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Citation: Gajanayake, A., Iyer-Raniga, U. 2022. Infrastructure Financing for Climate Change Adaptation in Australia: Practitioners' Perspectives. *Construction Economics and Building*, 22:4, 1–16. <https://doi.org/10.5130/AJCEB.v22i4.8184>

ISSN 2204-9029 | Published by UTS ePRESS | <https://epress.lib.uts.edu.au/journals/index.php/AJCEB>

RESEARCH ARTICLE

Infrastructure Financing for Climate Change Adaptation in Australia: Practitioners' Perspectives

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DOI: <https://doi.org/10.5130/AJCEB.v22i4.8184>

Article History: Received 16/05/2022; Revised 29/08/2022 & 25/10/2022; Accepted 31/10/2022; Published 15/12/2022

Abstract

With increased climate-related risks and natural disasters, impacts on infrastructure assets are intensifying. As the need for adaptation actions increase, how finance is used to enable adaptation plays a vital role in the resilience of infrastructure. This research aims to understand how infrastructure adaptation measures are carried out, focusing on how financing is used to aid such efforts. Exploratory interviews with infrastructure and finance practitioners from a broad range of organisations were conducted to understand the dynamics of how infrastructure adaptation occurs. The findings reveal that infrastructure agencies conduct adaptation activities to maintain the serviceability of assets under climate change risks, with most climate financing targeting mitigation rather than adaptation. Most actions are taken at individual asset or agency level with little collaboration across agencies and sectors. The results illustrate a need for a more holistic, systems-level approach to adaptation across the infrastructure sector in Australia.

Keywords

Climate Adaptation; Climate Finance; Infrastructure Resilience; Natural Hazards; Sustainable Infrastructure

Introduction

With increased climate impacts felt around the globe, attention paid to impacts on infrastructure systems due to extreme weather and climatic events has increased over time. Extreme weather events and gradual climatic change, like sea level rise, can cause physical damage to infrastructure assets resulting in high financial impacts. Failing to invest significantly in the resilience of cities by 2030, is estimated to cost \$314 billion (USD) and subject approximately 77 million people to poverty due to the effects of climate change and natural disasters ([World Bank, 2016](#)). The latest IPCC report found that cascading natural disasters will impact cities and infrastructure in low-lying areas in Australia and of a high possibility that institutions and governance systems will not be able to manage climate risks ([Hennessy, Lawrence and Mackey, 2022](#)). This highlights the critical need for incorporating adaptation actions within infrastructure systems for the wellbeing of human society.

With the inevitability of climate change, the need for including adaptation techniques in infrastructure assets is vital for their serviceability in the long run. Infrastructure asset owners at all levels of government are faced with competing priorities in the adaptation area, with limited availability of funds, especially with temporally more pressing issues such as those observed during the COVID pandemic. This can result in lower levels of funding being allocated to climate adaptation, which is considered a longer-term issue ([Iyer-Raniga and Gajanayake, 2021](#)). Research on climate adaptation of infrastructure typically takes a discipline-focused approach, either looking at engineering solutions for adaptation of infrastructure or an economics and finance approach studying the most optimal mechanisms to fund such adaptation techniques. Although engineering solutions can be used effectively for adaptation, their implementation depends heavily on the political, social and economic factors in the different regions. In this light, it is vital to understand the interplay between these factors and the intricacies that play a role in financing infrastructure adaptation.

Infrastructure adaptation varies between the Global North and South, predominantly due to the type of funding allocated both for infrastructure as well as climate adaptation. Although Australia is considered a forerunner within the infrastructure sector, it is a laggard in the climate mitigation and adaptation sectors, falling behind its peers in climate-related actions ([Hurlimann, Warren-Myers and Browne, 2019](#)). Studying infrastructure adaptation for climate change within the Australian context is important given the increased climate events and natural disasters that have impacted the country within the last few decades. Therefore, understanding how infrastructure adaptation is carried out and how it is financed within Australia, can shed light on areas for improvement and any best practices that could be adopted in other regions.

For the purpose of this study, the term infrastructure is used in reference to engineered infrastructure as opposed to natural infrastructure such as forests, wetlands and rivers ([Bennett, Cassin and Carroll, 2016](#)). Engineered infrastructure includes both economic and social infrastructure such as transport, communication, utilities and health infrastructure ([Ng and Loosemore, 2007](#)), as well as public infrastructure designed specifically to reduce the impacts of climate change, such as coastal protection infrastructure. Infrastructure plays a significant role in the Australian economy with the infrastructure sector accounting for 9.4% of the GDP, with nearly half of new construction being transport-related infrastructure ([Bureau of Infrastructure, 2019](#)). Australia has close to 900,000 kilometres of roads, 35,000 kilometres of rail track, over 40 airports and 25 seaports ([Bureau of Infrastructure, 2019](#)). As a high proportion of the Australian population lives close to the coast, most of the transport infrastructure is situated in coastal regions. Coastal infrastructure is prone to hydro-meteorological disasters, which are exacerbated due to climate change. The major categories of infrastructure prone to climate-related damages are coastal protection infrastructure, transport infrastructure and utilities ([NCCARE, 2013](#)).

This study builds on previous research conducted by the authors ([Iyer-Raniga and Gajanayake, 2021](#)), which analysed different financing mechanisms used for infrastructure adaptation in Australia and found that optimal financing relies heavily on the socio-political factors within the sector. The aim of this

paper is to understand the nuanced socio-political factors impacting climate financing, which are often overlooked when a discipline-focused engineering or economic lens is used. Therefore, this study takes an interdisciplinary approach, which helped in understanding the financial, socio-political and infrastructure management-related factors whilst also identifying enablers and barriers to effective infrastructure adaptation.

Literature review

Climate finance has two main components, as articulated in the Lima Call for Climate Action a) mobilization of public and private finance towards mitigation and adaptation measures and b) provisioning of public finance from developed to developing countries, also known as the North-South transfer ([UNFCCC, 2017](#)). The expansion of climate finance has increasingly targeted the increase of the North-South transfer and the avenues to access private sector financing ([Moser, et al., 2019](#)). Although both these components are vital for the resilience of communities, climate finance research tends to focus more on providing finance through Official Development Assistance (ODA) from developed to developing nations ([Pickering, Betzold and Skovgaard, 2017](#); [Singh and Jayaram, 2021](#)). Current funding and aid are heavily allocated to emergency response and reconstruction projects, predominately in middle-income countries, where fractional amounts are earmarked for vulnerable countries and even less for disaster risk reduction ([Kellett and Caravani, 2013](#)). The difference between the amount of finance required for adaptation and the actual amounts invested is commonly referred to as the climate finance gap ([Fankhauser, et al., 2016](#)).

Climate adaptation is defined as adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities ([IPCC, 2007](#)). Within human systems, adaptation policies focus on making social systems more resilient to the effects of climate change. In contrast, climate mitigation aims to mitigate the occurrence of climate risks and focuses on greenhouse gas emission strategies ([Pielke Jr, 2004](#)). Adaptation strategies accept the inevitability of the effects of climate change and aim to build more resilient systems to deal with such effects ([Eisenack and Stecker, 2012](#)).

Adaptation actions may be distinguished between anticipatory and reactive actions based on the temporal dimensions of the actions taken. Anticipatory adaptation takes place before an event occurs and responds to assumptions about the future such as climate change projections or scenarios ([Eisenack and Stecker, 2012](#)). Reactive adaptation in contrast relies on resources and adaptive capabilities available after an event ([Gajanayake, et al., 2018](#)). Three broad categories of adaptation actions could be identified in the literature as technological, institutional and knowledge ([Pielke Jr, 2004](#); [Eisenack and Stecker, 2012](#); [Biagini, et al., 2014](#)). Climate financing options are considered a stimulator to enhance adaptation actions and not a direct action.

The cost of adaptation activities could be categorised based on the type of action and the type of infrastructure:

- cost of adapting (or replacing) existing operations and infrastructure;
- cost of building infrastructure that is needed to adapt to climate change such as coastal protection; and
- the additional costs of climate-proofing new infrastructure investments ([Parry, et al., 2009](#)).

Reconstruction of damaged infrastructure typically aims at minimising financial costs, while strengthening assets is often assumed to be the best approach to increase road infrastructure resilience ([Gajanayake, Khan and Zhang, 2021](#)). Literature on infrastructure project sustainability generally focuses on much broader sustainability-related factors with less focus on financing adaptation measures ([Okoro,](#)

[Musonda and Agumba, 2019](#)). However, as most infrastructure assets are intended to last for many decades, and the long timeframes required to design and build them, the need for incorporating climate adaptation into such assets is vital ([Hallegatte, 2009](#)). In addition to safeguarding infrastructure, building stocks are also affected by climate change, as adaptation measures are required to maintain indoor comfort with rising average temperatures ([Nguyen, Ding and Runeson, 2020](#)).

Barriers to effective climate change adaptation can be classified into three groups; social and cultural; information and technological; financial and market-related ([Waters, Barnett and Puleston, 2014](#)). Financial and market-related barriers are considered the most significant. Although adaptation-related costs can be relatively high, such costs are often underestimated and incomplete, while the data suggests that adaptation actions are extremely cost-effective in contrast to inaction ([Ekstrom and Heitsch, 2018](#)). A country's socio-political factors also affect the financial and market-related barriers to adaptation, which has a greater effect on bilateral climate finance ([Peterson and Skovgaard, 2019](#)). Investments in green infrastructure have been found to be undermined by the lack of organisational understanding of the associated financial and social value and a historical reluctance by decision-makers ([Mell, 2021](#)). As the majority of engineered infrastructure is publicly provisioned, or heavily regulated, governmental policy and institutional behaviour play a critical role in infrastructure financing decisions ([Owusu-Manu, et al., 2021](#)). Investment in climate mitigation also has its own barriers, such as commercialization risk and the fact that financial and public institutions are designed for different investment needs ([Granoff, Hogarth and Miller, 2016](#)).

Climate finance literature also focuses on understanding pricing models based on environmental economic principles and how they can be used to pay for infrastructure adaptation. A variety of options such as user fees ([Edwards, 2009](#)), general revenue of local or state governments ([Kriesel, Keeler and Landry, 2004](#)), hedonic pricing-based levies ([Morgan and Hamilton, 2010](#)) and the use of insurance premiums to finance adaptation ([Keenan, 2018](#)) have been studied. These studies typically take an economics and finance approach to analyse the efficacy of different financing options. However, it is argued that public policies and financial markets can be misaligned leading to disincentivising the required level of adaptation practices ([Cleveland, et al., 2019](#)). Private financing in adaptation actions has been found to target areas where high returns on investment may be earned and not necessarily where most areas of investment are needed ([Bisaro and Hinkel, 2018](#)).

Much of the climate adaptation literature in Australia focuses on coastal infrastructure, most likely due to the higher risk such infrastructure face due to extreme weather events ([Harvey, 2019](#)). Two main methods have been identified for financing adaptation for coastal infrastructure; funded through government revenues or by imposing charges on the beneficiaries of the infrastructure ([Ware, et al., 2015](#)). The use of private financing for adaptation was found to be limited, which was mainly due to the lack of available funding and not the lack of access to capital from governments. Most of the literature uses a case study approach to understand how climate financing has been used within different areas, either through government funding ([Ware and Banhalmi-Zakar, 2020](#)) or private financing ([Pauw, et al., 2016](#); [Stoll, et al., 2021](#)).

Financing of infrastructure adaptation needs to be analysed from a holistic view, considering the multiple stakeholders involved in decision-making ([Hafezi, et al., 2017](#)). This is vital as climate adaptation must be paid for irrespective of the financing method ([Ware, et al., 2015](#)). However, grounded research that takes into consideration holistic, stakeholder perspectives is limited. Studies that use such methods have focused on expert interviews with development banks and agencies to understand the intricacies of ODA-related climate financing ([Pauw, 2017](#)). There is a lack of research that focuses on understanding how infrastructure adaptation in the Global North is financed and how adaptation financing could be improved. This paper aims to fill this gap in research, by conducting interviews with a multitude of infrastructure practitioners in Australia to understand how climate financing of infrastructure occurs in practice. Note that in this context,

Australia being a developed nation refers to the Global North, even though it is part of the southern hemisphere.

This research is underpinned by the hypothesis that the lack of infrastructure adaptation within Australia is due to top-down political thinking that underestimates the severity of climate impacts ([Unsworth and Fielding, 2014](#)). However, it could be argued that inaction can be due to top-down as well as bottom-up psychological factors, such as ego, group, and system justification ([Jacquet, Dietrich and Jost, 2014](#); [Leviston and Walker, 2014](#)). The interviews aimed at eliciting information from participants not only on the financial and engineering factors influencing adaptation but also the more nuanced political and organisational factors as identified in previous literature ([Mell, 2021](#); [Owusu-Manu, et al., 2021](#)). The findings provide insights into a broad range of systemic barriers to implementing adaptation within the infrastructure sector and propose recommendations to overcome them as is explained in further detail in the forthcoming sections of the paper.

Methodology

This research used a qualitative research design. The research aimed to understand the practical nature of climate financing of infrastructure in Australia. A qualitative approach was suitable as it helps to obtain a holistic view of a complex system and to investigate social phenomena in a practical context ([Karlsson, et al., 2007](#)). Qualitative research aims to formulate meaning, examines contradictions in real life, and puts an organising framework around it to interpret these contradictory phenomena in a meaningful way ([Braun and Clarke, 2013](#)). Exploratory interviews aid in conducting an in-depth analysis of the complex human and cultural dynamics that influence decision-making ([Akotia, et al., 2020](#)). So, an in-depth exploratory study of the practical aspects of climate financing of infrastructure was undertaken by using interviews.

INTERVIEW DESIGN

In-depth interviews among selected participants were carried out as it was the most appropriate method to obtain relevant information regarding individual experiences and practical knowledge, which was the focus of the research ([Holstein, Gubrium and Pames, 2003](#)). Exploratory interviews also aided in following new dimensions of research that came up in specific interviews, which previous respondents did not reveal and in developing broader themes and ideas based on them ([Oppenheim, 2000](#)).

Semi-structured interviews were designed, with interview questions developed with a clear theme and with open-ended questions. The interview questions were designed to obtain information under the broad themes of; current practices in climate adaptation of infrastructure, barriers to implementing climate adaptation and possible future directions and opportunities. This approach was ideal for identifying gaps between the policy-level procedures set out in climate change strategies and real-life implementation.

INTERVIEW PARTICIPANTS

A diverse group of practitioners ranging from federal to state governments, infrastructure asset owners and representatives from peak industry bodies were selected for the interviews. A theoretical sampling method was used to recruit interview participants. The participants were selected based on their involvement in financing and decision-making related to climate change adaptation of infrastructure. A list of organisations involved in the infrastructure and climate finance sectors was identified in the initial desktop review stage of the project ([Iyer-Raniga and Gajanayake, 2021](#)). Participants were recruited by cold calling the identified organisations. Professional networks of the research team and snowball sampling were also used to reach more relevant participants. A total of 18 participants representing 17 organisations were interviewed ([Table 1](#)). The number of participants interviewed was deemed suitable as there was a saturation of ideas received from the respondents.

Table 1. Interview participants

Code	Type of Org	Industry/Sector	Type of operation	Region
P1	Government entity	Finance	Infrastructure Financing	National
P2	Private company	Energy Infrastructure	Infrastructure Delivery	National
P3	Government entity	Public Admin	Infrastructure Delivery	International
P4	Government entity	Public Admin	Infrastructure Financing	International
P5	Private company	Transport Infrastructure	Sea Port Operation	State
P6	Private company	Transport Infrastructure	Sea Port Operation	State
P7	Professional Association	Urban Planning	Advocacy	National
P8	Participant information withdrawn			
P9	Government entity	Public Admin	Infrastructure Advisory	National
P10	Government entity	Water Infrastructure	Utilities delivery	State
P11	Industry association	Built Environment	Advocacy	State
P12	Government entity	Public Admin	Infrastructure Advisory	State
P13	Industry association	Infrastructure	Sustainability Rating	International
P14	Industry association	Finance	Sustainable Investment	International
P15	Industry association	Building and Construction	Sustainability Rating/Advocacy	National
P16	Government entity	Public Health	Infrastructure Delivery	State
P17	Government Partnership	Infrastructure	Infrastructure Advisory	International
P18	Government Partnership	Infrastructure	Infrastructure Advisory	International

INTERVIEW PROCESS AND ANALYSIS

All interviews were conducted online using the recording and auto transcription function on MS Teams and were typically 60 minutes long. The transcripts were analysed using a qualitative thematic analysis approach. The qualitative analysis helped as an in-depth understanding of the infrastructure financing processes was required to identify underlying themes and differences in practice among participants. Coding of the transcripts was conducted manually by the main interviewer while listening to the recordings so that any emotional overtones and nuances captured in the interviews were not lost. The manual coding helped identify nuances and overtones in the wording used by participants in the interviews, which would have been lost if automatic coding was conducted. A total of 437 coding points were noted, and coding words were selected from a phrase or word from the transcript. An inductive coding approach was used to create the specific codes, where codes are determined progressively during data collection and analysis (Miles, Huberman and Saldana., 2014), while pre-determined codes were avoided to reduce interviewer bias in the coding process. The codes and relevant quotes from the transcripts were entered into an excel sheet. The codes were then used to generate 40 pattern codes, which were used to form themes emanating from the interviews.

Initial results of the thematic analysis and specific quotes selected were shared with the participants, to validate and ensure that quotes had not been taken out of context. This step increased the objectivity of the results and reduced researcher bias in the analysis process. It also allowed the interviewees to reconsider the words and phrases used and to make any changes to reflect their thinking.

Results and Findings

This section presents the main findings based on the thematic analysis that was carried out and is structured according to the main themes that were identified. The discussion is also supported by specific quotations selected from the interviews, to highlight important ideas mentioned by some of the participants.

ADAPTATION COST FACTORED INTO PROJECT COSTS

A common theme from the interviews was that no separate cost allocation was available for infrastructure adaptation measures. Interviewees mentioned that adaptation measures were included in the project during the design stage and the cost of such measures was part of the entire project cost. Adaptation measures were seen as part of the inherent engineering techniques used to ensure that the infrastructure met its long-term functionality. One participant mentioned that it was difficult to say whether such measures were “*purely an adaptation response*” as it was difficult to distinguish between project risk and climate adaptation. However, it was noted that this was not the case for infrastructure such as flood walls, which are designed purely as an adaptation response.

Applying a “*climate filter*” was a common method that practitioners used to factor in climate adaptation measures for projects at the design stage. Although this was common practice among organisations involved with ODA of infrastructure, this was not as common among internal infrastructure organisations focusing on local infrastructure financing. It was noted that adaptation activities would increase if projects were assessed against such climate standards during infrastructure prioritisation assessments within Australia.

“We don’t have specific, hard requirements around climate [and] resilience assessment” P9

A recurrent theme in the interviews (n=7) was the limitation of current decision-making methods for assessing the viability of infrastructure projects. The current approaches focused more on the socio-economic benefits of new projects, while climate and disaster risk assessments of projects were optional. This shortcoming was seen to be prevalent across a broad range of methods such as procurement models, funding

models, financial modelling tools, risk assessment and economic assessment frameworks. It was highlighted that current methods focus on *“the economic benefit that derives from a piece of infrastructure, not the economic benefit [of] the disaster avoided”*. Other factors that rendered current models insufficient were discount factors used in financial modelling, accounting for slow-moving changes and trying to assign monetary values to climate benefits.

DIFFERENCES BETWEEN MITIGATION AND ADAPTATION ACTIVITIES

A common view among participants was that more work was being done on mitigating climate change rather than adaptation practices. Mitigation activities were predominantly identified as actions to reduce carbon emissions and included a move towards net zero emissions and energy efficiency. A range of reasons was identified for this focus on mitigation in contrast to adaptation such as mandatory/regulatory focus on mitigation, mitigation being considered as the first step towards resilience and carbon emission targets being easier to understand. The most significant factor was the clear financial benefits to be gained by mitigation activities. Some participants opined that mitigation and adaptation should go together, which would be a *“no regrets pathway”*, and was especially important as they believed that mitigation targets might not be met.

“I thought we’d all be about resilience now, but everyone’s still trying to... meet carbon reduction targets”

P15

Adaptation was identified as a nebulous concept where *“there is [a] fear of this mysterious extra cost”*. Mitigation was seen as a more straightforward concept to grasp as mitigation measures could be quantified through carbon emissions targets and have direct financial benefits linked to such activities. This preference for actions that have a clear, quantifiable impact may be associated with the prevalence of such practices in the engineering field. In addition, the abundance of engineering professionals within the infrastructure sector may cause more work done on the mitigatory front.

“I’m an engineer, so I want measurable targets, for example so many grams per year. Targets [need] to be agreed on and recorded in black and white” P6

This factor may be further amplified by the quantitative decision-making tools widely used within the infrastructure sector. As highlighted in section 3.1, such tools tend to discount the benefits of adaptation actions. This can be further exacerbated, as the benefits of adaptation do not necessarily accrue to the infrastructure owner but to the broader community. It may also be that infrastructure planning requires a nuanced approach to a range of likely climate risks/hazards, with solutions arising depending on the type of hazard. All solutions may not necessarily consider the same set of priorities.

There was common agreement amongst most of the participants on how linking financial incentives to adaptation activities would increase their use in infrastructure projects. It was mentioned that the best method would be to include climate risks and adaptation benefits in the business case for a project. This could be done in multiple ways according to the type of infrastructure and climate risks. Some of these methods identified by participants were demonstrating the expected return on investment, reduction in insurance premiums and factoring in community costs. This quantification and monetisation of adaptation seem to focus on how best to work within the current decision-making processes without consideration of the difficulty (or even the impossibility) of converting such impacts to be measurable within those processes.

WHOLE OF LIFE APPROACH IS NOT CONSIDERED

Another theme from the interviews was that climate adaptation was factored into designing new infrastructure projects, while adaptation measures for existing infrastructure were limited. As a result, most of the infrastructure adaptation was seen as piggybacking on broader infrastructure growth. Including

adaptation measures in existing infrastructure was identified as expensive and hard to justify, especially when the existing infrastructure is more likely to be knocked down and rebuilt in the near future. This was a more significant issue in overseas infrastructure assistance, as ODA is predominantly provided for new infrastructure development, coupled with the lack of maintenance in some developing countries where assistance was being provided.

The focus on new infrastructure was evident not only for adaptation activities but for mitigation activities as well. It was mentioned that most carbon emissions targets focus on the operational phase of the infrastructure, with embodied emissions not being considered. It was identified that focusing on reducing operational emissions, without considering embodied emissions and emissions during decommissioning and disposal of existing infrastructure can lead to an “*artificial preference*” towards new builds. Another aspect that was raised was that considering whole-of-life impacts in decision-making could justify the better use of existing assets.

“Better using what we’ve got... in many instances [is] going to be less emissions intensive.” P12

Whole-of-life planning was considered an important aspect that would help build and maintain more resilient infrastructure. This was vital as the life of infrastructure assets is typically longer than other investments, especially under a scenario where climate impacts would become significant in the longer term.

IDIOSYNCRASIES OF THE INFRASTRUCTURE SECTOR

Participants also identified how the evolution of the infrastructure sector in Australia played a part in the industry’s hesitancy to adopt more innovative adaptation actions. It was explained that most infrastructure organisations are public entities or were public entities that were privatised recently. One participant mentioned that the level of ambition in these organisations was low and that bureaucratic structures are set up based on historical precedence while dealing with legacy revenue and tariff structures, which are not optimal for including adaptation measures. Some participants also identified the cultural aspect of pricing as a reason for resistance within the infrastructure sector. This was especially the case for transport infrastructure, with many public-private partnerships exhibiting demand-driven pricing structures.

“It’s just that it challenges established responsibilities and established views” P12

The ownership of infrastructure and who pays for adaptation costs was identified as a challenge to incorporating resilience measures in infrastructure. Most infrastructure assets are owned by state and territory governments, who are responsible for their operation and maintenance. The resilience of those structures to climate change impacts falls on the agencies that own and manage them. However, it was noted that funding for the repair and reconstruction of infrastructure after major disaster events was primarily obtained from the federal government. This has led to a misalignment of risks and costs between the States as asset owners and the federal government, which operates as the de facto insurer of last resort.

Federally funded disaster reconstruction work was identified to have a build-back-better component, where resilience measures can be promoted. However, it was identified that damage to assets due to events that were not considered major disaster events did not receive such funding. Therefore, the adaptation measures of such assets were limited. This was also the case with the new development of smaller infrastructure assets, as generally, a proportion of the asset value is set aside for adaptation work. This leads to smaller projects not being as resilient as bigger infrastructure projects. The financing processes used currently were also identified as playing a role in this, as there were thresholds for infrastructure advisory services both at the state and federal government level and the use of “*CapEx as a proxy for risk*” of assets. Some participants mentioned how such thresholds have recently increased, thereby leading to medium-sized projects not having the same level of built-in adaptation mechanisms.

SYSTEMS THINKING

A need for systems thinking approach was identified as a way forward by several participants (n=7). Although none of the participants used the specific term systems thinking, the participants alluded to terms such as “*systems nature of infrastructure*”, “*holistic planning*”, “*system level benefits*”, “*big picture level*” and “*integrated policies*”. Many participants identified that the current practice of building resilience into individual infrastructure assets was not the most optimal method, given the interdependencies between infrastructure systems and the wider socio-environmental systems. One participant provided an example by mentioning that the amalgamation of all transport infrastructure divisions in one state had led to broader adaptation work across the sector. Most agreed that the complex nature of infrastructure systems means that individual adaptation work done by one agency will not be enough to counter system-wide climate change impacts. Some participants believed that fundamental changes at a systems level were needed by building in modularity, behavioural change and nature-based solutions, which are not typically practised within the infrastructure sector at present.

“People are so focused on their own tiny little area that they... just don’t look at the broader picture and understand how everything works together or needs to work together.” P11

It was identified that agencies tend to work in their silos with little to no collaboration, which needs to be changed. It was also mentioned that a more holistic approach was needed even at the policy level as policies are developed and implemented in siloes. This is further exacerbated by the shared decision-making processes seen across different levels of government and the lack of alignment between policies and organisations. Although most agreed that adaptation considered at the big picture level would be helpful, it was also noted that location-specific risks needed to be considered in decision-making processes.

GOVERNMENT INVOLVEMENT

Federal government

The government’s role and how it can aid in adaptation activities across the infrastructure sector was also discussed by participants. The role of government funding was identified as an enabler for climate adaptation activities, with funds being used to help the early adoption of new technologies. It was noted by some participants that government funding should not crowd out private investments but be used to “*crowd in*” private investments by providing funds for areas where private funding is deemed to be too risky.

“It is less about a funding need in infrastructure, it is more about pushing change through the use of [government] money” P1

It was also noted that most of the mitigation work was led by the private sector, where there was a financial incentive for such investments. As such, some participants believed that the private sector should lead adaptation activities with the right regulatory guidance provided by the government.

An overwhelming majority of the participants (n=15) mentioned that better legislation and government commitment would aid climate change mitigation and adaptation within the infrastructure sector. A clear policy position, targets and regulatory requirements were seen as imperative for infrastructure agencies and the private sector to take bold steps towards building climate resilience. Although a majority of participants (n=9) agreed that increased federal government commitment would be helpful, some participants noted that this was less of an issue in the infrastructure sector, as infrastructure was owned by state and territory governments.

“Infrastructure is state-funded, so [the] federal quagmire does not have as bad an impact as it seems” P13

State and territory governments

The lack of federal government commitment was understood to have caused a “*bottom-up revolution*”, where individual organisations and state and territory governments are driving the change. Some of the work being done in organisations was identified as a necessity so as not to lose their “*social license to operate*”, and such work was undertaken more as the ‘right thing to do’ rather than a ‘must-have’. One of the participants shared an interesting viewpoint, where healthcare practitioners were pushing for climate resilience as they saw how it could impact the health and safety of communities in the longer term. Another shared that the defence establishment was aware of the national security implications of climate and disaster resilience.

“[Australian government] policy is probably behind... what shareholders and community want to a certain extent” P2

A majority of the participants (n=11) also saw the need for clear standards and guidelines that could be used to model climate impacts on infrastructure. Such standards could help decision-makers include adaptation measures and account for any risks posed to the operation of the assets. It was illustrated that integrating existing climate scenarios into local and state-level standards was critical. This level of modelling would help forecast specific risks and impacts to different types of infrastructure. It was agreed that such standard tools need to be developed at federal level, providing consistency across different infrastructure asset classes and state jurisdictions.

Discussion

The interviews illustrated a growing need for collaboration among agencies, across different infrastructure sectors and between the infrastructure and environment sectors. Collaboration between different infrastructure asset owners could increase the impact of adaptation measures and lead to spill-over benefits across the economy. Institutional fragmentation has often been identified as a significant impediment to effective climate finance ([Pickering, Betzold and Skovgaard, 2017](#)). Collaboration across jurisdictional zones is essential, given that most adaptation activities, especially coastal protection, are carried out at the local government level. Collaboration across jurisdictions has been found to smoothen the complex pattern of individual state-based policies ([Harvey, 2019](#)). An integrated approach to adaptation is vital as climate risks do not conform to man-made geo-political boundaries. Such collaboration should encompass more than just adaptation but provide a holistic view, as both public and private actors are often unfamiliar with the concept of adaptation ([Pauw, 2017](#)). Sustained partnerships and collaboration across institutions to better coordinate adaptation efforts have a better chance of creating long-standing patterns of thinking and habitual behaviour and breaking typical organizational silos ([Moser, et al., 2019](#)).

The current study found that the majority of the practitioners working on climate activities do this on top of their day-to-day work responsibilities and that there was no specific person responsible for climate action in organisations. The lack of leadership at higher levels of government and the ambiguity on who shoulders responsibility for adaptation has been identified as a barrier to adaptation across Australia ([Waters, Barnett and Puleston, 2014](#)). Similar to previous research, it was found that the lack of top-down commitment had resulted in more bottom-up action being implemented ([Unsworth and Fielding, 2014](#)) and that system justification, especially in the economic domain, was a major factor influencing the bottom-up actions seen within organisations ([Jacquet, Dietrich and Jost, 2014](#); [Leviston and Walker, 2014](#)). The lack of clear accountability was visible across agencies, where there wasn’t one central authority overlooking climate adaptation. This bodes a point on whether it is necessary to have an overall government department overseeing climate change impacts, which also has an overview across the other sections of government.

The need for private finance to be channelled to adaptation activities was an aspect that came up during the interviews. Although the use of private finance for adaptation activities is minimal, there are examples of

cooperation between public and private organisations to leverage adaptation finance (Pauw, 2017). However, over-reliance on private finance may not be optimal as climate adaptation is typically a public good, with positive externalities. It should also be noted that resilience may not be achieved simply by expanding private finance, as this has been argued to be a narrow search for solutions (Moser, et al., 2019). In instances where the private sector has invested in adaptation, it has been a reactive form of adaptation, which illustrates that adaptation from the private sector addresses internal business risks rather than risks to the community (Hess, 2021). Therefore, it may be unlikely that private institutions will invest the required sums needed for adaptation. These findings are similar to previous research which found that private financing can have unintended negative consequences on adaptation behaviour (Cleveland, et al., 2019). To overcome these barriers further government intervention is required to correct market failures and incentivise private finance, so it is channelled to areas of highest need.

This research illustrated that most climate finance is directed at mitigation activities rather than adaptation. This finding is consistent with that of Granoff, Hogarth and Miller (2016), which found that climate investment in infrastructure tends to focus narrowly on the project costs of low- versus high-carbon options. The skew towards mitigation, specifically on reducing carbon emissions, can be exacerbated if climate finance is private sector-centric (Samuwai and Hills, 2018), where private finance is provisioned based on returns on investment (Bisaro and Hinkel, 2018). Even as climate science shows that climate change is inevitable and adaptation needs to be incorporated, this focus on mitigation could be due to the quantifiable aspect of carbon emission reductions and the resulting ease of ascribing monetary values. Quantifiable indicators and metrics tend to drive society to ascribe a higher value to such impacts (Mau, 2020); hence mitigation can take centre stage at a socio-political level. However, adaptation activities are not easily quantifiable to a single value. Hence this could influence the ambiguity among practitioners on the most appropriate use of finance for adaptation. A reductionist approach of using narrow metrics to aid decision-making to solve complex, wicked problems such as climate resilience will not be optimal.

Conclusion

This research aimed at understanding how infrastructure financing for climate change adaptation occurs in Australia, focusing on the socio-political and organisational factors influencing decision-making. Qualitative data were gathered through in-depth interviews with practitioners in the infrastructure financing and adaptation sectors, followed by a thematic analysis of the data. The results show that adaptation within the infrastructure sector relies heavily on economic justification of decisions, with quantifiable indicators playing a big influence on decision-making. The reliance on quantifiable metrics has resulted in more work on the mitigation aspect in contrast to climate adaptation, which is comparatively harder to quantify and monetise. The findings illustrate that infrastructure adaptation is carried out in a siloed manner, either based on expertise or institutional fragmentation. Overall, this study strengthens the idea that more holistic, system-based approaches need to be adopted.

These findings suggest several factors that need to be considered by practitioners and policymakers. Designing in transdisciplinary approaches aimed at solving system-level problems is vital. This could be done both at inter-organisational and interpersonal levels by fostering collaboration among diverse participants. Including social scientists and ecologists in decision-making can aid the ideation of diverse solutions. The role of non-engineering solutions such as behaviour change, optimising existing assets and environmentally adaptive behaviour needs to be considered. Such solutions are typically overlooked with the saturation of personnel with engineering thinking within teams and organisations.

A limitation of this study is the lack of contextualisation of the findings to a specific region within Australia or to specific types of infrastructure. As the aim was to gain a broad understanding of the infrastructure sector within Australia, it was not possible to focus on specific types of infrastructure or asset

classes. An issue that was not addressed in this study was the specific engineering or financial mechanisms that were used for adaptation and their suitability within a given context. Although the current research is based on a small sample of participants, the findings shed light on how adaptation is carried out within the infrastructure sector and the challenges faced.

Further research in this area could focus on contextualising these findings to specific types of infrastructure or specific regions within Australia. Comparative analyses of how adaptation is practised among the different States within Australia or across different sectors and organisations can help researchers understand best practices and how to duplicate them across the broader infrastructure sector. As climate financing models typically focus on mitigation activities, economics and finance-related research can examine developing different financing models that could aid in adaptation actions. Discounted cash-flow techniques, which are commonly used in infrastructure decision-making, discount impacts occurring in the future and therefore tend to disregard long-term climate impacts. Further research could analyse how current financial modelling techniques could be improved to incorporate slow-moving and long-term climatic changes. Given the current spate of disasters in Australia, this is an area of urgent need.

Acknowledgments

The authors wish to thank the interview participants for the time taken to share their thoughts and expertise for the purpose of this study and Ojaswi Baidya for proofreading the final manuscript. This research was supported by a research grant from the Economic Research Institute for ASEAN and East Asia (ERIA).

References

- Akotia, J., Manu, E., Opoku, A. and Sackey, E., 2020. The role of built environment practitioners in driving the socio-economic sustainability aspects of sustainable regeneration. *Construction Economics and Building*, 20(2), pp.89-108. <https://doi.org/10.5130/AJCEB.v20i2.7145>
- Bennett, G., Cassin, J. and Carroll, N., 2016. Natural infrastructure investment and implications for the nexus: A global overview. *Ecosystem Services*, 17, pp.293-97. <https://doi.org/10.1016/j.ecoser.2015.05.006>
- Biagini, B., Bierbaum, R., Stults, M., Dobardzic, S. and McNeeley, S.M., 2014. A typology of adaptation actions: A global look at climate adaptation actions financed through the Global Environment Facility. *Global environmental change*, 25, pp.97-108. <https://doi.org/10.1016/j.gloenvcha.2014.01.003>
- Bisaro, A. and Hinkel, J., 2018. Mobilizing private finance for coastal adaptation: A literature review. *Wiley Interdisciplinary Reviews: Climate Change*, 9(3), p.e514. <https://doi.org/10.1002/wcc.514>
- Braun, V. and Clarke, V., 2013. *Successful qualitative research: A practical guide for beginners*: sage.
- Bureau of Infrastructure, T.a.R.E.B., 2019 *Yearbook 2019: Australian Infrastructure Statistics*. Canberra, ACT: BITRE.
- Cleveland, J., Crowe, J., DeBacker, L., Munk, T. and Plastrik, P., 2019. Hunting for money: US cities need a system for financing climate resilience and adaptation. *Federal Reserve Bank of San Francisco's Community Development Innovation Review*, 14(1), pp.71-78.
- Edwards, P.E., 2009. Sustainable financing for ocean and coastal management in Jamaica: The potential for revenues from tourist user fees. *Marine Policy*, 33(2), pp.376-85. <https://doi.org/10.1016/j.marpol.2008.08.005>
- Eisenack, K. and Stecker, R., 2012. A framework for analyzing climate change adaptations as actions. *Mitigation and Adaptation Strategies for Global Change*, 17(3), pp.243-60. <https://doi.org/10.1007/s11027-011-9323-9>
- Ekstrom, J.A. and Heitsch, S., 2018. ADAPTATION FINANCE CHALLENGES: Characteristic Patterns Facing.

- Fankhauser, S., Sahni, A., Savvas, A. and Ward, J., 2016. Where are the gaps in climate finance? *Climate and Development*, 8(3), pp.203-06. <https://doi.org/10.1080/17565529.2015.1064811>
- Gajanayake, A., Khan, T. and Zhang, G., 2021. A decision-making tool to assess external costs of disaster induced bridge failure. *International Journal of Disaster Risk Reduction*, 64, p.102506. <https://doi.org/10.1016/j.ijdrr.2021.102506>
- Gajanayake, A., Mohseni, H., Zhang, G., Mullett, J. and Setunge, S., 2018. Community adaptation to cope with disaster related road structure failure. *Procedia engineering*, 212, pp.1355-62. <https://doi.org/10.1016/j.proeng.2018.01.175>
- Granoff, I., Hogarth, J.R. and Miller, A., 2016. Nested barriers to low-carbon infrastructure investment. *Nature Climate Change*, 6(12), pp.1065-71. <https://doi.org/10.1038/nclimate3142>
- Hafezi, M., Sahin, O., Stewart, R., Ware, D. and Mackey, B., 2017. Participatory dynamic modelling approach for adaptation planning needs focusing on Small Islands Developing States. In: *12th Conference on Sustainable Development of Energy, Water and Environment Systems*. Dubrovnik, Croatia. .
- Hallegatte, S., 2009. Strategies to adapt to an uncertain climate change. *Global environmental change*, 19(2), pp.240-47. <https://doi.org/10.1016/j.gloenvcha.2008.12.003>
- Harvey, N., 2019. Protecting private properties from the sea: Australian policies and practice. *Marine Policy*, 107, p.103566. <https://doi.org/10.1016/j.marpol.2019.103566>
- Hennessy, K., Lawrence, J. and Mackey, B., 2022. *IPCC Sixth Assessment Report (AR6): Climate Change 2022 - Impacts, Adaptation and Vulnerability: Regional Factsheet Australasia*. . IPCC.
- Hess, J.S., 2021. Private sector climate change adaptation of accommodation suppliers in the small island of Koh Tao, Thailand. *Asian Geographer*, pp.1-18. <https://doi.org/10.1080/10225706.2021.1981956>
- Holstein, J., Gubrium, J. and Pames, A., 2003. Qualitative interviewing and grounded theory analysis. *Inside interviewing*, pp.311-31. <https://doi.org/10.4135/9781412984492>
- Hurlimann, A.C., Warren-Myers, G. and Browne, G.R., 2019. Is the Australian construction industry prepared for climate change? *Building and Environment*, 153, pp.128-37. <https://doi.org/10.1016/j.buildenv.2019.02.008>
- IPCC, 2007. *Impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change*. Cambridge University Press, Cambridge, United Kingdom/New York, NY, USA: Intergovernmental Panel on Climate Change.
- Iyer-Raniga, U. and Gajanayake, A., 2021. Infrastructure Financing for Climate Change Adaptation: Chapter 8-Australia. Available at SSRN 4189988. <https://doi.org/10.2139/ssrn.4189988>
- Jacquet, J., Dietrich, M. and Jost, J.T., 2014. The ideological divide and climate change opinion: “Top-down” and “bottom-up” approaches. *Frontiers in Psychology*, 5, p.1458. <https://doi.org/10.3389/fpsyg.2014.01458>
- Karlsson, L., Dahlstedt, Å.G., Regnell, B., och Dag, J.N. and Persson, A., 2007. Requirements engineering challenges in market-driven software development—An interview study with practitioners. *Information and Software technology*, 49(6), pp.588-604. <https://doi.org/10.1016/j.infsof.2007.02.008>
- Keenan, J.M., 2018. Regional resilience trust funds: an exploratory analysis for leveraging insurance surcharges. *Environment Systems and Decisions*, 38(1), pp.118-39. <https://doi.org/10.1007/s10669-017-9656-3>
- Kellett, J. and Caravani, A., 2013. *Financing disaster risk reduction: a 20 year story of international aid*. Global Facility for Disaster Reduction and Recovery.
- Kriesel, W., Keeler, A. and Landry, C., 2004. Financing beach improvements: Comparing two approaches on the Georgia coast. *Coastal Management*, 32(4), pp.433-47. <https://doi.org/10.1080/08920750490487467>

- Leviston, Z. and Walker, I., 2014. System legitimacy and support for climate change policy in Australia. In: *Biennial Conference of the International Society of Justice Research*. New York, NY, June 19-22.
- Mau, S., 2020. Numbers matter! The society of indicators, scores and ratings. *International Studies in Sociology of Education*, 29(1-2), pp.19-37. <https://doi.org/10.1080/09620214.2019.1668287>
- Mell, I., 2021. 'But who's going to pay for it?' Contemporary approaches to green infrastructure financing, development and governance in London, UK. *Journal of Environmental Policy & Planning*, 23(5), pp.628-45. <https://doi.org/10.1080/1523908X.2021.1931064>
- Miles, M.B., Huberman, A.M. and Saldana., J., 2014. *Qualitative data analysis: An expanded sourcebook*: Sage.
- Morgan, O.A. and Hamilton, S.E., 2010. Estimating a payment vehicle for financing nourishment of residential beaches using a spatial-lag hedonic property price model. *Coastal Management*, 38(1), pp.65-75. <https://doi.org/10.1080/08920750903398287>
- Moser, S., Ekstrom, J., Kim, J. and Heitsch, S., 2019. Adaptation finance archetypes: local governments' persistent challenges of funding adaptation to climate change and ways to overcome them. *Ecology and Society*, 24(2). <https://doi.org/10.5751/ES-10980-240228>
- NCCAREF, 2013. *Policy Guidance Brief: Climate proofing Australia's infrastructure*. National Climate Change Adaptation Research Facility.
- Ng, A. and Loosemore, M., 2007. Risk allocation in the private provision of public infrastructure. *International journal of project management*, 25(1), pp.66-76. <https://doi.org/10.1016/j.ijproman.2006.06.005>
- Nguyen, D.M., Ding, G. and Runeson, G., 2020. Energy and economic analysis of environmental upgrading of existing office buildings. *Construction Economics and Building*, 20(4), pp.82-102. <https://doi.org/10.5130/AJCEB.v20i4.7239>
- Okoro, C.S., Musonda, I. and Agumba, J.N., 2019. Validity and reliability of a transportation infrastructure sustainable performance framework: A study of transport projects in South Africa. *Construction Economics and Building*, 19(2), pp.126-43.
- Oppenheim, A.N., 2000. *Questionnaire design, interviewing and attitude measurement*: Bloomsbury Publishing.
- Owusu-Manu, D.-G., Edwards, D., Ghansah, F.A., Asiedu, R.O., Tagoe, D.S.N. and Birch, T., 2021. Assessing the policy Provisions and institutional behavioral factors influencing rail infrastructure financing in developing countries. *Journal of Infrastructure Systems*, 27(2), p.05021004. [https://doi.org/10.1061/\(ASCE\)IS.1943-555X.0000610](https://doi.org/10.1061/(ASCE)IS.1943-555X.0000610)
- Parry, M.L., Arnell, N., Berry, P., Dodman, D., Fankhauser, S., C, H., Kovats, S., Nicholls, R., Satterthwaite, D., Tiffin, R. and Wheeler, T., 2009. *Assessing the costs of adaptation to climate change: a review of the UNFCCC and other recent estimates*. London, 1843697459.
- Pauw, W.P., 2017. Mobilising private adaptation finance: developed country perspectives. *International Environmental Agreements: Politics, Law and Economics*, 17(1), pp.55-71. <https://doi.org/10.1007/s10784-016-9342-9>
- Pauw, W.P., Klein, R.J., Vellinga, P. and Biermann, F., 2016. Private finance for adaptation: do private realities meet public ambitions? *Climatic Change*, 134(4), pp.489-503. <https://doi.org/10.1007/s10584-015-1539-3>
- Peterson, L. and Skovgaard, J., 2019. Bureaucratic politics and the allocation of climate finance. *World development*, 117, pp.72-97. <https://doi.org/10.1016/j.worlddev.2018.12.011>
- Pickering, J., Betzold, C. and Skovgaard, J., 2017. *Managing fragmentation and complexity in the emerging system of international climate finance*: Springer. 1-16. <https://doi.org/10.1007/s10784-016-9349-2>
- Pielke Jr, R.A., 2004. What is climate change? *Energy & environment*, 15(3), pp.515-20. <https://doi.org/10.1260/0958305041494576>

- Samuwai, J. and Hills, J.M., 2018. Assessing climate finance readiness in the Asia-Pacific region. *Sustainability*, 10(4), p.1192. <https://doi.org/10.3390/su10041192>
- Singh, S. and Jayaram, R., 2021. Climate finance: a systematic literature review. *International Journal of Economic Policy in Emerging Economies*, 14(5-6), pp.566-80. <https://doi.org/10.1504/IJEPEE.2021.118977>
- Stoll, P., Pauw, W., Tohme, F. and Gruening, C., 2021. Mobilizing private adaptation finance: lessons learned from the Green Climate Fund. *Climatic Change*, 167(3), pp.1-19. <https://doi.org/10.1007/s10584-021-03190-1>
- UNFCCC, 2017. *Lima Call for Climate Action*. United Nations Framework Convention on Climate Change.
- Unsworth, K.L. and Fielding, K.S., 2014. It's political: How the salience of one's political identity changes climate change beliefs and policy support. *Global environmental change*, 27, pp.131-37. <https://doi.org/10.1016/j.gloenvcha.2014.05.002>
- Ware, D. and Banhalmi-Zakar, Z., 2020. Strategies for governments to help close the coastal adaptation funding gap. *Ocean & Coastal Management*, 198, p.105223. <https://doi.org/10.1016/j.ocecoaman.2020.105223>
- Ware, D., Colleter, G., Carley, J. and Cox, R., 2015. An overview of financing models for coastal protection in Australia. In: *Australian Coasts and Ports 2015 Conference*. Auckland, New Zealand, 15-18 September.
- Waters, E., Barnett, J. and Puleston, A., 2014. Contrasting perspectives on barriers to adaptation in Australian climate change policy. *Climatic Change*, 124(4), pp.691-702. <https://doi.org/10.1007/s10584-014-1138-8>
- World Bank, 2016. *Investing in urban resilience: Protecting and promoting development in a changing world*. World Bank Group.