Climate Change Resilience Strategy – Redefining Flood Protection At Kansai International Airport

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On the 4th of September 2018, Typhoon Jebi swept across Shikoku Island, Japan and continued tracking over Osaka Bay, leaving in its wake thirteen fatalities and extensive damage to the region. Kansai International Airport (KIX), which serves Osaka, was heavily damaged by that major weather event. At the peak of the storm, five meter high waves spilled over the seawalls, resulting in severe flooding on the island and the airport. As a direct consequence to the typhoon, the airport was closed for three days but resumed partial operation on day 4 and full passenger operations after 17 days, on September 21st.

FIGURE 1: Kansai International Airport after Typhoon Jebi (Source: Mainichi Shimbun)

This article summarizes what happened at Kansai Airport as a result of the typhoon and presents some lessons learned and the resulting strategies that will be implemented to deal with such events in the future. The article covers three main subjects:

- The damages sustained by the airport due to typhoon JEBI.
- Defensive strategies against flooding for use at the airport design and construction stage.
- Strategies that have been adopted to protect the airport against future flood events.

DAMAGE EXTENT AND IMPACT OF DAMAGE

The damages to Kansai International Airport that were caused by Typhoon JEBI were severe and of three main types: physical, operational, and economic.

Physical and Operational Damage

As shown in Figure 2 the cargo area was completely flooded and cargo operations were unable to resume until after a complete clean-up of the cargo area was finished at the beginning of November, 2018.

As shown in Figure 3, the main access bridge to/from the airport was severely damaged during the typhoon and reopened its train access on September 18th while public traffic reopened October 1st , with restrictions. It was not fully reopened until April 8th, 2019, a full seven months after the storm.

Initially, the physical damage to the access bridge delayed the evacuation of stranded passengers and staff, an operational scenario which had never been foreseen. Operational staff first had to re-establish access via the bridge on an emergency basis to evacuate passengers and personnel. After that, they had to set up procedures to allow for the limited reopening of the bridge on September 7th.

The following chart details the recovery of airport operations over a five-week period.

ECONOMIC DAMAGE

Direct and indirect economic damage to both the airport and the Kansai region were significant as a result of the partial operation of the airport during the period of recovery. In addition to the lost revenues by all stakeholders due to suspended operations, the costs of recovery operations themselves were significant.

FIGURE 2: Flooded Air Cargo Area after Typhoon Jebi – Kansai International Airport

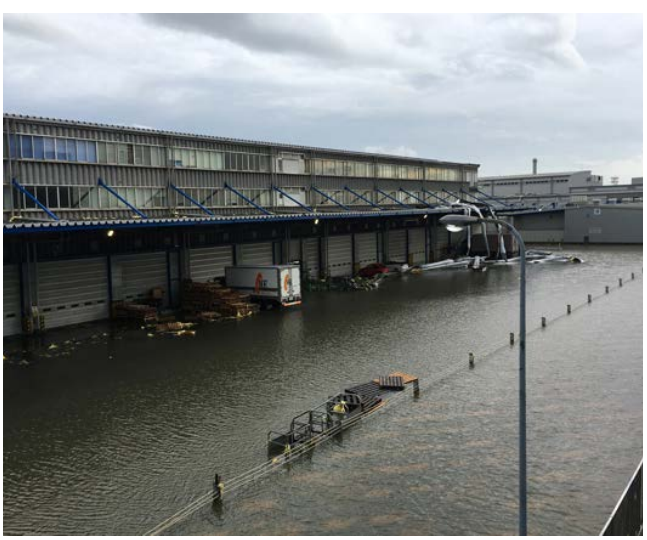
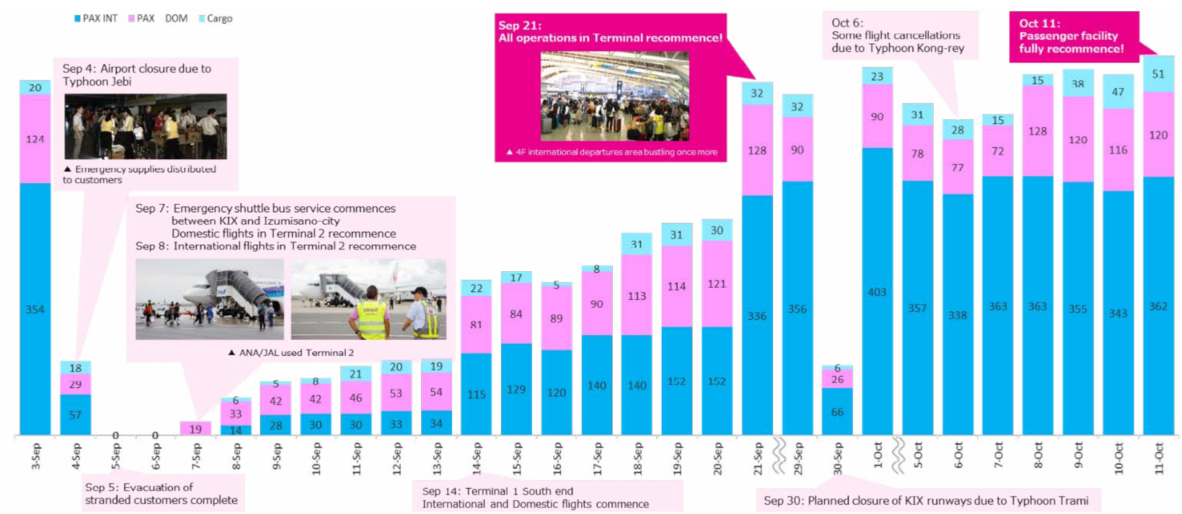


FIGURE 3: Damaged Access Bridge caused by Typhoon Jebi – Kansai International Airport

FIGURE 4: Timeline of Physical and Operational Recovery Operations After Typhoon Jebi – Kansai International Airport



The Kansai Region is one of the main gateways to Japan for tourism and industry. The Asia Pacific Institute of Research has estimated that the impact on the region was some 60 bnJPY (USD$ 500 M) as a consequence of the airport closure. That is equivalent to 0.3% of the entire Kansai Region GDP.

IMAGE DAMAGE

Immediate wake of the typhoon and during recovery operations, criticisms were raised by airline passengers, airlines and other airport businesses because the airport's response to dealing with the crisis did by not fulfill their expectations. Both airport management and local authorities were criticized heavily for alleged mismanagement of the situation.

The damages to the Kansai economy and to the airport stakeholders, demonstrate the critical nature of the airport in the region. The Typhoon Jebi disaster has made it abundantly clear the airport community has a definite social responsibility towards the local community to better plan for and manage such crisis situations. In fact, the airport operator has a duty to plan for these extreme events. And it starts with the initial design of the facility, including all subsequent modifications to the design.

INITIAL DESIGN ASSUMPTIONS – KANSAI INTERNATIONAL AIRPORT

Kansai International Airport (KIX) was designed as an innovative man-made island. The main technical challenge in its design was to allow for an expected settlement of the soil of around 12 m. However, since 2005 the settlement at KIX has exceeded initial estimates and is already at about 14 m. The original design allowed for what was believed at the time to be adequate elevation above sea level that would prevent any possible flooding. Adequate elevation coupled with a gravity drainage system, was believed to be sufficient defense against the sea. However, due to the additional two meters of soil settlement this is not anymore the case and the criticality of the sea defense and drainage are now of prime concern. The infrastructure design needs to be modified.

The Intergovernmental Panel on Climate Change (IPCC) now predicts sea level rise beyond which was taken into account at the design stage for KIX. IPCC projections on sea level rise do not include storm surges that occur when a severe storm/typhoon such as the one which struck KIX.

ADAPTATION OF THE DESIGN

Revising the Business Contingency Plan (BCP)

In view of the consequences of typhoon JEBI and the risk of recurrence of such an event, the airport operator has revised its Business Contingency Plan (BCP) to further promote the direct involvement of stakeholders in the response to such a crisis. In addition, the airport operator has evaluated not only the weakness of the airport, but also of all airport stakeholders in the context of a possible future flood event. This will better address the public interest and the continuity of operations of all stakeholders.

Revision of the Design Parameters

Obviously the design parameters have been revised to take into account the newly measured values. In addition, climate change effects have been partially incorporated into these values by:

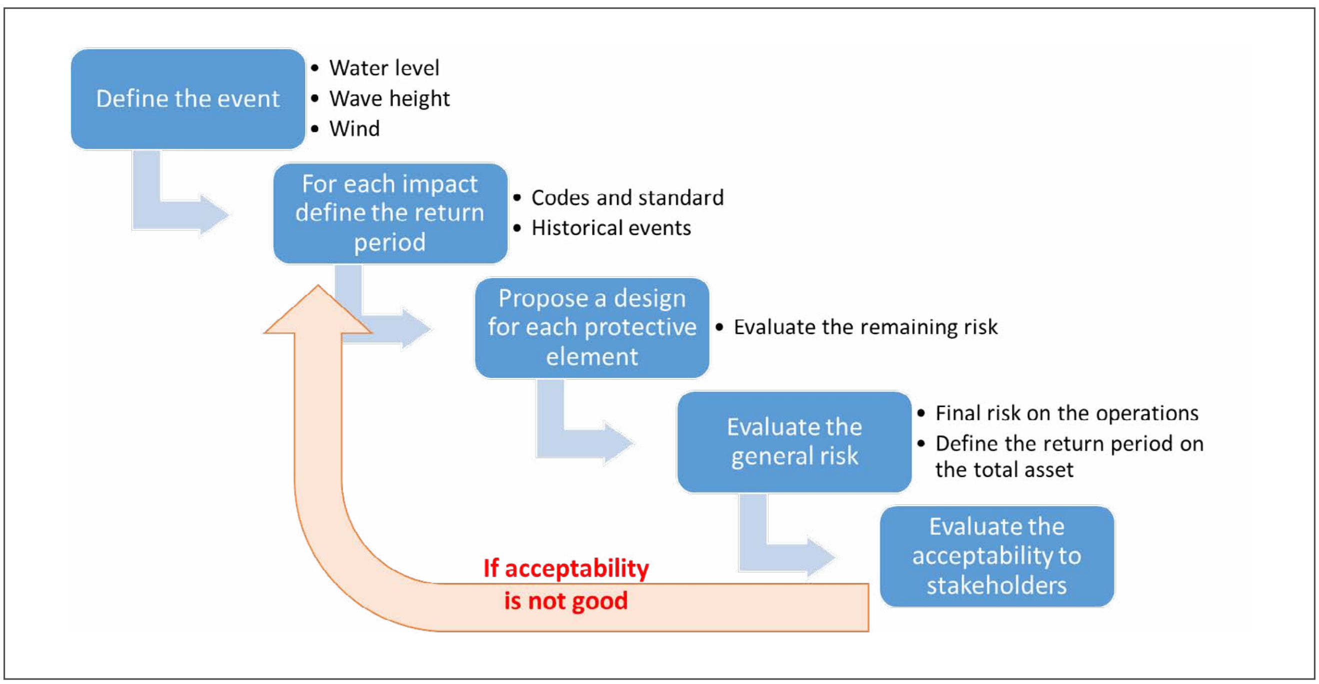
- Including some allowances for rises in sea-level.
- Adopting a conservative approach when estimating storm surge wave heights.
- Setting design parameters higher than what is required in the technical design standard.

Definition of a Resilience Strategy

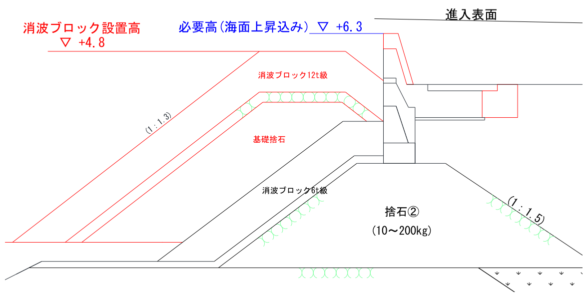
Even if the new or modified structures are based on the current design standard, the infrastructure will be adapted to be more resilient to deal with future extreme events, in order to ensure the acceptability by all of the stakeholders.

The decision process for evaluating possible events and developing a corresponding resiliency strategy is presented in Figure 5 below.

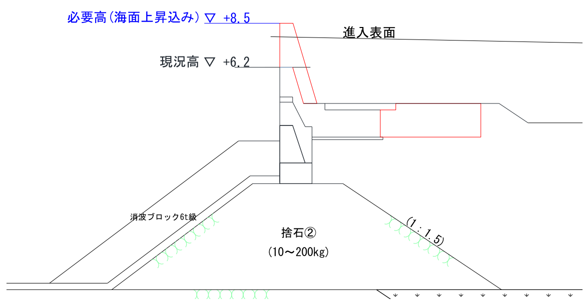
FIGURE 5: Flow Diagram for Developing an Infrastructure Resiliency Strategy



For instance, the overtopping rate required as per the Japanese standard can be achieved following several defense strategies. Following is the cross-section of the protective barrier with a raised tetrapod and protective seawall.



Below is the cross-section of the protective barrier with a raised protective seawall only.



A comparison of the overtopping rate based on different wave conditions is shown below.

Cross section design parameters		Design 1: With raised tetrapods	Design 2: Seawall raise only
Design wave height (50 years return period)		3.9m (WSW)	
Seawall height		CDL+8.5m	CDL+6.3m
Overtopping $m^3/m/s$	50 years	0.02	0.02
	100 years	0.044	0.035
	200years	0.103	0.063

The retained solution (with raised of tetrapods) is the one which will provide the best resilience in case of an event that is greater than the design standard.

Conclusion

The flood protection in KIX is being revised from the infrastructure point of view to integrate new factors that are linked to climate change:

- Sea level rise
- Frequency of events
- Power and Intensity of events

Furthermore, the strategy has been extended to events more powerful than the design level in order to establish a robust resilience plan.

Typhoon Event			Volume of water on 1st island	Airport Functions		
Typhoon size VS design	Return period	Equivalent Wind speed				
Flood > "resist" assumptions ⇒ major damage	Beyond probabilistic model		10 M m3 2 m in average	Drainage	PTB	Cargo
				AFL	BHS	Hotel
Flood < "resist" assumptions ⇒ minor damage and early restart	1 in 750 years	89 m/s	6 M m3 1.2 m in average	Drainage	PTB	Cargo*2
				AFL	BHS	Hotel
	1 in 500 years	80 m/s	3 M m3 60 cm in average	Drainage	PTB	Cargo*1
				AFL	BHS	Hotel
Typhoon > "prevent" assumptions ⇒ some flooding	1 in 400 years	75 m/s	1 M m3 20 cm in average	Drainage	PTB	Cargo
				AFL	BHS	Hotel
Typhoon < "prevent" assumptions ⇒ no flooding	1 in 200 years (incl. JEBI class)	63 m/s (Jebi 46.3 m/s)	< 0.2 M m3	Drainage	PTB	Cargo
				AFL	BHS	Hotel