-industry knowledge sharing and learnings from industries and environments with similar complexities, such as cities. ●

 **Regulations/Mandates**
 Recommendations present possible regulations or mandates which can facilitate improvement in resilience practices and address the identified challenges.

- 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. ●
- Airport and government bodies should continue to work together to build integrated disaster resilience. ●●●
- 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. ●
- Mandate quick scans to assess hazard exposure and resilience planning as part of all greenfield and brownfield developments. ●

 **Airport Practices**
 Recommendations present common practices captured during the study.

- Airports should engage local and regional stakeholders for increasing airport resilience practices and support the acceleration of resilience in the catchment area. ●●
- Airports should conduct periodic vulnerability assessments and develop a resilience strategy. ●●
- Airports should move towards a more proactive approach rather than reactive towards hazard management and resilience planning. ●
- Airports and insurers should collaborate to mitigate climate risk, this will be mutual beneficial. ●

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>)



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



Source: Royal HaskoningDHV webpage (<https://www.royalhaskoningdhv.com/en/projects/climate-resilience-in-japan>)

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.

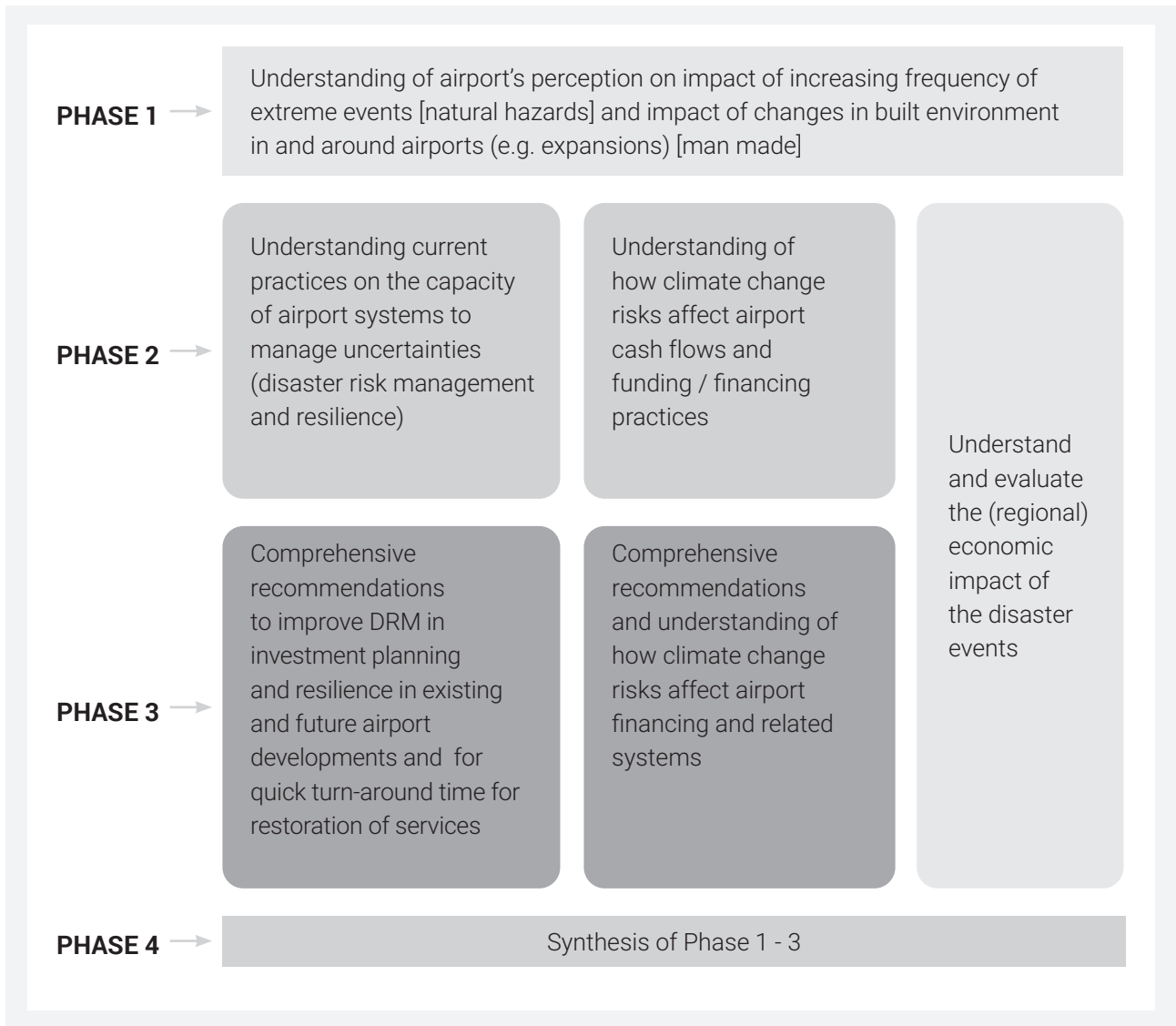
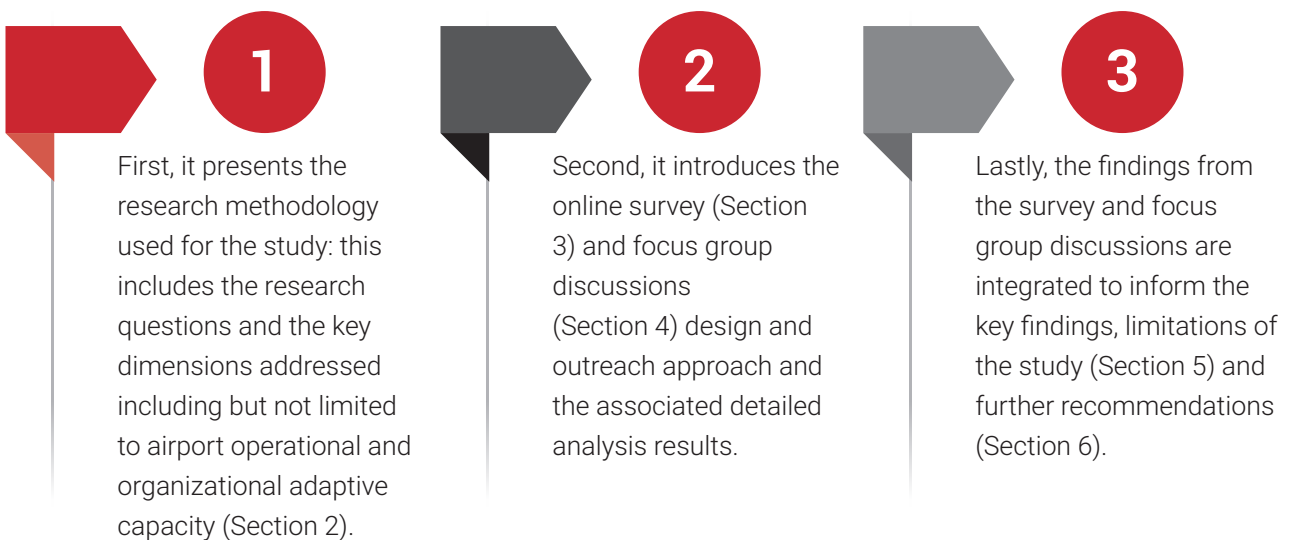


Figure-1 Phase 1 of the Global Study on Disaster Resilience of Airports in the context of the overall study

This report is structured as follows:





2

RESEARCH METHODOLOGY

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



Figure - 2 The research methodology used in mapping perceptions and practices of airport managers and operators

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)¹. For example, the “Bow tie” Model shown in Figure 3 is commonly used in the aviation industry and includes a risk assessment component.

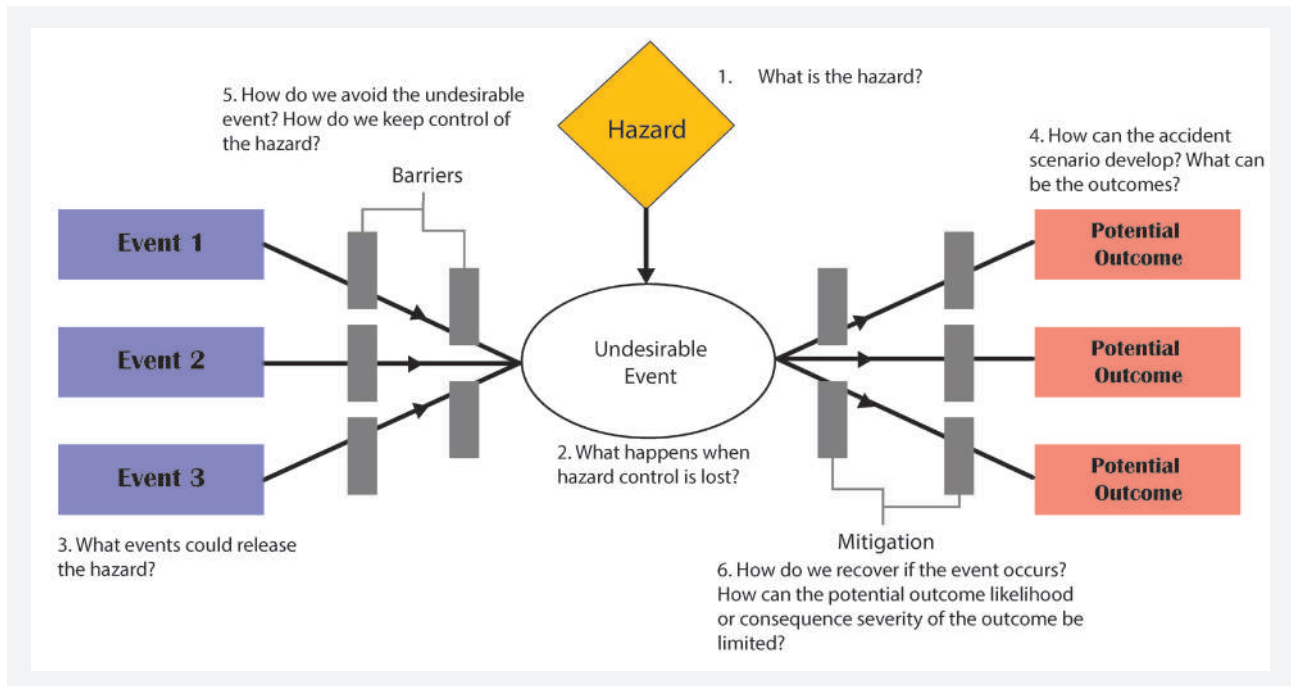


Figure-3 An overview of the “Bow tie” model, commonly used in the aviation industry (adapted from ICAO, 2018)

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).

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.

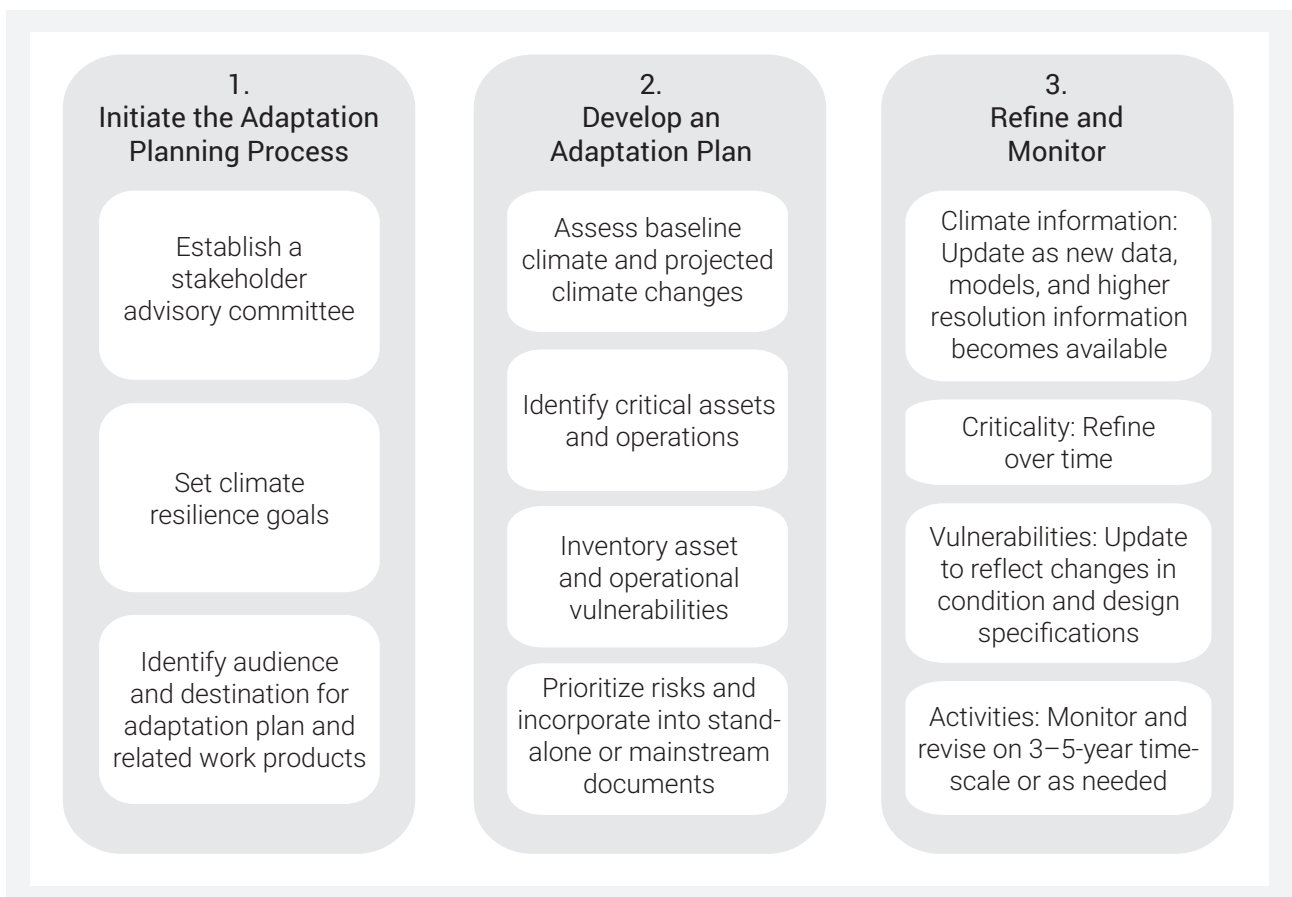


Figure-4 Components of resilience planning as proposed by ICAO (ICAO, 2019)



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.

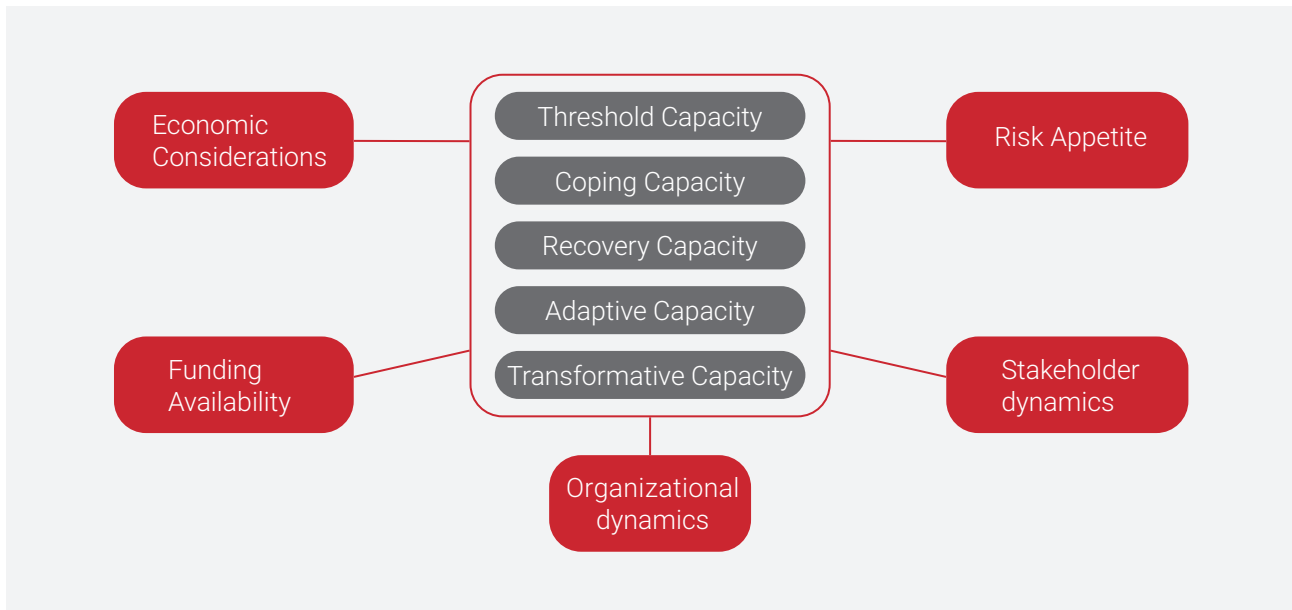


Figure-5 Internal and External factors impacting resilience capacities of an organization

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.



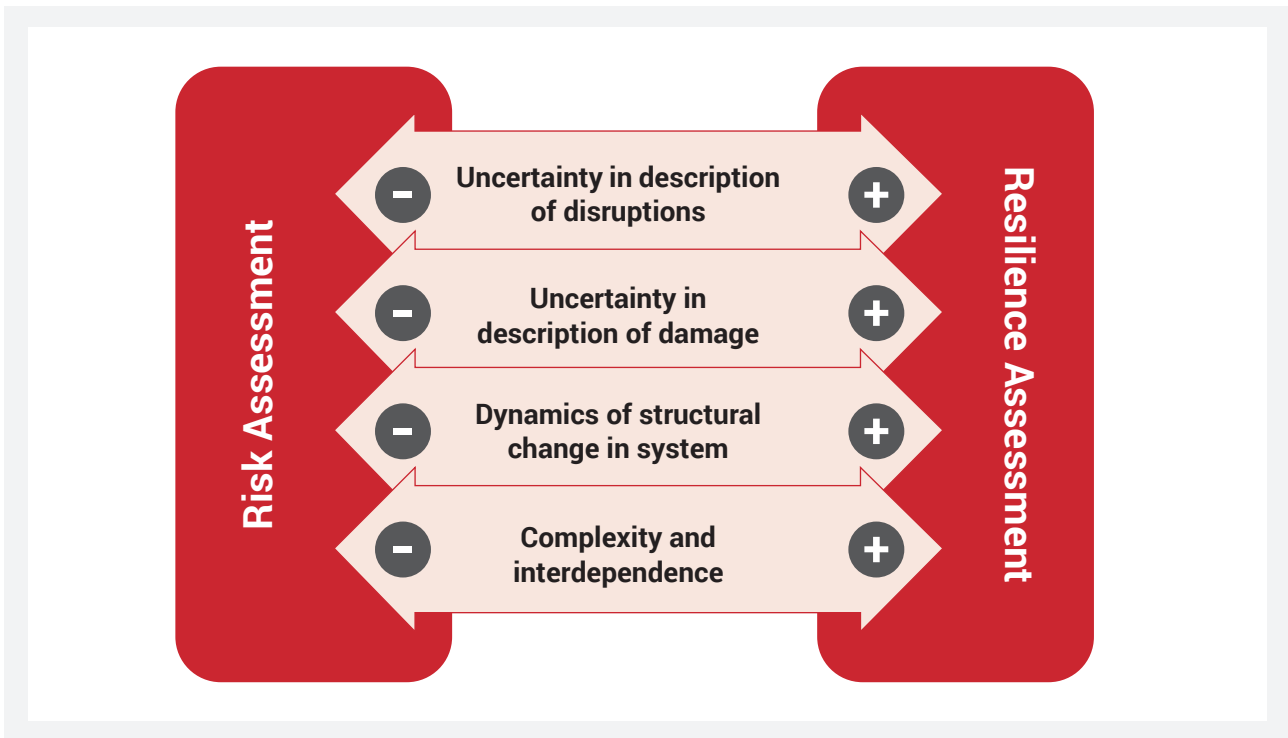


Figure-6 Factors for choosing resilience assessment as a complementary approach to risk assessment

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., Burbidge, 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



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

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



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.



Table 2 Question type and estimated completion time.

Question type	Number of questions	Estimated completion time per question
Checkboxes	5	1 min
Demographic and general information	6	< 1 min
Dropdown	1	< 1 min
Dichotomous	5	< 1 min
Multiple choice	6	< 1 min
Open-ended	3	2 – 3 min
Rating matrix	5	4 min
Semantic differential scale	3	< 1 min
Slider scale	1	< 1 min
	35	40 – 45 min

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.

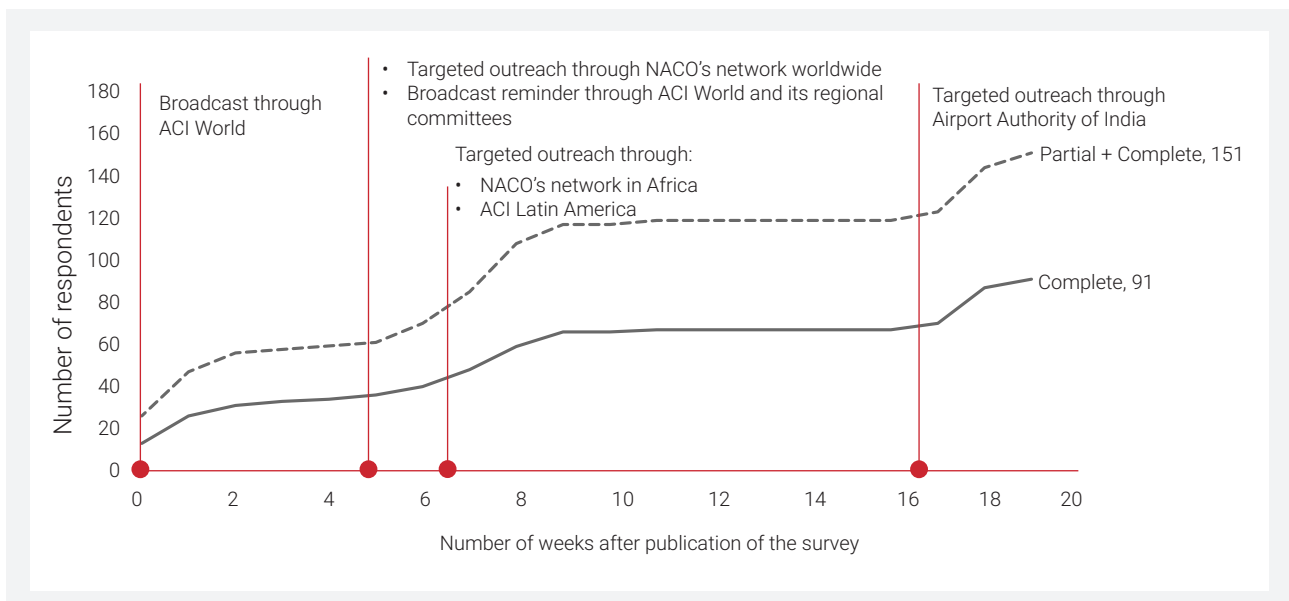


Figure - 7 Survey outreach timeline



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.

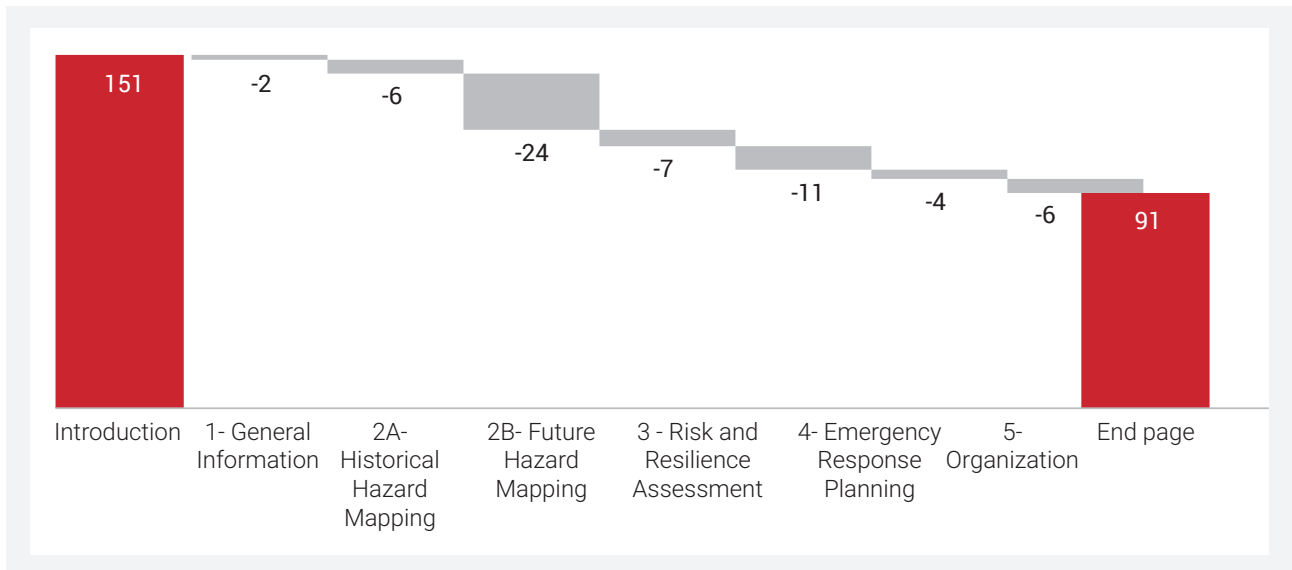


Figure - 8 Leakage between survey sections (Source: NACO analysis from survey results)

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

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

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.

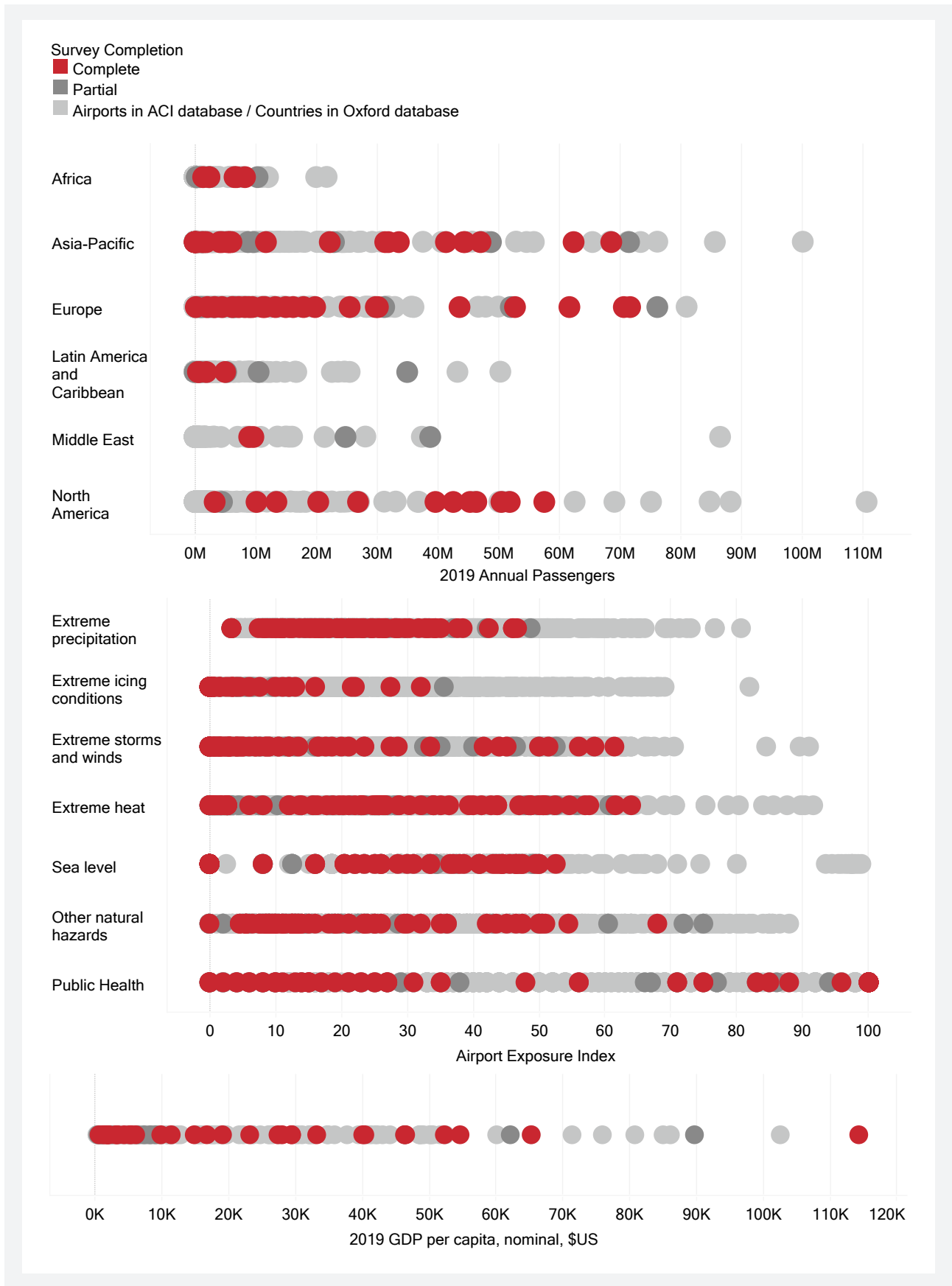


Figure - 9 Sample representativeness of respondents over regions, hazards and GDP per capita

(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.



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

Table 4 Number of participants per region

Region	Complete Responses	Partial Responses	Total
Africa	6	5	11
Asia-Pacific	30	8	38
Europe	26	7	33
Latin America & Caribbean	5	7	12
Middle East	2	2	4
North America	12	1	13
Total	81	30	111

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

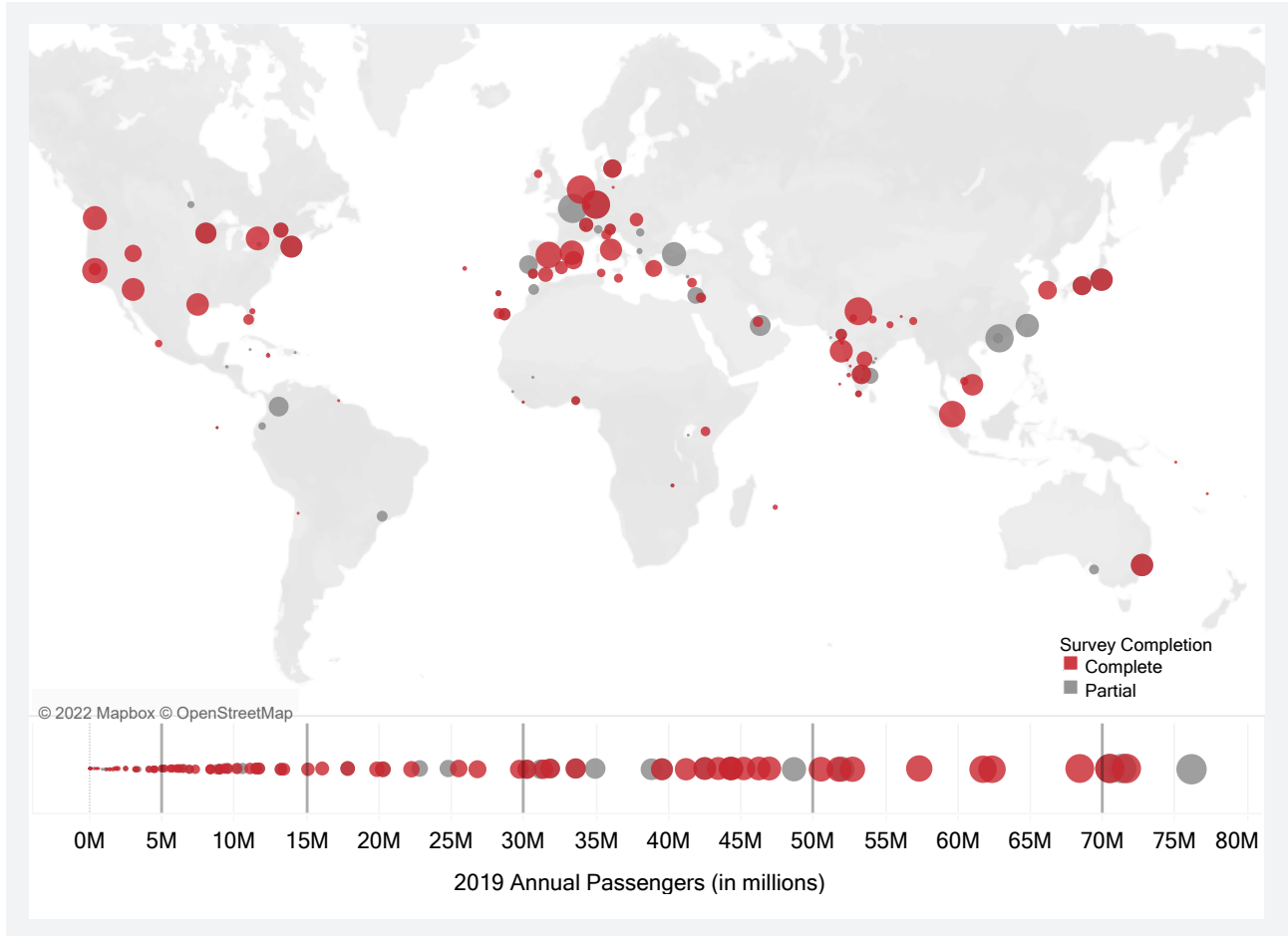


Figure - 11 Survey responses by airport size (Source: NACO analysis from survey results, ACI database)

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

Airport size	Complete Responses	Partial Responses	Total
0-5M	29	12	41
5-15M	21	7	28
15-30M	9	4	13
30-50M	13	4	17
50-70M	7	1	8
>70M	2	2	4
Total	81	30	111



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

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

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.

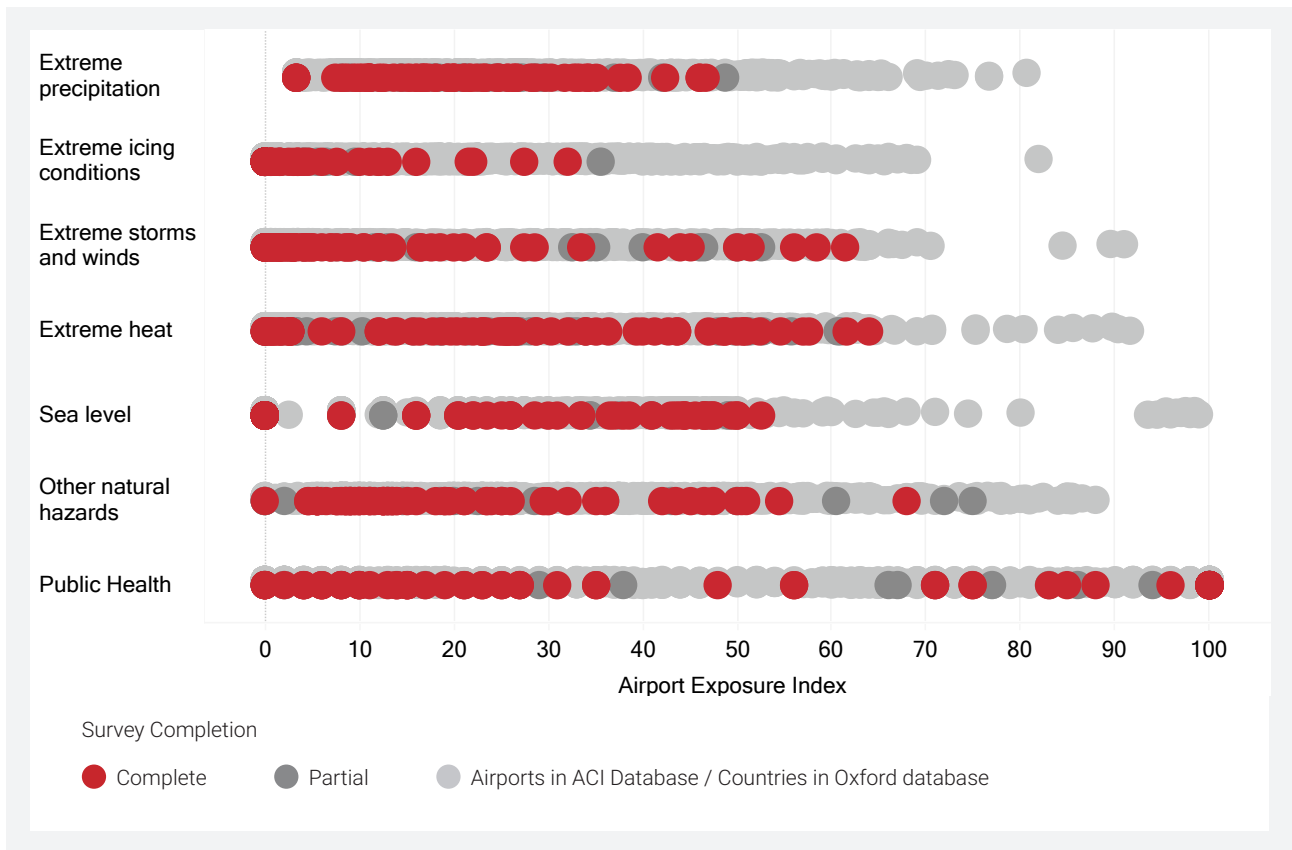


Figure - 12 Hazard exposure of participating airports (Source: NACO analysis from survey results, RHDHV Multi Hazard Risk Platform)

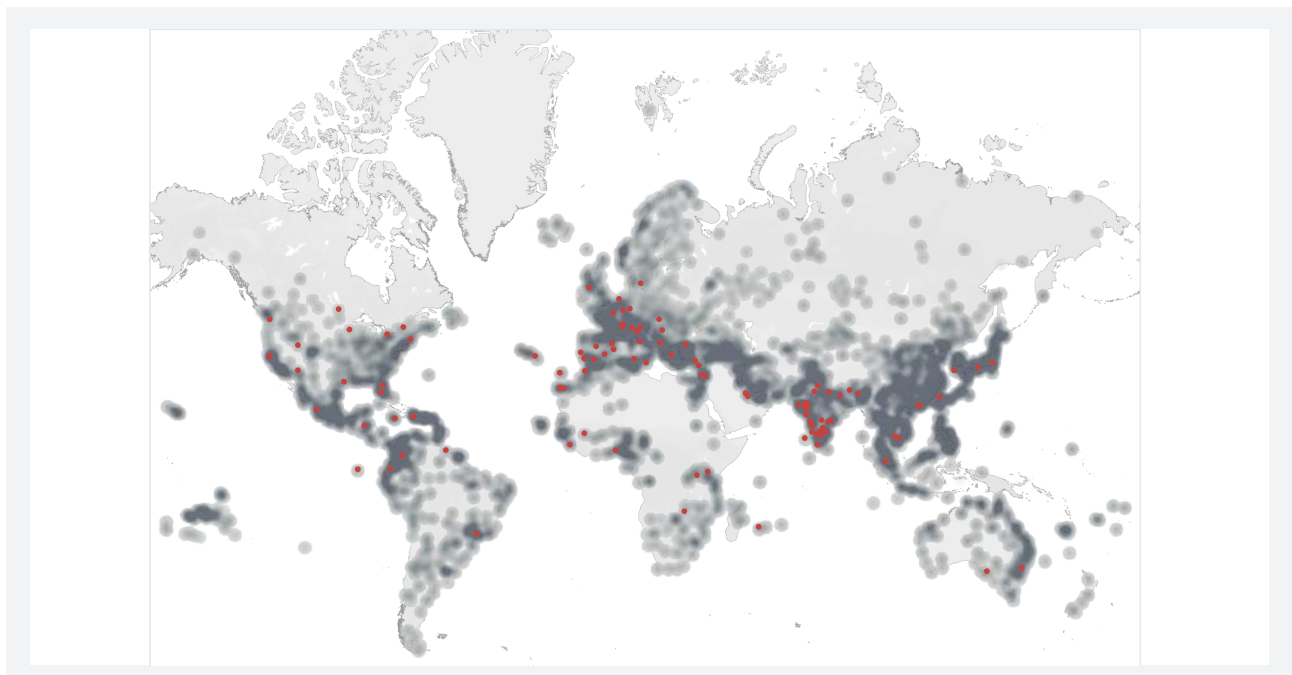


Figure - 13 Overall hazard exposure of participating airports (Source: NACO analysis from survey results, RHDHV Multi Hazard Risk Platform)

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

Income group	Complete Responses	Partial Responses	Total
High income	21	4	25
Upper middle income	6	7	13
Lower middle income	9	4	13
Low income	1	2	3
Total	37	17	54

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.

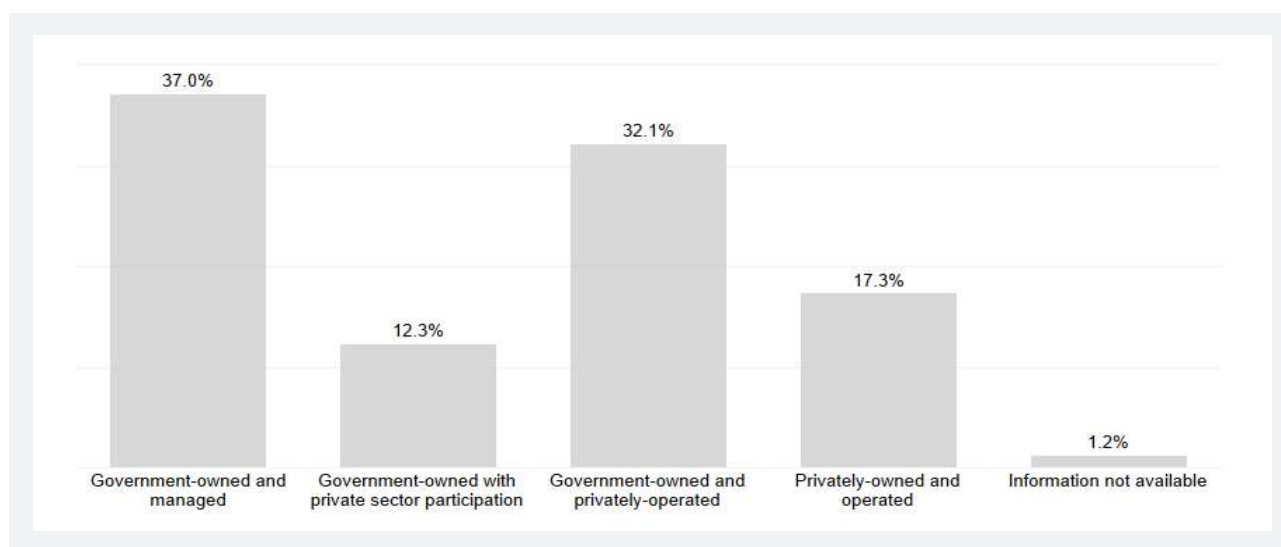


Figure - 14 Survey respondents by ownership model (Source: NACO analysis from survey results)

**Table 8** Ownership model of participating airports

Ownership Model	Complete Responses	Partial Responses	Total
Government-owned and managed	30	11	41
Government-owned and privately-operated	10	3	13
Government-owned with private sector participation	26	11	37
Privately-owned and operated	14	4	18
Information not available	1	1	2
Number of airports	81	30	111

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

Department Category	Complete Responses	Partial Responses	Total
Airport Operations	33	12	45
Safety, Security and Compliance Management	14	7	21
Planning, Strategy and Airport Development	10	4	14
General Management	8	13	21
Asset Management and Technical Services	6	2	8
Emergency Response (including firefighting services)	5	2	7
Environmental affairs and sustainability	8	6	14
Quality, Health Safety & Environment	4	6	10
Risk management and corporate resilience & Compliance	1	2	3
Other	2	6	8
Total	91	60	151

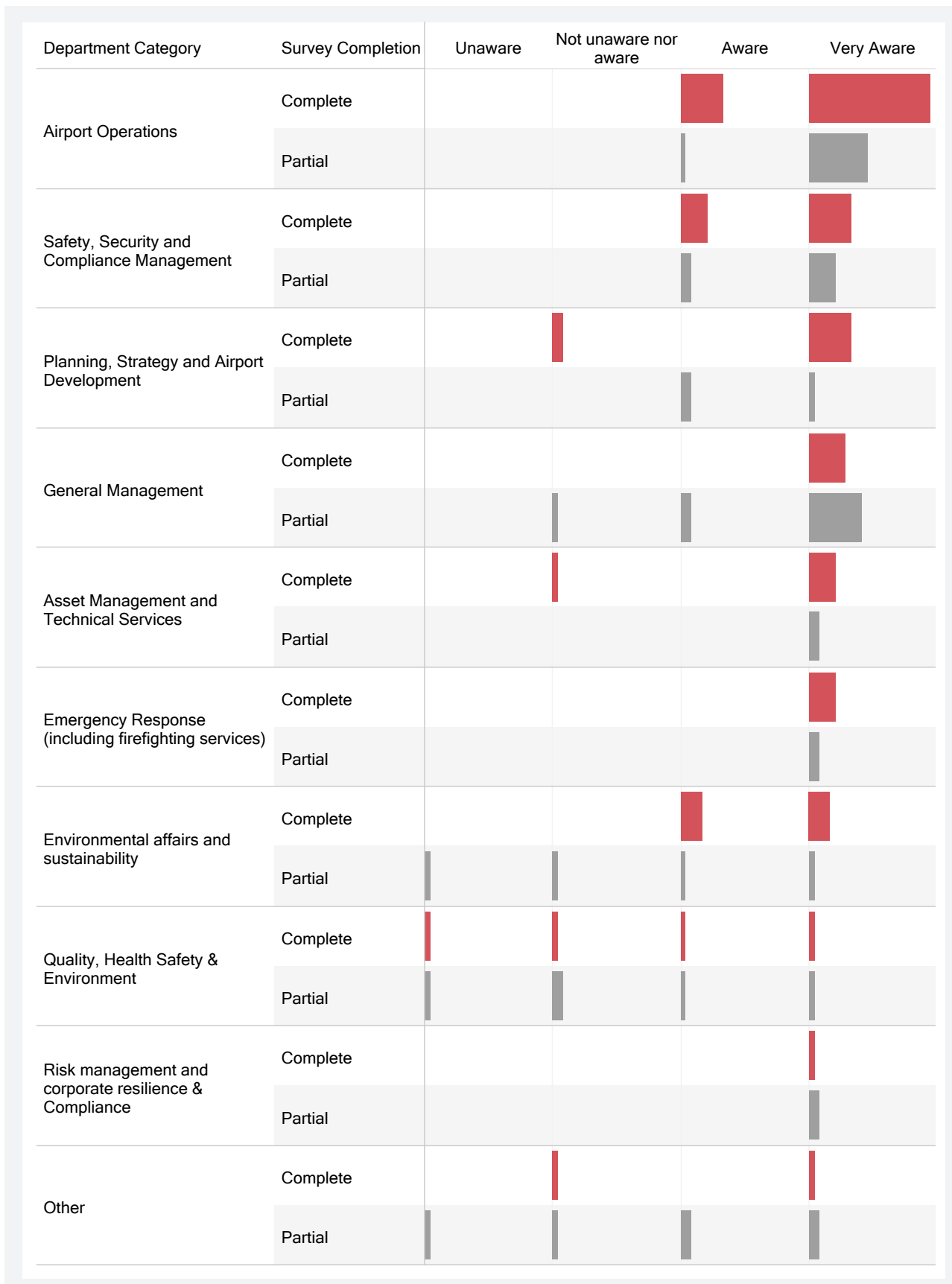


Figure - 15 Airports' response on awareness to hazardous events and disasters

(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.

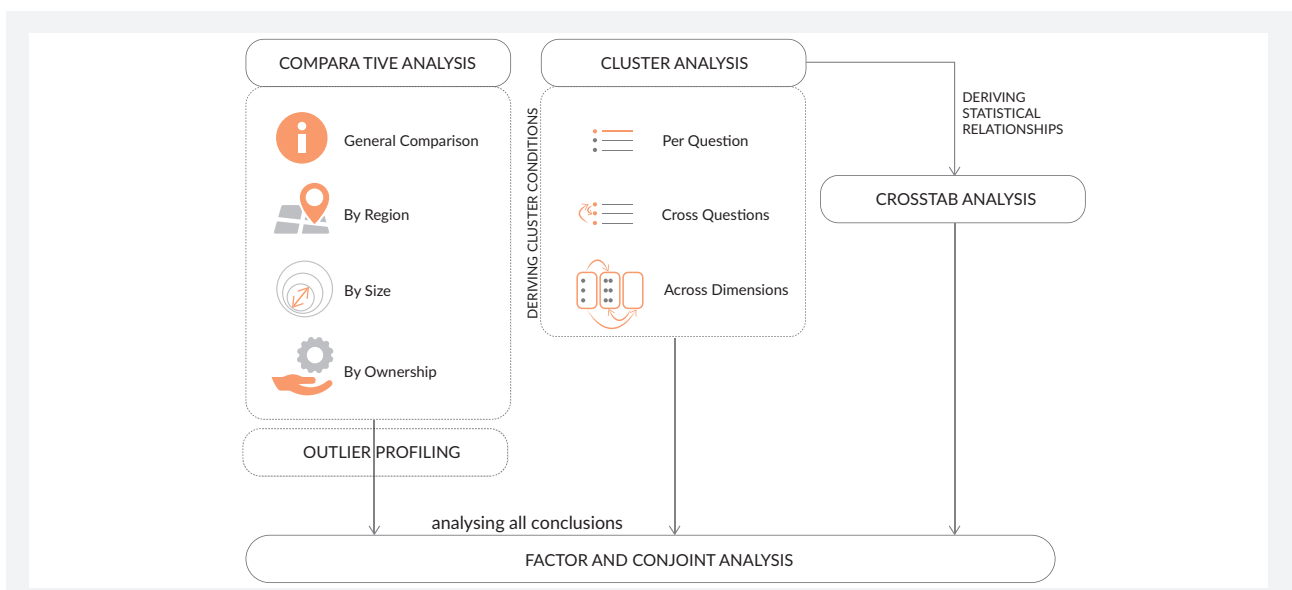


Figure - 16 Research Methodology (Source: NACO analysis of Survey results)



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

Severity	0	1	2	3	4	5
Safety & Health	No impact	Impact not likely to cause damages	Injuries requiring first aid only	<ul style="list-style-type: none"> Injury requiring medical treatment (lacerations, burns, fractures) Reduced efficiency of operations due to increased workload 	Serious injuries or life-threatening occupational medical conditions	Multiple deaths and injury
Infrastructure & Operational Disruption	No impact	Flight delays of 15 minutes maximum	Partial restrictions and flights delay lower than 2 hours	Restrictions in operations <ul style="list-style-type: none"> Flight delays lower than 8 hours 	<ul style="list-style-type: none"> Closure for more than 8 hours Major damage to equipment 	<ul style="list-style-type: none"> Closure for multiple days Destruction of equipment or infrastructure
Economic Loss	No impact	Insignificant costs	Indirect economic loss to airport partners	Indirect economic loss to the airport	Direct economic loss to airport partners	Direct economic loss to the airport
Image	No impact	Insignificant impact	Local negative PR	<ul style="list-style-type: none"> Regional media coverage Negative publicity 	<ul style="list-style-type: none"> National media coverage Impact on brand image 	<ul style="list-style-type: none"> International media coverage Impact on brand image

**Table 11** Understanding hazard terminologies

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



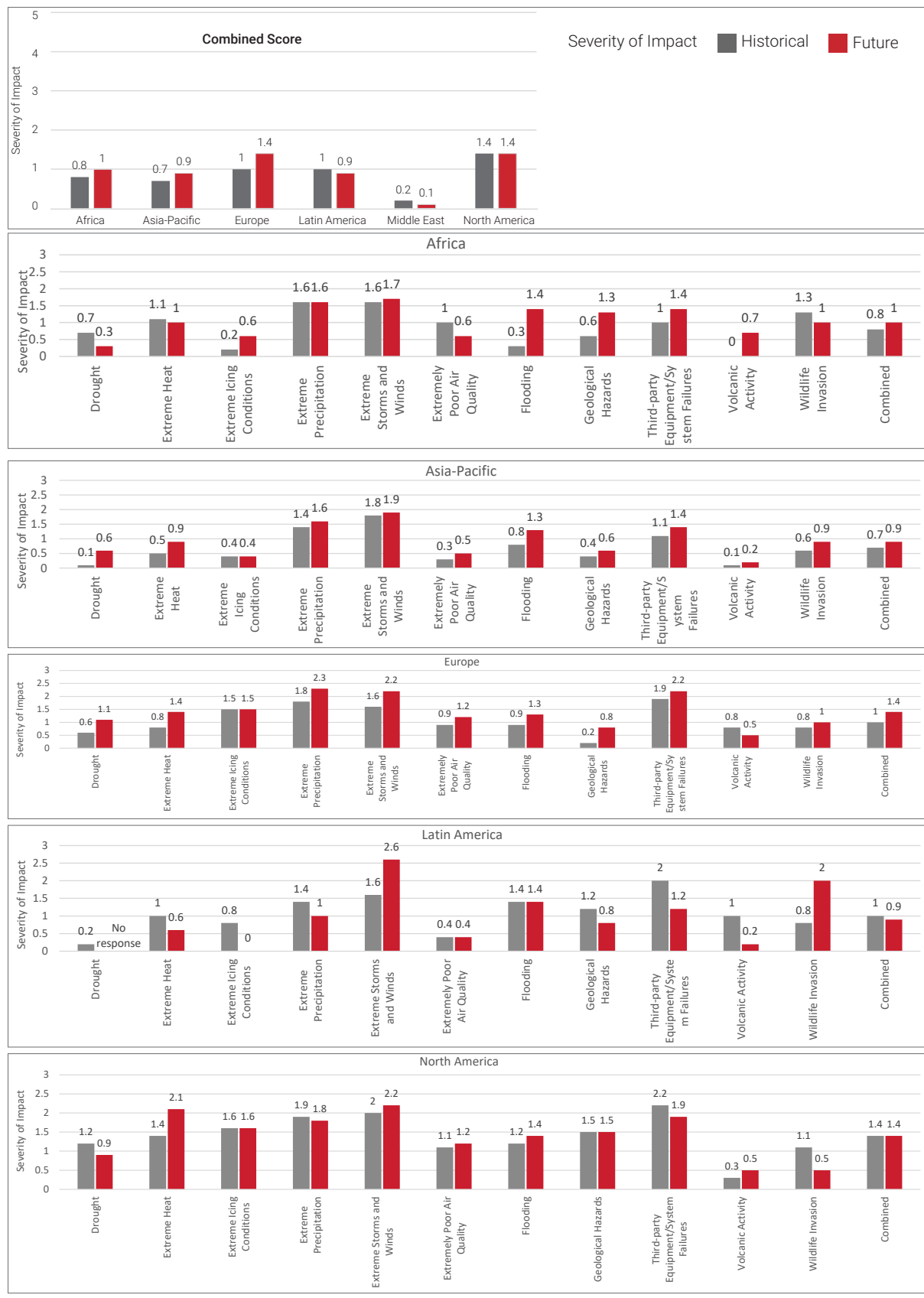


Figure - 17 Historical and future severity of impact across regions
 (Source : NACO analysis of Survey results)



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.



Baseline & Hazard Exposure



Infrastructural Adaptive Capacity





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.

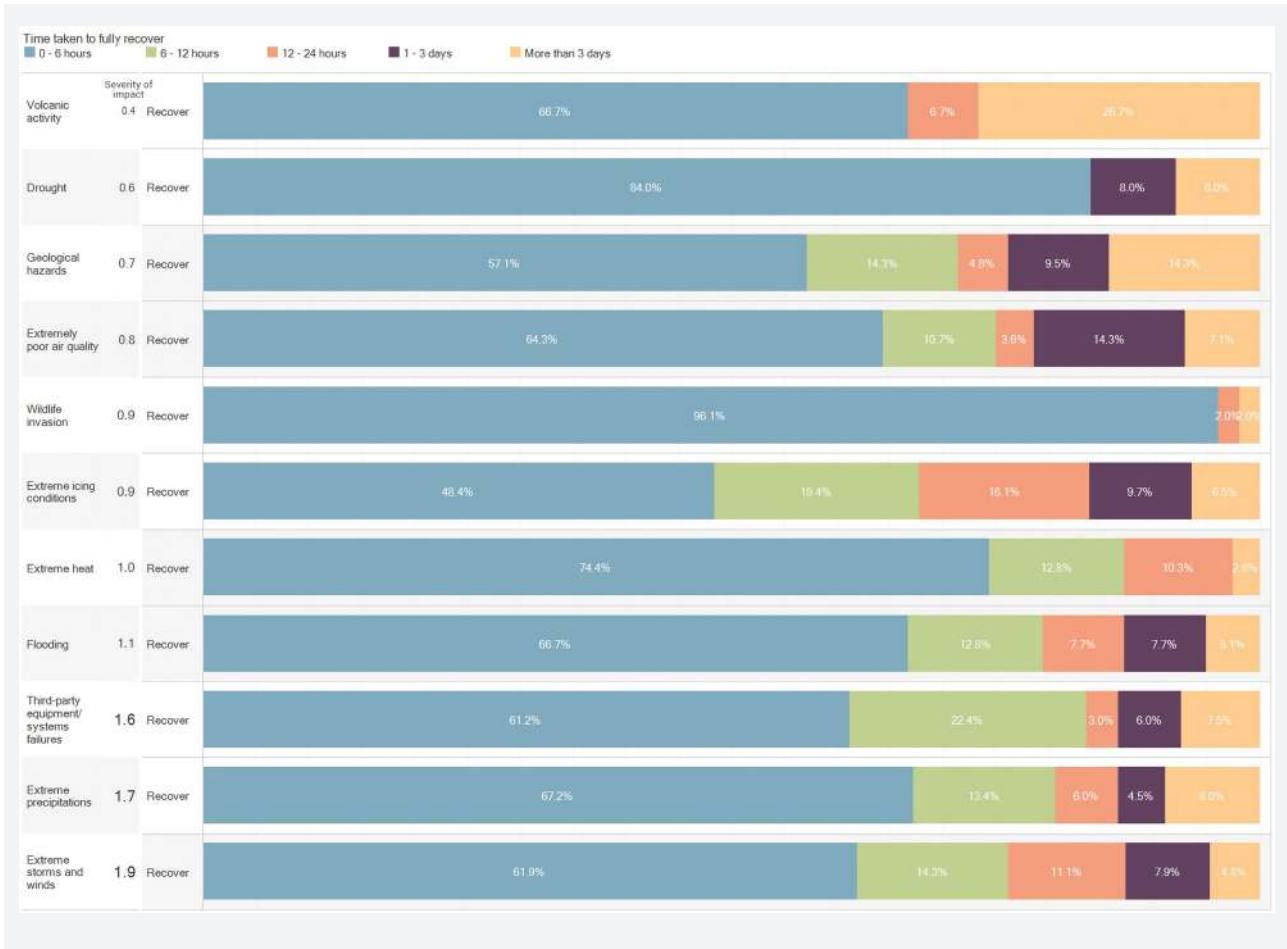


Figure - 20 Time taken to fully recover operations by hazard type
(Source : NACO analysis of Survey results)

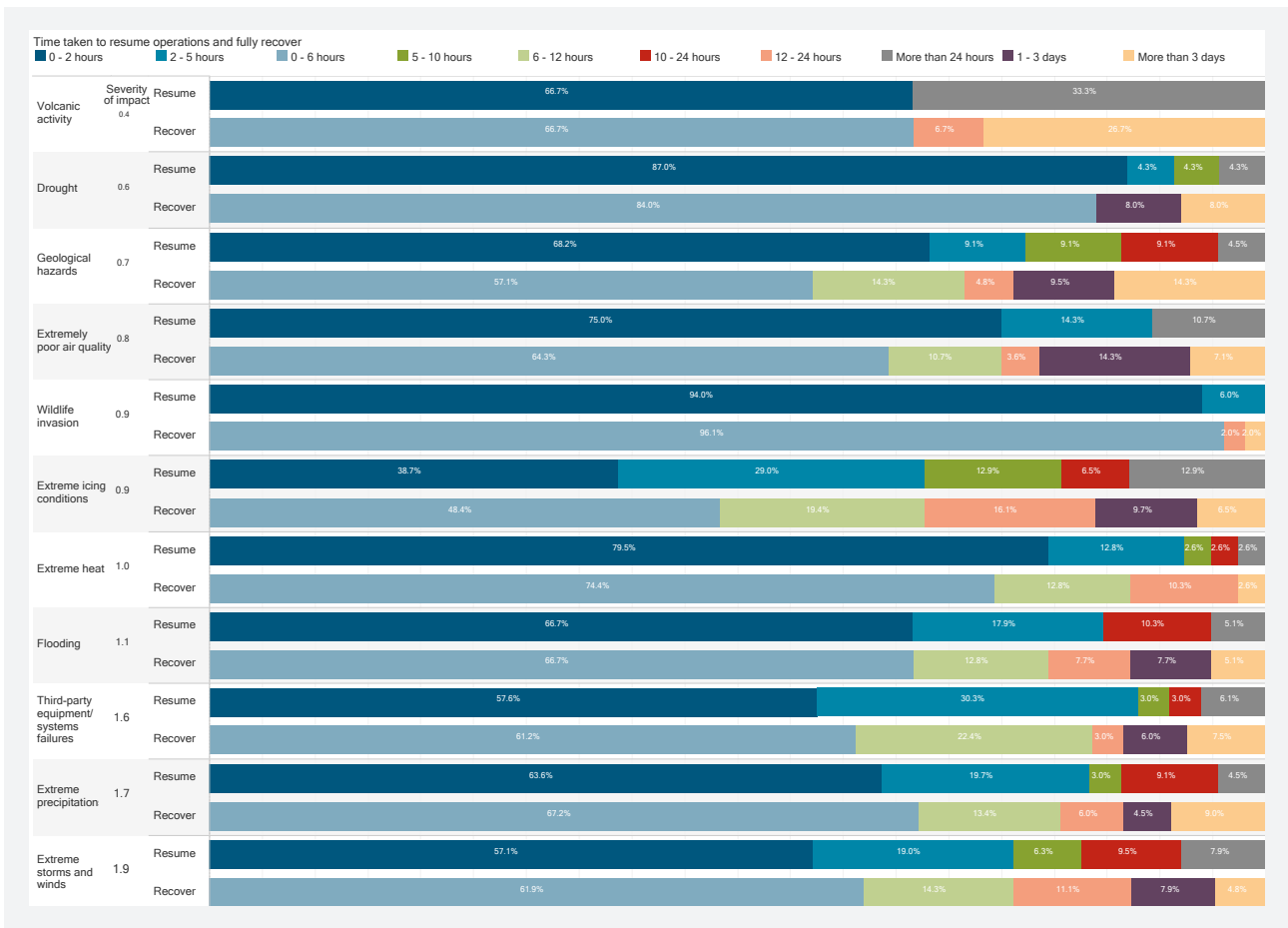



Figure - 21 Comparison of time taken to resume and recover by hazard type
 (Source : NACO analysis of Survey results)

 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 difference 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.

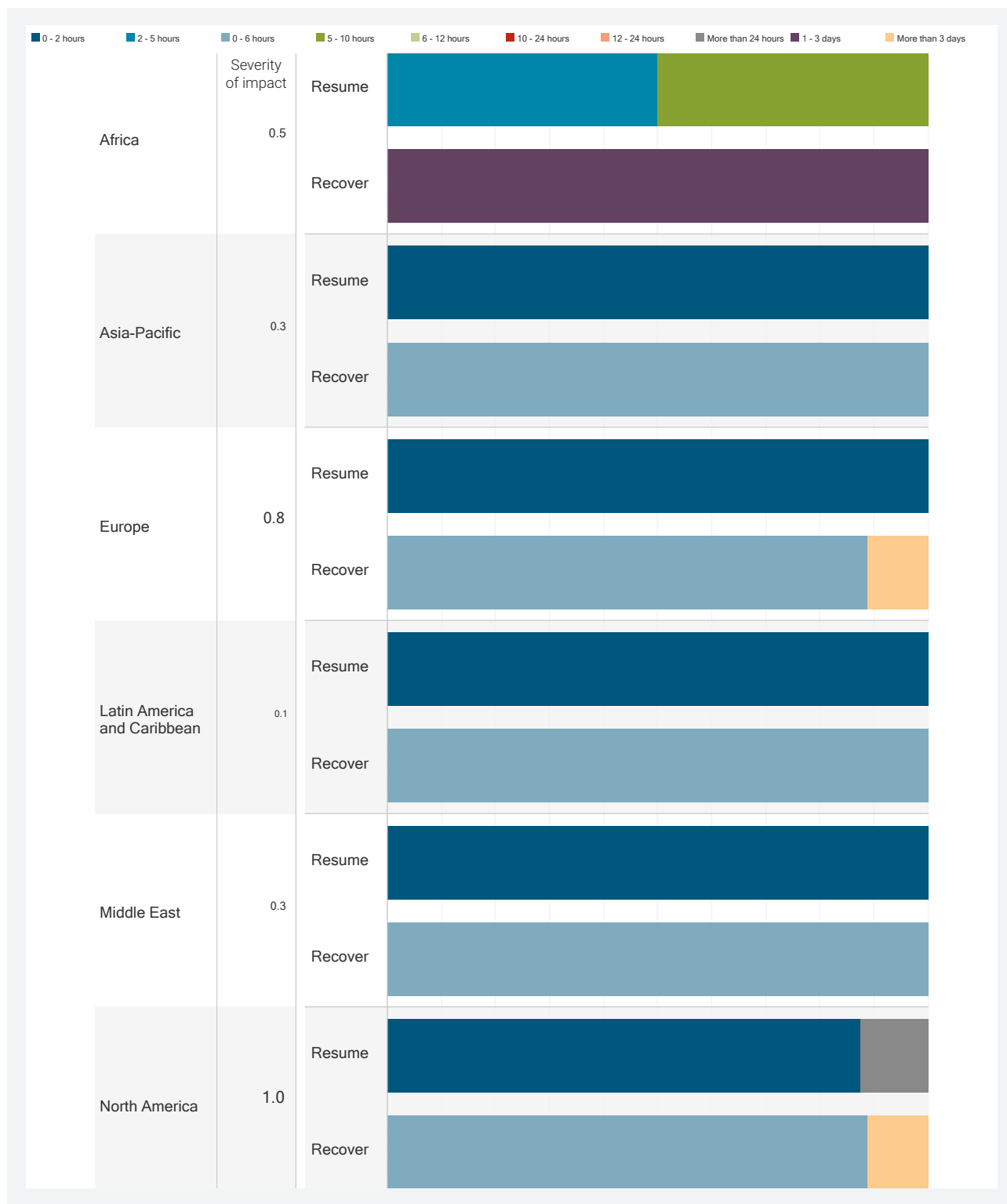


Figure - 22 Comparison of time taken to resume and recover from Drought

(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.

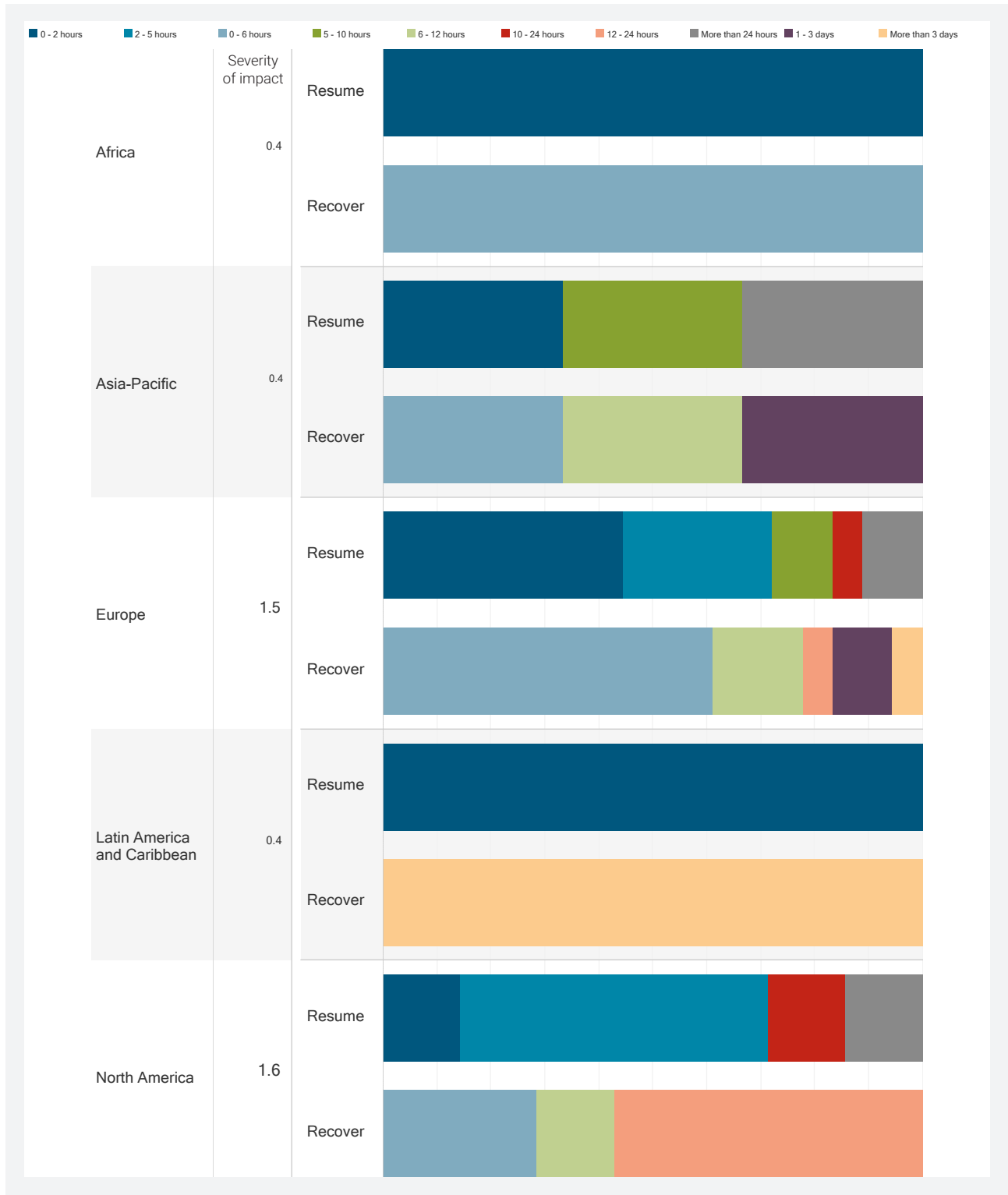


Figure - 23 Comparison of time taken to resume and recover from icing

(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.

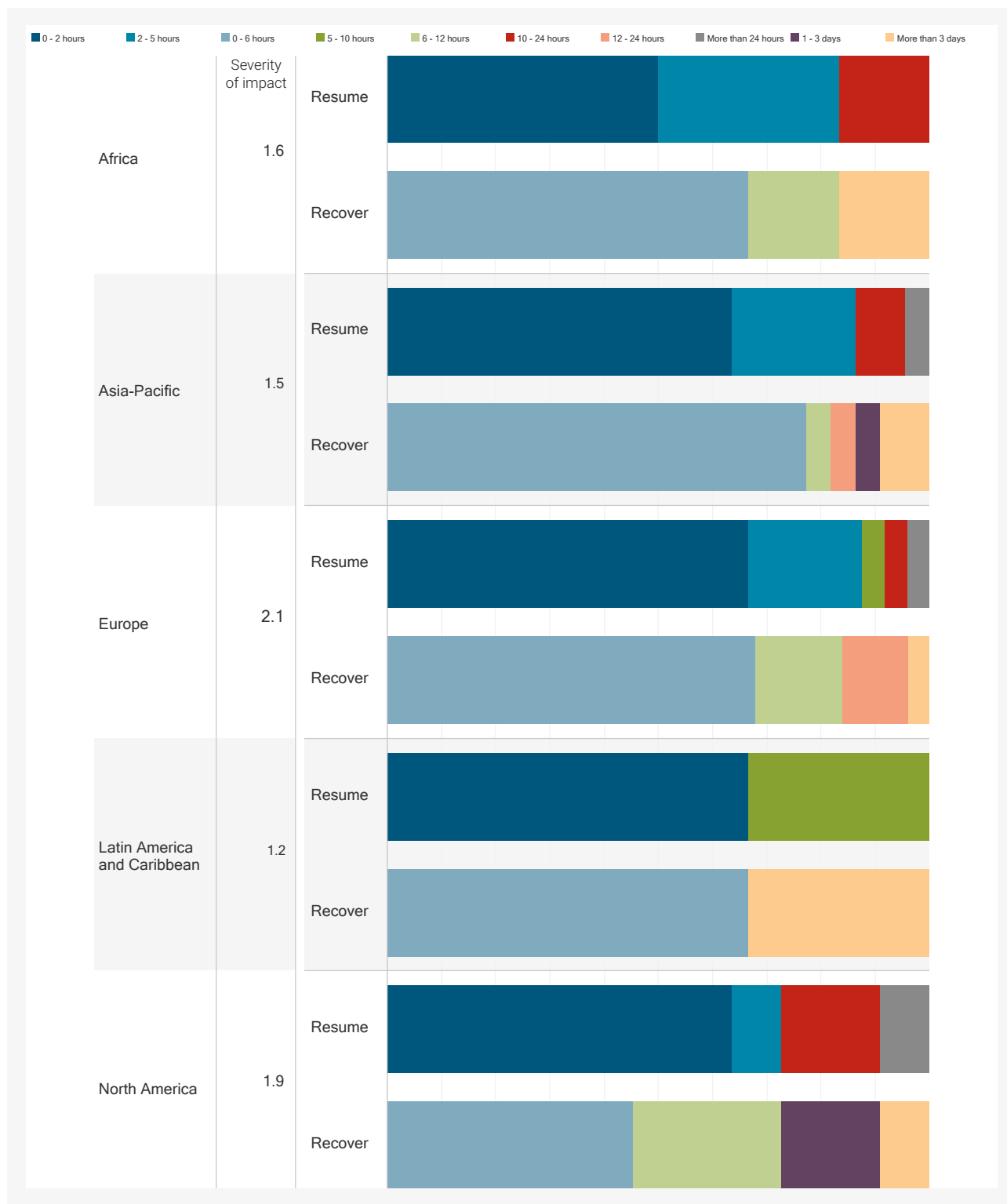


Figure - 24 Comparison of time taken to resume and recover from precipitation

(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.

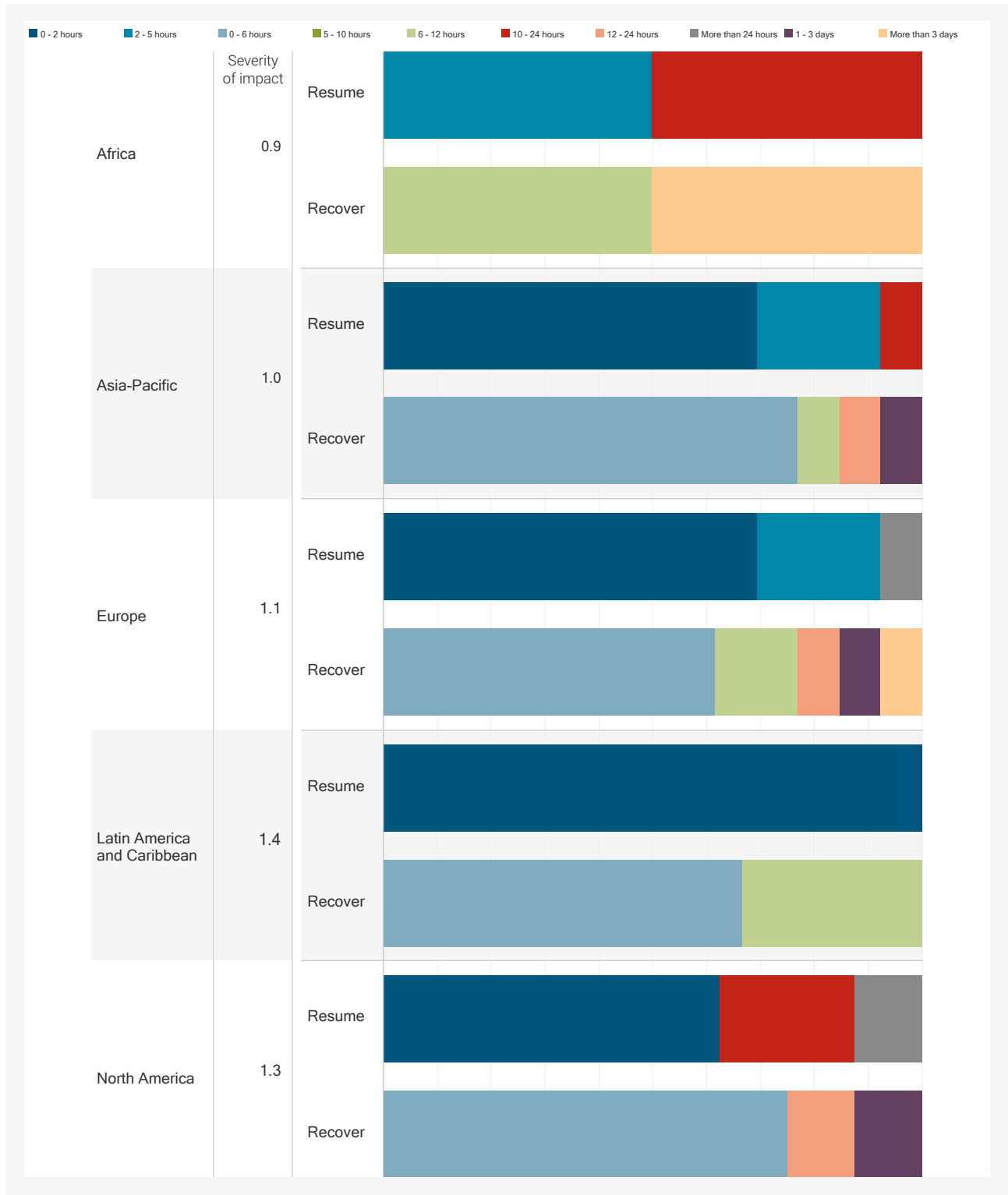


Figure - 25 Comparison of time taken to resume and recover from flooding

(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.

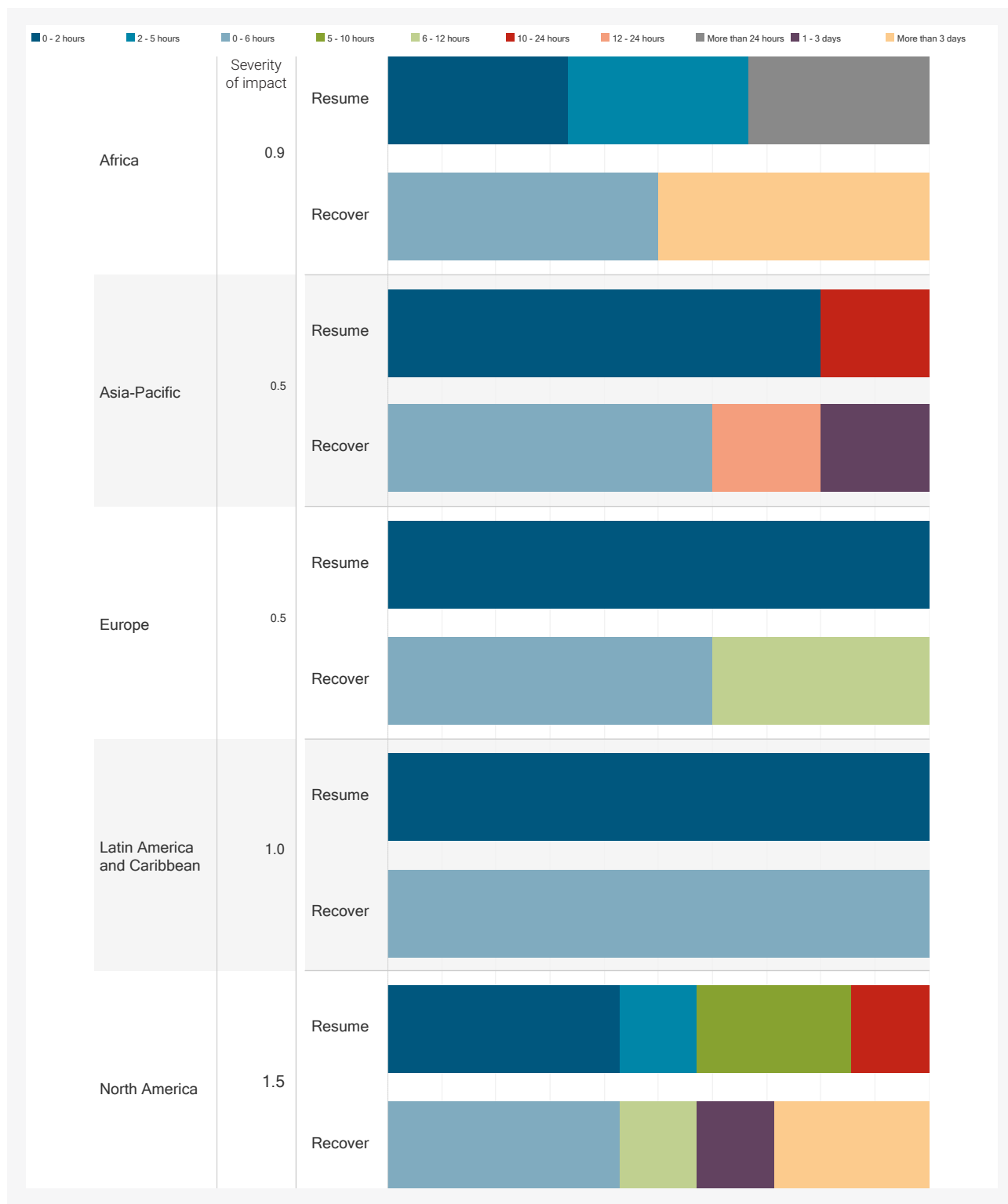


Figure - 26 Comparison of time taken to resume and recover from geo hazards

(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.

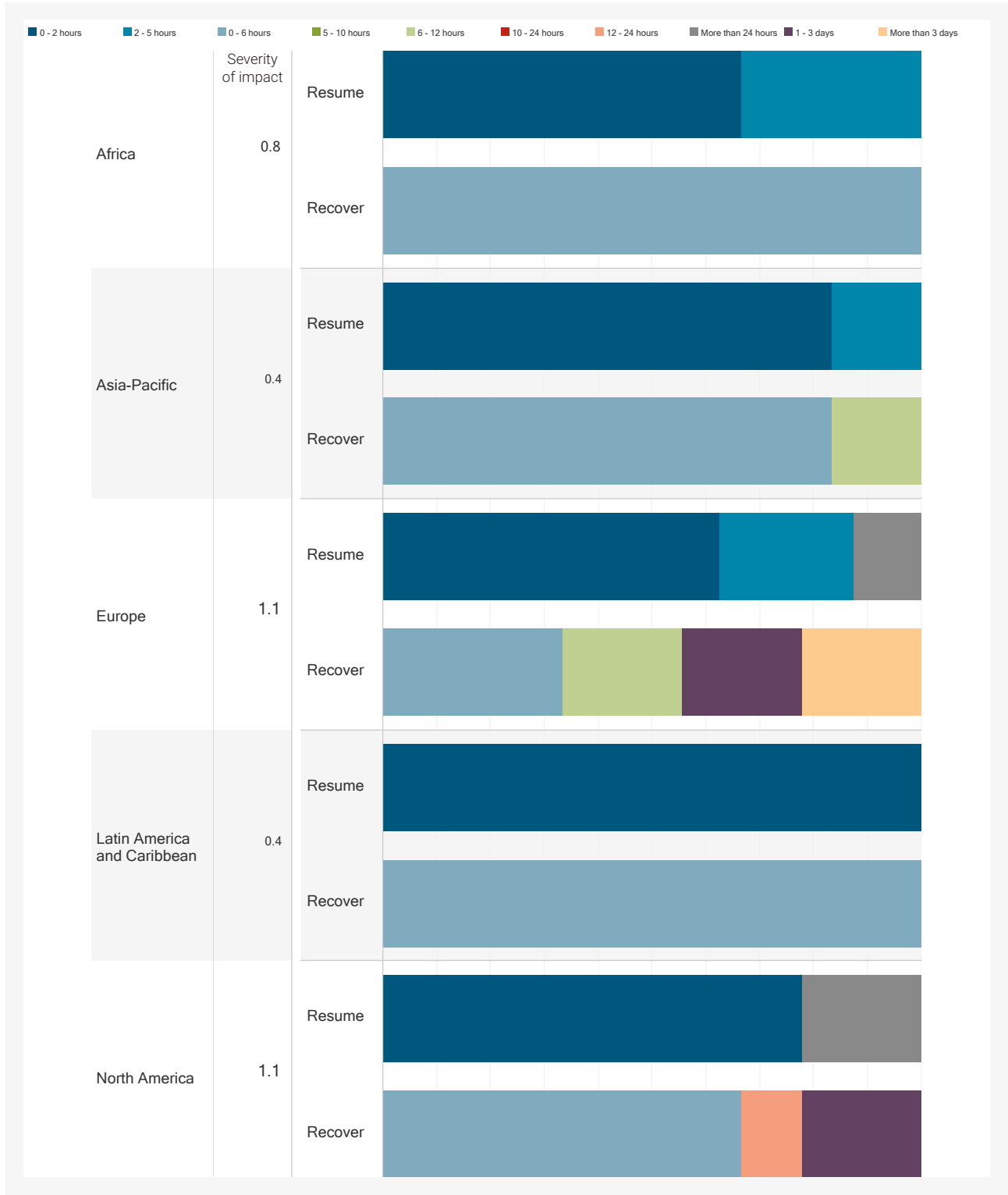


Figure - 27 Comparison of time taken to resume and recover from air quality
(Source : NACO analysis of Survey results)



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.

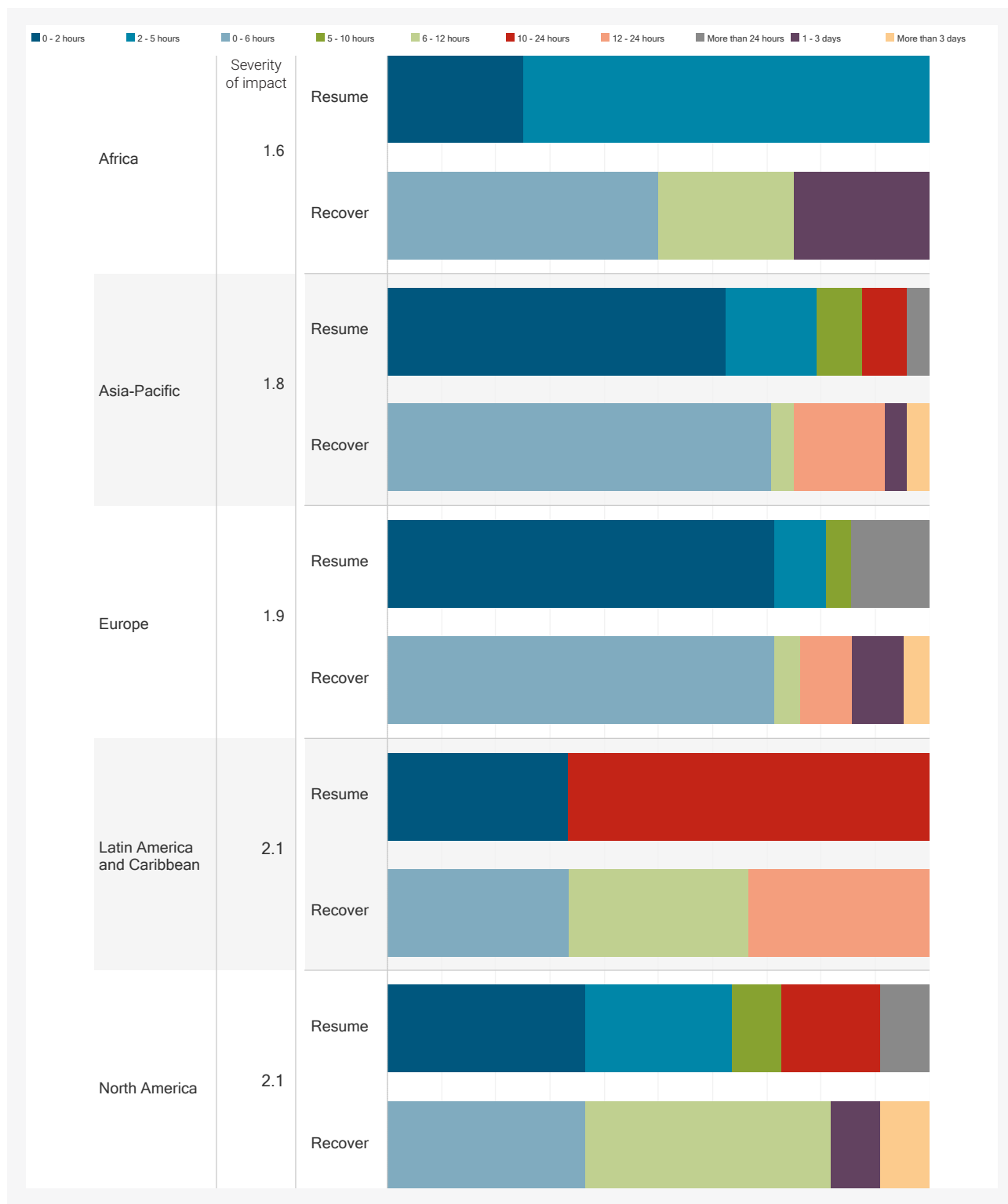


Figure - 28 Comparison of time taken to resume and recover from storms

(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.

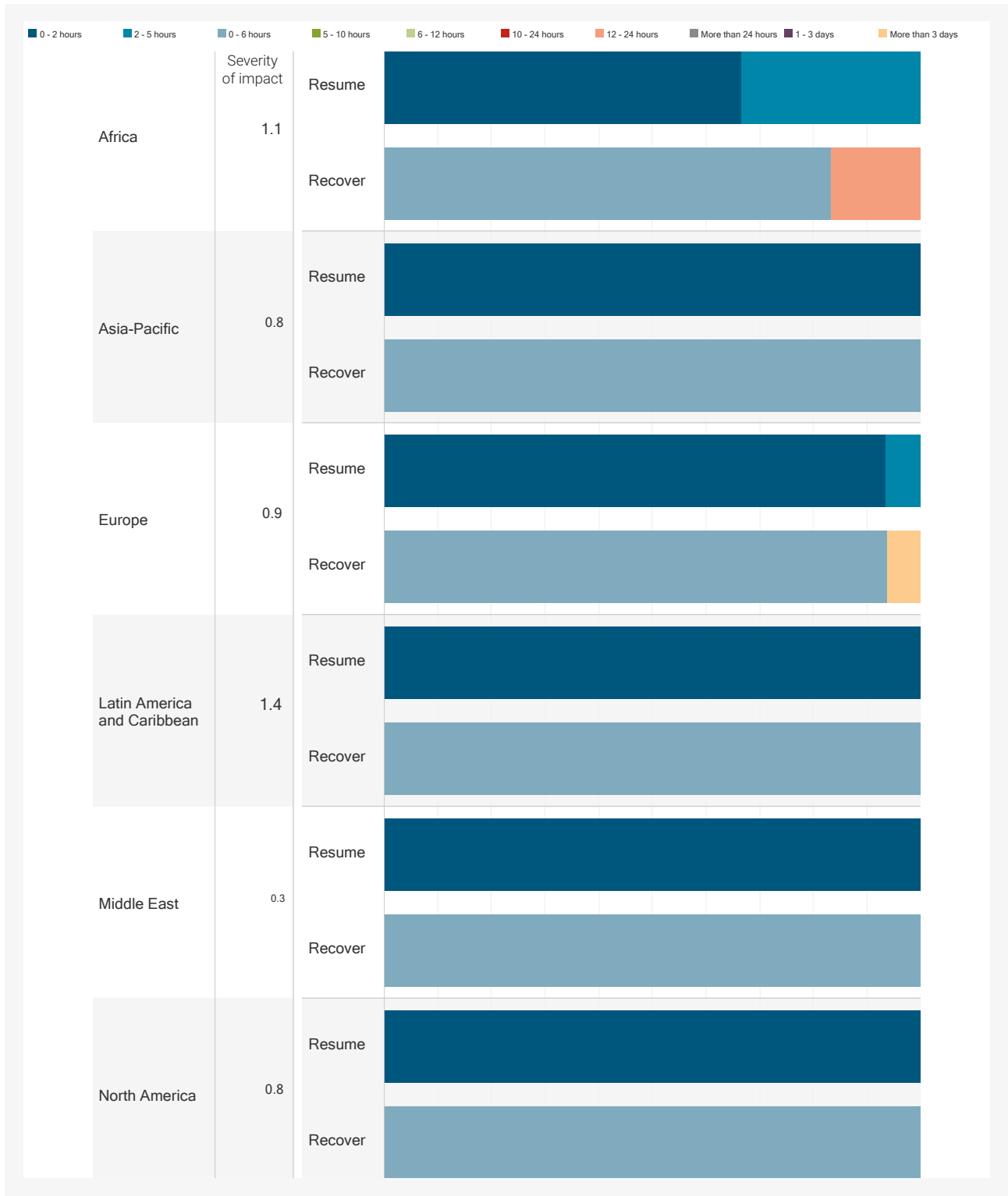


Figure - 29 Comparison of time taken to resume and recover from wildlife invasion

(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.

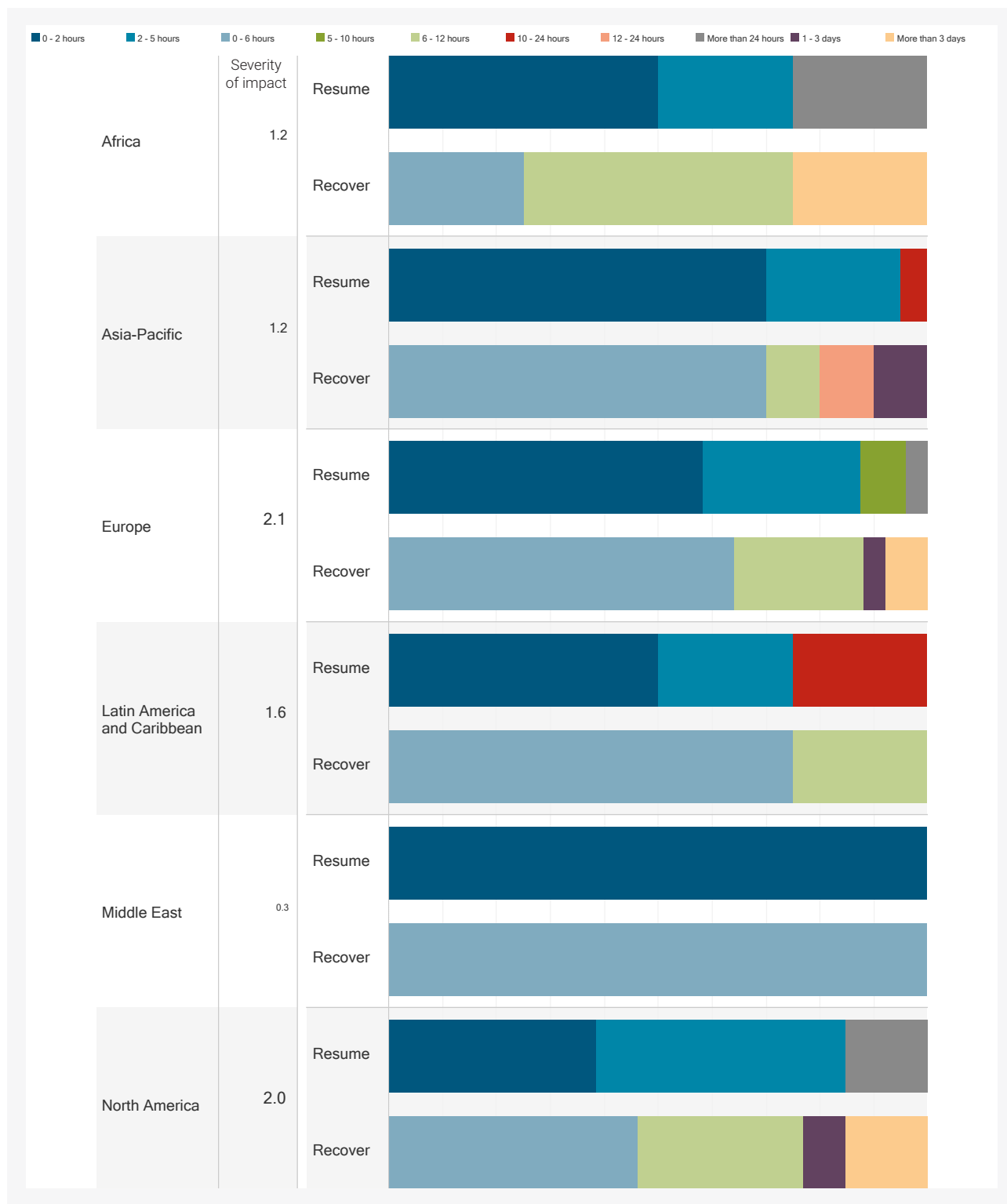


Figure - 30 Comparison of time taken to resume and recover from third-party equipment failure

(Source : NACO analysis of Survey results)



Extreme heat

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

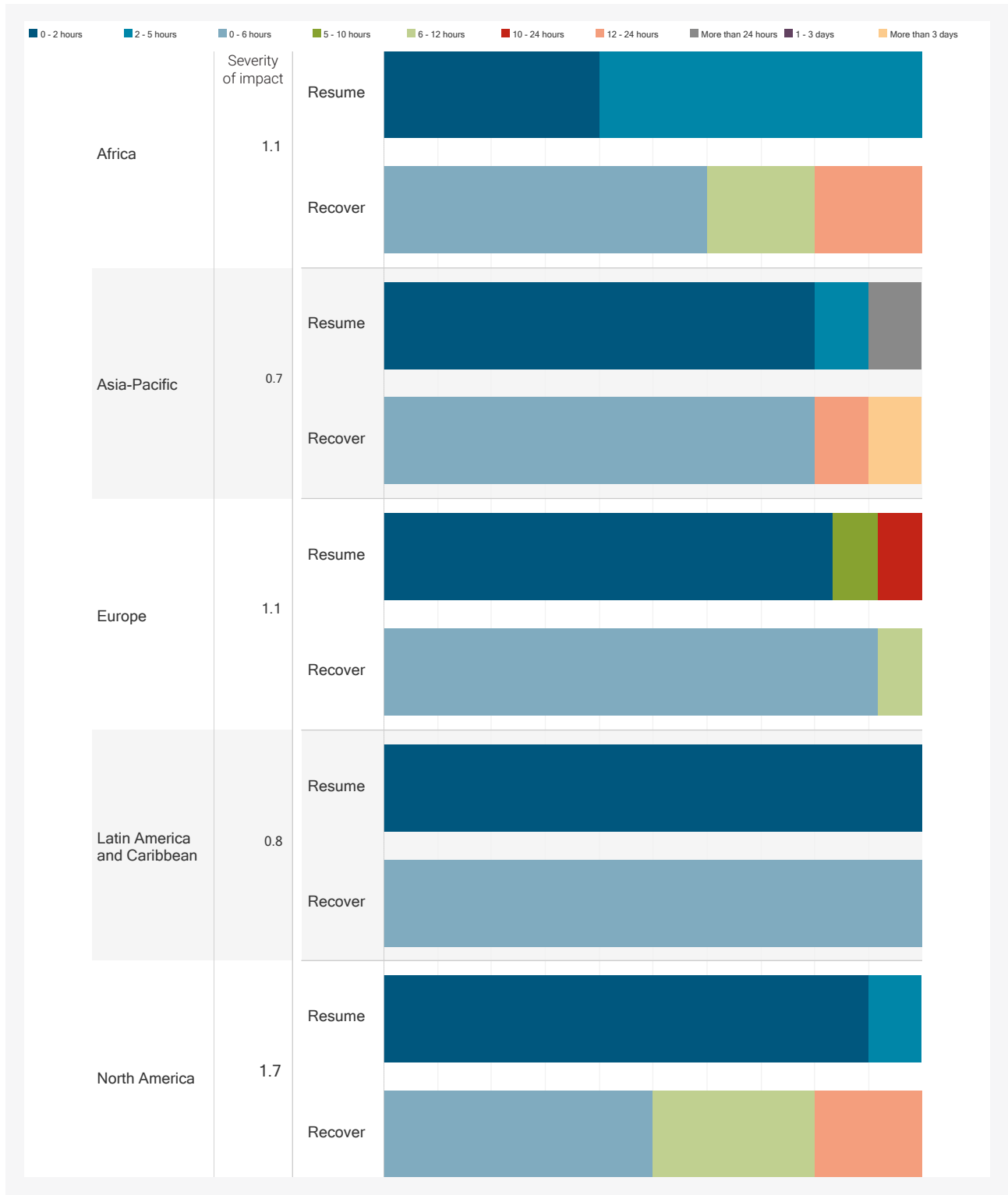


Figure - 31 Comparison of time taken to resume and recover from extreme heat

(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.

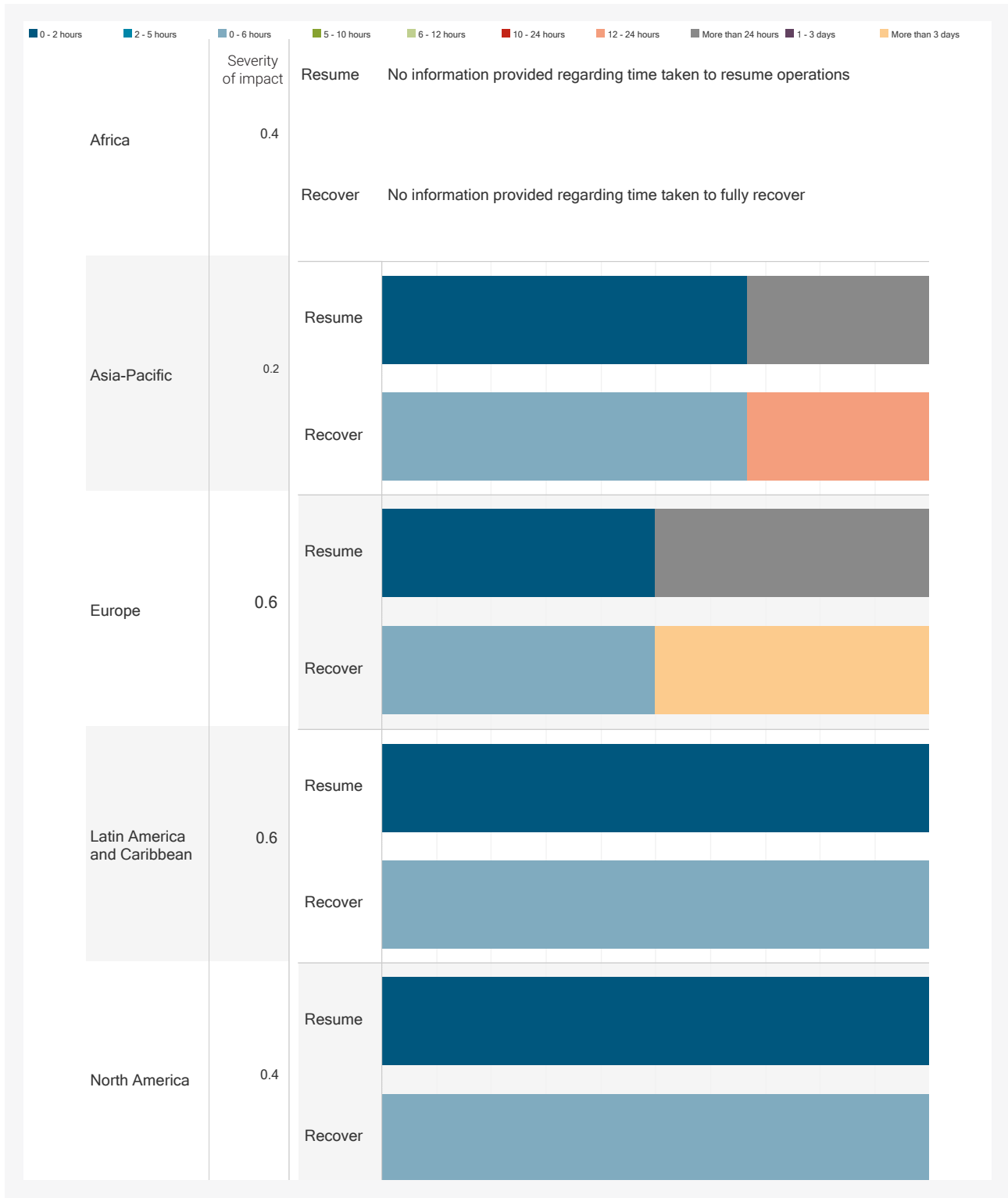


Figure - 32 Comparison of time taken to resume and recover from volcanic activity

(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.

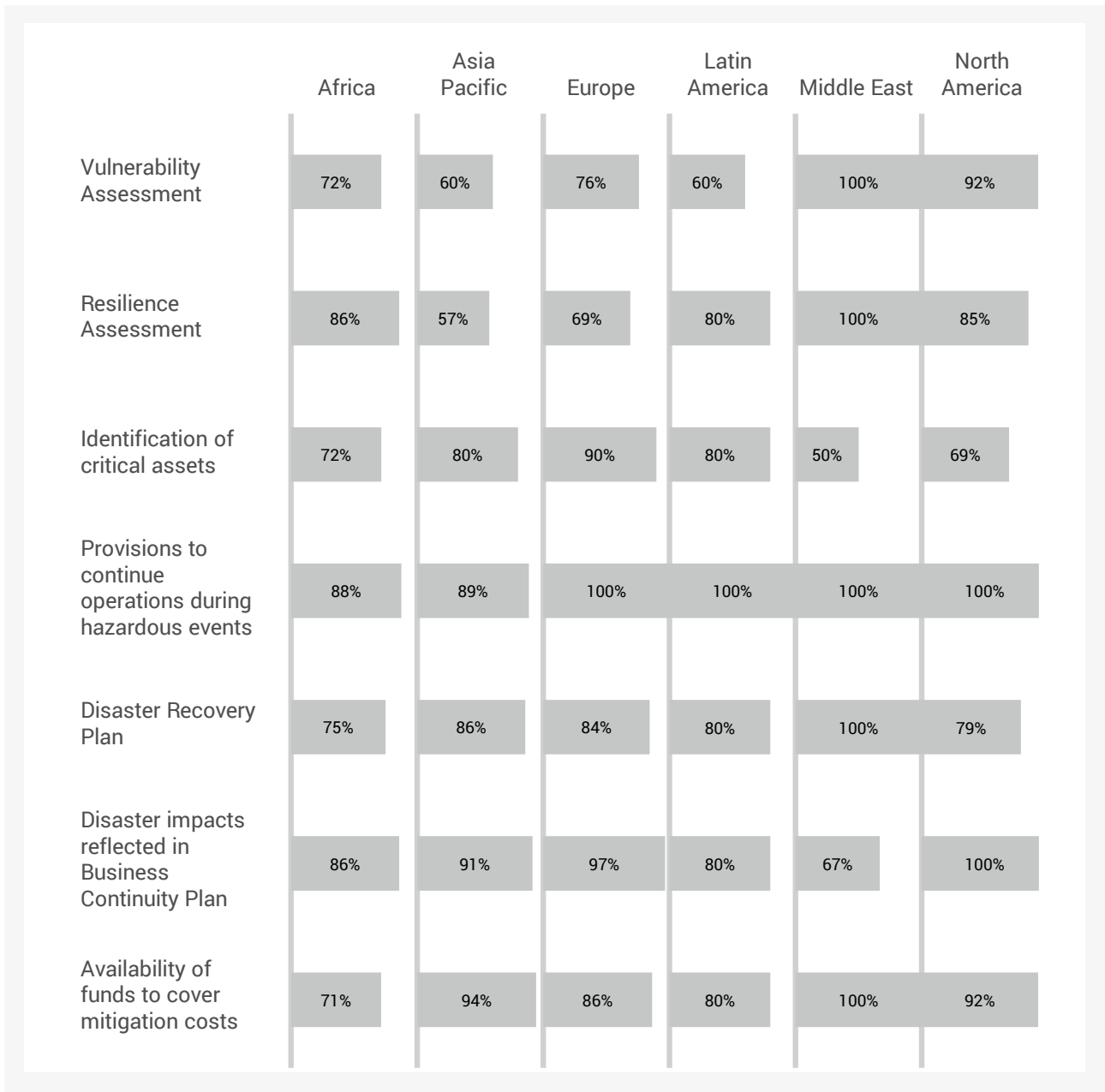




Figure - 33 Comparison of risk and resilience practices by region.

(Source : NACO analysis of Survey results)

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

 Baseline & Hazard Exposure

 Organizational Adaptive Capacity



3.5.6 Vulnerability Assessment Practice

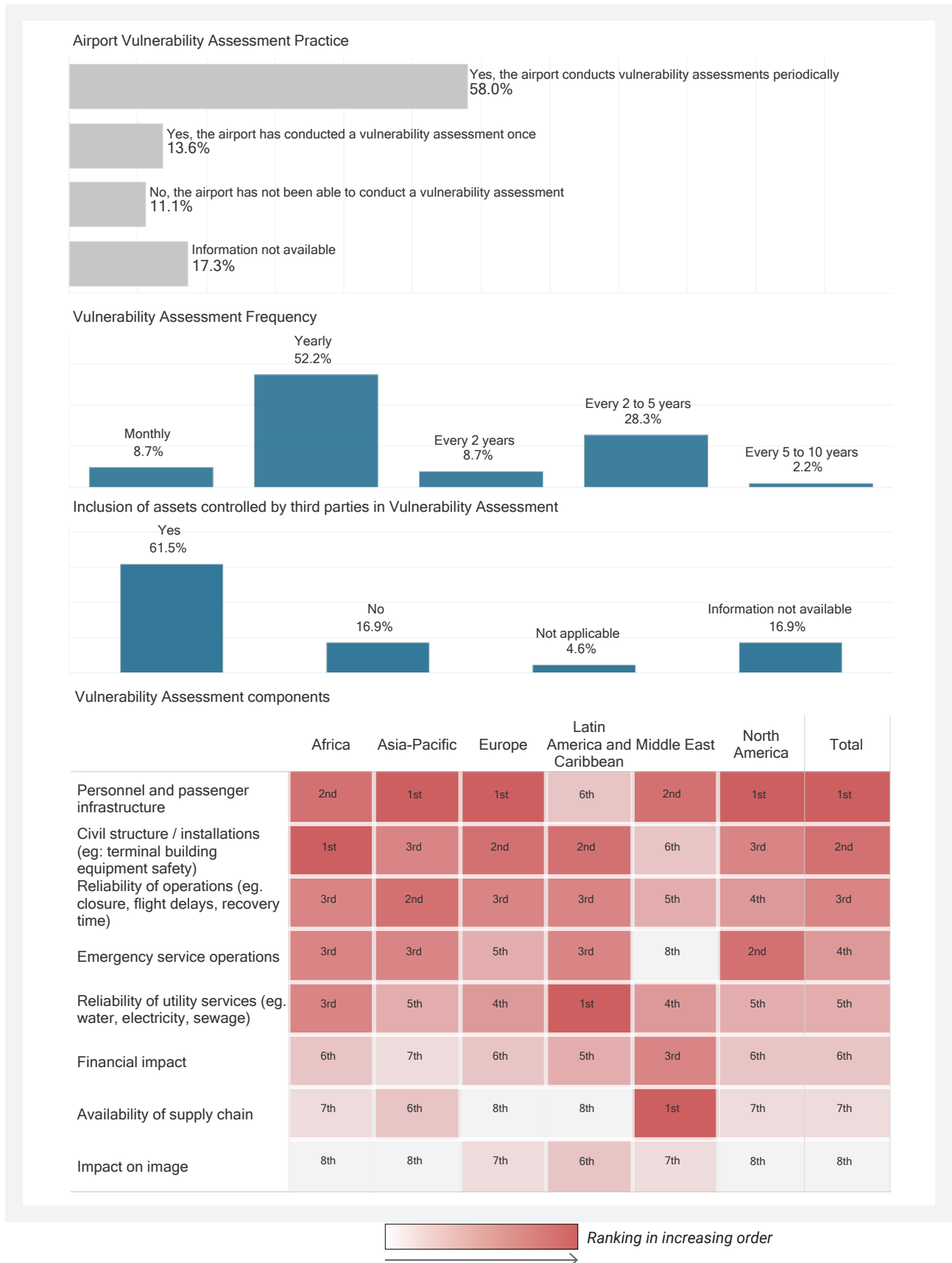


Figure - 34 Overview of Vulnerability Assessment Practices

(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.

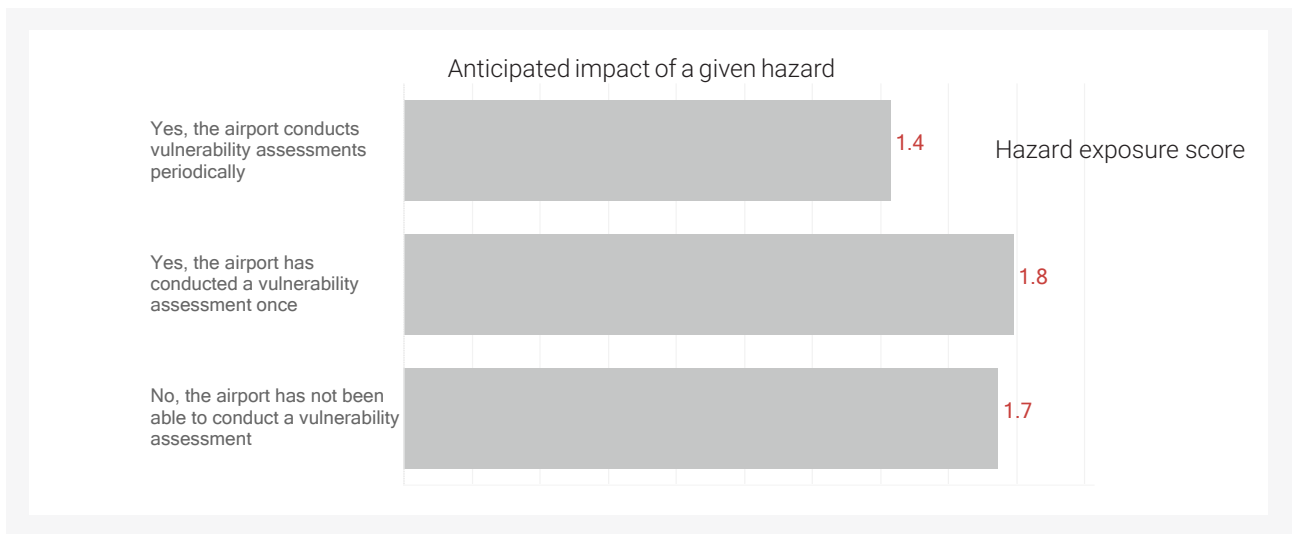


Figure - 35 Future hazard exposure vs vulnerability assessment practices

(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.



Baseline & Hazard Exposure



Organizational Adaptive Capacity



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 percentage of respondent airports from all regions, except Africa have a Disaster Recovery Plan

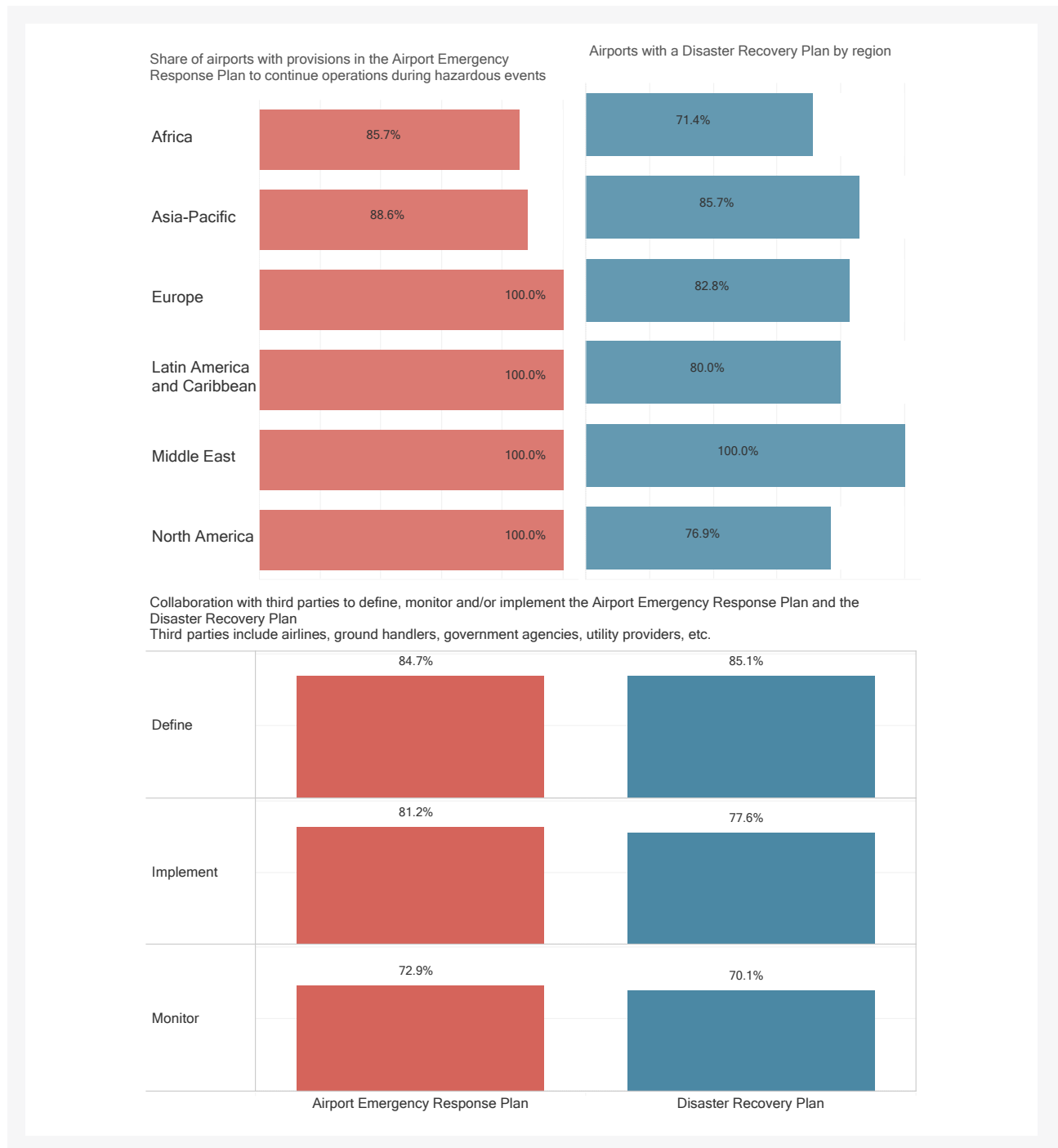


Figure - 36 Overview of Airport Emergency Response Planning and Disaster Recovery Planning practices.

(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.



Baseline & Hazard Exposure



Organizational Adaptive Capacity



3.5.9 Organizational Adaptive Capacity Overview

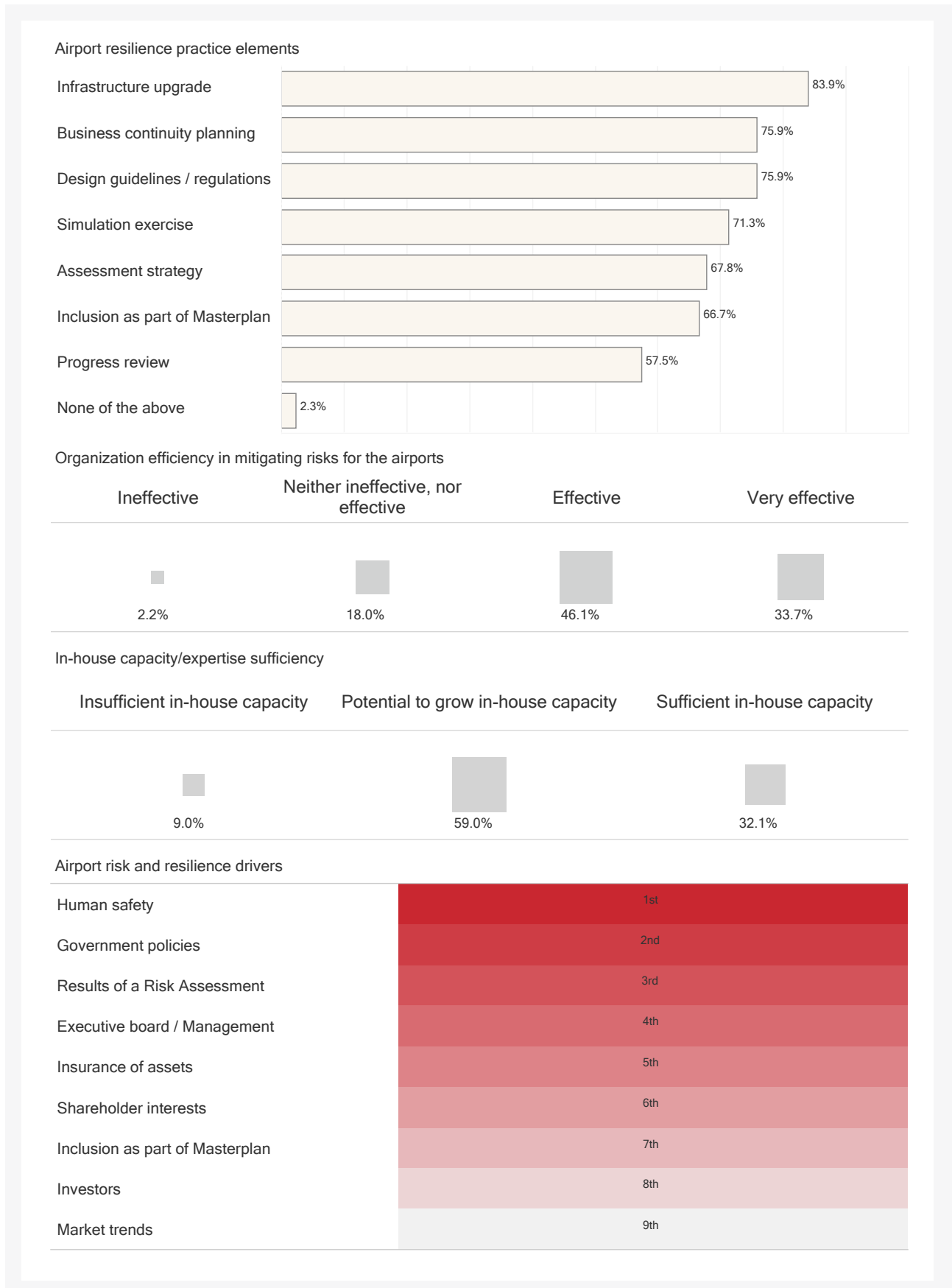


Figure - 37 Overview of Airport Resilience practices.

(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



Operational Adaptive Capacity



Organizational Adaptive Capacity



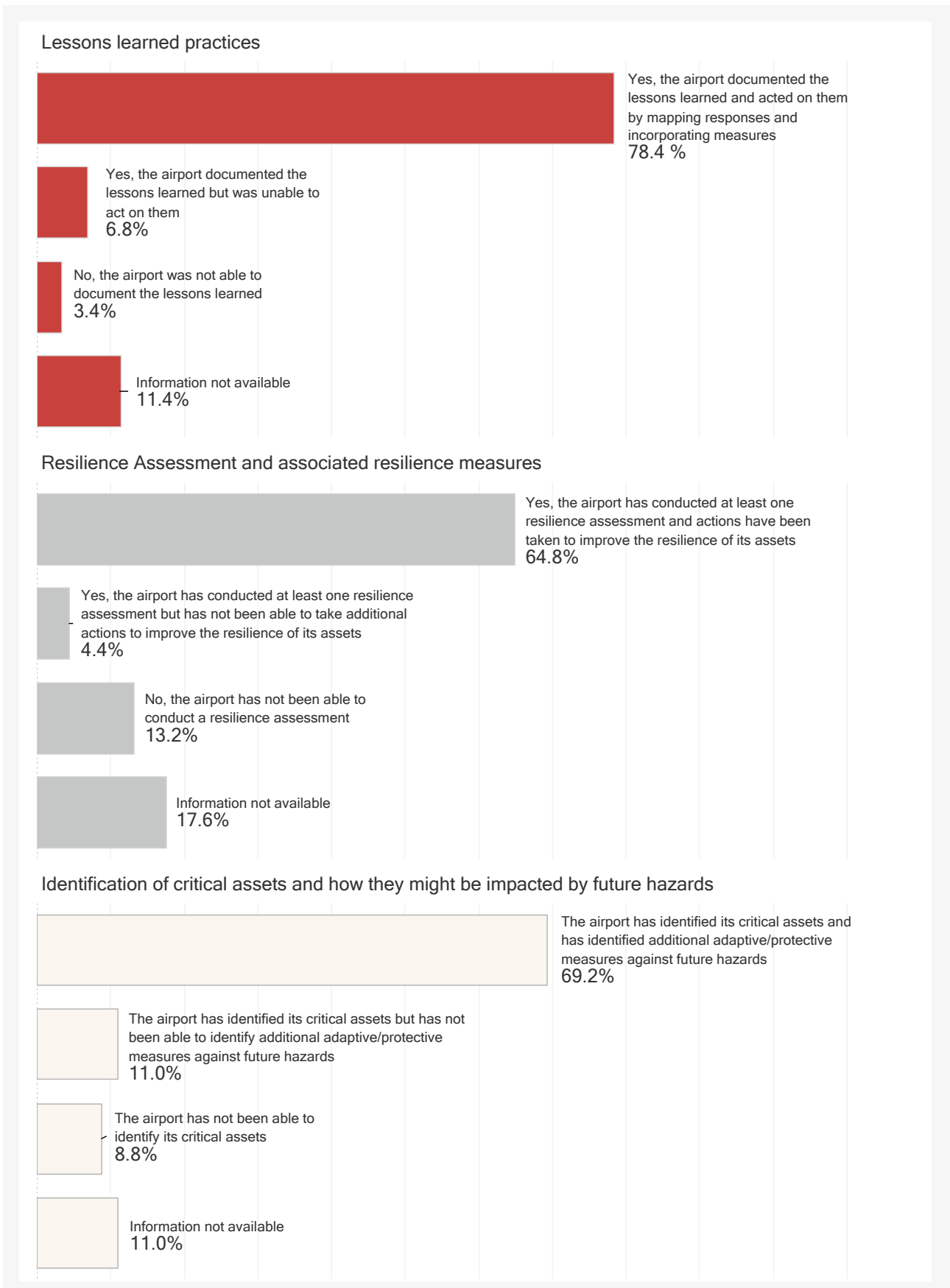


Figure - 38 Overview of Airport Resilience Practices (Lessons learned and resilience measures)

(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 percentage of the airports have conducted a resilience assessment atleast once and have consequently taken action to improve the resilience of its assets. Further, 69.2 percentage 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 percentage 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.



At organizations with effective practices, the indicated resilience practice drivers are:

- 1. Executive board / management,**
- 2. The results of a risk assessment,**
- 3. Government policies**

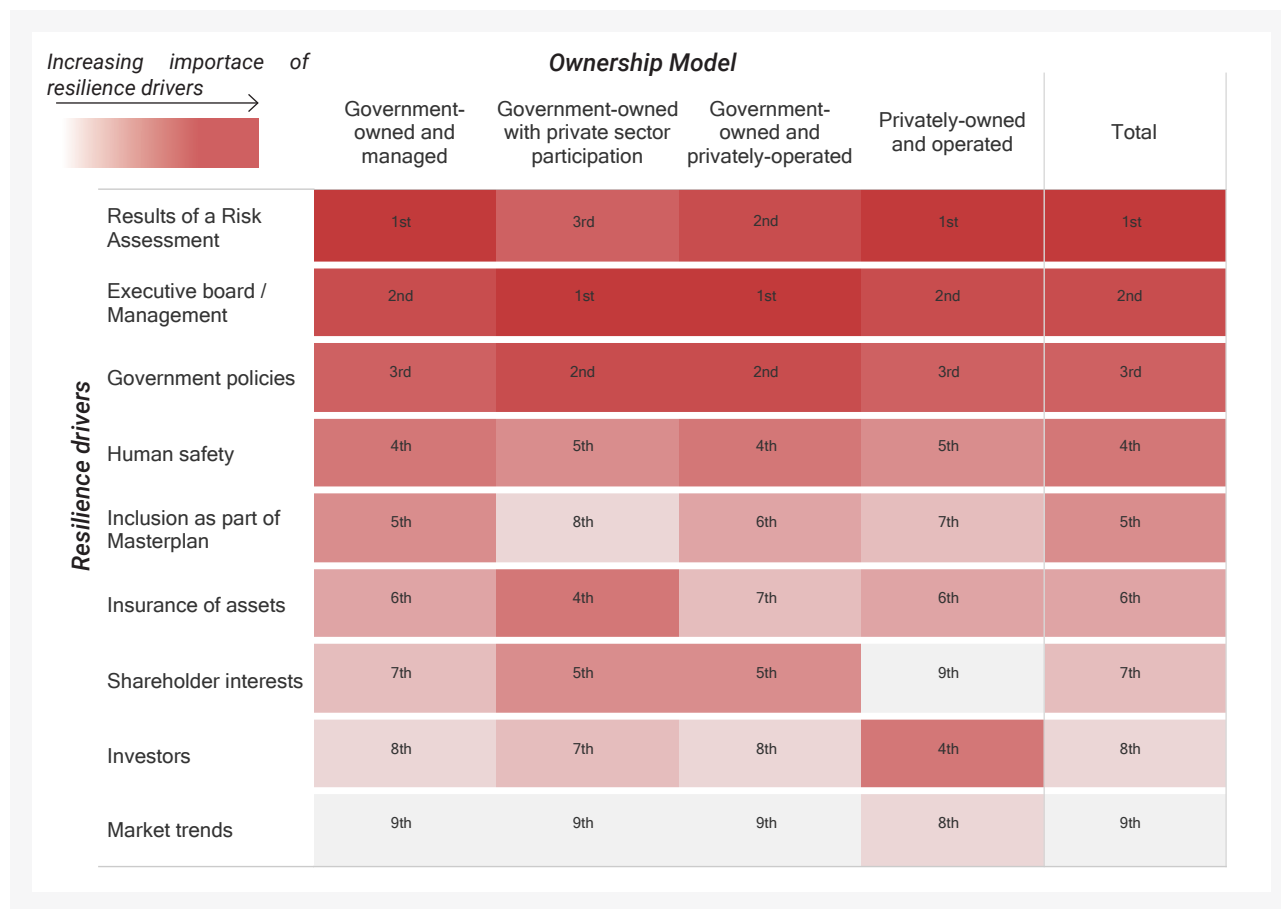


Figure - 39 Ranking resilience drivers by Ownership model.

(Source : NACO analysis of Survey results)



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.

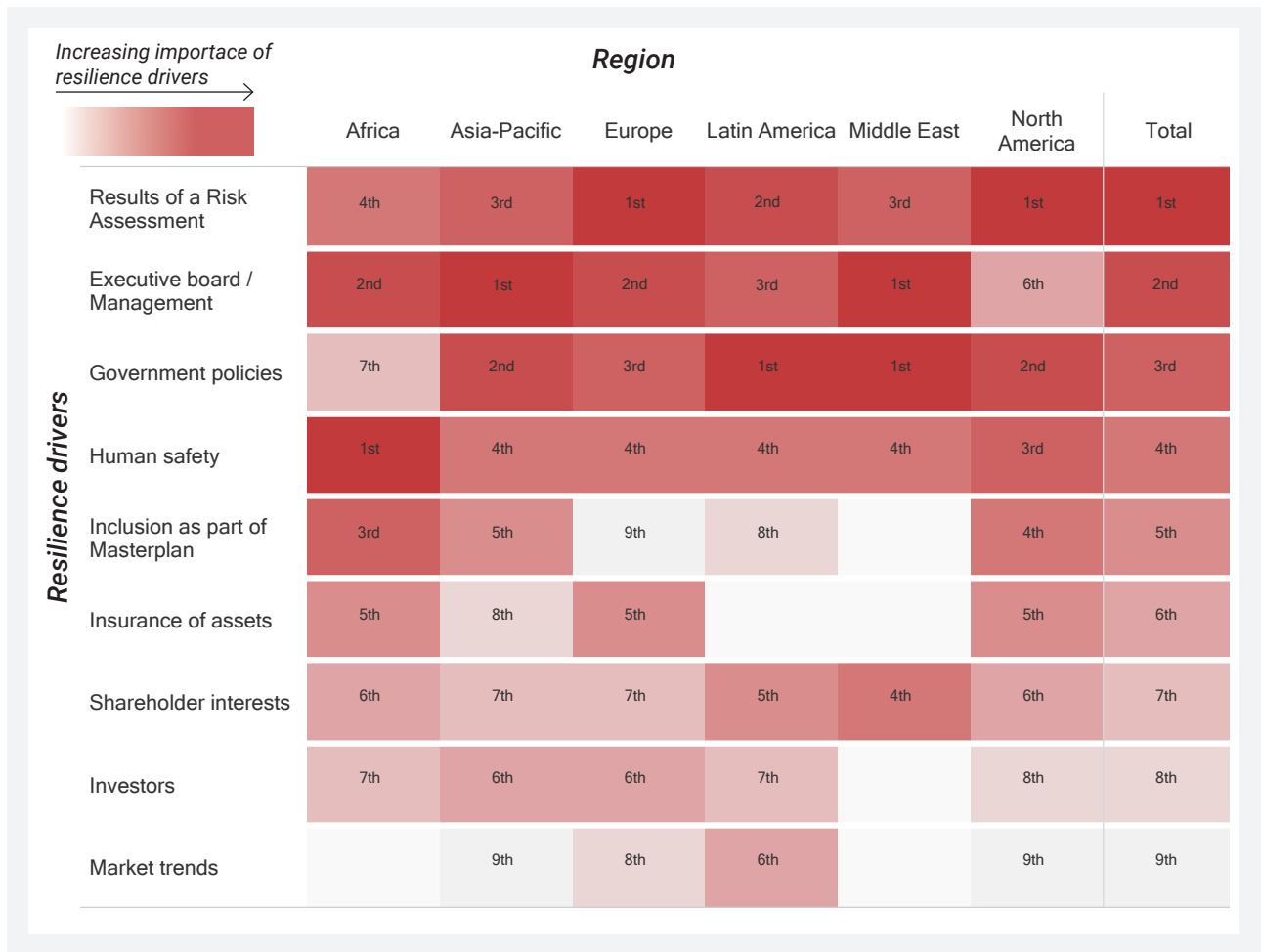


Figure - 40 Ranking resilience drivers by Region.

(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.

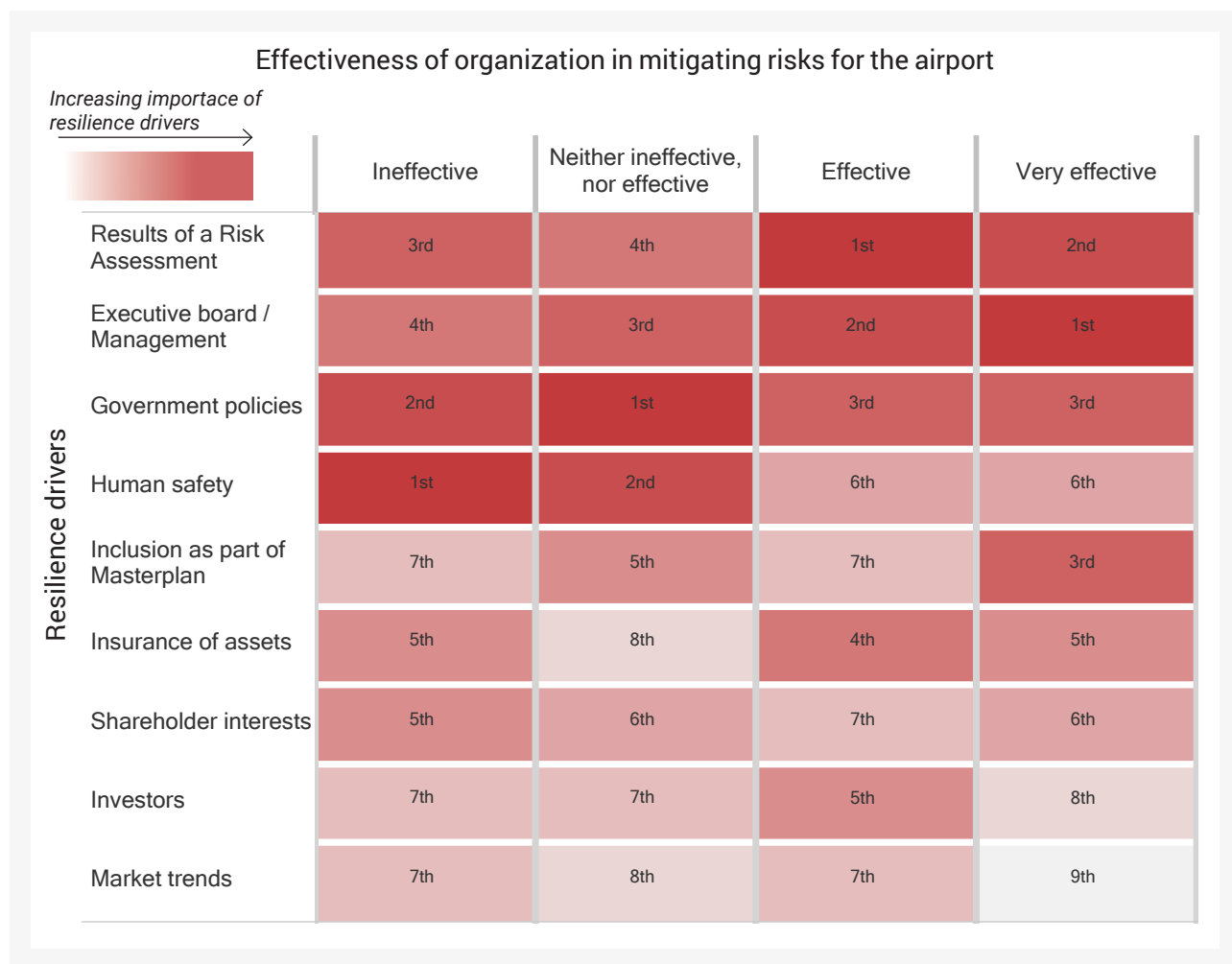


Figure - 41 Ranking resilience drivers by effectiveness of organization in mitigating risk for the airport.

(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**

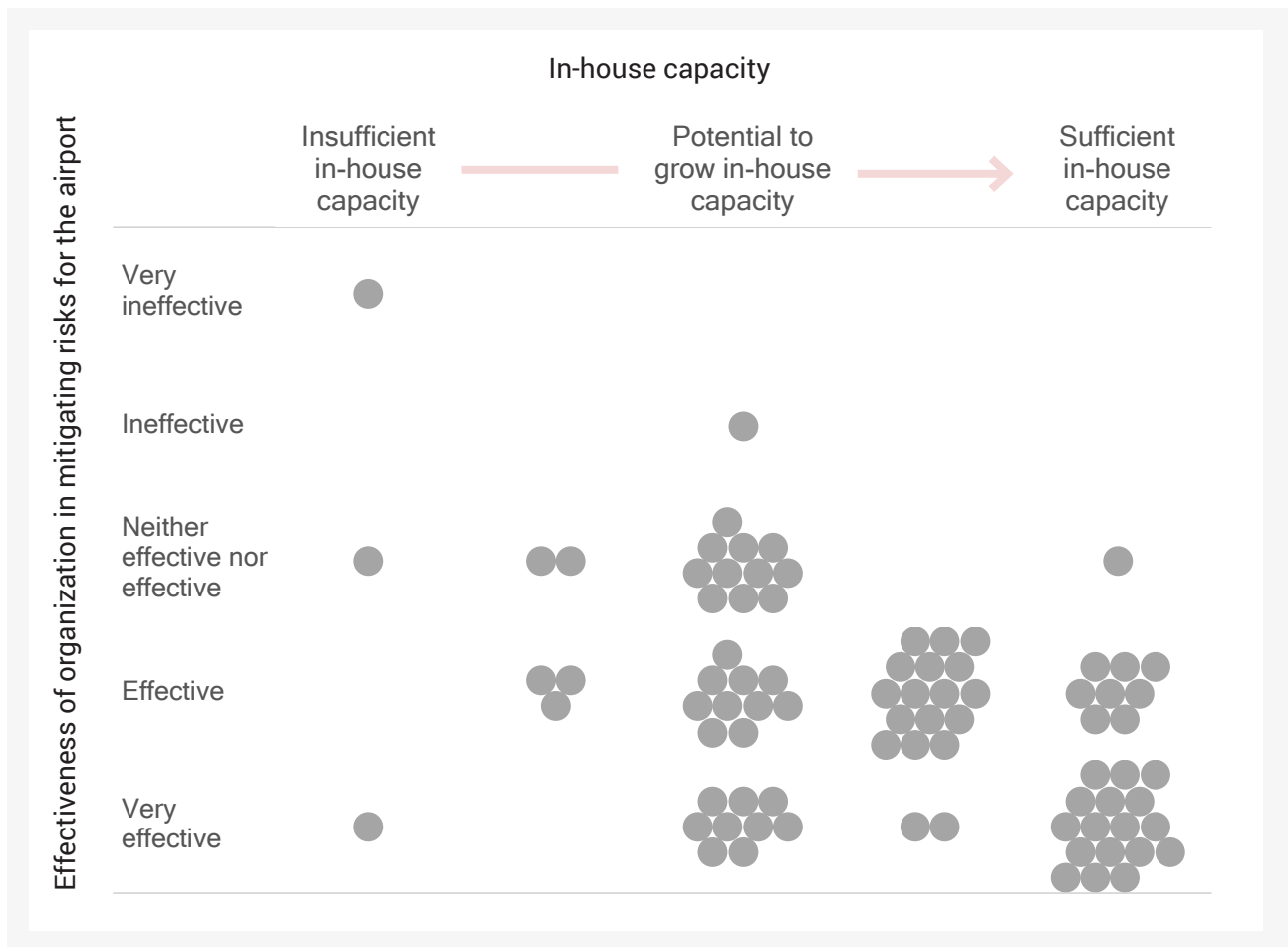


Figure - 42 Effectiveness of organization in mitigating risks for the airport vs the availability of In-house capacity.

(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.

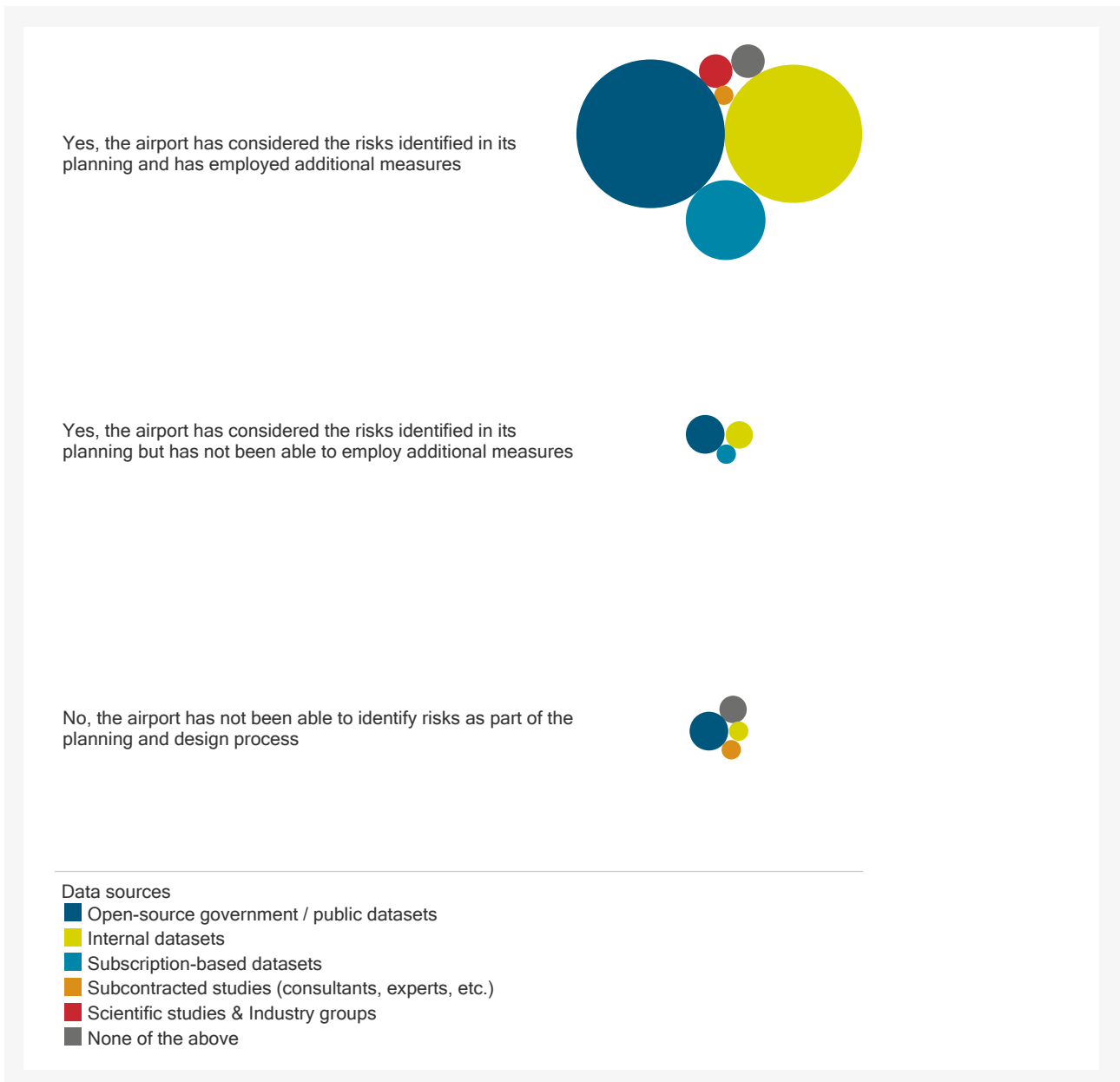


Figure - 43 Overview of data availability for airports vs their risk mitigation practices

(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.



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.

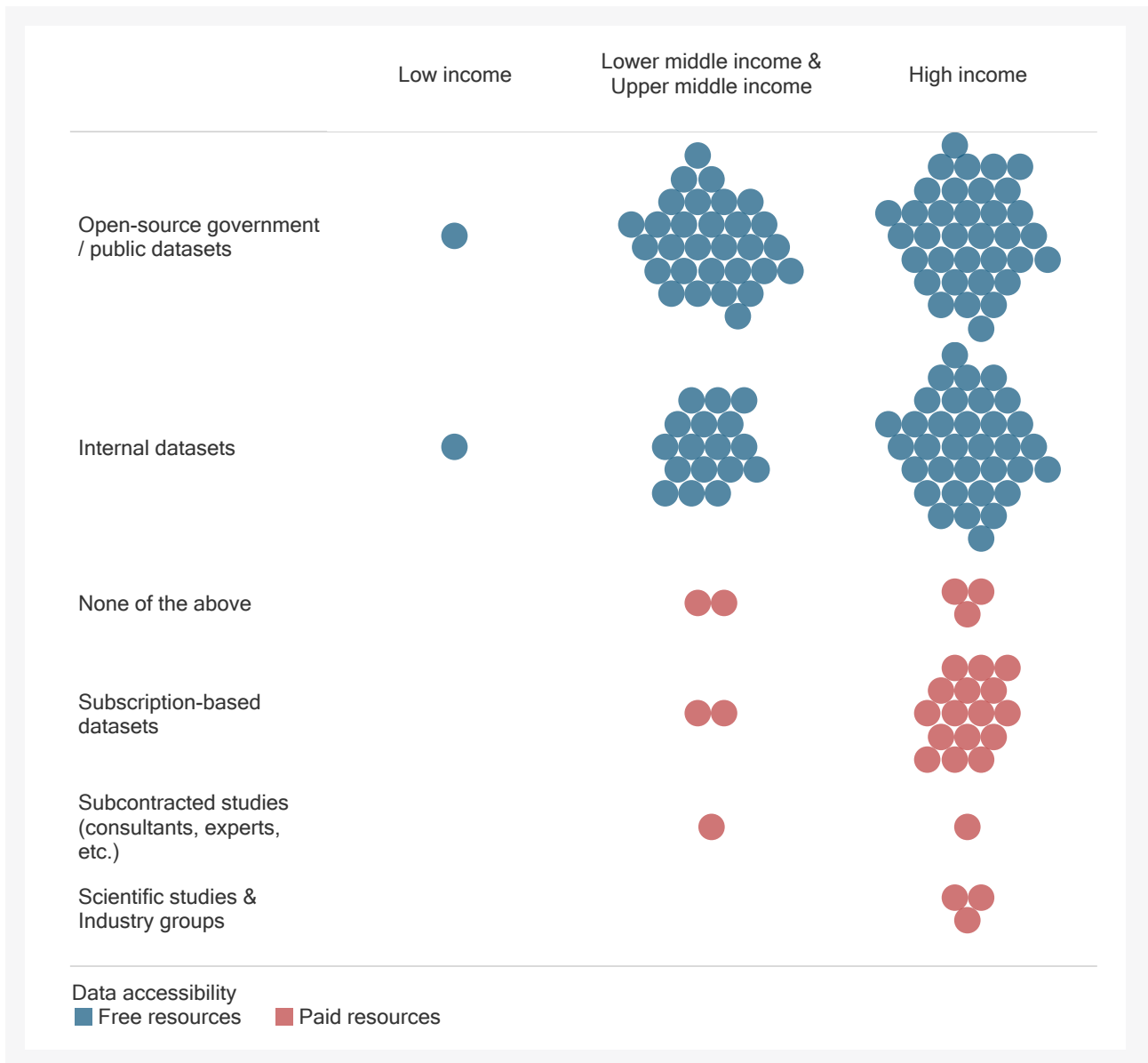


Figure - 44 Access to datasets vs economic profile of the airport’s country

(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)



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.



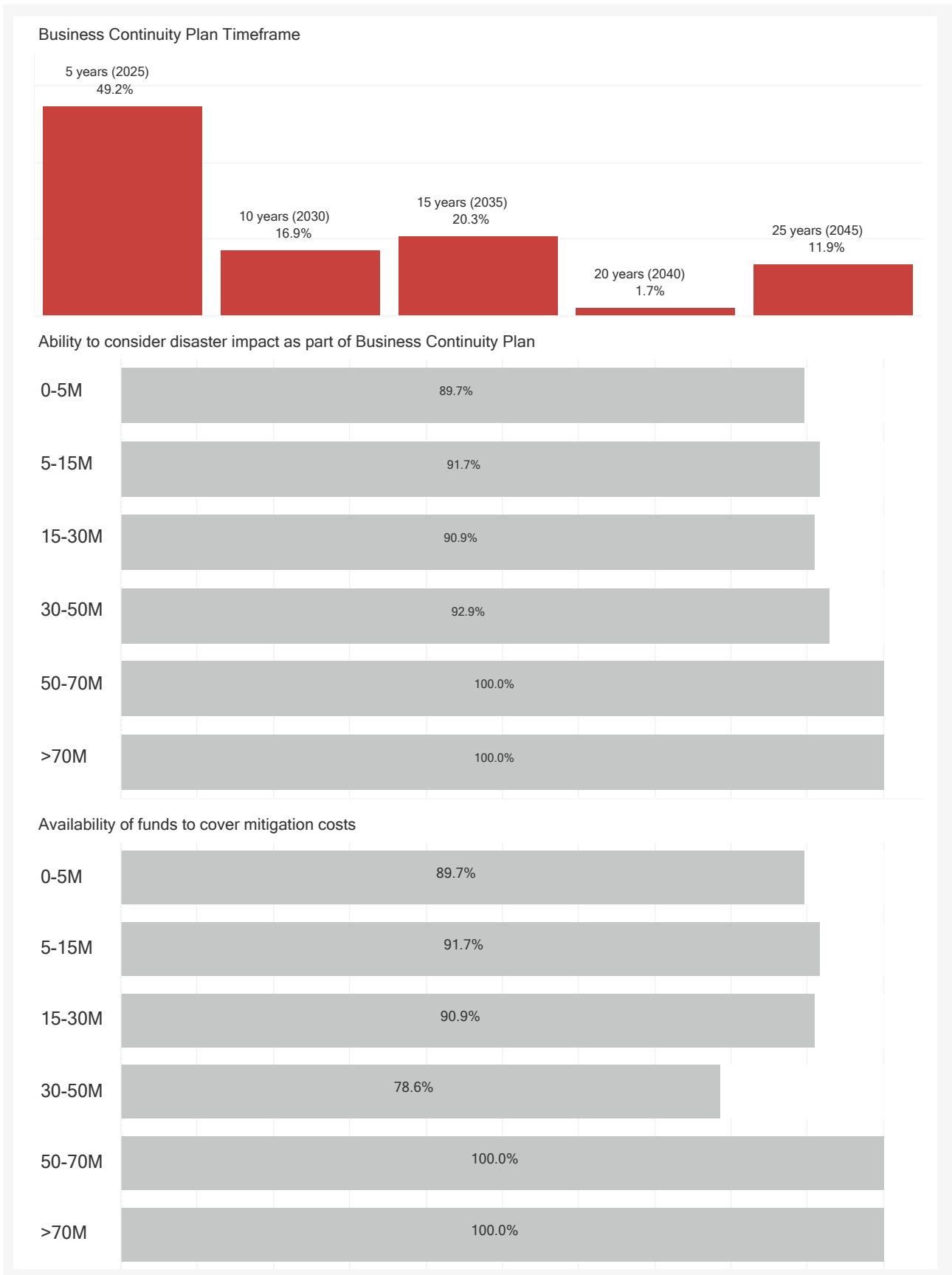


Figure - 46 Overview of Business Continuity Plans and the inclusion of resilience practices.

(Source : NACO analysis of Survey results)



3.6 Mitigation and Protection Measures

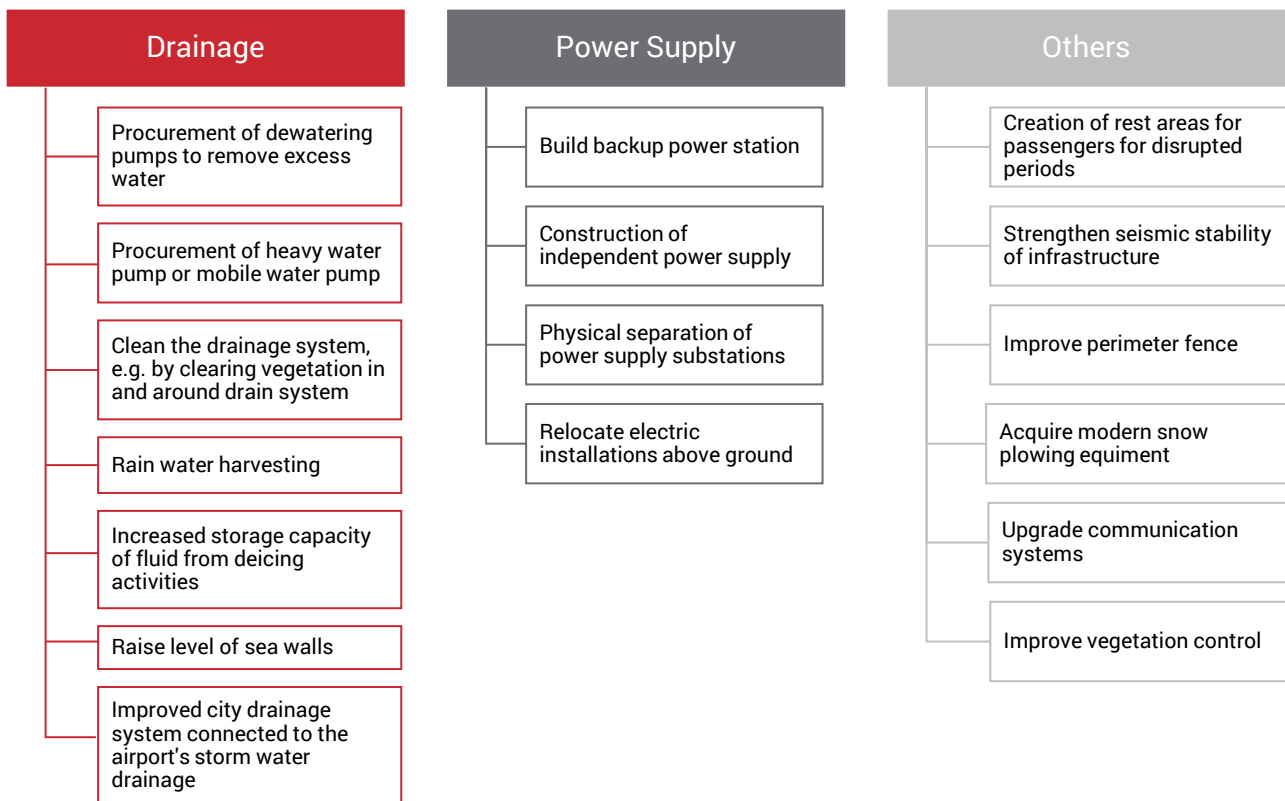
Mitigation Measures

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



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

a) Infrastructure



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



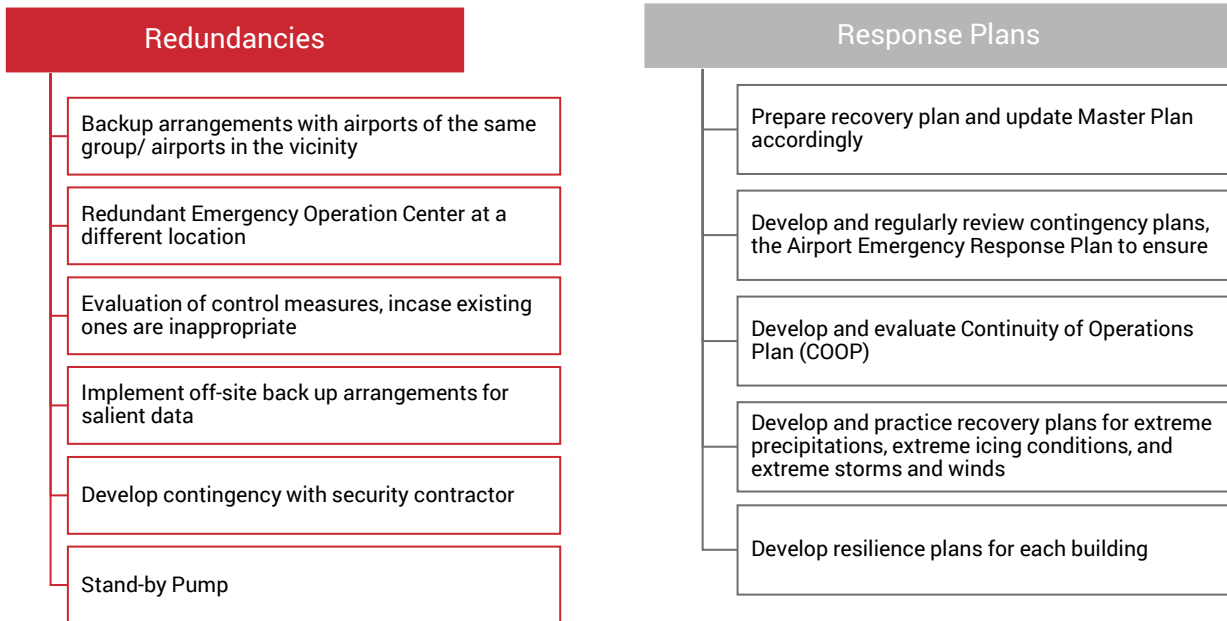
Infrastructural Adaptive Capacity



Operational Adaptive Capacity



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



Organizational Adaptive Capacity

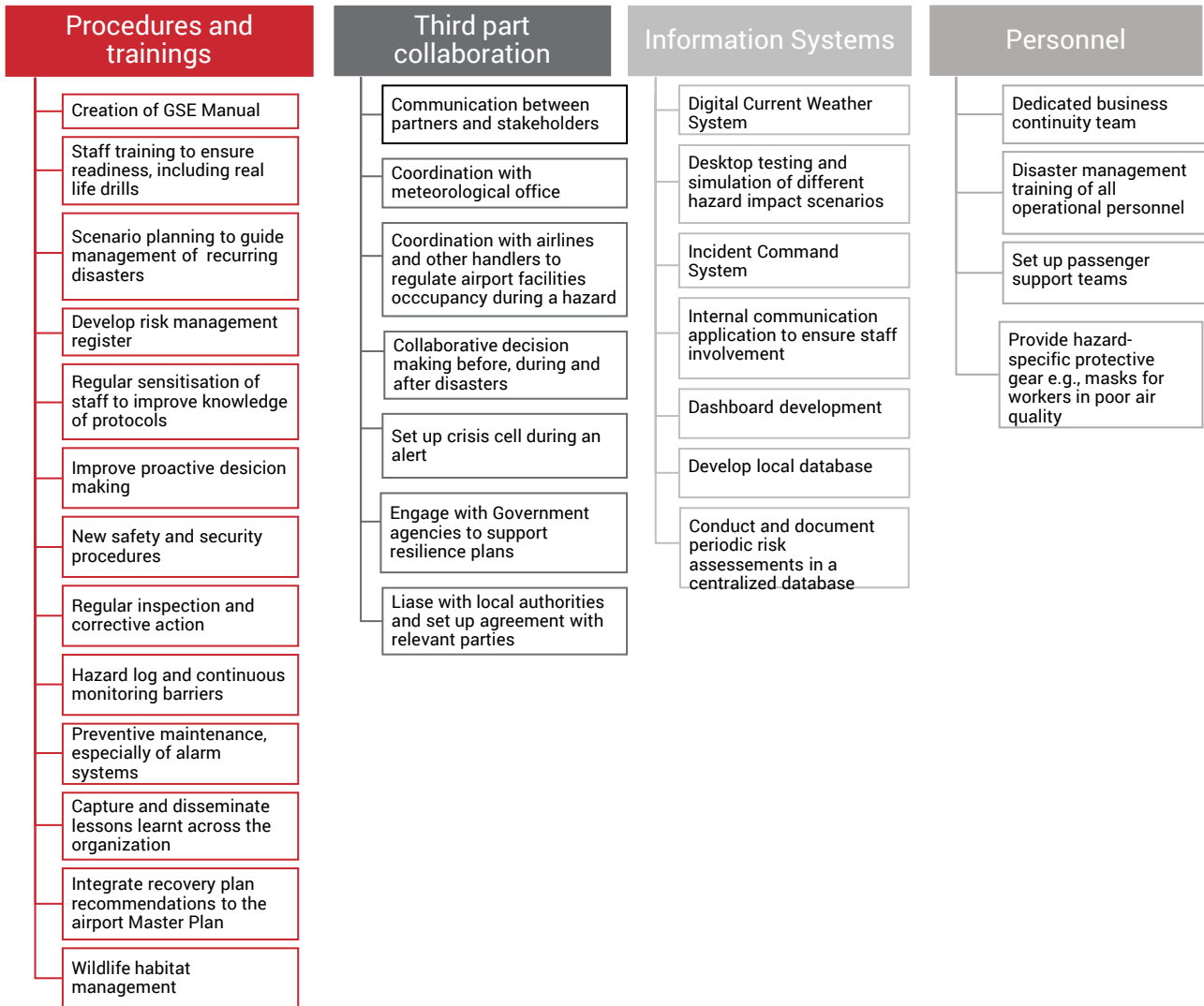


Operational Adaptive Capacity





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



Organizational Adaptive Capacity



Operational Adaptive Capacity



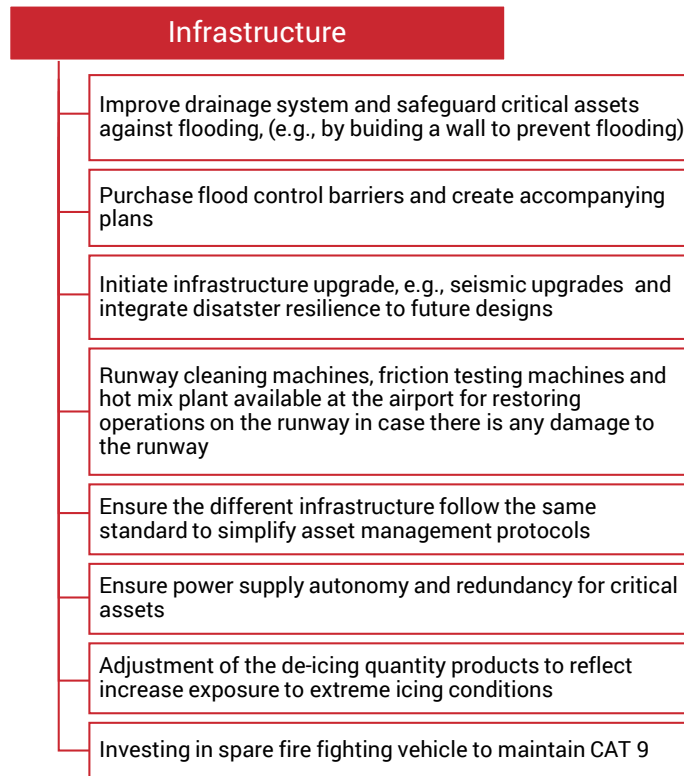
Protective Measures for Critical Assets

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



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.



Operational Adaptive Capacity



Infrastructural Adaptive Capacity



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

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, incase 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.

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



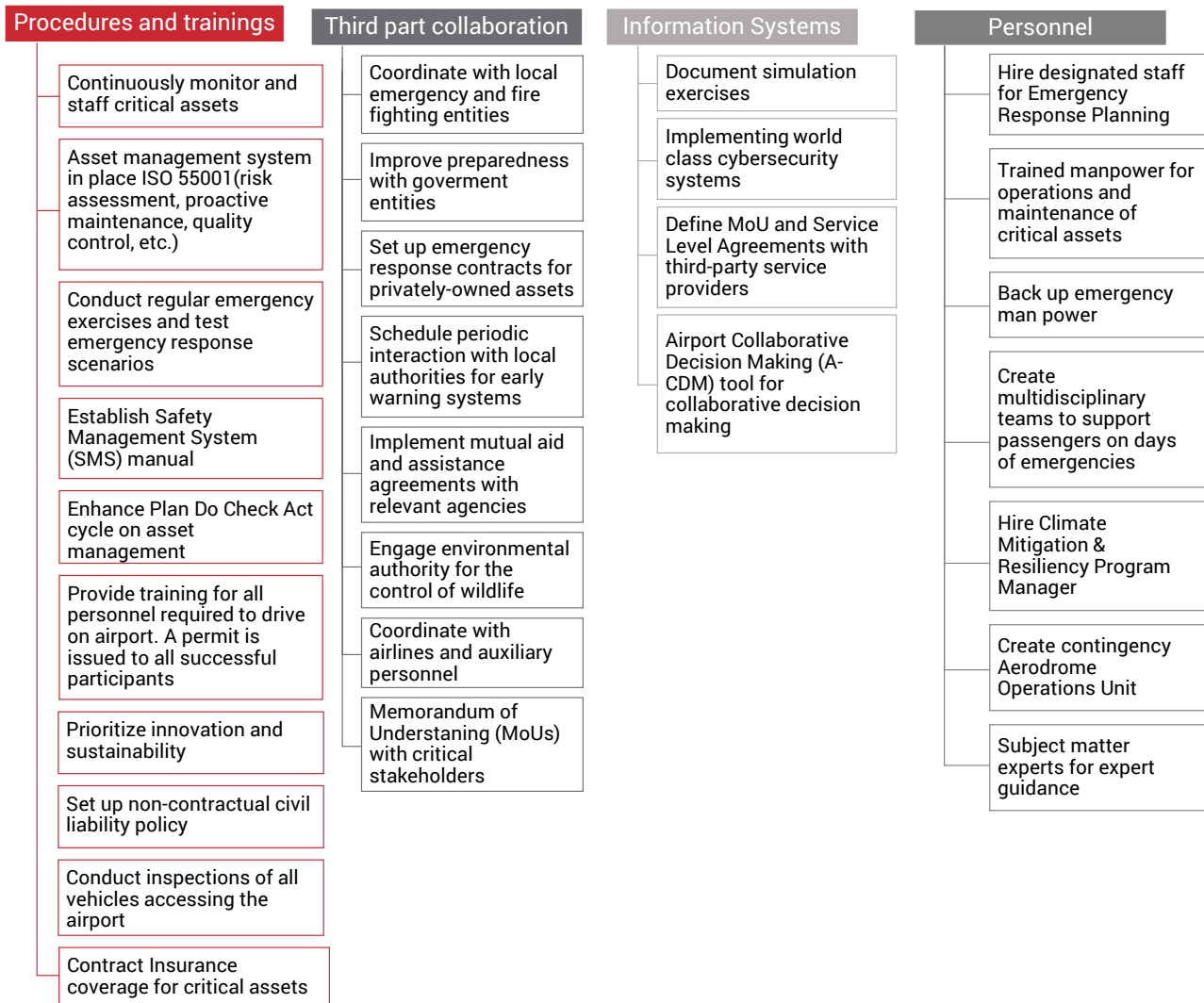
Protective measures relating to operations follow three rationales:

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 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.

- Organizational Adaptive Capacity
- Operational Adaptive Capacity



Key policies or efforts that can be undertaken by the industry and government authorities, to improve the resilience of airports

Authorities and Regulatory Bodies	Appoint national level expert group or task force for knowledge sharing and advisory for existing policies and updating the civil aviation regulation (CAR)
	Mandatory dedicated department for emergency and resilience management
	Resilience planning costs should be calculated under aeronautical expense
	Standardisation of policies for resilience of airports, local guidelines / regulations for resilience
	Improvement of land-use planning around airports
	Financial support from government / federal transport or infrastructure grants
	Government to provide response infrastructure e.g.: early warning system, evacuation guidance
	Update design standards as per IPCC global climate scenarios
	Show flexibility in regulations and implementation of new policies at the time of a disaster event
	Address cyber crime
	Improve definitions and more precise regulatory roles and responsibilities for various stakeholders
Organization	Ensure airport staff, tenants and stakeholders have necessary resources for safety management and response, including training
	Conduct regular drill exercises and inspections
	Emphasize scenario-planning as part of disaster mitigation plans, include previous lessons learned in the designs and plans
	Process automation and adaptation to new technologies to reduce downtime of services
	Conduct periodic assessment and identify risks
	Collaborate with external stakeholders during the development phase
	Improvement of facilities, disaster-related fund releases, and risk assessment matrices
Industry and Institutions	Conduct research on impact of climate change on major international airports
	Develop a resilience action plan and adaptation plan for airports with defined timelines and monitoring methodologies for the next 10 to 20 years
	Joint forums and planning activities
	Create standards and models
	ACI and ICAO to engage more actively to share best practices and knowledge
	Mandatory resilience training
	Shared database of lessons learned after disaster impact



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.





4

FOCUS GROUP DISCUSSION

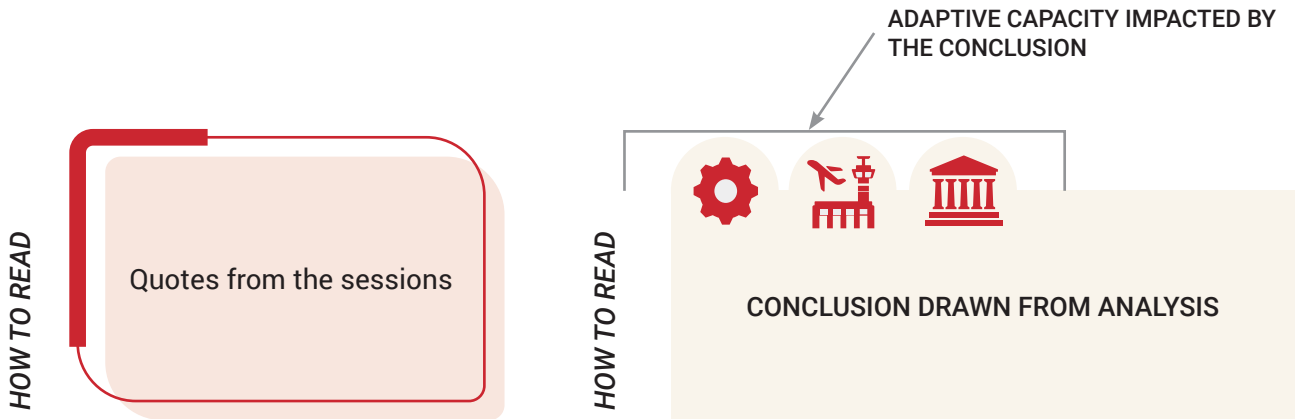
- 4.1. Methodology
- 4.2. Data Collection
- 4.3. Data Analysis and Results

09



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.

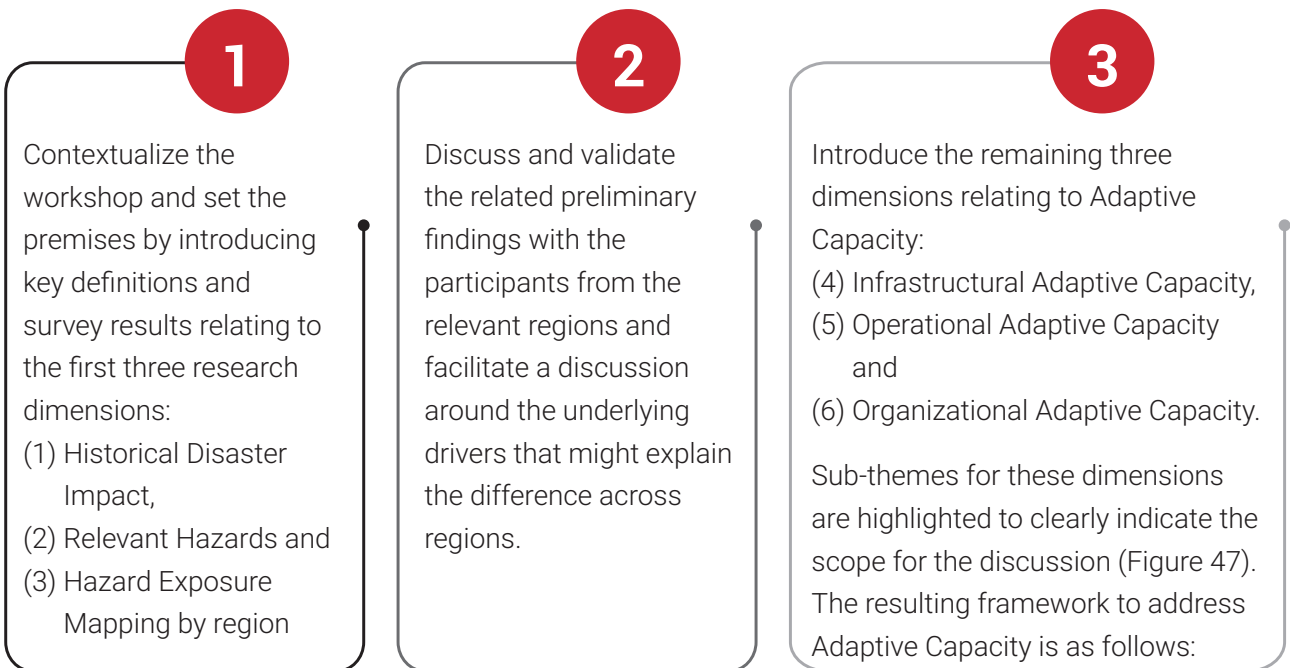
The content of each workshop is informed by the following considerations:





This content was then tailored to capture participants expectations for each workshop.

The workshop was organized as follows:



Adaptive Capacity

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

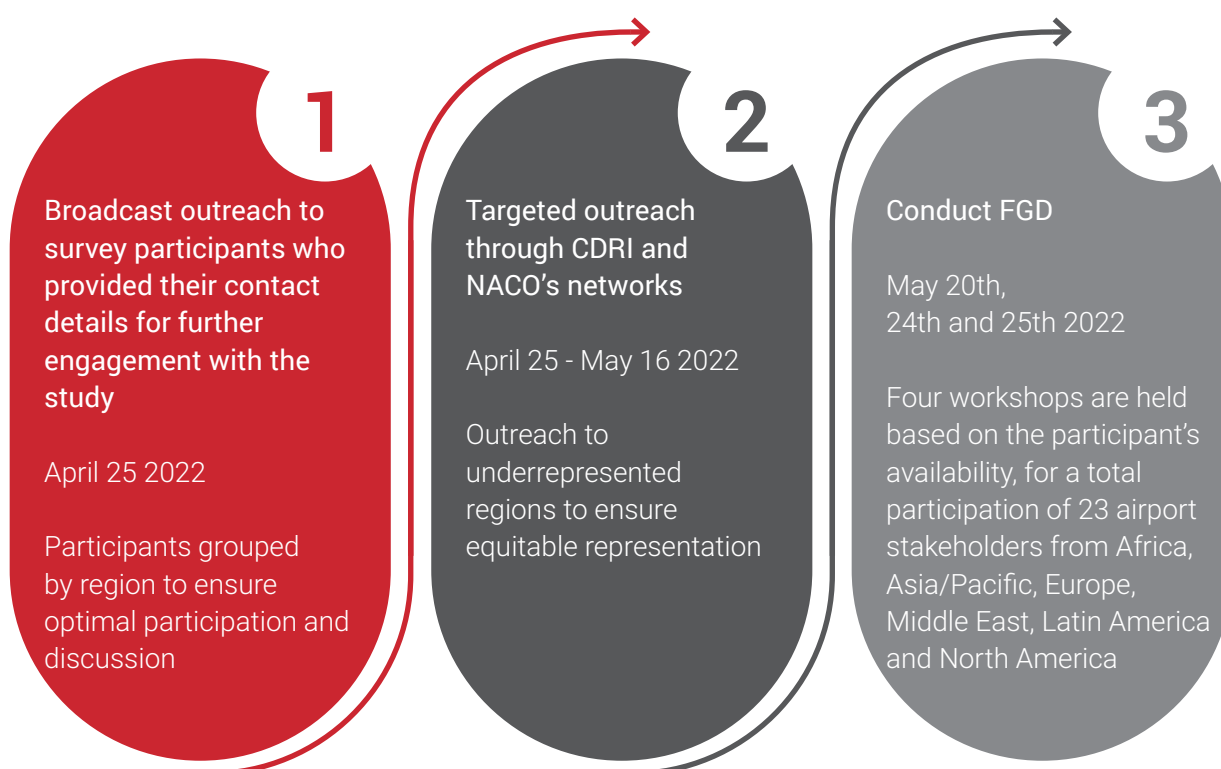
The format and content were evaluated and validated by internal experts with resilience expertise and an understanding of regional knowledge sharing practices and capabilities.



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



4.2 Data Collection



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.





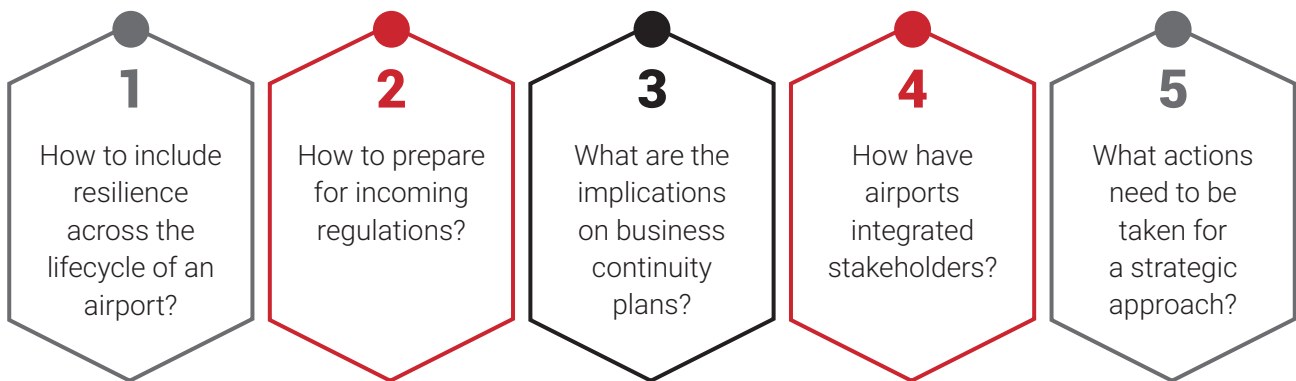
4.3 Data Analysis and Results

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:



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.



Airports in Europe and North America mention that they are facing increased rainfall in shorter periods of time.

“Even though we have protocols and measures in place for recovery, we are struggling with allocating adequate equipment to build redundancies for key assets and utilities.

If there is a disruption on the runway, equipment is needed to respond to it. We lack redundancies in the availability of this equipment to enable quick response and resume operations.”

“Power supply is a major issue. The city power supply is insufficient at certain times in the year and generators need to be used. Some power outages last for more than 3 days and cause significant disruption in operations. Regional and national resilience plans are key for active and effective response.”

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.

“Our asset maintenance plans are in place and addresses disruption scenarios. However, the pandemic drained the airport financially and this had an impact on the equipment inventory.

Addressing the economic consequences post-impact can be a challenge.”

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

Asset Group	Number of measures
Runway	23
Terminal	22
Communication systems	17
Utilities	15
Machinery and Equipment	13
Access links	12
Airfield	11
Land	6
Multiple Assets	2



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 marshallers, updated contingency plans, and stand-by teams for emergency response are also in place.

"We have a multi asset environmental team that is available once the threat has passed."

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.

"We have an alternate independent centre to run operations during disasters. This data centre has been built on an independent area with its own power supply for redundancy."

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.

-  Operational Adaptive Capacity
-  Organizational Adaptive Capacity



“Drills conducted with airlines to test collaborative responses to disasters is requisite for effective disaster response.”

Given the volatile geo-political situations in some regions, some airports rely on business continuity exercises with close contractors and suppliers across the globe to gather information on regional disruptions and prepare for possible disruptions in supply chains.

“As airports, it is difficult for us to act without the effort or enforcement of regulations by governments.”

“To avoid miscommunication, we developed streamlined procedures and set up Airport Operations Command Centres to host all key stakeholders.”

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.

“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.”

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.



5

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.





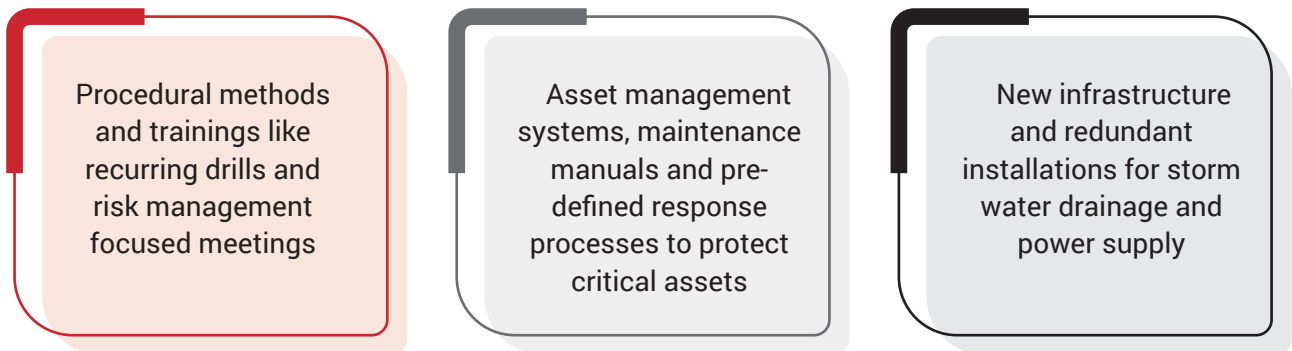
5.2 How do airports perceive their resilience to climate, environmental and natural hazards? Risk Assessment Practices

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:



However, although recognised as crucial, redundancy of infrastructure and utilities is often difficult to address because of financial constraints.

- Baseline & Hazard Exposure
- Infrastructural Adaptive Capacity
- Operational Adaptive Capacity
- Organizational Adaptive Capacity



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 percentage of respondents reporting availability of funds to cover mitigation costs, and 80 percentage of respondents report that their organization is effective in mitigating risks for the airport.

More than 89 percentage 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.

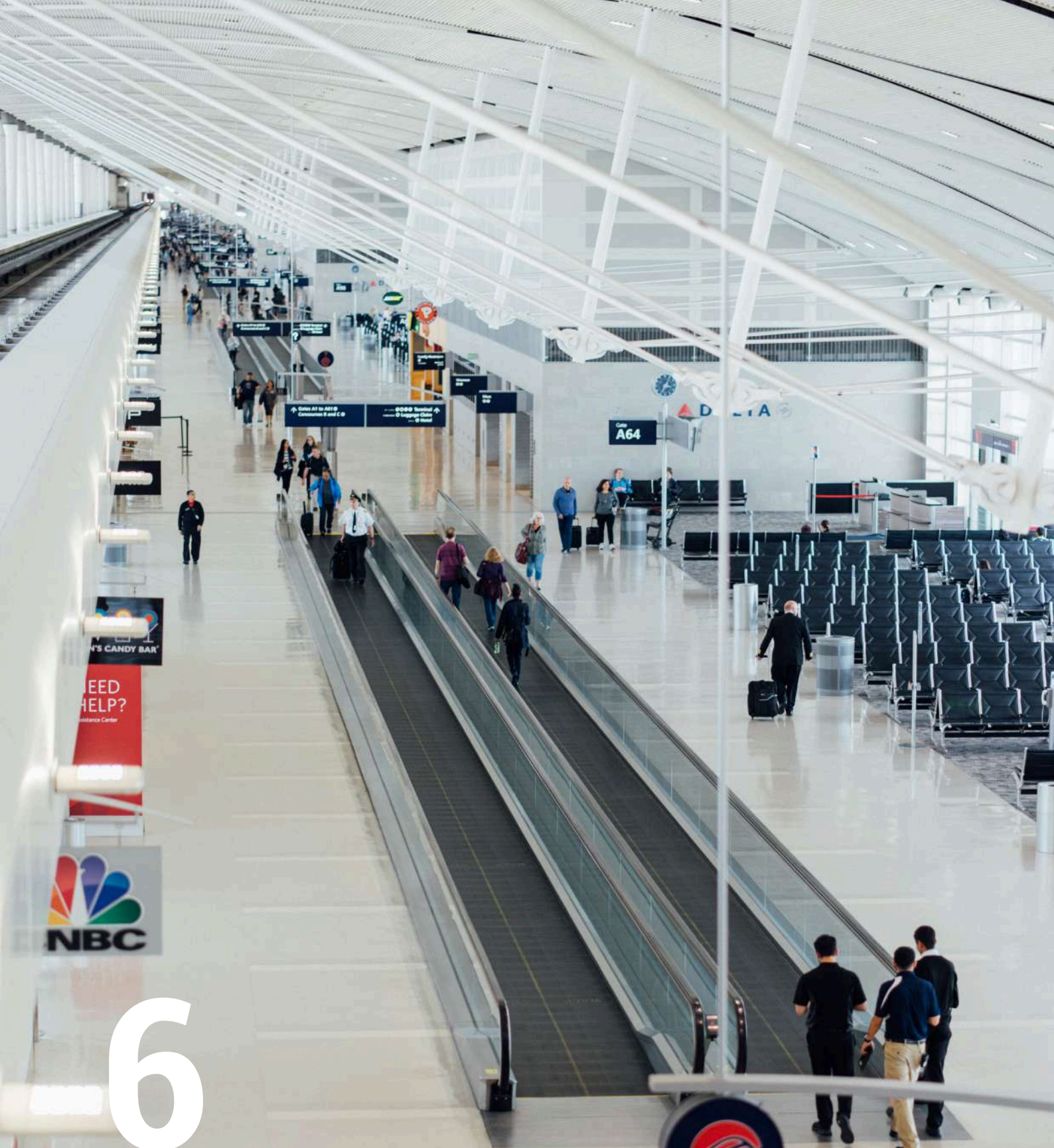
Limitations

The research methodology described in this document and findings presented are subject to certain limitations associated with a survey and perception analysis study.

-  Operational Adaptive Capacity
-  Organizational Adaptive Capacity



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 Caribbeans, 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.




6

WAY FORWARD

↑ Gates A1 to A61
Concourses B and C



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.

 Conduct in-depth studies of risk and resilience practices at airports to understand differences in ability to resume operations and recover across regions	
Expert Opinion	For Phase 2, it is recommended to assess the level of detail of vulnerability assessments and how they inform airport decision making. This would set the basis for identifying a register of existing practices, as well as establishing industry guidelines and mandates for other airports.
Illustrative Example / Case Study	The results of the survey and FGD indicate that most airports conduct vulnerability assessments. However, all airports expressed the need to learn about disaster resilience practices in place at other airports. For example, based on the survey results, although airports in Africa resume operations at the same rate as other regions, the airports in the region appear to take longer to fully recover. In this case, there is an opportunity for African airports to learn from other airports about recovery practices.
Proposed Action Plan	<ol style="list-style-type: none"> 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



Establish a broader understanding of risk appetite of airports

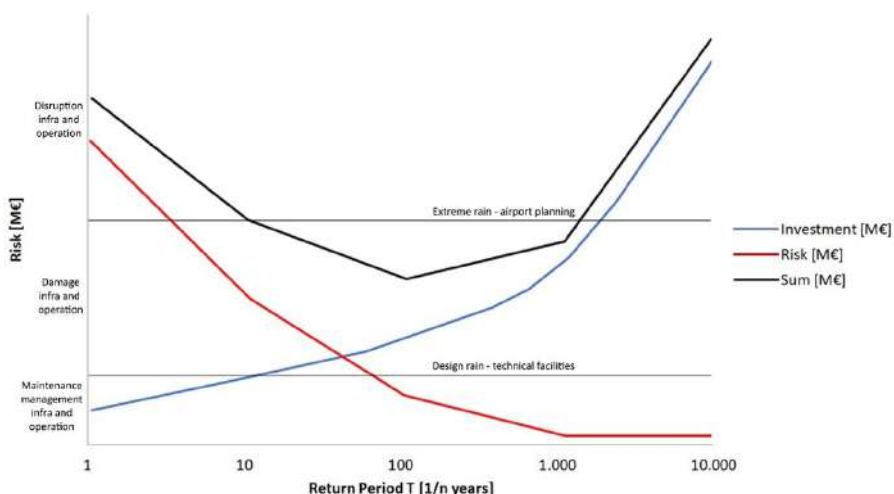
Expert Opinion

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.


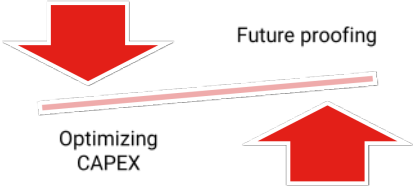
Illustrative Example / Case Study

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.





	<p>Rockhampton Airport</p> <p>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.</p> 
<p>Proposed Action Plan</p>	<p>For airports: Foster 'Risk dialogue' with relevant stakeholders in order to decide what is the organization's risk appetite. Key considerations might include:</p> <ol style="list-style-type: none"> 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 



Airports should engage local and regional stakeholders to increase airport resilience practice and support the acceleration of resilience in the catchment area

Expert Opinion

Airports, local and regional government authorities depend on each another 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.

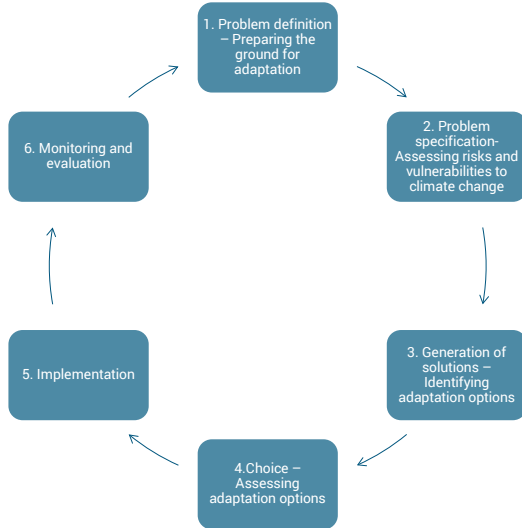




Illustrative Example / Case Study	<p>The World Bank Resilience Projects</p> <p>The majority of the World Bank-funded resilience projects include critical and vital assets such as airports as part of the assessment. This systemic approach accounts for the responsibility of various regional departments 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.</p> <p>Singapore PUB Coastal Protection Study</p> <p>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.</p>
Proposed Action Plan	<p>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.</p>



Airports should conduct periodic Vulnerability Assessments and develop a resilience strategy

Expert Opinion	<p>Vulnerability Assessments are influenced by the following,</p> <ol style="list-style-type: none"> (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 <p>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.</p> <p>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’)</p> 
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Articles/Reference:	According to the ISO 14090 adaptation cycle, this could be every six years or as part of development plans.
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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.

Expert Opinion	<p>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.</p> <p>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.</p>
Illustrative Example / Case Study	<p>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.</p> <p>The OECD framework for governance of infrastructure mentions data support as one of the key actions to be taken in infrastructure governance. (IATA, 2020)</p> <ul style="list-style-type: none"> 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	<p>For multilateral institutions (ACI, ICAO, CDRI, IATA):</p> <ul style="list-style-type: none"> • 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. <p>For governments and local authorities</p> <ul style="list-style-type: none"> • 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. <p>For airports</p> <ul style="list-style-type: none"> • Lobby with governments to highlight the scarcity of data and actively participate in the research process.
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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	<p>The Rockefeller Foundation developed a city resilience framework that presents seven qualities of resilient cities</p> <ul style="list-style-type: none"> • 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





	<ul style="list-style-type: none"> • 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. <p>Rotterdam City:</p> <p>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.</p> <p>The city built dedicated area for flooding with a dual function. These areas act as reservoirs during flooding, and otherwise serve a recreational use.</p>
<p>Proposed Action Plan</p>	<ul style="list-style-type: none"> • 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. <p>Reference to ISO, that has developed an international standard in Indicators for Resilient Cities: https://www.iso.org/standard/70428.html</p>



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

<p>Expert Opinion</p>	<p>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.</p>
<p>Illustrative Example / Case Study</p>	<p>Netherlands – Integrated National Approach</p> <p>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.</p>
<p>Proposed Action Plan</p>	<p>For airports</p> <ul style="list-style-type: none"> • 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






	<p>For governments:</p> <ul style="list-style-type: none"> • 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
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Airports should move towards a more proactive approach rather than reactive towards hazard management and resilience planning.

Expert Opinion	<p>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.</p> <p>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.</p>
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Illustrative Example / Case Study	<p>Key examples and framework for pro-active resilience planning include:</p> <p>Boston Logan International Airport – Resiliency Strategy</p> <p>Flood barriers help protect from storm surge at Boston Logan International Airport (Progress report infographic, 2018 BOS Annual Sustainability & Resiliency Report)</p> <div style="display: flex; align-items: flex-start;">  <div style="margin-left: 10px;"> <p>KPI</p> <p>Percentage of capital projects that address resiliency of massport facilities at Boston Logan International Airport.</p> <p>Target</p> <p>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.</p> <p>Trend</p> <p>60 percentage of critical assets enhanced with resiliency measures.</p> <p><small>Note : Critical assets include electrical power, diesel fuel pumping stations, telecommunication systems and public safety including police and fire.</small></p> </div> </div> <p>Build Back Better</p> <p>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.</p> <div style="border: 1px solid #ccc; padding: 10px; margin: 10px 0;"> <p style="text-align: center;">Build Back Better</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td colspan="3" style="background-color: #f8d7da; text-align: center;">Disaster Risk Reduction (DRR)</td> <td colspan="2" style="background-color: #d4edda; text-align: center;">Community recovery</td> <td colspan="3" style="background-color: #d1ecf1; text-align: center;">Effective Implementation</td> </tr> <tr> <td style="background-color: #f8d7da; text-align: center;">Resilient physical assets</td> <td style="background-color: #f8d7da; text-align: center;">Multi-hazard-based Land Use</td> <td style="background-color: #f8d7da; text-align: center;">DRR education and awareness</td> <td style="background-color: #d4edda; text-align: center;">Psychological and social recovery</td> <td style="background-color: #d4edda; text-align: center;">Business recovery</td> <td style="background-color: #d1ecf1; text-align: center;">Institutional mechanism</td> <td style="background-color: #d1ecf1; text-align: center;">Legislation and regulation</td> <td style="background-color: #d1ecf1; text-align: center;">Monitoring and evaluation</td> </tr> </table> </div> <p>LaGuardia Airport Design</p> <p>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.</p>	Disaster Risk Reduction (DRR)			Community recovery		Effective Implementation			Resilient physical assets	Multi-hazard-based Land Use	DRR education and awareness	Psychological and social recovery	Business recovery	Institutional mechanism	Legislation and regulation	Monitoring and evaluation
Disaster Risk Reduction (DRR)			Community recovery		Effective Implementation												
Resilient physical assets	Multi-hazard-based Land Use	DRR education and awareness	Psychological and social recovery	Business recovery	Institutional mechanism	Legislation and regulation	Monitoring and evaluation										



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

<p>Expert Opinion</p>	<p>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.</p>
<p>Illustrative Example / Case Study</p>	<p>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.</p> <p>Hong Kong Airport 2021 - TCFD Statement</p>  <p>The diagram illustrates the TCFD framework as four concentric circles. From the outermost to the innermost, they are: Governance, Strategy, Risk management, and Metrics and targets. Each layer is associated with a specific description:</p> <ul style="list-style-type: none"> Governance: Organizational governance around climate related risks and opportunities Strategy: Actual or potential impact of climate-related risks and opportunities on business, strategy, and financial planning Risk management: Organizational process to identify, assess and manage climate related risks Metrics and targets: Metrics and targets used to assess and manage relevant climate-related risks and opportunities
<p>Proposed Action Plan</p>	<p>Airports are advised to use the TCFD framework for their current and new developments</p>





Airports and insurers should collaborate together to mitigate climate risk for mutual benefits.

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	<p>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, Nov2020). 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</p> <p>National Flood Insurance Reform Act</p> <p>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:</p> <ol style="list-style-type: none"> (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. <p>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.</p>
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.



SECTION 2A: HISTORICAL HAZARD MAPPING

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

Severity	0	1	2	3	4	5
Safety & Health	No impact	Impact not likely to cause damages	Injuries requiring first aid only	Injury requiring medical treatment (lacerations, burns, fractures) Reduced efficiency of operations due to increased workload	Serious injuries or life-threatening occupational medical conditions	Multiple deaths and injury
Infrastructure & Operational Disruption	No impact	Flight delays of 15 minutes maximum	Partial restrictions and flights delay lower than 2 hours	Restrictions in operations Flight delays lower than 8 hours	Closure for more than 8 hours Major damage to equipment	Closure for multiple days Destruction of equipment or infrastructure
Economic Loss	No impact	Insignificant costs	Indirect economic loss to airport partners	Indirect economic loss to the airport	Direct economic loss to airport partners	Direct economic loss to the airport
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

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.

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

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?

	0 - 2 hours	2 - 5 hours	5 - 10 hours	10 - 24 hours	More than 24 hours
Extreme heat (high temperature, wildfires...)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Extreme icing conditions (cold, snow...)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Extreme precipitation (rain, pluvial floods...)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Extreme storms and winds (tropical cyclones ...)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Flooding (fluvial floods ...)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Wildlife invasion (sudden increase of wildlife on airport site...)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Geological hazards (permafrost thawing, landslide, earthquake...)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Drought	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Extremely poor air quality	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Third-party equipment/systems failures	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Volcanic activity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>



10. How long did it take to fully recover?

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

	0 - 6 hours	6 - 12 hours	12 - 24 hours	1 - 3 days	More than 3 days
Extreme heat (high temperature, wildfires...)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Extreme icing conditions (cold, snow...)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Extreme precipitation (rain, pluvial floods...)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Extreme storms and winds (tropical cyclones ...)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Flooding (fluvial floods ...)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Wildlife invasion (sudden increase of wildlife on airport site...)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Geological hazards (permafrost thawing, landslide, earthquake...)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Drought	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Extremely poor air quality	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Third-party equipment/systems failures	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Volcanic activity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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?

<input type="radio"/>	Yes, the airport documented the lessons learned and acted on them by mapping responses and incorporating measures
<input type="radio"/>	Yes, the airport documented the lessons learned but was unable to act on them
<input type="radio"/>	No, the airport was not able to document the lessons learned
<input type="radio"/>	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.

Severity	0	1	2	3	4	5
Safety & Health	No impact	Impact not likely to cause damages	Injuries requiring first aid only	Injury requiring medical treatment (lacerations, burns, fractures) Reduced efficiency of operations due to increased workload	Serious injuries or life-threatening occupational medical conditions	Multiple deaths and injury
Infrastructure & Operational Disruption	No impact	Flight delays of 15 minutes maximum	Partial restrictions and flights delay lower than 2 hours	Restrictions in operations Flight delays lower than 8 hours	Closure for more than 8 hours Major damage to equipment	Closure for multiple days Destruction of equipment or infrastructure
Economic Loss	No impact	Insignificant costs	Indirect economic loss to airport partners	Indirect economic loss to the airport	Direct economic loss to airport partners	Direct economic loss to the airport
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

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

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

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.

	0	1	2	3	4	5	N/A
Aircraft	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Operational buildings (passenger and cargo terminal, etc)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Airfield (Runway, Taxiway, Aprons)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Utility Systems (Electrical, Drainage, Fuel)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Communication systems	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Machinery / Vehicles / Equipment	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Personnel and Passengers Infrastructure	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Landside Infrastructure (airport access roads, parking facilities, ...)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other Buildings	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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?

<input type="radio"/>	Yes, the airport conducts vulnerability assessments periodically
<input type="radio"/>	Yes, the airport has conducted a vulnerability assessment once
<input type="radio"/>	No, the airport has not been able to conduct a vulnerability assessment
<input type="radio"/>	Information not available

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?

<input type="radio"/>	Yes
<input type="radio"/>	No
<input type="radio"/>	Not applicable
<input type="radio"/>	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?

<input type="radio"/>	Yes, the airport has considered the risks identified in its planning and has employed additional measures
<input type="radio"/>	Yes, the airport has considered the risks identified in its planning but has not been able to employ additional measures
<input type="radio"/>	No, the airport has not been able to identify risks as part of the planning and design process
<input type="radio"/>	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**?

<input type="radio"/>	Yes, the airport has conducted at least one resilience assessment and actions have been taken to improve the resilience of its assets
<input type="radio"/>	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
<input type="radio"/>	No, the airport has not been able to conduct a resilience assessment
<input type="radio"/>	Information not available



21. What type of data do you have access to predict future hazards and improve adaptation?
Please, select all that apply.

<input type="checkbox"/>	Open-source government / public datasets
<input type="checkbox"/>	Subscription-based datasets
<input type="checkbox"/>	Internal datasets (e.g. airport-specific modelling)
<input type="checkbox"/>	Other (please specify) <input type="text"/>
<input type="checkbox"/>	None of the above

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?

<input type="checkbox"/>	The airport has not been able to identify its critical assets
<input type="checkbox"/>	The airport has identified its critical assets but has not been able to identify additional adaptive/protective measures against future hazards
<input type="checkbox"/>	The airport has identified its critical assets and has identified additional adaptive/protective measures against future hazards
<input type="checkbox"/>	Information not available

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?

<input type="radio"/>	Yes
<input type="radio"/>	No
<input type="radio"/>	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**?

<input type="radio"/>	Yes
<input type="radio"/>	No
<input type="radio"/>	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.

	Define	Implement	Monitor
Airport Emergency Response Plan	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Disaster Recovery Plan	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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** ?

<input type="radio"/>	Yes
<input type="radio"/>	No
<input type="radio"/>	Information not available



If able, please provide more details below.

* 28. To your knowledge, are there funds available to cover mitigation costs?

<input type="radio"/>	Yes
<input type="radio"/>	No
<input type="radio"/>	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

1	2	3	4	5	6	7	8	9	N/A
---	---	---	---	---	---	---	---	---	-----

Human Safety

1	2	3	4	5	6	7	8	9	N/A
---	---	---	---	---	---	---	---	---	-----



Results of a Risk Assessment

1	2	3	4	5	6	7	8	9	N/A
---	---	---	---	---	---	---	---	---	-----

Executive Board/ Management

1	2	3	4	5	6	7	8	9	N/A
---	---	---	---	---	---	---	---	---	-----

Investors

1	2	3	4	5	6	7	8	9	N/A
---	---	---	---	---	---	---	---	---	-----

Shareholder Interests

1	2	3	4	5	6	7	8	9	N/A
---	---	---	---	---	---	---	---	---	-----

Market Trends

1	2	3	4	5	6	7	8	9	N/A
---	---	---	---	---	---	---	---	---	-----

Insurance of Assets

1	2	3	4	5	6	7	8	9	N/A
---	---	---	---	---	---	---	---	---	-----

Inclusion as part of Masterplan

1	2	3	4	5	6	7	8	9	N/A
---	---	---	---	---	---	---	---	---	-----

32. Which of the following are being included in the airport's resilience practice?

Please, select all that apply.

<input type="radio"/>	Assessment strategy
<input type="radio"/>	Infrastructure upgrade
<input type="radio"/>	Inclusion as part of Masterplan
<input type="radio"/>	Progress review
<input type="radio"/>	Design guidelines / regulations
<input type="radio"/>	Business continuity planning
<input type="radio"/>	Simulation exercise
<input type="radio"/>	Other (please specify)
	<input type="text"/>
<input type="radio"/>	None of the above



33. In your opinion, how effective is your organization in mitigating risks for the airport?

Very ineffective Neither ineffective, nor effective Very effective

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

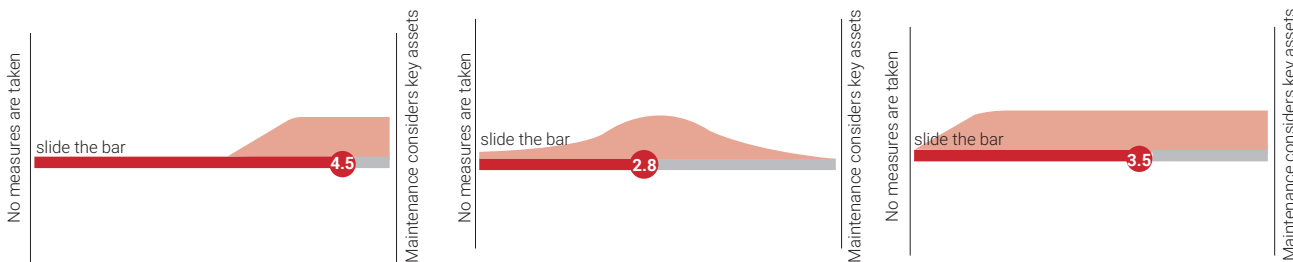
Email Address



ANNEXURE-B

FOCUS GROUP DISCUSSIONS RESULTS

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



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

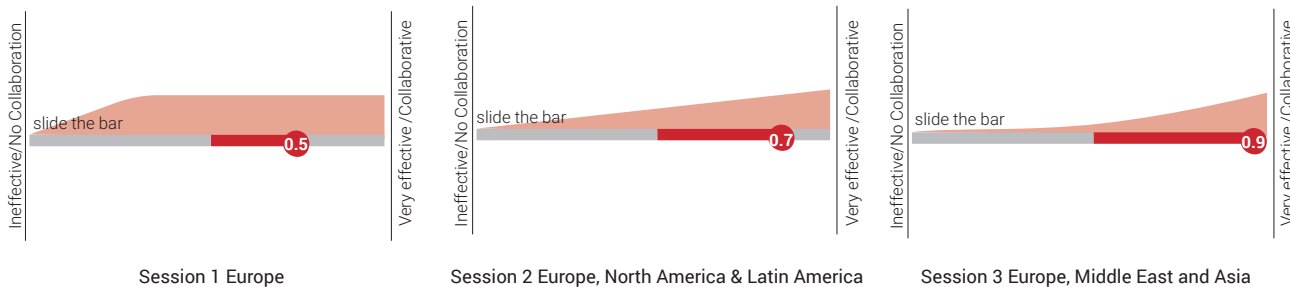
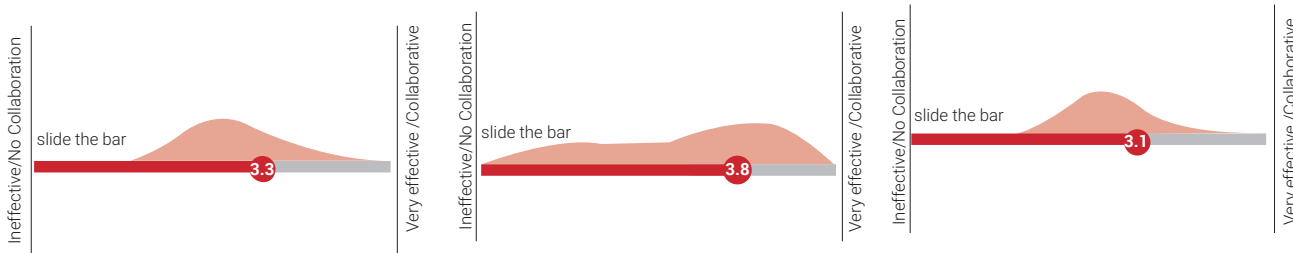


Figure a: Mentimeter results overview – Asset Maintenance and Early Warning Systems

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



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

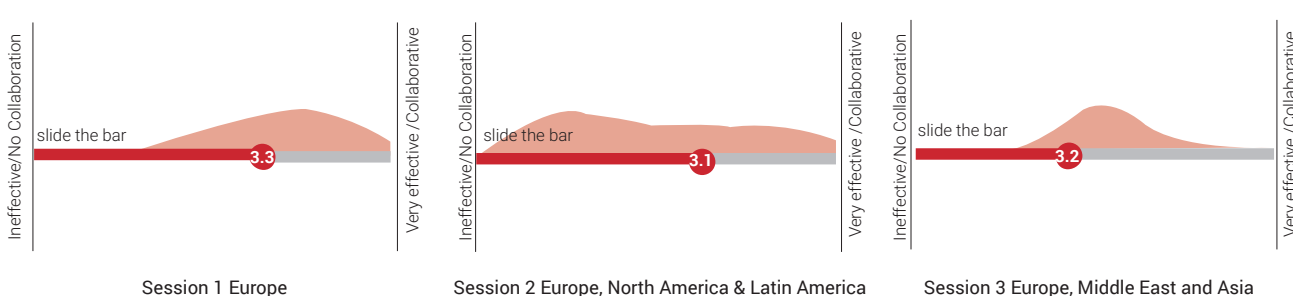


Figure b: Mentimeter results overview – Collaboration with stakeholders

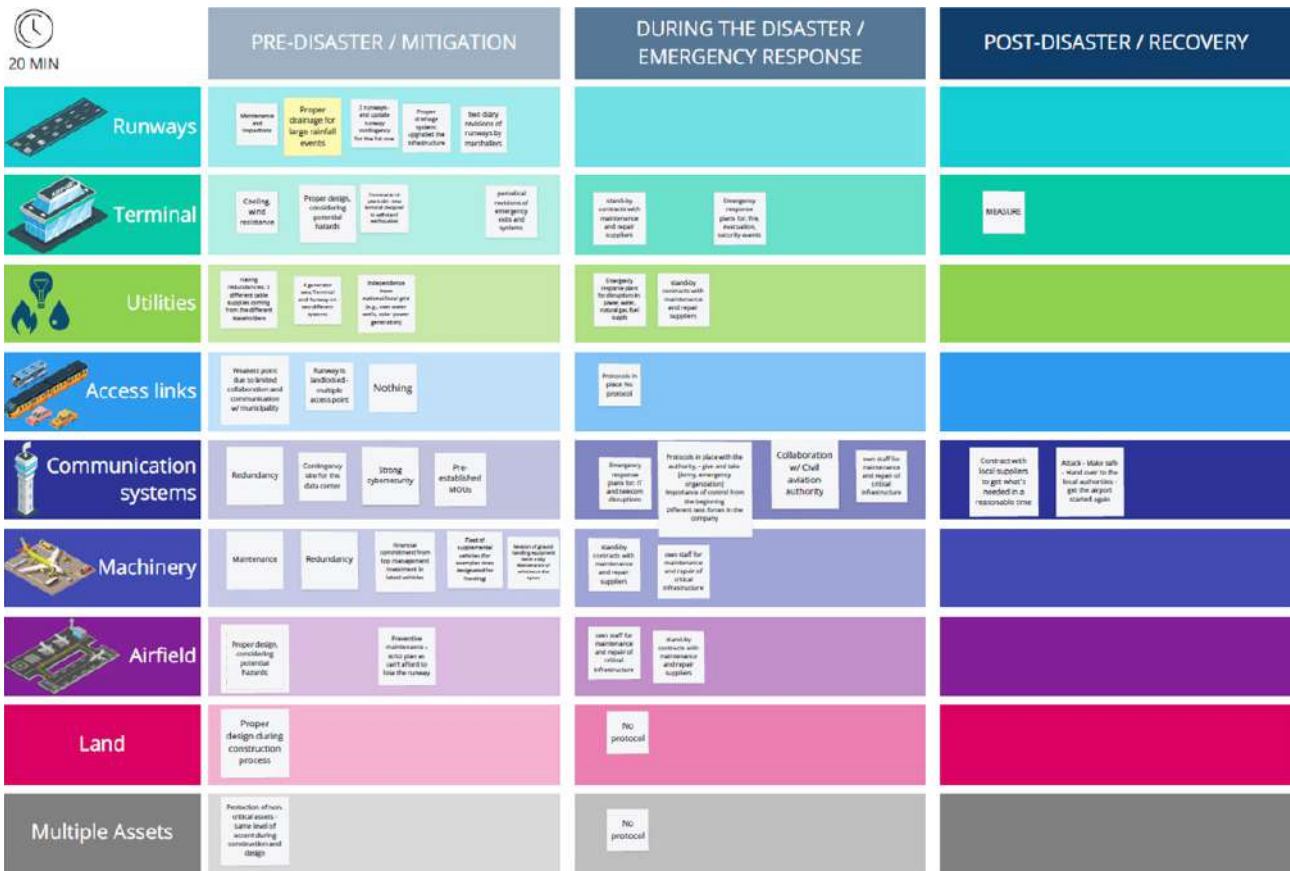


Figure c: What measures does your airport take to safeguard its critical assets against disaster?

Table a: Focus Group Discussion Output

ASSET	PRE-DISASTER / MITIGATION	DURING THE DISASTER / EMERGENCY RESPONSE	POST-DISASTER / RECOVERY
Runways	<ul style="list-style-type: none"> Ensuring proper drainage system for large rainfall events Effective Maintenance and inspection plans, Update runway contingency (diary revision by marshallers) Runway redundancy Overflow Water Storage Tank 	<ul style="list-style-type: none"> Emergency Response Plan Stand-by team / Multi Asset environmental team for response Diversion and continuity plans Agreement with Suppliers 	<ul style="list-style-type: none"> Disaster recovery plan Airport Personnel to assess and clean the runways Ops inspection and maintenance Prioritized flight plans
Terminals	<ul style="list-style-type: none"> Proper design to include potential hazards Periodical revisions of emergency systems and exits Improved cooling designs and wind resistance Effective drainage design, use of pump Maintenance plan and team to ensure structure is ready Regular inspections 	<ul style="list-style-type: none"> Stand-by contracts with maintenance and repair suppliers Emergency response plan includes fire evacuation and security events Emergency Plan integrated with response of third parties and authorities Stand-by team for disaster (ARFF) Crisis centre for coordination Alternate modes of communication – Satellite phones 	<ul style="list-style-type: none"> Disaster Recovery Plan Engineers are onsite to assess damage and immediately access our maintenance team.



ASSET	PRE-DISASTER / MITIGATION	DURING THE DISASTER / EMERGENCY RESPONSE	POST-DISASTER / RECOVERY
Utilities	<ul style="list-style-type: none"> • Include redundancies in design – supplies coming from different stakeholders • Back up for power supply – Separate systems for Runway and Terminal • Independent from national / local grid (e.g. : for water and power) 	<ul style="list-style-type: none"> • Emergency response plans for all utilities • Stand-by contracts with maintenance and repair suppliers • Contingency plans 	<ul style="list-style-type: none"> • Making utilities available within 2-12 hours after disaster • Revert to grid if off-grid
Access links	<ul style="list-style-type: none"> • Multiple egress and access roads • Weakest point due to limited collaboration and communication with municipality • Teams staged for multiple scenarios 	<ul style="list-style-type: none"> • Standard Protocols • Often not an issue for airports with multiple access roads • Efficient public transport connectivity 	<ul style="list-style-type: none"> • Quick clean up of debris
Communication Systems	<ul style="list-style-type: none"> • Redundancies in the form of hotlines • DR site and cloud systems • Backup Communication systems • Control tower and airport communication protocols • Wireless communications are checked to ensure viability • Contingency sites for data centres • Alternate communication rooms • Pre-established MOU's for response • Strong cyber security 	<ul style="list-style-type: none"> • Use of cloud systems • Alternate communication methods like satellite phones • Communications access checked every 30 minutes during an even to ensure emergency services can assist • Virtual Crisis Centre is setup for direct communication • Independent physical centre set up to manage response • Emergency response plans for IT and telecom disruptions • In house staff for maintenance and repair 	<ul style="list-style-type: none"> • Fixed on priority • Contract with local suppliers
Machinery	<ul style="list-style-type: none"> • Redundancies in procedures and equipment to ensure business continuity • All machinery is staged for known events • Financial commitment from top management for investment in latest equipment • Dedicated machinery for specific event (eg for flooding) • Review of ground handling equipment twice a day, maintenance of equipment on the Apron 	<ul style="list-style-type: none"> • Equipment stored in areas which are deemed safe (separate buildings) • Stand-by contracts with maintenance and repair supplier • Own staff trained for maintenance and repair of critical infrastructure 	<ul style="list-style-type: none"> • Post event shakedown and assessed for damage
Airfield	<ul style="list-style-type: none"> • Drainage control • Proper design considering potential hazards • Preventive maintenance 	<ul style="list-style-type: none"> • Storm drainage management • Closed to all traffic and inspected during safe periods • Emergency Response plans • Own staff trained for maintenance and repair • Stand-by contracts with other suppliers 	<ul style="list-style-type: none"> • Master plan adequacy • Checked by engineers for structural and physical damages and immediately scheduled for repairs



ASSET	PRE-DISASTER / MITIGATION	DURING THE DISASTER / EMERGENCY RESPONSE	POST-DISASTER / RECOVERY
Land	<ul style="list-style-type: none"> Proper design and construction 	<ul style="list-style-type: none"> Protocols in cooperation with authorities Access to property is restricted until deemed safe 	<ul style="list-style-type: none"> Assessment to check for damage
Other	<ul style="list-style-type: none"> Protection of non-critical assets is at the same level during the design and construction stages 		

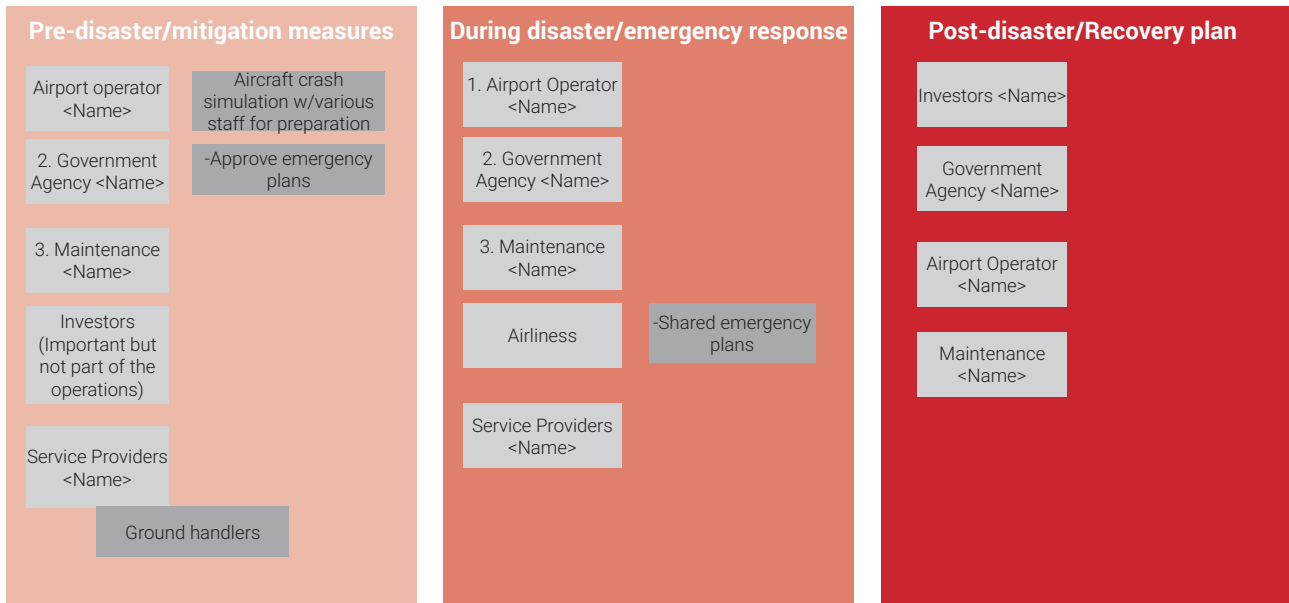


Figure d: Which stakeholders do you collaborate with to implement the measures mentioned?

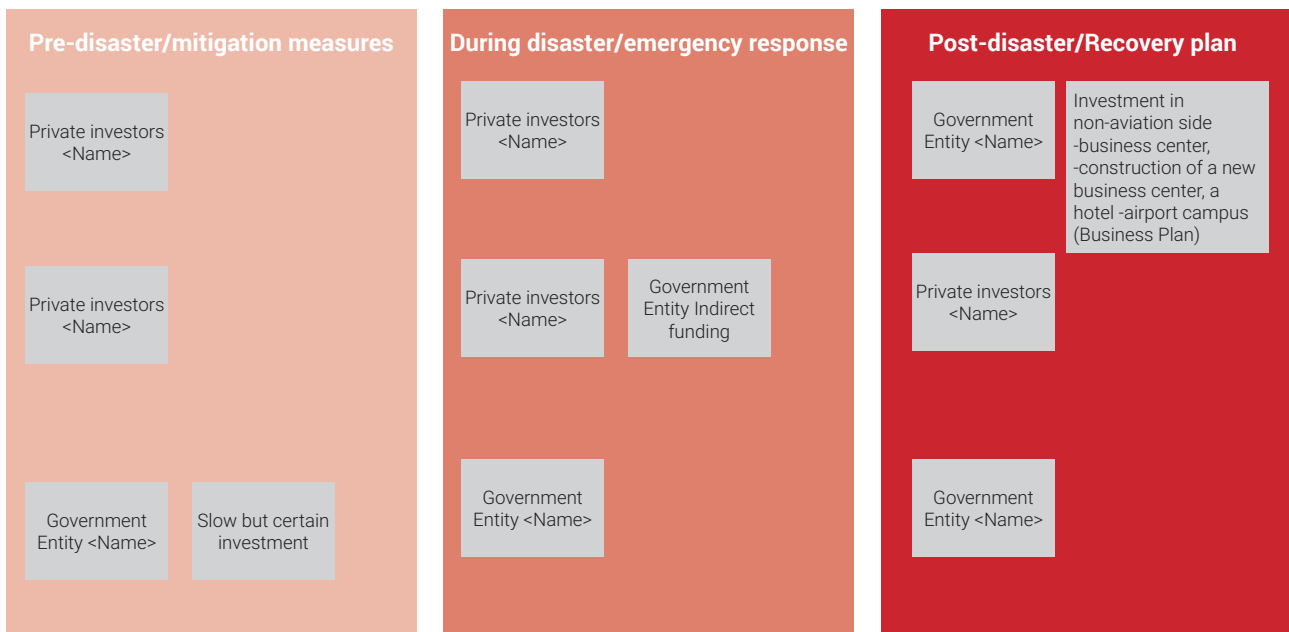


Figure e: What are your primary sources of funding for the measures mentioned?



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.

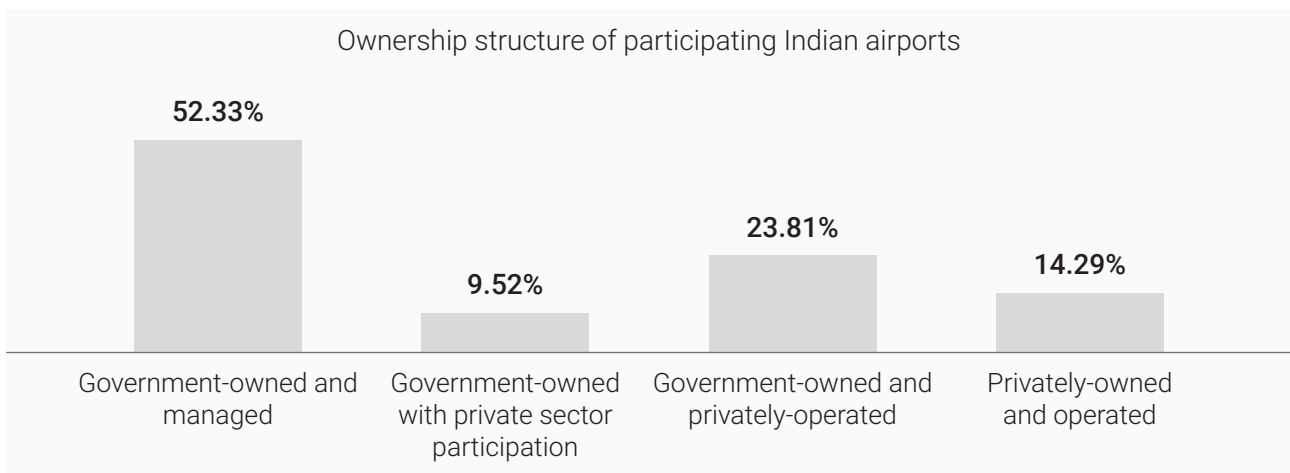


Figure i Ownership structure of participating Indian airports

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



Figure ii Airport's response on awareness to hazardous events and disasters



Airport size and hazard exposure

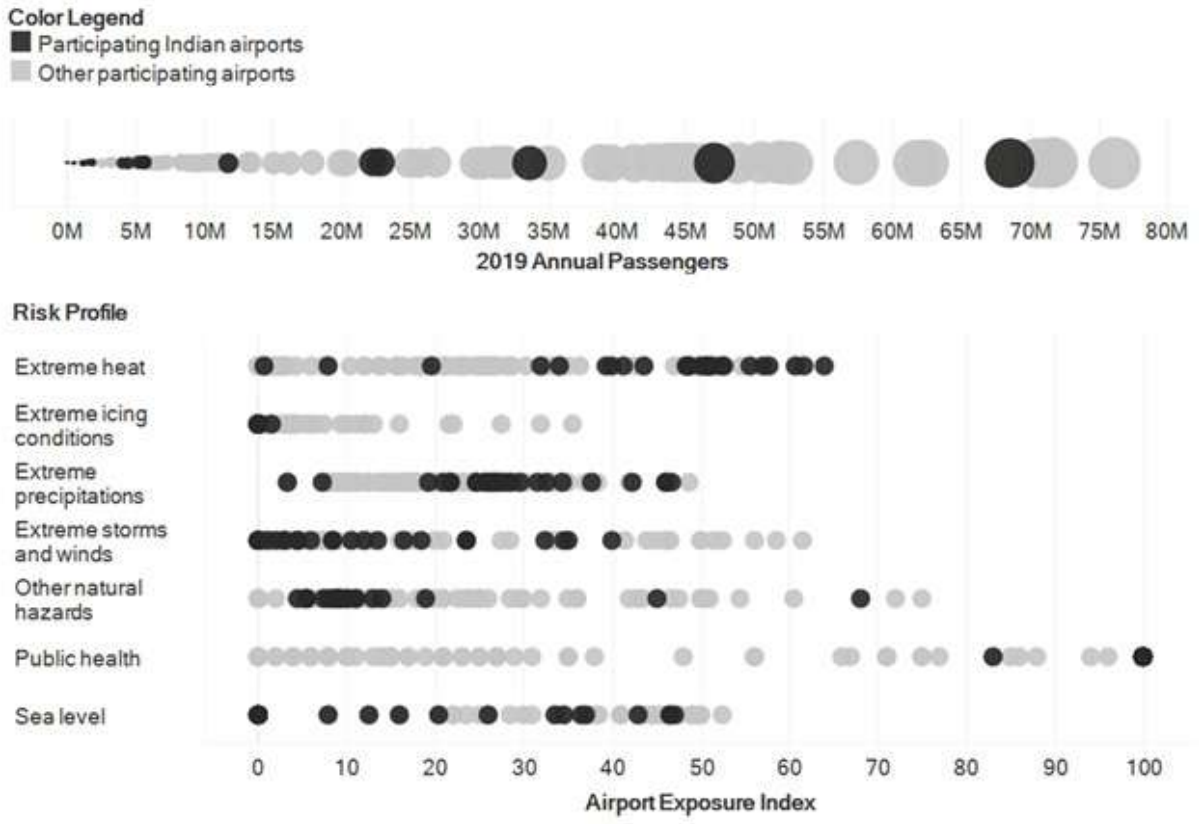


Figure iii Hazard exposure of participating airports (Source: NACO analysis from survey results, RHDV Multi-Hazard Risk Platform)

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.

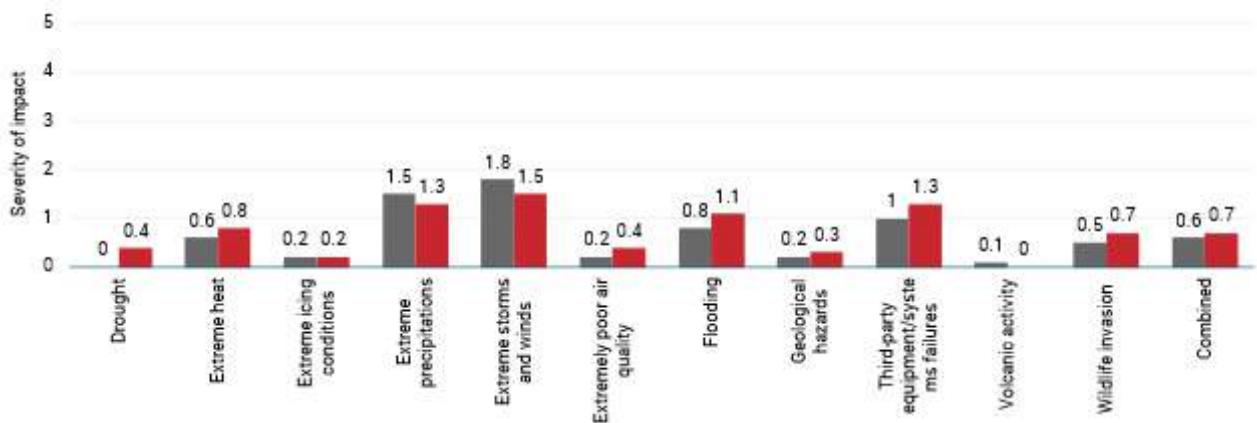
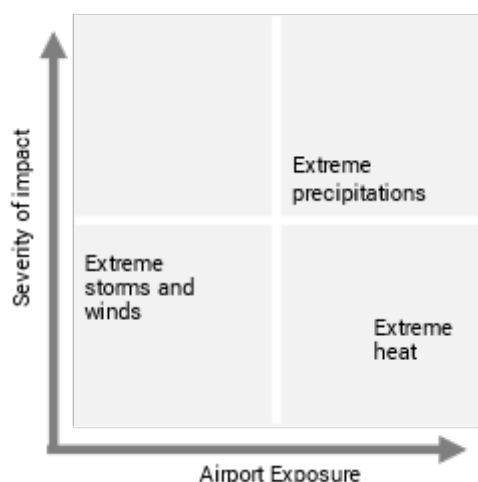


Figure iv Historical and future severity of impact (Source: NACO analysis of survey results)

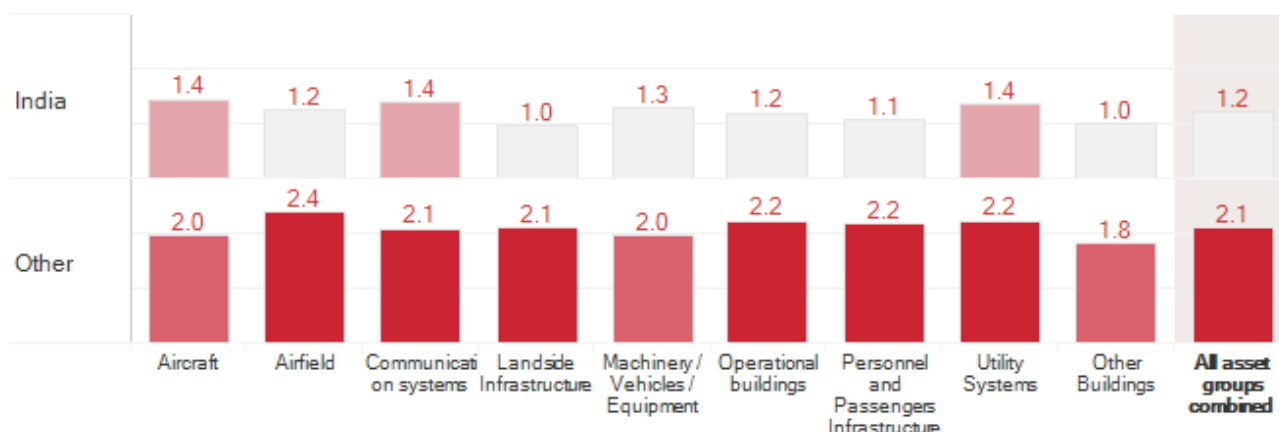


However, this exposure does not directly correlate to the historical impact of these different hazards on the airports. Indeed, based on the survey results as shown in figure iv, participating Indian airports are currently most impacted by extreme storms and winds and extreme precipitation. In the future, 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



Anticipated severity of impact on different asset groups



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

43 percentage of participating Indian airports conduct Vulnerability Assessments periodically, compared to 63 percentage in the rest of the world.

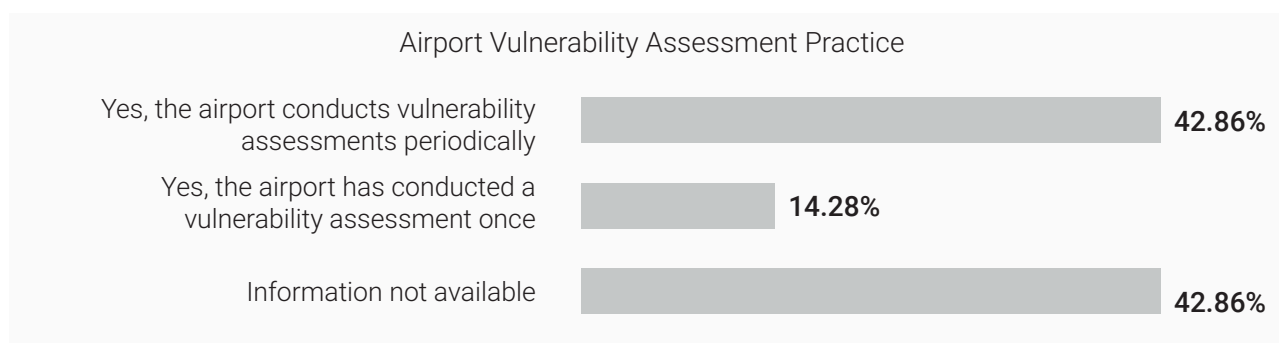


Figure v Airport vulnerability assessment practice

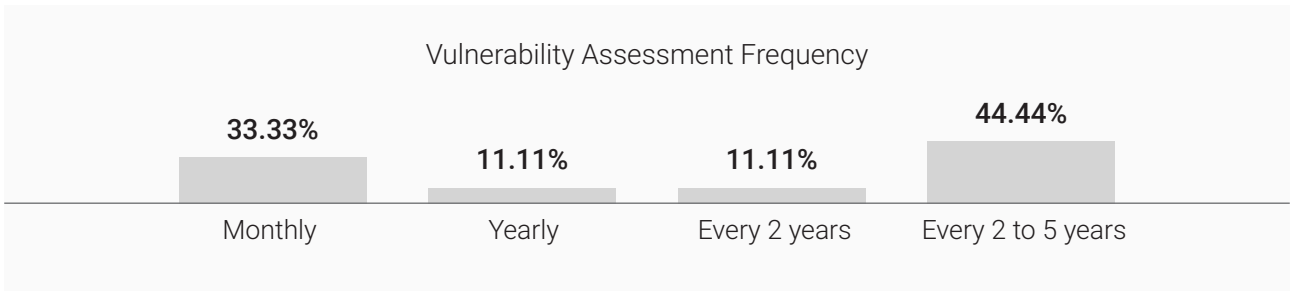


Figure vi Vulnerability assessment frequency

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. Risk and Resilience Practices

	India	Other
Personnel and passenger infrastructure	3rd	1st
Civil structure / installations (eg: terminal building equipment safety)	4th	2nd
Reliability of operations (eg. closure, flight delays, recovery time)	2nd	3rd
Emergency service operations	1st	5th
Reliability of utility services (eg. water, electricity, sewage)	5th	4th
Financial impact	6th	6th
Availability of supply chain	7th	7th
Impact on image	8th	8th

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.

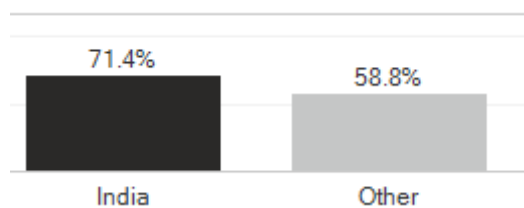


Figure viii Inclusion of assets controlled by third parties in vulnerability assessment

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.

Airport risk and resilience drivers

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

Organisation efficiency in mitigating risks for the airports

India vs other	Ineffective	Neither ineffective, nor effective	Effective	Very effective
India		12.0%	32.0%	56.0%
Other	3.1%	20.3%	51.6%	25.0%

In-house capacity/expertise sufficiency

	Insufficient in-house capacity	Potential to grow in-house capacity	Sufficient in-house capacity
India	9.1%	54.5%	36.4%
Other	8.9%	60.7%	30.4%

Figure ix Overview of airport resilience practice



Based on survey results, resilience is embedded within existing practices. This is relatively high in comparison to the other participating airports' reported practices.

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

Figure x Resilience practice elements at Indian airports

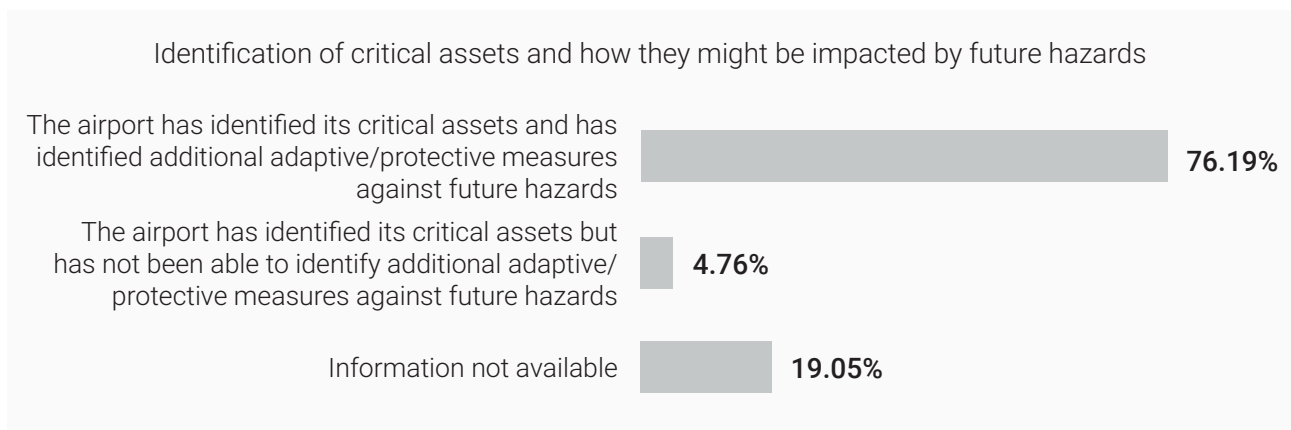


Figure xi Identification of critical assets and how they might be impacted by future hazards

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

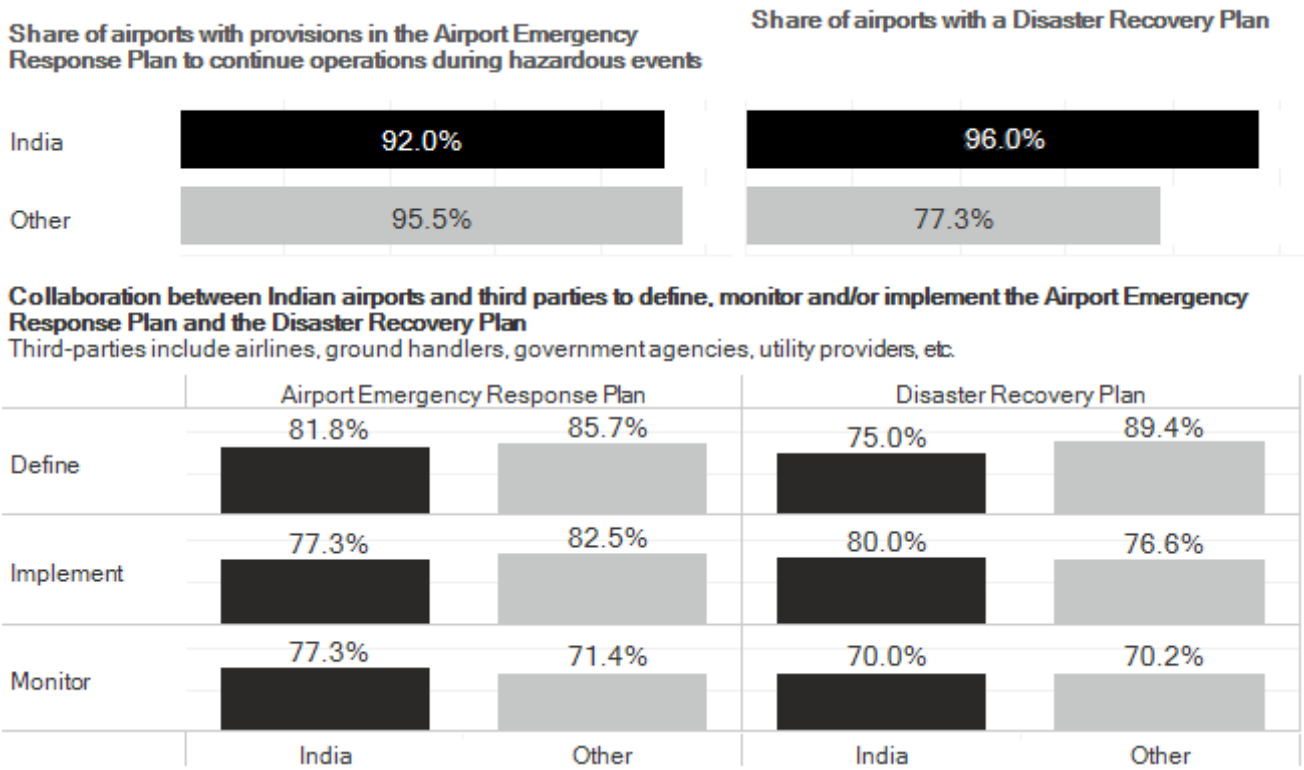


Figure xi Overview of airport emergency response planning and disaster recovery planning practices

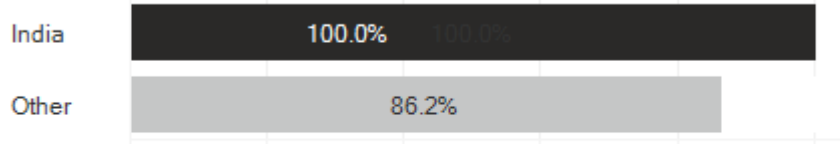
Most (>90%) Indian participating airports indicated having an Airport Emergency response Plan to continue operations during hazardous events, as well as a Disaster Recovery Plan.

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.

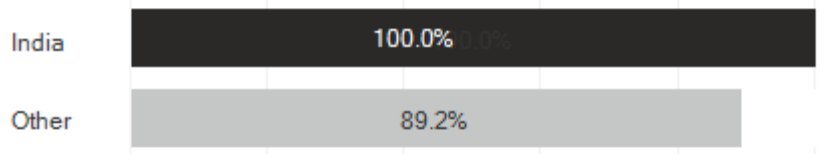


Business Continuity Plan

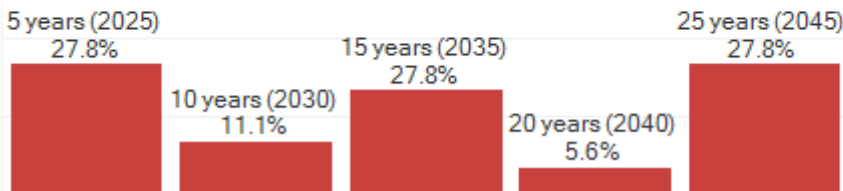
Availability of funds to cover mitigation costs



Ability to consider disaster impact as part of Business Continuity Plan



Business Continuity Plan Timeframe at Indian Airports

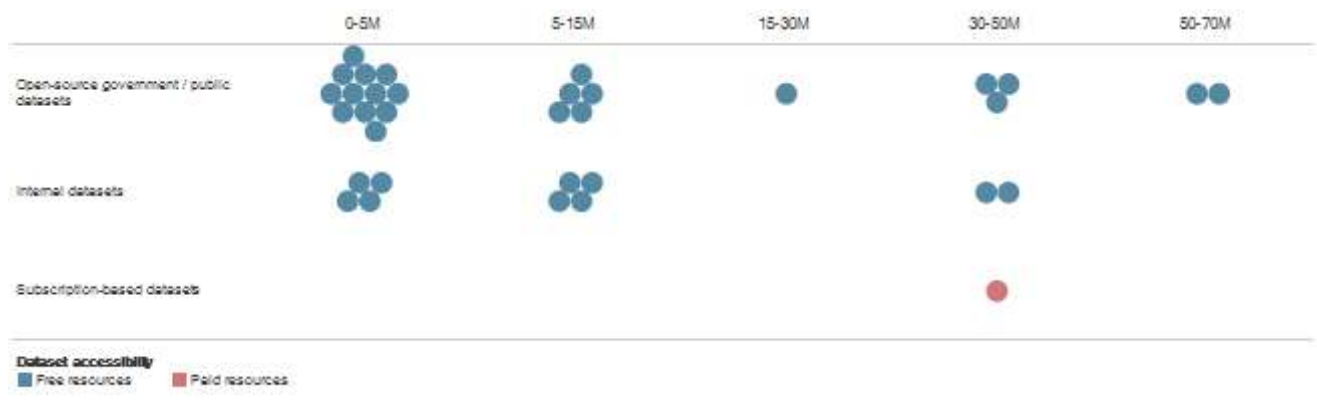


All participating Indian airports indicate they have funds available to cover mitigation costs and the ability to consider disaster impact as part of the Business Continuity Plan. The participating Indian airports mainly consider the 5-, 15- and 25-year timelines for their business continuity plan.

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.

Data availability at Indian airports



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



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