Adapting Airports to a Changing Climate in the Asia Pacific Region

Rekibuddin Ahmed
Manager- Environment
Delhi International Airport Limited

Contents

List of Figure

List of Table

Executive Summary

Climate change is the biggest threat faced by humanity as on today. Various scientific institutions, including IPCC has repeatedly warned about the risk and impacts of climate change. Even though climate change has impacted the whole world, the level of impact remains different from place to place.

The Asia Pacific region is one of the most vulnerable region to climate change risks globally. This report focuses on the climate change impacts of the Asia Pacific Airports. Climate change impacts faced by the Airports, the key operational and business risk have been reviewed. In addition to this, key adaptation measures implemented by the Airports have also been looked at. The latter part of the report discusses some of the new and innovative climate change adaptation solutions and collaboration opportunities for Airports of this region.

To understand the climate change impacts on airports and how airports are responding to these, a survey among some of the Asia Pacific Airports were carried out. The key findings of the survey are- 89% all the responding airports consider climate change as risk for their operation and growth. Climate change impact is considered as very high by 23% of the airports, high by 44%, medium by 22% and low by 11% of the airports.

Some of the key climate change impacts faced by the responding Airports are- changing precipitation (89% of the Airports), rise in temperature (67% of the Airports), extreme weather conditions (60% of the Airports), sea level rise (56% of the Airports) and water scarcity (25% of the Airports). All these climate change risk leads to impacts such as- infrastructure damage, operation restrictions, flight cancellation & diversions, damages to associated facilities and utilities, impact on road network, safety concerns in the Airside, damages to aircrafts because of high wind, frequent floods, water scarcity, revenue loss, loss of business opportunities, impact on trade and tourism, loss of life and community conflicts etc.

According to the survey, 89% the participating Airports have confirmed that they face physical risk, where as 33% of the Airports have also faced transitional risk such as technological risk, market related risk, policy and legal risk etc. Further, 78% of the participating Airports have carried out climate related risk and vulnerability studies at their Airports.

The climate change concerns at Airports needs to be addressed using a top down approach. To ensure this, organizations adopt climate change adaptation requirements as one of the policy commitments. Among the participating Airports in the survey, 67% of the Airports have confirmed that climate change adaptation is a part of their policy statement. When it comes to incorporating the findings of climate change impact requirements, 89% of the Airports also confirmed that, they have started integrating climate change requirements into Airport planning and design.

Some of the initiatives adopted by the Airports of this region, based on the survey inputs are- watershed assessment using IT based tool WATSCAN, sea wall protection, tie down areas, rain water harvesting, flood modelling, improved storm water drains, green building development, better building design for protection against storm, develop robust utility system, electricity back up system, lighting warning system and community water management systems etc.

To understand the risk of climate change and the impact it may create, Airports need to adopt a risk mapping approach. In this risk mapping, a risk categorization can be assigned to all the possible risk identified by the Airport, based on the severity of the impacts and frequency of occurrence. This will help Airports in prioritizing their risk in terms of strategy and mitigation measures to be adopted. Based on the risk categorization, Airports may require to carry out in depth studies and assessments to understand the implications of the risk and prepare suitable mitigation strategies. Apart from this, Airports may also focus on new and innovative climate change adaption measures such as – business continuity planning, nature based solution, revised design and operation approach, use of data analytics, use of digital twin, advanced weather prediction system, competency development and innovative climate financing tools etc. As Airports are part of a global industry which is closely connected, collaboration and support among the Airports will play a major role in identifying and addressing climate change concerns. Some of the collaboration opportunities for Airport are- information and knowledge sharing, taking up pilot projects, mentorship program to led by matured Airports which have successfully addressed climate change adaptation to a great extent etc.

There is no denying of the fact that climate change is happening all over the world and impacts are getting severe. However with right strategy, assessment and initiatives, the impacts can be eliminated or reduced. Airports need to innovate, take measures and grow sustainably. By this, Airports can help aviation sector to become a truly sustainable and resilient mode of transportation.

1. Introduction

Climate change is evident in the entire world with a varying degree of impact. In many parts of the world it has led to climate related impacts such as loss of infrastructure, loss of property, loss of life and livelihood, migration of population, loss of biodiversity, impact on agricultural productivity to name a few. The impact continues to worsen as the use of fossil fuel is still rampant in many parts of the world. As per scientific predictions this is only a beginning and the worst of climate change is yet to be seen.

The Asia and Pacific region is one of the most vulnerable region to climate change risks [1]. It is home to more than 40% of natural disasters and 84% of people affected globally [2]. Some of the major cities along the coastlines are increasingly becoming vulnerable to climate change risks and disasters such as flood events, sea-level rise, and droughts etc. This is primarily because of its geographical location, dependence on the natural resources and agriculture sectors. Dense population, long coastal areas, and weaker economic condition of a significant part of its population also contributes towards climate change vulnerability of the region.

The ACI Asia Pacific region map [3] is presented in Figure 1. There are in total 56 countries and 1654 number of airports in this region [4]. Most of this airports are located in low-lying coastal area which are exposed to severe climate risk such as excessive and erratic rainfall, flood, frequent cyclones, increasing temperature and heat waves etc.

According to a recent assessment carried out by New Castle University, a mean sea level rise in line with IPCC’s 2 degree scenarios will put more than 100 coastal airports below MSL (mean sea level) [5]. The study also revealed that the airports in East Asia, Southeast Asia and the Pacific dominate the top 20 positions amongst the most vulnerable Airports for present day and lower sea level rise scenarios.

In order to complete this study, a survey among some of the Asia Pacific Airports was carried out. The Airports which have responded to the survey have handled more than 491 million passengers in the year 2019. The findings of the survey have been discussed in the report.

Figure 1: ACI Asia Pacific Region

2. Key climate change impacting airport(s) in the region

Climate change has impacted the Asia Pacific region in a very significant way. The recent increased cases of extreme weather conditions have repeatedly proven this fact. The survey requested the participating airports to respond, whether climate change is considered as a risk at their Airports. In this, 89% of the participating Airports have confirmed that, they consider climate change as a risk to airport operation and future growth, whereas almost 11% of the Airports do not consider it as a risk yet (Figure 2). The response of the Airport was also matched with similar survey carried out by ACI [24], where 88% of the responding Airports from Asia Pacific region confirmed that, they have been impacted by climate change.

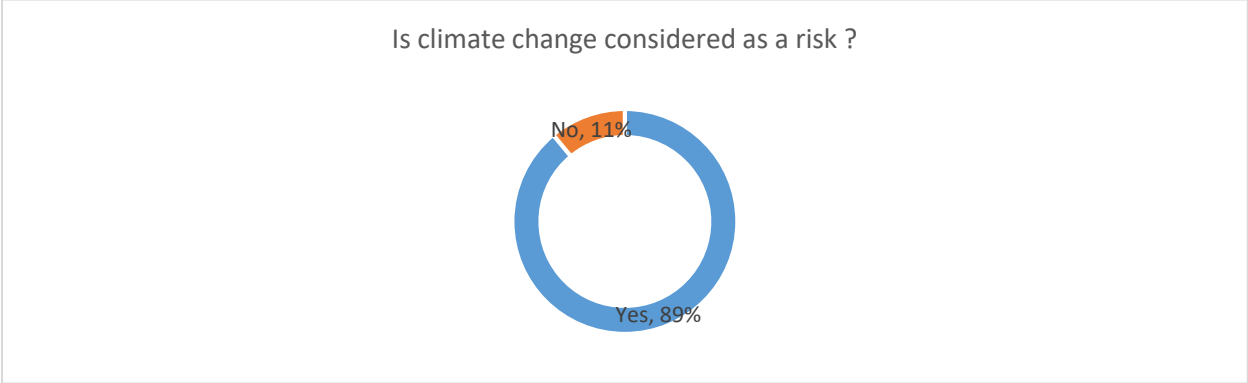

Figure 2: Break up of Airports that consider climate change as a risk

Further the airports were requested to rate climate change impacts faced by Airports on a scale of 1 to 5, 1 being the low and 5 being extremely high. Climate change impact is considered as

very high by 23% of the airports, it is consider as high by 44%, medium by 22% and low by 11% of the airports (Figure 3).

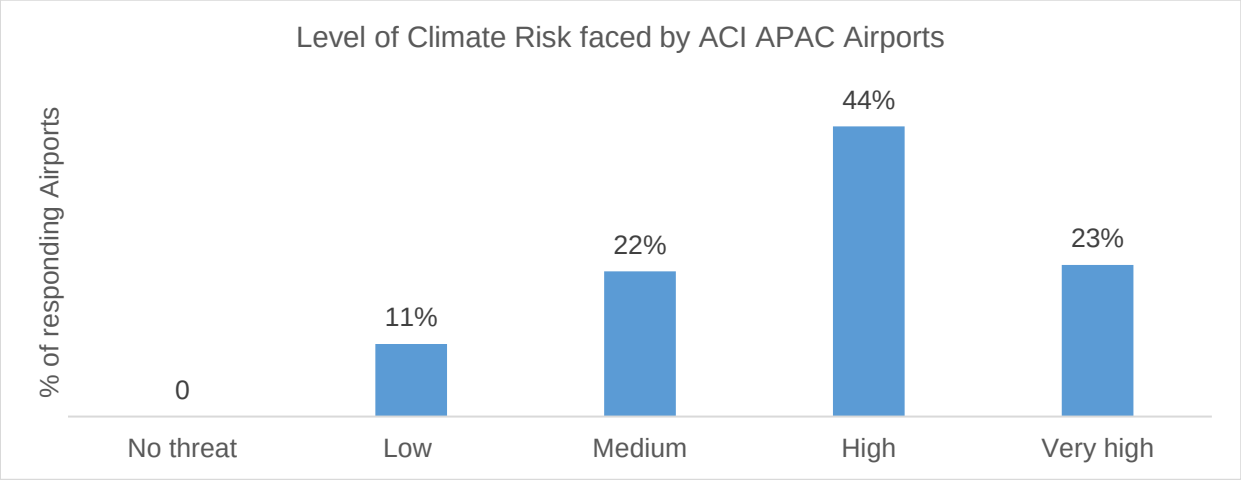

Figure 3: Climate change impact rating by ACI Asia Pacific Airports

According to the survey, the key climate change impacts faced by the Airports are- sea level rise, changing precipitation, rise in temperature, increased storm frequency, intensity and water scarcity (Figure 4).

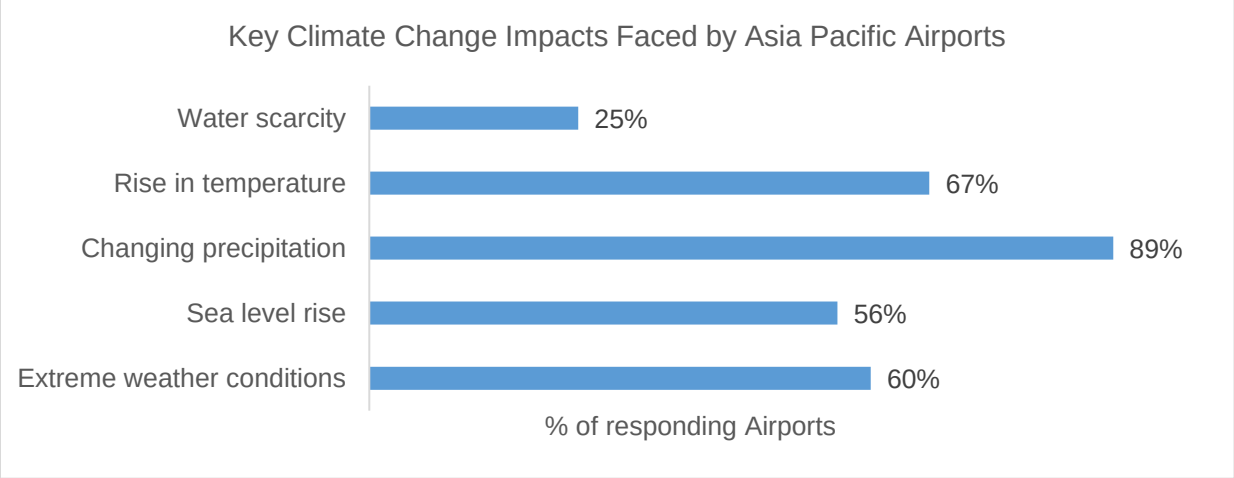

Figure 4: Key Climate change impacts faced by Asia Pacific Airports

3. Assessment of climate change impacts

3.1. Extreme weather conditions

In the Asia Pacific region, the frequency and intensity of extreme weather effects such as cyclones, storms, floods etc. has increased in the recent years. Extreme climate events will create increasing impact on human health, livelihoods, and poverty, with the type and magnitude of impact varying across Asia [6]. Natural disasters are four times more likely to affect the population of the Asia Pacific than those in Africa and 25 times more likely than those in North America or Europe [7]. As per the Climate Change Vulnerability Index of risk management group Maplecroft, all the seven cities facing “extreme risk” are in Asia: Yangon, Bangkok, Jakarta Dhaka, Manila, Ho Chi Minh and Kolkata [8].

3.2. Sea Level Rise

According to IPCC, the Global mean sea level (GMSL) is increasing because of increased melting of ice from Greenland and Antarctic [9]. The global average mean sea level has increased at a rate of 3.3 mm per year since the 1990s [10]. The North Indian Ocean as well as the Northwest Pacific Ocean has witnessed significantly higher sea level rise as compared to the other global mean, impacting the Asia Pacific region and its Airports. According to China Water Risk (CWR) that has carried out an assessment of climate change impacts on 20 cities of the APCA region, 25 airports of these cities face dire climate risk from sea level rise even in 1.5 degree temperature rise scenario [11].

3.3. Changing Precipitation

Climate change is altering rainfall patterns in Asia, both in terms of the amount of rainfall and its timing. Climate models indicate that rising temperatures will increase heavy rainfall during the rainy seasons and extend the dry durations during dry seasons. These changes will, in turn, shift seasonal water availability and increase floods and droughts.

The total number of flood events in Asia increased from 303 events during 1970–1980 to 1,541 events during 2011–2020 [12]. During the same periods, the total number of drought events increased from 85 to 152. These floods and droughts has endanger human lives, damage homes and public infrastructure, destroy crops, and harm the economy.

3.4. Rise in temperature

According to IPCC 5th AR, it is very likely that mean annual temperature is on the rise in the past century covering most of the Asian region [13]. The year 2020 was the warmest year on record for Asia [14]. The mean temperature was 1.39 °C above the 1981–2010 average value.

3.5. Water Scarcity

Climate change is making water scarce as in many parts of this region, as the water resources are is getting depleted or are getting polluted. On the other hand, the rising temperature is leading to higher demand of water in the form of potable, irrigation, cooling requirements.

Airports are water intensive facilities. Considerable amount of water is required for uninterrupted operation. Some of the key water consuming activities within the airport are potable purpose, cooking and cleaning, HVAC systems, in toilets, firefighting, irrigation purposes etc. As the airports of this region are growing remarkably in terms of through puts such as passenger, ATM and cargo movements, existing airports are undergoing expansion and new airports are also getting constructed, which also consumes significant amount of water.

The primary sources of water in Airports are municipal water supply from the city and ground water extraction within the Airport. As water is a shared resource, for both the sources of water, Airports face consumption competition from neighboring communities and other nearby industries.

According to Aqueduct Water Risk Atlas, the entire Asia Pacific region suffers from medium high to extremely high water risk (Figure 5) [15]. The ACI APAC region have been highlighted using a rectangular box.

Considering the importance of water for airport operation and development, water scarcity will be a major barrier for the growth and long term business sustainability of Airports in this region.

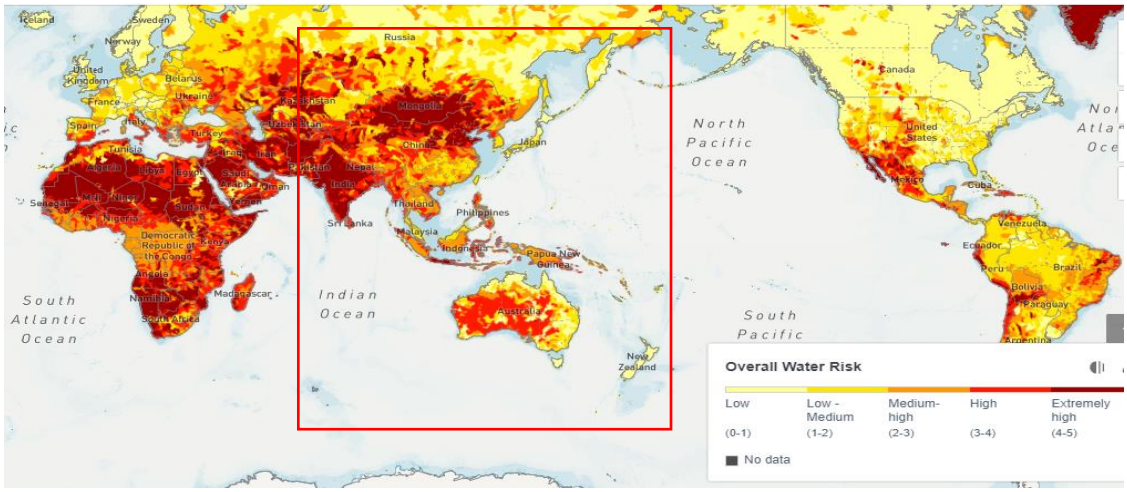

Figure 5: Aqueduct Water Risk Atlas

3.6. Changing wind pattern

Climate change has impacted wind pattern and intensity in terms of change in prevailing wind direction and speed of wind. For examples, IPCC has reported weakening of the seasonal, annual mean as well as maximums over the land in China including the Tibetan region from the 1960s-1970s to the 2000s [16]. This climate change impact is highly relevant for airports because of the inherent dependency of Airport operation on prevailing wind direction and speed.

3.7. Summary of Climate change impacts faced by Airports

The summary of climate change impacts faced by Airports are presented in Table 1. In the Table 1, the below abbreviations have been used.

- SLR: Sea Level Rise, CP: Changing precipitation, RT: Rising Temperature, CWPI: Changing Wind Pattern & Intensity, WS: Water Scarcity.

Table 1: Summary of Climate change impacts faced by Airports

Possible impacts at Airports	SLR	CP	RT	CWPI	WS
Increased flooding risk	▬	▬			
Ingress of sea water leading to infrastructure damage	▬				
Pollution of ground as well as surface water	▬	▬			
Changing precipitation leading to flood or prolonged drought		▬			

Possible impacts at Airports	SLR	CP	RT	CWPI	WS
Damage to airport infrastructure such as buildings, surfaces, roads and utilities	▬	▬	▬	▬	
Disruption to airport operation	▬	▬	▬	▬	▬
Faster aging of infrastructure and repairing requirements	▬	▬	▬		
Prolonged exposure to excessive heat leading to thermal cracking of paved surfaces			▬		
Impact on takeoff profile of aircrafts due to reduced lift			▬		
Requirement of longer runway to compensate for lighter air			▬		
Increased cooling requirements of buildings			▬		
Impact on equipment performance because of excessive heat			▬		
Impact on ATF handling and distribution due to increased temperature			▬		
Increased fire risk in the airside area			▬		
Impact on airport operation in terms of changes in prevailing wind pattern				▬	
Increased damage to on ground assets such as aircrafts, vehicles equipment				▬	
Increased Foreign Object Damages of aircraft engines				▬	

4. Operational and business risks faced by the airport(s)

Climate change is one of the key business and operation risk for Airports of the Asia Pacific region. For better understanding the climate risk type faced by the Airport, the survey requested the Airports to respond to climate risk types as per TCFD recommendations [17]. The TCFD recommendations categorizes the climate risk into transitional risk and physical risk. Most of the transitional risk can be associated with business risk and physical risk can be associated with operational risk. Among the participating Airports 89% of the airports confirmed physical risk as

the key risk, where as in addition to this 33% of the Airports also confirmed facing transitional risk (Figure 6). This also indicated many of the Airports faces both the risk simultaneously.

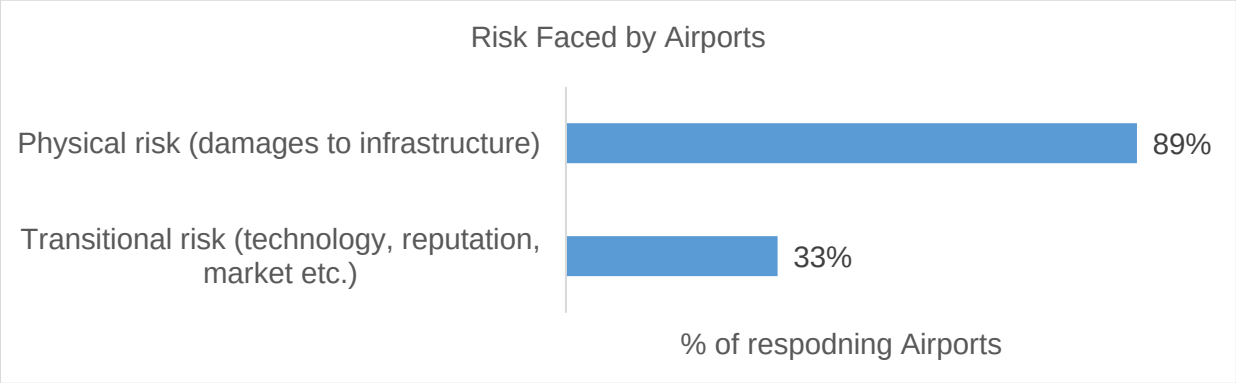

Figure 6: Risk faced by responding Airports

4.1. Transitional Risk

The key transitional risk identified for Airports following the Recommendations of the Task Force on Climate-related Financial Disclosures (TCFD) [18] are:

4.1.1. Policy and legal risk

The release of IPCC’s 6th Assessment Report has re-established the climate vulnerability and threat being faced by the world. The report has confirmed that climate change is happening at a faster rate and the world might exceed the 1.5 degree limit faster than as estimated earlier.

Most recently, the Glasgow Climate Pact in COP 26 has requested countries to review their emission reduction plan to ensure that 1.5 degree limit isn’t bridged. COP 26 also saw a number of countries committing to Net Zero Emissions, with a majority of countries targeting 2050 as the target year. Among Asia Pacific countries, Bhutan as already achieved Net Zero Status, whereas few other countries- Japan, South Korea and New Zealand has enacted law to achieve Net Zero by 2050 [19]. Apart from this many other countries such as India, China, Bahrain, Indonesia, Sri Lanka etc. has already put in place public commitment to achieve net zero emissions.

Based on this two recent climate events, countries all over the world are adopting stricter policy and legal requirements as they are moving towards net zero world. This will increase policy and legal risk for Airports, as there is an increased level of expectation for Airports to adopt a net zero approach.

ACI World along with the five ACI regions in collaboration with the member airports have developed and adopted a long term carbon goal to achieve net zero by 2050. ACI World has declared this commitment on 8th June 2021 [20]. Under this, ACI also urged government to facilitate necessary support. ACI World is also one of the signatories to a joint declaration aiming to achieve net zero status by 2050 [21]. This declaration also includes other aviation stakeholders such as Airlines, Manufactures and Air Navigation Service Providers etc.

4.1.2. Technology Risk

Aviation is indeed a technology driven sector, which works on innovation on a regular basis to improve the safety, security and provide superior flying experience to mankind. With increasing impact of climate change the Aviation sector including Airports need adopt low emission technologies. Failure of which may lead to technological risk for this sector. The increased Policy and Legal risk will also increase technology risk for Airports as policy makers will strive to ensure stricter clean technology adoption through various policy instruments.

Airports need to identify and adopt efficient technologies for supporting and facilitating Airport operation primarily to reduce congestion, delays and improve ground movement of Aircrafts. This will also enhance operation efficiency and profitability of Airports.

Airports need to adopt cleaner technologies that can utilize alternative fuels, promote electrification of fleets and enhance deployment of renewable energy technologies to meet its energy demand. Developing smart and green buildings by integrating technology and sustainable infrastructure concepts will further enhance resource optimization. These means will reduce the contribution of Airports towards climate change and also ensure protection from climate change impacts.

4.1.3. Market Risk

Climate change also poses a significant market risk for Airports. Because of climate change impacts, the region where the airport is located may lose its share of tourist, which will impact the profitability of the Airport as tourist passengers lead to increased revenue generation.

Another market risk for airport are failure develop itself as transit hub. Because of climate impacted operational disturbances, airlines may not prefer climate change impacted airports as their preferred transit hub.

4.1.4. Reputational Risk

Failure to adopt climate change mitigation and adaptation measures also carries significant reputational risk for Airports in today’s scenario. Governments, citizens, NGOs, neighboring communities are increasingly expecting airports to take measures to contribute less towards climate change and Airports are also expected to better adapt to the impacts of climate change. The reputational risk of airports may hinder its ability to attract investors, take up development and expansion projects, lose talent pools etc.

4.2. Physical Risk

As the survey revealed, majority of the Airports consider physical risk as the key climate risk. The recommendations of TCFD has further categorized physical risk into acute risk and chronic risk. Acute risk refers to severe climate impacts such as storms, cyclones, extreme winds etc., whereas chronic risk refers to long term shift in climatic conditions such as sea level rise, longer heat waves etc. Bothe the chronic and acute climate risk leads to infrastructure damages.

The airport infrastructure such as buildings, ATC Tower, paved surfaces such as runway, taxi way, apron, road networks and utilities such as electrical distribution systems, water pipelines etc. are vulnerable to physical damages because of climate change.

5. Adaptation measures implemented at the airport(s)

The climate change concerns at Airports needs to be addressed using a top down approach. To ensure this approach, organizations adopt climate change adaptation requirements as one of the policy commitments. The Airports were requested to provide information regarding availability of a policy commitment towards climate change adaptation. Almost 67% of the Airports has responded positively (Figure 7).

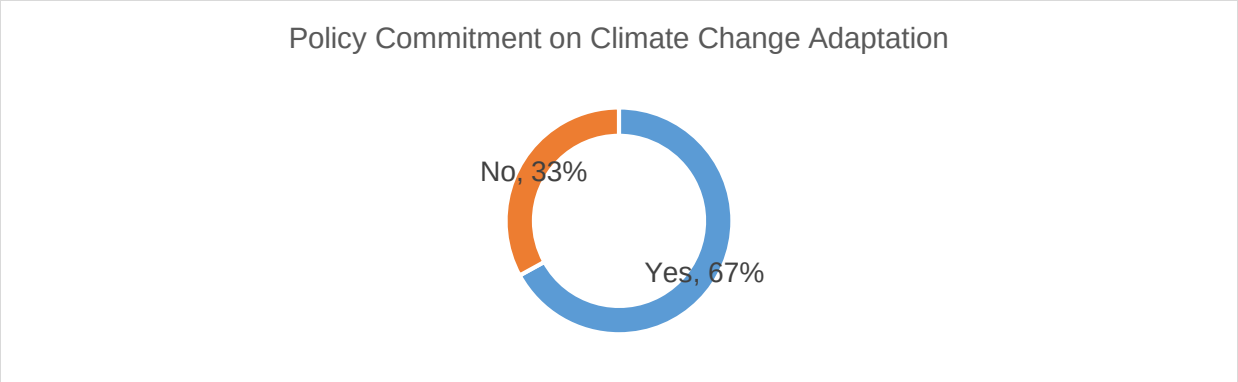

Figure 7: Policy commitment on climate change adaptation by responding airports

According to the survey conducted, 78% of the Airports have carried out risk and vulnerability assessment of key climate change impacts identified by them (Figure 8). This result was matched with similar survey carried out by ACI [24]. As per the ACI survey 62% of the Airports have either carried out a risk and vulnerability study or are in planning stage of conducting such studies.

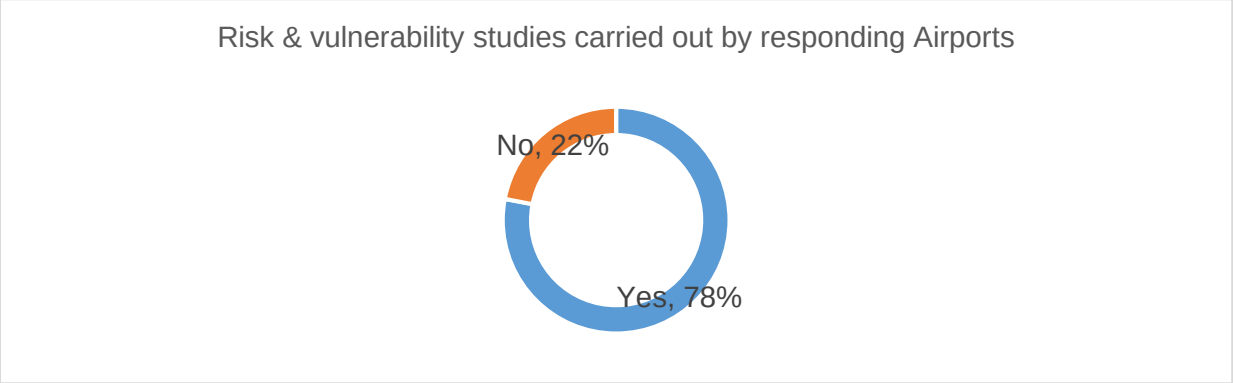

Figure 8: Risk & vulnerability studies carried by responding Airports

The Airports were further requested to respond, if they have considered climate change requirements in the Airport design, 89% of the responding Airports confirmed that climate change requirements are indeed part of Airport design (Figure 9).

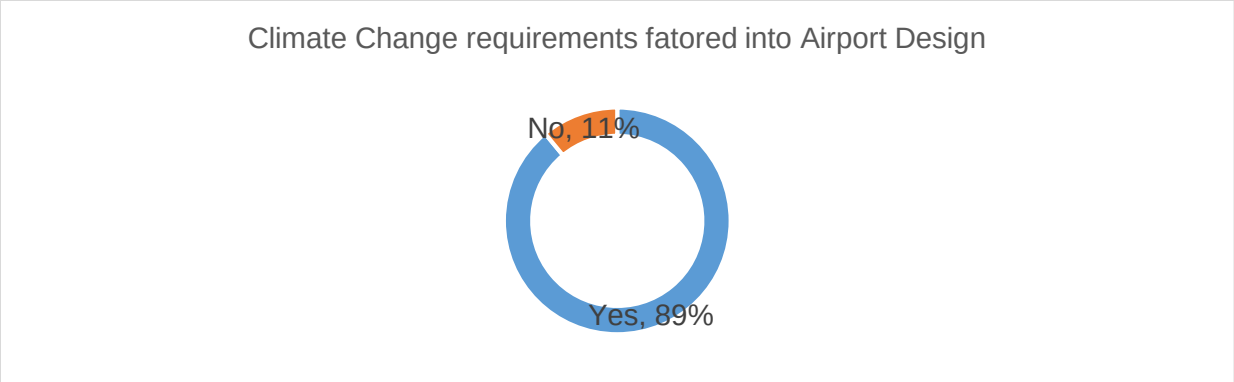

Figure 9: Climate Change requirements factored into design of the responding Airports

Airports were also requested to list down some the key adaptation measures implemented. A summary of the response received in the survey are presented in Table 2.

Table 2: Adaptation measures adopted by APAC Airports

Impacts	Adaptation measures
Water scarcity	• Water shed assessment using advances data analysis and simulation tool WATSCAN • Community water management systems
Sea level rise	• Sea wall protection • tie down areas
Flooding	• Rain water harvesting • Flood modelling • Improved storm water drains
Temperature rise	• Green building development
Extreme weather events/ Storm	• Better building design for protection against storm • Develop robust electrical system • Electricity back up system • Lighting warning system
Others	• Risk assessment studies

6. Case Study of Delhi Airport

6.1. WATSCAN Study under taken by Delhi Airport

6.1.1. Project details

Water scarcity is one of the prime climate change risk faced by entire Delhi and its surrounding region. To evaluate the water scarcity risk and plan for effective mitigation measures, Delhi Airport had carried out a detailed study of the entire Airport. The study was carried out using WATSCAN tool which is an IT based, remote sensing and GIS based decision support system.

6.1.2. Outcome

This study assessed the water generation, accumulation, evapo-transpiration and ground water availability at the water shed level of the entire study area. This study also assessed natural drainage and water flow pattern. Some of the key findings of the study are presented in the graphical form (Figure 10, 11, 12, 13) [22].

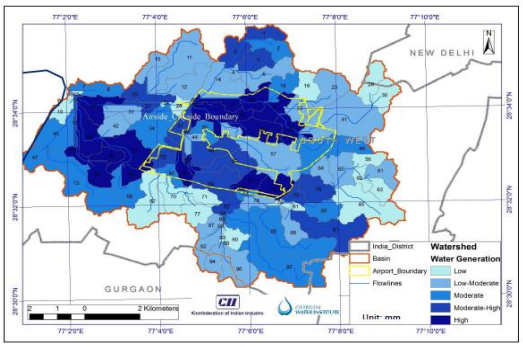

Figure 10: Water Generation (in mm) in DIAL Micro Watershed

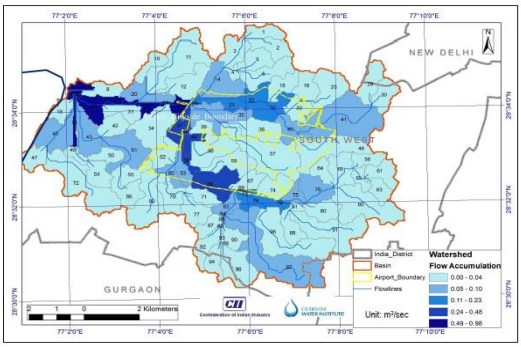

Figure 11: Water Accumulation in DIAL Micro Watershed – Normal Rainfall Year

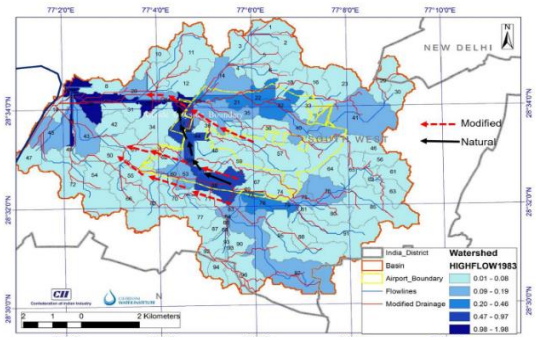

Figure 12: Modified drainage for managing high flows in the airport

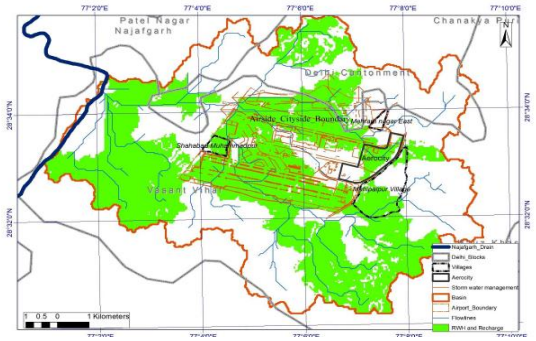

Figure 13: Potential locations for groundwater recharge in the DIAL watershed

Based on the study output, Delhi Airport has added more than 250 RWHS and two rain water reservoirs of capacity 2.2 million liters and 4.74 million liters. These interventions will ensure water availability in the region and improve water security of Delhi Airport.

7. Recommendations- Climate Change Adaptation Strategies for Airports

Climate change is a global issues, however, climate change adaptation requires location actions. There is no fit for all climate change solutions, as the impacts varies from location to location, so does the solutions. Hence it is important for Airports to identify the key impacts, its risk and vulnerability of the Airport to climate change. In order to address this, Airports may follow the below approach-

Identify

- **Identify** the current as well as future risk of climate change

Analyze

- **Analyze** the risk and their impacts

Understand

- **Understand** the linkages between the risk by conducting risk and vulnerability study

Categorization

- **Categorization** of risk using a risk matrix

Develop & Implement

- **Develop** & Implement risk mitigation plan & identify opportunities

Review

- **Review** of risk and effectiveness of mitigation measures on a periodic basis

7.1. Scenario analysis

Scenario analysis is a strong tool that can be used to identify and analyze the climate related risk and its impacts faced by Airports. The TCFD guidance can be used for scenario analysis [23]. Airports may consider its business strategy, future growth, and infrastructure demand, national and regional climate change requirements to create scenarios and analyze how the Airport will perform, under various climatic conditions. Airports can also review how it will get impacted because of the IPCC 1.5 or 2 degree scenario. This approach will enable airports to assess the effectiveness and resilience of their climate change strategies. Based on the expertise and need of the Airport, qualitative, quantitative or detailed data driven sophisticated scenario analysis may be carried out.

7.2. Understand the linkage between the climate change impacts

All the climate change impacts are inter linked (Figure 14). It is observed that one impact may lead to multiple other impacts. For example, climate change leads to temperature increase, which also increases water demand and may lead to water scarcity, whereas rising of sea levels may also lead to water scarcity by polluting some of the surface as well as underground water sources.

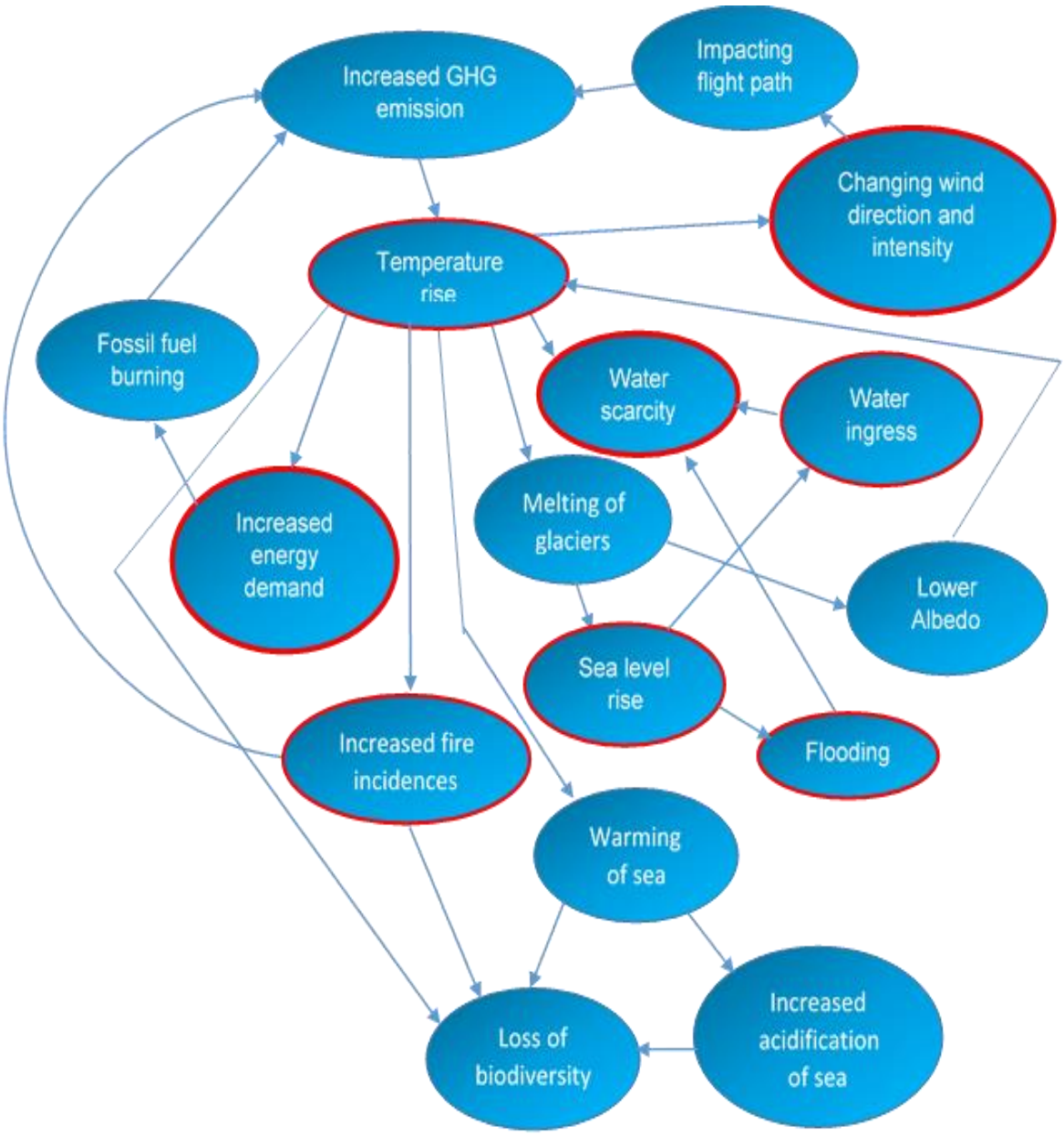

Figure 14: A representation of linkages between climate change cause and impacts

In addition to this, temperature increase also leads to more energy demand and if the source of energy is fossil fuel based, it will further contribute towards more GHG emissions and thus further

contributing to climate change. Once linkages between the impacts faced by the Airport are known, it will help the airports in adopting appropriate strategies for both mitigation as well as adaptation. Some of the linkages between the cause and impacts of climate change is shown in Figure 14. The shapes with red circles indicate the direct impacts faced by Airports.

7.3. Categorization of Risk

Airports can undertake a risk mapping exercise to categories various types of climate risk. A risk matrix can be developed for all risk and its impacts. Risk categorization is a function of severity of impact and frequency of occurrence. In this certain score can be attached to both the severity and frequency. Based on the score, the impact can be categorized as low risk, medium risk, high risk and very high risk. An example of categorization of impacts based on their risk is presented in Figure 15.

Frequency of impacts		Very high	High	Medium	Low
Severity of impacts		4	3	2	1
Very high	4	16	12	8	4
High	3	12	9	6	3
Medium	2	8	6	4	2
Low	1	4	3	2	1

Figure 15: Risk categorization of impacts

Here, as a reference following categorization criteria can be followed- 16- Very high risk (physical damage and long term operation closure), 12-9- high risk (physical damage and temporary but complete operational closure), 8-6- medium risk (physical damage and temporary reduced capacity for operation), 4-1- low risk (no physical damage but certain operational changes needed).

Based on the risk categorization, risk mitigation strategies can be adopted and opportunities for the airports may be identified. Some of the transitional risk and probable mitigation measures are summarized in Table 3.

Table 3: Transitional risk, potential impacts and mitigation

Risk Type	Potential Impacts	Risks Mitigation
Policy and Legal Risks	• Stricter government mandates on climate action • Passing on countries COP 26 commitments & Net Zero Targets to Airports	• Airport level strategy to reduce emission • Align Airport’s emission reduction objectives in line with country/regional objectives
	• Enhanced emissions-reporting obligations	• Adopt robust GHG management system in line with ACI ACA
	• Exposure to litigation	• Mitigation & adaptation measures in place • Communication strategy • Engagement with community via social media • Engagement with Government Agencies/regulators
Technology	• Early retirement of existing assets	• Substitution of existing technologies with lower emissions options • Initiate technology evaluation, pilot projects for adoption • Adopt automation, digitization
	• Costs of transition to lower emissions technology	• Adopt life cycle cost approach • Identify innovative business model & financing mechanism for meeting expenses • Working with aviation stakeholders for reduced airport emission

Risk Type	Potential Impacts	Risks Mitigation
Market Risk	Impact on revenue generation • Impact on tourism • Impact on volume of transfer passenger • Threat toward becoming a transit hub	• Focus on non-aero revenue generation of the Airport • Ensure better passenger experience • Carry out climate change risk assessment and implement adaptation measures
Reputation Risk	• Conflict with community • Negative stakeholder feedback • Shareholder concerns	• Ensure periodic communication regarding the mitigation and adaptation measures adopted by the airport. • Engagement via social media • Engagement and collaboration with stakeholders to discuss and resolve issues

The physical risk and probable mitigation measures are summarized in Table 4.

Table 4: Physical risk, probable impacts and mitigation measures

Risk Type	Potential Impacts	Cause	Risk Mitigation
Physical Risk on Infrastructure	Damage to Airfield (including Runways, Taxiways and Aprons)	• Temperature rise • Changing precipitation	• Formation of dedicated team • Regular inspection • Runway surface condition testing
	Deterioration of pavement surface and breakup into Foreign Object Debris (FOD)	• Temperature rise • Changing precipitation • Increased intensity of storms	

Risk Type	Potential Impacts	Cause	Risk Mitigation
	Drainage and run-off systems capability	• Changing precipitation	• Flood modelling, • adequate drain design, • RWHS, • Landscape development
	Electrical systems (including lighting and signage)	• Temperature rise • Changing precipitation • Increased intensity of storms • Changing wind	• Develop onsite energy generation system to avoid impact from grid outages • Develop more than 1 layers of redundancy in power systems • Use of backup power system
	Impeded ground access	• Changing precipitation • Increased intensity of storms	• Develop Multi modal connectivity
	Increased fire risk	• Temperature rise	• Have in place adequate fire stations • Identify key fire hazard and develop action plan
Physical Risk on operation	Increased runway length needed due to decreased lift and thrust at higher ambient temperature	• Temperature rise	• Plan for runway length considering all safety requirements and ICAO guidelines.
	Reduced visibility (aircraft & ATC operation)	• Changing precipitation	• Develop CAT IIIB compliant runway as per the operational need

Risk Type	Potential Impacts	Cause	Risk Mitigation
		• Increased intensity of storms	
	Reduced water availability due to drought	• Changing precipitation	• Efficient water use, water recycle and reuse, • Undertake water shed evaluation
	Increased heating, ventilation and air conditioning demand and duration	• Changing precipitation	• Adopt green building concept. • Ensure superior building envelope with low u value, higher SRI value, • Develop efficient HVAC system

The entire risk mapping and mitigation measures needs to be reviewed periodically to identify any changes in the severity or frequency of the impacts and for assessing the effectiveness of the mitigation measures.

7.4. New innovative climate change adaptation solutions

Airports need to identify the climate risk, its impacts before deciding on any adaptation solutions. Apart from the conventional engineering solutions, Airports need to identify new and innovative solutions-

7.4.1. Adoption of Business Continuity Planning System

Airports can also adopt business continuity planning for their airports or if it is already in place, climate change risk can be integrated into the Business Continuity Planning System. Under this, assets which are most vulnerable and key to ensure the Airports continuous operation are identified and alternative as well as fall back actions are prepared in case of any emergency. This will help airports in building resilience towards climate change.

7.4.2. Nature based solution

Nature based solutions are one of the most effective solutions for climate change. For example the protection and plantation of mangroves help in addressing climate impacts such as, storm surge, protection of surface water from sea water ingress.

7.4.3. Green Infrastructure

Green infrastructure development concepts can greatly help Airports in addressing climate change concerns. It helps in addressing some of the key concerns of climate change such as flood by better storm network design and rain water storage facility, provision of bio swales, rain gardens etc. It helps in preventing heat island effect of developed areas, better thermal insulation helps in less heat ingress into the building ensuring lower HVAC requirements. It also guides airports to take water conservation measures to address water scarcity concerns. Right selection of materials and adherence to indoor environment criteria further ensures lesser environmental footprint and better human health.

7.4.4. Revised design and operation approach

Airport need to integrate climate risk and its impacts in the design and operation of Airports infrastructures. The standards and basis of design calculations need to be re-assessed for current climate impacts.

7.4.5. Use of data analytics

Use of climate related data to establish correlation between past climatic conditions and its impacts can give lot of insight into planning and implementation of climate change adaptation measures.

7.4.6. Digital twin

Use of digital twin is also increasingly seen as a key climate change adaptation measure. Actual data of climate variables can be used as inputs to carry out “what if” analysis. With machine learning and artificial intelligence, digital twin can give future prediction of climate risk and impacts. This approach is very useful in testing and visualizing the climate risk faced by the Airport and its impact.

7.4.7. Advanced weather prediction system

Use of advanced weather systems that can predict climate impacts and extreme weather events with great accuracy. This will help airports and all the relevant stakeholders to adopt necessary measures to eliminate or reduce the physical impacts as operational constraints.

7.4.8. Climate Finance

As the climate change adaptation measures often need huge capital investments, hence Airports need to identify innovative climate finance instruments to fund these projects. Airports can explore green financing options for this. In many cases they may also collaborate with government departments as the benefit of climate change adaption measures goes beyond the beyond the boundary wall of the Airports.

7.4.9. Competency development

There is an urgent need for Airports to develop competency among decision makers to identify the climate change risk, understand the complexities and enable them to adopt feasible solutions.

7.5. Collaboration among Airports

Aviation is a global industry, where all the stakeholders can contribute towards the growth of each other. Being a very closely interlinked industry, collaboration can play a major role in improving environmental performances of Airports including addressing climate change.

7.5.1. Information sharing

Airports may collaborate on information sharing regarding climate change impacts or changes in weather pattern. Closely located airports can work together in identifying and communicating climate related risk and extreme weather events.

7.5.2. Knowledge sharing

Airports may also share the learnings form their experiences. The success and failure of various interventions can be shared which may help other airports facing similar risk and impacts.

7.5.3. Pilot projects

Airports may collaborate together to work on some of the pilot projects. For example 10 airports can work on 10 different pilots, rather than 1 airport working on all the 10 pilot projects to

understand the feasibility and effectiveness. This will reduce the time, efforts and resource requirements by Airports to a great extent. The findings may be shared among the Airports.

7.5.4. Climate change Mentorship Program for Adaptation

Following the ACI mentorship program for climate change mitigation, a mentorship program can be developed for climate change adaptation as well. Under this, Airports which have implemented significant amount of measures for climate change adaptation may guide Airports who lack technical competency to address such issues.

8. Conclusion

There is no denying of the fact that climate change is happening all over the world and impacts are getting severe. However with right strategy, assessment and initiatives, the impacts can be eliminated or reduced. As aviation sector is one of the most vulnerable industry from climate change. In addition, the Airports of the Asia Pacific region are further at risk because of the geographic nature of this region. Airports of this region can address climate change and build resilience by a mix of mitigation and adaptation strategies.

List of Abbreviations

ACA	Airport Carbon Accreditation
ACI	Airports Council International
APAC	Asia Pacific
AR	Assessment Report
ATC	Air Traffic Controller
ATM	Air Traffic Movement
CAT IIIB	Category IIIB
COP	Conference of Parties
CWR	China Water Risk
FOD	Foreign Object Debris
GHG	Greenhouse Gas
GMSL	Global Mean Sea Level
HVAC	Heating, Ventilation, and Air Conditioning
ICAO	International Civil Aviation Organization
IPCC	Intergovernmental Panel on Climate Change
RWHS	Rain Water Harvesting Structure
SRI	Solar Reflective Index
TCFD	Task Force on Climate-Related Financial Disclosures

References

[1]https://www.adb.org/sites/default/files/publication/159335/adbi-climate-change-asia-and-pacific-how-can-countries-adapt.pdf

[2] https://www.adb.org/sites/default/files/publication/663931/awdo-2020.pdf

[3] https://www.airportcarbonaccreditation.org/participants

[4] https://centreforaviation.com/data/profiles/regions/asia-pacific

[5] https://www.sciencedirect.com/science/article/pii/S2212096320300565?via%3Dihub

[6] https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap24_FINAL.pdf

[7] https://www.adb.org/sites/default/files/evaluation-document/36114/files/rise-natural-disasters-asia-pacific.pdf

[8] https://www.adb.org/sites/default/files/evaluation-document/36114/files/rise-natural-disasters-asia-pacific.pdf

[9] 03_SROCC_SPM_FINAL.pdf (ipcc.ch)

[10] https://public.wmo.int/en/media/press-release/weather-and-climate-extremes-asia-killed-thousands-displaced-millions-and-cost

[11] https://www.chinawaterrisk.org/wp-content/uploads/2020/11/CWR_2020_Waterproofing_APAC_to_Avoid_Atlantis.pdf

[12] https://blogs.adb.org/blog/climate-change-impacts-in-asia-are-essentially-water-story

[13] https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap24_FINAL.pdf

[14] https://public.wmo.int/en/media/press-release/weather-and-climate-extremes-asia-killed-thousands-displaced-millions-and-cost

[15] https://www.wri.org/applications/aqueduct/water-risk-atlas/#/?advanced=false&basemap=hydro&indicator=w_awr_def_tot_cat&lat=-4.565473550710278&lng=103.35937500000001&mapMode=view&month=1&opacity=1&p

onderation=DEF&predefined=false&projection=absolute&scenario=optimistic&scope=baseline&timeScale=annual&year=baseline&zoom=2

[16] https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap24_FINAL.pdf

[17] https://assets.bbhub.io/company/sites/60/2021/10/FINAL-2017-TCFD-Report.pdf

[18] https://assets.bbhub.io/company/sites/60/2021/10/FINAL-2017-TCFD-Report.pdf

[19] https://eciu.net/netzerotracker

[20] https://aci.aero/2021/06/08/net-zero-by-2050-aci-sets-global-long-term-carbon-goal-for-airports/

[21] https://aci.aero/2021/10/05/aviation-industry-unites-to-adopt-2050-net-zero-carbon-goal/

[22] WATSCAN Report of Delhi Airport

[23] https://assets.bbhub.io/company/sites/60/2020/10/FINAL-TCFD-Technical-Supplement-062917.pdf

[24] Climate Change Resilience and Adaptation Survey, (2021), ACI