# Climate Change and Coastal Transport Infrastructure—How Do We Keep Australia Moving?

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**Abstract** Transport infrastructure across the spectrum of airports, seaports, road and rail involves assets that are long-lived, and what is designed today must be done so in the context of expected increases in the intensity of extreme weather events. Much of Australia's transport infrastructure is located close to the coast and is vulnerable to sea level rise and its associated processes (e.g. erosion, inundation), and other climate change-related extremes storms, heatwaves, droughts and floods. Faced with the uncertainties of the timing and severity of climate change, decisions about what, where and how to build new coastal transport infrastructure as well as maintaining existing ones will become more and more challenging in the future. This paper summarises the risks to coastal infrastructure from climate change and the key drivers that owners and operators of transport infrastructure in Australia should consider to help them adapt to the effects of coastal climate change and extreme weather events. This includes both the siting and design of new infrastructure as well as strategies to build resilience of current infrastructure to future impact. Showcasing the National Climate Change Adaptation Research Facility's (NCCARF) on-line adaptation decision support tool, CoastAdapt, the paper outlines guidelines and information available to infrastructure owners and operators to build resilience and adapt to future climate risks including a recent case study undertaken with North Queensland Airports.

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J. Mathew et al. (eds.), *Asset Intelligence through Integration and Interoperability and Contemporary Vibration Engineering Technologies*, Lecture Notes in Mechanical Engineering, https://doi.org/10.1007/978-3-319-95711-1_17

## 1 Introduction

As the growing risk of climate change become more evident, nearly 200 Governments agreed in 2015 as part of the Paris Agreement to pursue efforts to further reduce emissions and halt global temperature increases [8]. However, even if current carbon mitigation targets are achieved, this will not avoid major global impacts and as such there is an urgent need for strong adaptation and mitigation strategies [6].

Coastal transport infrastructure such as airports, seaports, road and rail play a significant role in the national economy and community through passenger movement, imports and exports of goods. A significant proportion of Australia's transport infrastructure is located close to the coast and vulnerable to climate change, sea level rise and its associated processes (e.g. increased intensity of extreme weather events, erosion and inundation). The design life of transport infrastructure is long making it critical that it is designed with consideration of expected future increases in the intensity of extreme weather events. Faced with the uncertainties of the timing and severity of climate change, decisions about what, where and how to build new coastal transport infrastructure as well as maintaining existing assets will become more and more challenging in the future. A number of guidelines are available to assist the transport sector to understand climate risks and adaptation (e.g. Ng Ak et al. [5]). However, there are few guidelines available which apply across coastal infrastructure types and are specific to the Australian context. The Australian Government commissioned the National Climate Change Adaptation Research Facility (NCCARF) to develop a national coastal climate change risk management tool called CoastAdapt which includes a range of national climate change and sea level rise projections, guidelines on risk assessment and adaptation planning. Although not specifically designed for the transport sector, CoastAdapt's information can assist decision makers of this sector to manage their future climate change risks. This was demonstrated by a recent project with Northern Queensland Airports where CoastAdapt was used to investigate climate change risks of Mackay and Cairns airport (see Fisk [3]). This paper highlights how some of the CoastAdapt information can be used by the coastal transport sector in Australia in managing their climate change risks.

## 2 Climate Risks for Transport Infrastructure

The key coastal climate risk parameters that are considered most relevant to transport infrastructure assets and operations (including workforces) are outlined in Table 1.

**Table 1** Key climate change parameters of concern for transport infrastructure

| Parameter | Effects |
|---|---|
| An increase in the severity of cyclones, hurricanes or extreme storm events | That could result in:<br>• Increased high wind events<br>• Increased storm surge (tide) events<br>• Increased major flooding events in the form of either:<br>– overland flooding (rainfall leading to flooding from the catchment or watershed that flows into the port) or<br>– flooding from the sea (storm tide inundation) |
| Changes in rainfall patterns | That could result in:<br>• Heavier rainfall and fog events (causing impacts to visibility and safe maritime navigation)<br>• More frequent flooding and/or flooding at different times of the year to current conditions<br>• Changes to water supply and availability |
| Increasing temperatures | That could result in:<br>• Increased incidents of very hot days and heatwaves<br>• Increased evaporation and fire risk<br>• Increases in water temperature |
| Sea level rise | That as a result of higher mean sea level could result in:<br>• More frequent erosion events<br>• More frequent and far-reaching tidal inundation associated with storm surge and storm tide events<br>• Permanent inundation of coastal areas<br>• Exacerbate the effect of cyclones and extreme storm events listed above. |

## 3 What Are the Major Drivers for Taking Action?

High-level vulnerability mapping assessments of future climate change including sea level rise that have been undertaken at the Australia-wide level [1] and by the various State and Territory Governments have demonstrated that transport infrastructure owners and operators have powerful reasons to begin planning and adapting now to climate risks given their inherent vulnerability. Other drivers for consideration of climate change come from sources that are external to organisations. In particular, recent recommendations made by the Taskforce on Climate-Related Financial Disclosures in December 2016 reported on the need for organisations to include climate-related risks in their mainstream financial filings. The advice and recommendations apply to large asset owners and operators in particular, as they sit on the top of the investment chain. While still in its early stages, the recommendations of the Taskforce place an increasing importance on understanding climate risk and disclosing mitigation and adaptation actions to minimise this risk [8]. Similar guidance released from Australian Prudential

Regulation Authority (APRA) warned that climate change risks can threaten the entire financial system and advised investors to consider climate change risks in their decisions [7]. These reports make it clear that investors, owners and operators in the transport sector will need to start to better understand climate change risks and plan for action.

## 4 Climate Change Risk Management of Coastal Transport Infrastructure Using CoastAdapt

CoastAdapt has developed the Coastal Climate Adaptation Decision Support (C-CADS) framework which is based on ISO31000 risk management framework but tailored for climate change risks (Fig. 1). C-CADS provides general guidelines for climate change adaptation planning which can be used along with CoastAdapt datasets for developing resilience and adaptation pathways of coastal organizations (e.g. local councils, businesses). The following sections complement the C-CADS framework and set out key issues that need to be considered by the coastal transport sector which would allow them to better use this national resource CoastAdapt.

### *4.1 Assess Risks and Vulnerabilities*

In a general sense and as outlined in DIICCSRTE [2], transport infrastructure can be exposed to significant climate risks through:

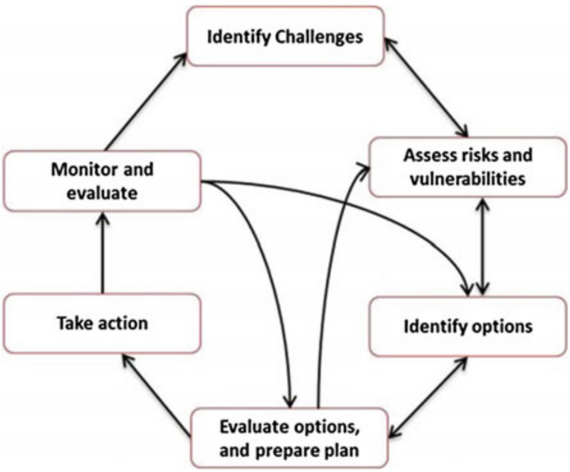


**Fig. 1** Coastal Climate Adaptation Decision Support (C-CADS). *Source* www.coastadapt.com.au

- **risks to assets**. Changing climate may damage major assets including roads, rail, airport facilities and port facilities. Support structures and infrastructure (yards, workshops, etc.) and energy infrastructure and communications facilities will also be potentially affected. Damage to assets can force owners to retire assets early or make major upgrades following damage.
- **risks to operations**. More frequent or intense extreme weather events may disrupt business operations or else the usability or reliability of services. Examples include the effect of floods on rail and road transport and electricity supply, disruption of ports and airports by cyclones and major storms, and reduced productivity of outdoor workers due to high temperatures.
- **critical dependencies**. Extreme weather events may interrupt supply chains or services such as transport, cargo, electricity, gas or water supply on which businesses depend. A changing climate may also affect global trading patterns, for example, by changing the supply of agricultural products or mining products.
- **national economy**. Climate change impacts are a potential drag on the national economy, with a flow-on effect to individual businesses.
- **insurance and capital markets**. Climate change shocks may affect the availability of insurance and access to capital, either locally or worldwide.

From a business perspective, future climate change has the potential to affect the valuation of infrastructure assets by impacting cash flows, operational cost and capital expenditure. The risk posed by climate change may not necessarily be to the asset itself but to the goals and objectives that may be compromised if the asset is impacted or damaged. Thus the primary risks that need to be considered are those to the reliability and performance of the assets and whether relevant targets and performance metrics can continue to be met.

To begin to assess these risks, CoastAdapt advocates a 3-phase risk assessment methodology and provides guidance on three potential risk assessment processes that can be undertaken by an asset manager of a transport authority: (i) a first pass risk screening can be used with existing national datasets to identify most at risk assets and relevant stakeholders; (ii) a second pass risk assessment can be done by having a risk workshop with relevant stakeholders to investigate potential consequences of climate change risks and identify the most critical ones; and (iii) a third pass (detailed) assessment which can be conducted to gain better information for any critical at-risk sector through site-specific biophysical modelling. Key information and data inputs for a climate risk assessment process will generally need to include the following contextual information:

- Picking a timeframe for the assessment (for example—current day, 2050 and 2100), the climate change emissions scenario to be used (most likely, best case, worst case), the spatial study area of the assessment and scope of the assessment.
- Knowledge of climate risks and trends for the local and regional area including expected changes to sea level rise, rainfall patterns, temperature and sea state conditions.

- Knowledge of asset registers and the condition of assets at the study area, the relative value and significance of assets and where available, more detailed vulnerability or hazard mapping.

In order to assist risk assessments, CoastAdapt provides access to sea level rise projections, temperature and rainfall extreme projections for all coastal councils in Australia which can be used by the transport sector to start understanding their future risks (a first-pass or second-pass assessment). CoastAdapt also provides present-day geomorphic information (*Smartline* showing erodibility of the coastline and *Sediment compartment* providing high-level information on sediment movement within a secondary compartment) and historical flood information (*Water Observation from Space* showing the historical presence of water analysing 27 years of Landsat data). These data can assist transport authorities to understand the likelihood of impact from climate change in a risk assessment processes.

Consequence is the other half of the risk equation—that is assessing the consequence of climate hazards on asset condition, life and function or on the operations of the transport authority. Assessing consequence can be far more difficult and subjective to assess without a detailed understanding of the asset and/or operation being impacted and should generally involve content specialists such as asset managers and maintenance staff.

The concept of the adaptive capacity of assets and operations is also important for evaluating risk consequence. Some key considerations here include:

- The design life and resilience of the asset to impacts (particularly if it is not a permanent asset or structure);
- Existing emergency/evacuation management procedures and protocols that can mitigate the risk;
- The degree to which the asset can be reconfigured or redesigned to accommodate changes in climate or extreme weather events;
- Technological changes including the ability to work longer/function during periods of more challenging conditions.

## *4.2 Identify Options for Risk Treatment*

In responding to risks identified, there will be a range of planning and management options available. Focussing on assets, adaptation for transport infrastructure will need to be split between existing assets and new (proposed) assets—with different adaptation tools available to manage current and future risks. Figure 2 shows an example decision tree for assessing options for resilience and adaptation for transport infrastructure, separated between existing assets and new assets.

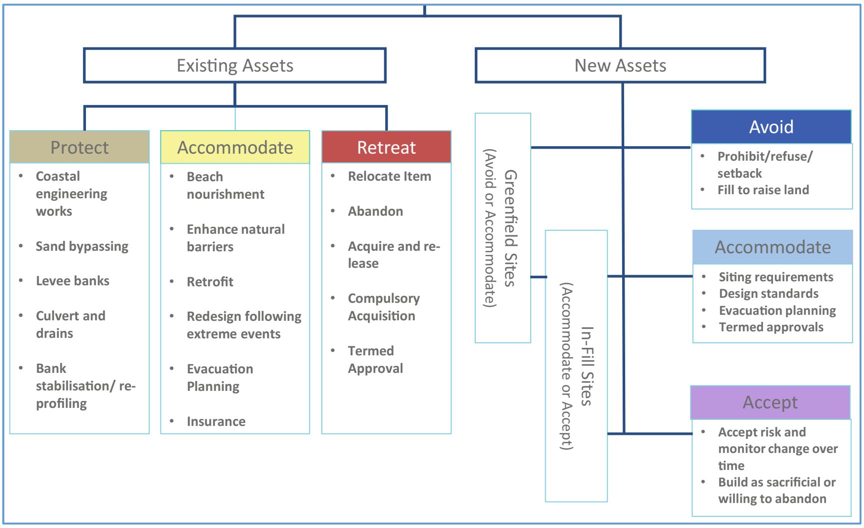


**Fig. 2** Decision tree for application of resilience and adaptation options for transport infrastructure. *Source* Authors

## 4.3 Taking Action and Adaptive Pathways

Implementation of identified options can be done in stages as outlined in CoastAdapt as a pathways approach, originally proposed by Kwadijk et al. [4]. It can allow transport authorities to minimize their current expenditure on managing climate change risks and keep options open. Under the approach, rather than determining a final outcome or decision at an early stage, decision-makers are able to build a strategy that will follow changing circumstances over time. The timing of adaptation activities can also be very important. For example, it makes sense to delay expensive engineering retrofits until threats are more immediate. Alternatively, the implications of sea level rise need to start to be considered now as new port infrastructure will likely be expected to have a design life into the latter part of the 21st century and beyond.

## 4.4 Case Study on Climate Risk Assessment—NQA

This section outlines a short case study on how a transport infrastructure entity (North Queensland Airports) is starting to understand and consider climate change risks for its assets and operations. This case study was undertaken using the tools and guidance contained within CoastAdapt and further information about this and other case studies are available from https://coastadapt.com.au (Figs. 3 and 4).


**Fig. 3** Aerial image of Cairns Airport. *Source* © Google Earth


**Fig. 4** Aerial image of Mackay Airport. *Source* © Google Earth

### Case Study—Climate Risk Assessment for North Queensland Airports

North Queensland Airports (NQA) operates the Cairns and Mackay Airports on leased state land. The airports are situated on the tropical North Queensland coast. Both have been built on low elevation coastal land (reclaimed mangrove ecosystems), are situated in cyclonic regions, experience high temperatures during summer and have climate-sensitive assets and operations. In particular, intense cyclones and associated storm surges and flooding can damage airport infrastructure as well as impact operations by causing temporary closures. Under future climate change and sea level rise, these impacts are likely to intensify.

To better understand climate risks to the airports both now and in the future, NQA undertook an internal risk screening and risk assessment process using the mapping tools and guidelines published in CoastAdapt. The risk screening and assessment process looked at present-day and future risks (at 2030 and 2070).

A broad range of climate change risks were selected for assessment, including:

- increasing average temperatures, including more extremely hot days (greater than 35 °C), and increasing evaporation/drought
- average wind speed increase (noting that higher winds affect aircraft operations and ground handling procedures)
- coastal erosion
- increasing frequency and severity of storm surges and storm tides
- more intense rainfall leading to flash flooding
- more intense storms leading to larger riverine and overland flooding
- higher groundwater table during rainfall peaks (affecting pavements)
- more frequent and more intense bushfires (smoke events)
- more intense lightning storms and events, and fog events
- cumulative impacts from adjacent development (that address or exacerbate climate change impact).

Risks were identified and assessed using the first pass and second pass guidance documentation provided in CoastAdapt (NCCARF 2016). Through a series of workshops (facilitated by the authors), NQA staff assigned risks on the basis of how they could potentially affect each airport's built assets (i.e. runways, taxiways, buildings, aviation precincts) and/or airport operations (i.e. efficiency, productivity and safety). Current climate risks at the airports were all assessed as 'Low' on the basis of the range of risk mitigation and treatment measures already being implemented. Given their existing exposure to coastal hazards, the assessment identified the specific engineering solutions already in place at the airports such as the storm tide levee and pumping system at Cairns Airport and the flood detention drainage system at Mackay Airport.

Future risks from storm surge and tidal inundation exacerbated by higher sea levels were identified as relevant at both airports in the longer term (by 2070). Other future risks include increased flash flooding (from more intense rainfall events) and hence localised erosion. The risk assessment and associated information will be used by NQA to inform their long-term planning.

## 5 Conclusions

With powerful reasons and drivers to build resilience and adapt because of their exposure and limited adaptive capacity, transport infrastructure on the coast will benefit from an adaptive, pathways approach to respond to future climate change. In addition to the existing suite of guidance available from CoastAdapt, specialist guidelines being funded by NCCARF will assist transport authorities and organisation to navigate through an appropriate risk assessment process and to develop appropriate treatment options and triggers.

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