Istanbul Airport: Climate Change Adaptation Strategy and Action Plan

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Istanbul Airport project area lies over an area of 76.5 million square meters to the north of Istanbul, 35 km away from the city center. Airport development will be completed in four phases. The first phase of the airport has three runways and a main terminal that serves 90 million passengers per year. Once all phases are completed, the airport will have six runways and two terminal buildings and three air traffic control (ATC) towers and will host flights to more than 300 destinations with an annual capacity of 200 million passengers. The airport is neighbored by the Black Sea, which has very important assets, namely, the fuel jetty and fuel pipeline systems that feed fuel farms with a 300.000m^3 fuel storage capacity.

INTRODUCTION

IGA's Climate Change Adaptation Strategy and Action Plan aims at developing an adaptation response to the risks identified by this study, which have been determined and prioritized through:

- A consideration of the scale and importance of the risk in terms of likelihood and consequence for IGA[1] in the short- and medium-/long-term.
- An appraisal of the adequacy of the current control measures in place to deal with that risk.
- Consideration of the timescales involved both in terms of when the risk may occur and how long it may take to implement adaptation measures.

Purpose

Infrastructure assets are under specific threat especially in densely populated zones due to extreme weather conditions based on climate change. A strategic approach and long-term planning becomes critical for new projects. In this respect, IGA aims at identification, analysis and management of climate change risks on the planning, construction and operation of the project as part of a climate change adaptation study. Such an assessment and study pose utmost importance as a first of its kind climate change adaptation report for a gigantic infrastructure project.

Rationale

Airports impacted by extreme weather events are on the rise. Rain storms can flood runways and overwhelm storm water systems. Heat waves can damage runways and aircraft tires. Winter storms increase snow removal requirements. Thousands of passengers are left stranded — 70 per cent of airport delays are caused by extreme weather — and the economic impact to airports can be in the billions. And all of these weather events impact passenger, worker and community safety.

Although there is not yet legislation in Turkey for climate change adaptation, IGA has initiated a climate change adaptation plan for this gigantic project. As a result of this work, IGA has comprehensive control measures and contingency plans for managing climate-related risks, and for the most part, they will be considered sufficient to manage climate change risks in the short- and long-term.

1 Istanbul Grand Airport, concessionaire of BOT Contract for İstanbul Airport.

TABLE 1: Sample Worksheet for Analysis of Climate Vulnerability

Adaptation Implementation Worksheet				
Asset	Climate Impact			
	Precipitation	Wind	Temperature	Humudity/Fog
Tower	Damage Risk (Visibility range)	Damage Risk (Destruction)	Damage Risk (Acclimatization)	Damage Risk (Acclimatization, Visibility range)
Aircraft Parking Apron Areas	Damage Risk (Flood)	Damage Risk (Destruction)	Damage Risk (Acclimatization)	Damage Risk (User, Buildings)
Utility Buildings	Damage Risk (Flood)	Damage Risk (Destruction)	Damage Risk (Acclimatization, Fire Risk)	Damage Risk (Acclimatization)
Reservoirs	Damage Risk (Flood)	Damage Risk (Destruction)	Damage Risk (Acclimatization)	Damage Risk (Acclimatization)
RMS	Damage Risk (Flood)	Damage Risk (Destruction)	Damage Risk (Acclimatization)	Damage Risk (Acclimatization)
Water Treatment Plant	Damage Risk (Flood)	Damage Risk (Destruction)	Damage Risk (Acclimatization)	Damage Risk (Acclimatization)
De-icing	Damage Risk (Flood)	Damage Risk (Destruction)	Damage Risk (Acclimatization, Operational Risk)	Damage Risk (Acclimatization)
Energy Distribution System	Damage Risk (Flood)	Damage Risk (Destruction)	Damage Risk (Acclimatization, Operational Risk)	Damage Risk (Acclimatization)
Fuel Farms	Sea level rise	Damage Risk (Destruction)	Damage Risk (Operational Risk)	Damage Risk (Visibility range)
Vehicle tunnels (jet fan)	Damage Risk (Flood)	Damage Risk (Operational Risk)	Damage Risk (Acclimatization)	Damage Risk (Accident Risk)
Transformer Buildings	Damage Risk (Flood)	Damage Risk (Destruction)	Damage Risks (Fire Risk,Explosion Risk)	Damage Risk (Accident Risk)
De-icing	Damage Risk (Flood)	Damage Risk (Destruction)	Damage Risk (Corruption Risk)	Damage Risk (Corruption Risk)
Fuel Storage	Damage Risk (Flood)	Damage Risk (Destruction)	Damage Risks (Fire Risk,Explosion Risk)	Damage Risk (Acclimatization)
Gas Station	Damage Risk (Flood)	Damage Risk (Destruction)	Damage Risks (Fire Risk,Explosion Risk)	Damage Risk (Acclimatization)
Mobile Gas Station	Damage Risk (Flood)	Damage Risk (Destruction)	Damage Risks (Fire Risk,Explosion Risk)	Damage Risk(Visibility range, Acclimatization)
Electrical Infrastructure (ICT)	Damage Risk (Flood)	Damage Risk (Operational Risk)	Damage Risk (Acclimatization, Corruption)	Damage Risk (Acclimatization, Corruption Risk)
Roads / Viaducts, Art Buildings	Damage Risk (Flood)	Damage Risk (Destruction)	Damage Risk (Corruption Risk)	Damage Risk
Lighting	Damage Risk (Flood)	Destruction	Damage Risk	Damage Risk

Scope, Approach and Methodology

The general scope of the study is defined as the first phase[2] of IGA, which has been operational since the 29 October 2018 for parametric change in the pillar years of 2030, 2050 and 2080.

The geographic scope is clearly those years which will cover the assets of the airport. The operational scope will identify the authority of IGA for the operational functions, such as access to the airport.

In this paper, only the climate change adaptation aspects will be given although IGA has the mitigation aspects for the whole climate change action plan content.

CLIMATE VULNERABILITY ANALYSIS

The table below is a worksheet for analysis of climate vulnerability, which has been used for elaboration of risks on assets. Through the parameters explained above, the study looks into potential hazards at the micro level based on assets of the function.

MODELLING THE CHANGE OF PARAMETERS UNDER CLIMATE CHANGE

Models and Scenarios Used:

HadGEM2-ES, MPI-ESM-MR and CNRM-5.1 are chosen as the reference period in order to obtain climate simulations of 50x50km and 10x10km resolution. Then three global climate models selected from the CMIP5 database are downscaled to resolution 50x50 and 10x10 km utilizing the RegCM4 regional climate model. Reference period simulations of the models are matched and compared with the monitored values. All three global models are based on two scenarios; namely, **RCP4.5** and **RCP8.5** (Url-1).

RCPs form a set of greenhouse gas concentration and emissions pathways designed to support research on impacts and potential policy responses to climate change (Moss et al. 2010; van Vuuren et al. 2011).

The simulation results have been evaluated by four parameters, namely; temperature, precipitation, relative humidity and wind anomaly. Additionally, three climate indices have been derived based on simulated atmospheric fields; FD0, TX35 and R25. **FD0** indicates the number of days in a year with freezing temperatures; **TX35** is the number of days in a year in which the temperature exceeds 35°C ; and **R25** is the number of days that receive precipitation of more than 25mm.

2 Main terminal building, 3 runways and auxiliary buildings.

CLIMATE CHANGE ADAPTATION

Infrastructure Design:

During the design of all landside and airside infrastructure components, Q_{100} flows have been considered in the calculations to meet extreme flood events though FAA 150/5320-5D Section 2-2.4 recommends Q_5 or Q_{10} for storm water infrastructure while the Turkish regulation dictates Q_{25} for such large catchment areas.

Superstructure Design:

During the design of the superstructures, static projects have been prepared considering climate change impacts. In this regard, loads of the structural elements have been taken more conservatively than the regulatory standards such as:

Wind: Wind loads have been calculated by carrying out wind tunnel tests for terminal buildings and have been taken as 225 kg/m^2, which is two times higher than the regulatory standard.

Snow: Snow load has been calculated using historical meteorological data. Although, snow load for Istanbul is known as 75 kg/m^2, 125 kg/m^2 has been taken for terminal buildings.

Temperature: Temperature variance has been taken between -24°C and +24°C for the heat effect.

Fuel Jetty and Pipelines:

Fuel jetty and its relevant elements have been designed by considering meteorological data for a 100-year return period as well as expected global sea level rise, which is 110 cm for year 2100. This cumulative 110 cm rise reflects seasonal change, tidal effect, atmospheric pressure and Coriolis Effect, storm surge, wave surge, and global sea level rise due to climate change. Of this 110 cm sea level rise, 50-60 cm is assumed to occur due to climate change impact. The overload test was done with 120 per cent wave height in laboratory conditions. Since there is no national sea level rise assessment study, assumption for sea level rise has been taken from the report of the Intergovernmental Panel on Climate Change (IPCC) for year 2100 that was published in 2013.

According to the guidelines and requirements of the General Directorate of Infrastructures Management under the Ministry of Transportation, the critical cross section of the fuel jetty design feature has been physically tested and the design has been controlled. The critical section is the section in which the highest wave is encountered.

According to the laboratory test results:

- Main breakwater has been widened.
- Crest level has been increased from 9,5 m to 10,5 m.
- The length of the main mole has been increased from 550 m to 650 m.
- Additional armor layers were installed to the round part of the secondary mole. The volume of the round X Block was increased from 12m3 to 16m3. For the Istanbul Airport fuel jetty, the largest x-Block armor layer (16m3) in the world has been used.

Operational Efficiency by Layout of the Airport:

At the Istanbul Airport, the layout of airside is planned to provide the maximum efficiency and operational flexibility while maintaining the highest safety and minimal operational risks. In order to provide maximum efficiency, a wide variety of operational conditions should be considered that include weather related conditions such as low visibility, snow/ice, heavy winds, heavy rains, etc., or operation-related conditions such as maintenance, accidents, emergencies, etc.

In order to achieve the above benefits, planning started with the usual runway and airside design elements such as wind direction and obstruction analysis. Once the direction of runways were identified based on prevailing winds, and the profile of runways were identified based on obstructions, operational considerations then guided the next design decisions. For increased capacity and maximum safety, runways were separated to provide "independent approach" capabilities, and additionally, .each primary runway was paired with an auxiliary runway to provide better air traffic management (ATM) flexibility.

By doing so, the primary runway could be used for arrivals as well as the auxiliary runway, thereby increasing capacity while maintaining safe operations. In addition, auxiliary runways help to maintain capacity during heavy maintenance of primary runways. Details of the runways such as rapid exit taxiways and runway entrance taxiways are designed for minimum runway occupancy time and maximum flexibility durıng aircraft line-ups for take-off. As experience in aviation shows, the drainage concept and infrastructure is quite critical for safe airside operations. The longitudinal profile and cross section of runways were designed to provide the shortest drainage root to minimize any risk of water accumulation that may lead to critical issues from aquaplaning to area flooding.

The next step in the design of the Istanbul Airport airside layout was the arrangement of a taxiway system. Parallel taxiways on both sides of runway pairs allow for independent operation of runways. However, the most critical innovative approach on the taxiway system is utilizing end-around taxiways. An end-around taxiway is essentially a route for an aircraft to taxi around an active runway without stopping or delaying any runway operation. This allows continuous taxiing while preventing any runway incursion risks. This setup creates a highly efficient taxiway system with minimum runway incursion risk. Another important element of the airside taxiway design is to have dedicated taxiways for arrival and departure which again minimize the risk of aircraft traffic clash.

The aprons were designed based on their intended operations. For stands, the MARS approach was used for efficiency enabling either one wide body or two narrow body aircraft to be parked at a MARS). For de-icing aprons, locations were identified based on taxi times between the de-icing apron and runway take-off positions and capacity was identified based on the number of aircraft that may need de-icing simultaneously. The drainage on apron areas was done using slot drains for efficient results. This also allowed proper storage locations for waste management such as de-icing fluid collection or oil separation.

The airside infrastructure is strengthened by the All communications, navigation and surveillance systems (CNS)/ATM systems installed for operations. All primary runways are instrumented as CAT IIIb. In addition, every runway pair is serviced by its own own Doppler Very High Frequency Omni Range (DVOR)/distance measuring equipment (DME), which is a unique feature. The aeronautical ground lighting (AGL) is designed as CAT III with follow-the-green capability. The entire airfield is controlled by Advanced-Surface Movement Guidance and Control System (A-SMGCS) and controllers operate usıng using integrated Controller Working Position (iCWP) with integrated integrated Electronic Flight Strips (EFS). All CNS/ATM and AGL systems are integrated into A-SMGCS allowing controllers maximum sıtuational awareness and controlling capabilities.

Overall, the Istanbul Airport airside layout and the systems installed work as one system for maximum efficiency. The layout may look complex due to the number of taxiways, however when closely reviewed , the operations are actually quite straightforward and simple.

Early Alarm Systems:

LIDAR, LLWAS and C-band radar will be installed at the airport to get early information and to communicate with the airline operators and air navigation systems.

LIDAR (Light Detection and Ranging; Laser Imaging Detection and Ranging):

LIDAR is the observation system that works with the principle of reflection of the laser beam from the object and radar similar to the working principle. LIDAR gives instant information by changing the wind intensity (3-dimensional) with height. Information about wind data measured by LIDAR and wind shear can be transferred directly to the computer screen.

LLWAS (Low Level Wind Alert System):

This system observes the sudden changes in low wind speed and intensity in the final approach. Wind shear can be observed in the atmosphere for many reasons (frontal state, sea ground interaction, convective situation, etc.). In the history of aviation, it is one of the most critical events causing many accidents.

C-band Radar:

In the frequency band between 300 MHz and 1 GHz (i.e. 350-400 km coverage); special radars, such as early warning radar, or wind profile (wind profiler) for meteorological observations, have been developed. These frequencies are minimally affected by meteorological formations such as cloud or rain, thus achieving very long ranges. With this type of radar, the position, speed, direction of movement of the meteorological target can be determined; and the type, intensity and amount of the meteorological incident can be realized.

Management Systems:

The management system includes new technologies and approaches for operating, maintaining, managing, and sustaining the infrastructure like the the Internet of things (IOT)-based management system.

Adaptation of Operations:

The continuity of operations under rapidly changing climate conditions are based on the diligent evaluation of possible damage to basic operational activities and prioritization of risk factors. By definition, the risk is the product of probability and impact, which are both arbitrary from the perspective of those who are managing the risk. For the IGA climate change action plan and the related risk management procedures, the subject climate change model highlights the frequency whereby the operator assesses the impact. The risk or significance of the case is reached by multiplying these two factors.

In addition to these implemented macro scale adaptation measures, IGA has carried out risk analysis and identified vulnerable assets and operations due to climate change impacts with micro scale. These assets and operations will continue to be monitored.

CONCLUSIONS

As the climate change action plan envisions the implications of climate change impacts on infrastructure and the adaptation options for each utility in the project, climate change is a global phenomenon with many local impacts.

This study has evaluated the effects of four climate parameters; precipitation, wind, temperature and humidity/fog on the structures and infrastructure utilities. In addition to major structures, micro scale components of assets and operations have been elaborated and vulnerabilities identified with detailed risk assessments using global and regional climate change models for the pillar years 2030, 2050 and 2080.

For the first phase, major structures at the Istanbul Airport have been constructed taking into consideration climate change impacts. Since the project has further phases, similar studies will be carried out and adaptation

RISK DESCRIPTION		PROBABILITY	IMPACT	SIGNIFICANCE
Temperature	Climatization equipments capacity problems	5	3	15
	Pavement cracks	5	2	10
	Fire	4	5	20
	Increase in health problems	3	3	9
	Operational delays cause of temperature	4	5	20
Precipitation	Flooding damage	4	5	20
	Infrastructure overflows	5	4	20
	Accidents	4	4	16
Wind	Operational delays cause of wind	3	4	12
	Collapse of structures	3	4	12
	Damage of external equipments	3	3	9
	Roof damage	3	3	9
Humidity	Operational delays cause of humidity	3	4	12
	Isolation materials damage	3	3	9
	Damage of climatization equipments	3	3	9

VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH
1	2	3	4	5

requirements will be embedded within the Master Plan. Additionally, the operational Phase 1 climate change risks on assets and operations will be elaborated in further detail with more climate indices that will include CDD (consecutive dry days), CWD (consecutive wet days), FD (frost days), ID (iced days), R99TOT (the most rainy days), T<5 (days with temperatures below 5 ^{0}C) for the years up to 2050 since there are too many uncertainties for the years beyond that point to include them in the plans.

More importantly, a climate change adaptation action plan is an ongoing process in which the operator should take different but concurrent steps to identify new risks, propose risk mitigation strategies, review the existing impact for maintenance in good time while addressing the potential impact, and to offer remedies. The potential risk for loss of operational capacity and business volume due to climate change has to be continuously observed as an aspect of financial and economic management. Staff and executive management awareness for investment in adaptation and greenhouse gas (GHG) emission reduction is necessary, especially for preferential assessment of new technology.

The asset inventory and actual impact on the assets due to climate change and resulting loss of operational capacity should be reported regularly. Disaster risk reduction and management is an important part of the climate change action plan. Strong community engagement and stakeholder participation is essential.

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CHAPTER EIGHT

Towards a Circular Economy