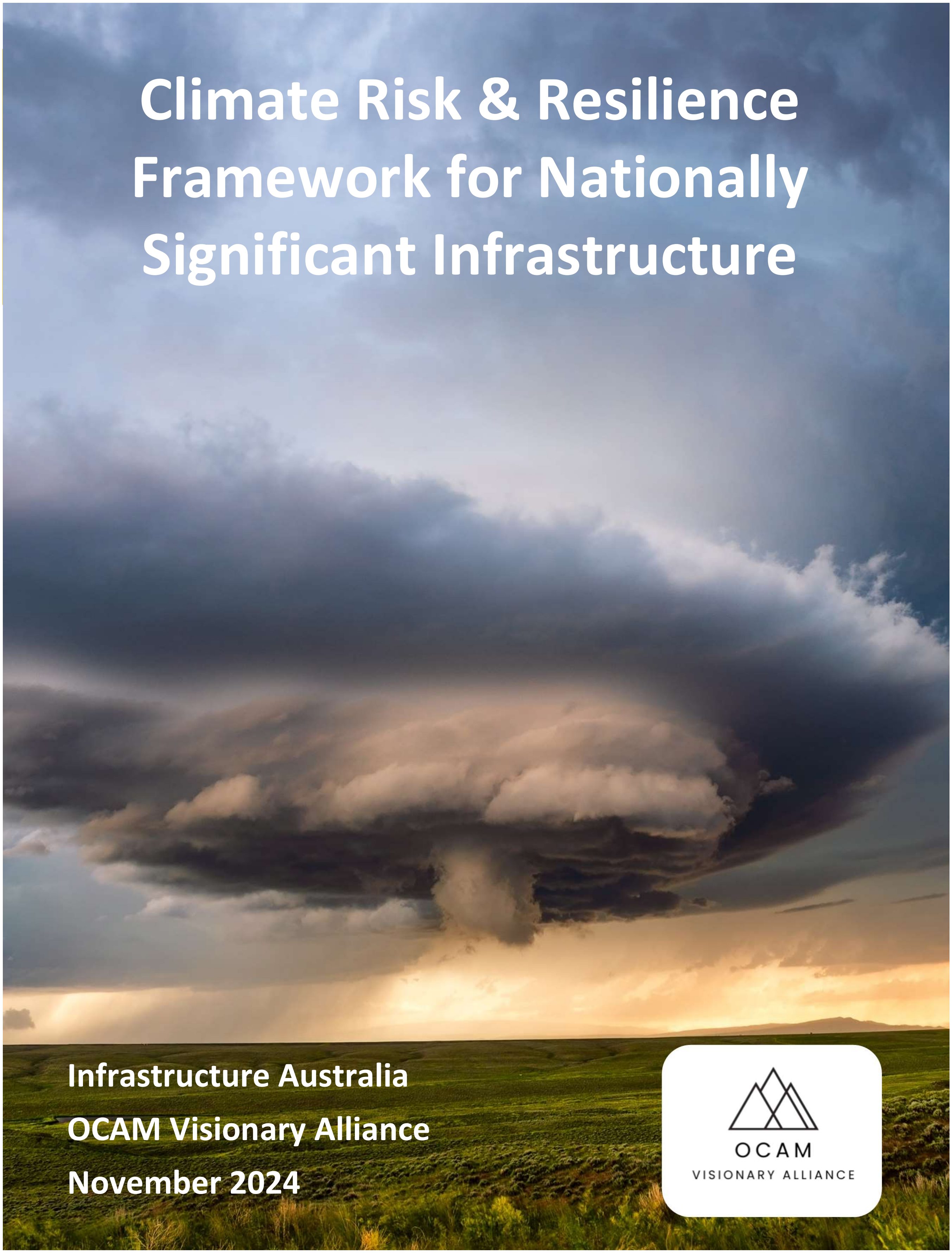
Climate Risk & Resilience Framework for Nationally Significant Infrastructure



Infrastructure Australia

OCAM Visionary Alliance

November 2024

Executive Summary

This report presents the development of a comprehensive climate risk and resilience assessment framework for Infrastructure Australia (IA). Designed to address the challenges posed by climate change, this framework integrates data-driven methodologies to evaluate and quantify climate-related risks to nationally significant infrastructure assets. The framework aims to guide IA and its stakeholders in prioritising investment decisions, ensuring Australia's infrastructure remains resilient in the face of increasing future climate hazards.

A risk assessment framework has been developed along with a detailed methodology and risk matrix. The Risk Matrix documented within this report includes quantifying key risk criteria using publicly available data and aims to provide a platform which can be used by different parties to provide a consistent analytical approach.

The framework addresses three critical drivers for IA:

- **Consistency in Risk Assessment**: Delivering a robust and adaptable approach to assessing risks across diverse infrastructure sectors and assets.
- **Evidence-Based Decision Making**: Leveraging both quantitative and qualitative data to analyse infrastructure hazards, vulnerabilities, and exposures.
- **Future-Proofing Services**: Identifying gaps in data and methodologies to provide innovative recommendations for further development and investment.

Methodology:

The methodology evaluates climate risk through three key components, Hazards, Exposure and Vulnerability.

The step-by-step methodology includes a scoring matrix linked to measurable criteria and relevant data sources, ensuring consistency and objectivity. Its adaptable design enables application across diverse asset types, geographic regions, and future climate scenarios.

Data Analysis

The framework relies on publicly available data from trusted sources and includes a detailed review of each resource. While the data is generally adequate, significant gaps in real-time and asset-specific information limit its comprehensiveness. Recommendations for improving data collection include:

- Establishing a centralised data hub for ease of access.
- Integrating private datasets and public data sets with real-time monitoring.
- Leveraging emerging technologies like AI to better future forecasting and predictive analytics.

Proof-of-Concept

The framework was tested on the Burnley Tunnel in Melbourne, evaluating its exposure to flooding, storms, and other hazards under a high-emissions climate scenario projected for 2050. The assessment produced actionable insights, including:

- A moderate risk rating (3.1 out of 5) for the Burnley Tunnel under a likely flooding scenario.
- Identification of critical gaps in data, such as the lack of real-time monitoring and asset condition assessments.
- Opportunities for refinement, such as expanding the framework to other infrastructure sectors and incorporating dynamic climate predictions.

Key Findings

- Strengths: The framework provides a standardised, scalable, and adaptable approach to climate risk assessment, integrating quantitative data with qualitative insights.
- Limitations: Data gaps and data availability to public and asset-specific details, limits the accuracy and reliability of the risk assessment.
- Opportunities: Enhancing automation, data integration, and combining all GIS mapping capabilities into one location could streamline processes and improve usability.

Recommendations

1. Data Integration: Consolidate data sources into a centralized GIS-based platform for efficiency and consistency.
2. Automation: Develop tools that automate data extraction, scoring, and visualisation to minimize manual effort and errors.
3. Dynamic Predictions: Incorporate real-time data and dynamic climate modelling to improve the accuracy of future risk assessments.
4. Gain feedback from users, feedback from stakeholders and government decision makers.

The Climate Risk and Resilience Framework represents a pivotal step in safeguarding Australia's infrastructure against the mounting challenges of climate change. By offering a standardized, data-driven approach, the framework empowers Infrastructure Australia to deliver actionable advice that drives informed decision-making. The proof-of-concept application not only demonstrates its practical value but also highlights opportunities for further refinement to meet evolving challenges.

This framework underscores a commitment to protecting communities by mitigating risks, prioritizing resilience, and ensuring Australia's infrastructure is ready to withstand the demands of a changing climate. Through its continued evolution and implementation, it has the potential to play a central role in building a safer, more secure future for all Australians.

Contents

List of Figures

List of Tables

Introduction

The climate is changing, from scorching heatwaves to treacherous storms, ferocious wildfires and devastating floods, and so the question becomes, what can we do to prepare? The European Union's Copernicus Climate Change Service declared 2023 to be hottest year on record, reaching average temperatures 0.6°C higher than the average seen in 1991-2020 (Climate Council, 2024a). Coal, oil and gas emissions are changing our atmosphere, leading to more frequent and severe extreme weather events (Climate Council, 2024b).

The direct concerns of these extreme weather events are often shared through the public realm, and yet they also have significant impact on our assets and infrastructure. With the increasing frequency and severity of natural hazards due to climate change, the resilience of infrastructure has become a critical priority for not only our citizens but the Australian government as well. As a result, it has become a key area of interest for Infrastructure Australia (IA), ensuring that they will continue to provide high quality, evidence-based advice to the Government for future priorities for infrastructure investment and to increase climate resilience within Australia.

The economic cost of natural hazards is projected to more than double by 2050, prompting the question, how do we reduce these costs, mitigate the risks and ensure that we are maintaining our infrastructure and assets such that we keep our community safe and resilient to climate change (Australian Government, 2023). To produce a robust risk assessment to identify key risk areas, we must follow 3 steps:

1. **Risk Identification** – catalogue assets and their potential vulnerabilities.
2. **Risk Analysis** – evaluate the risk based on three key criteria: hazards, exposure and vulnerability.
3. **Risk Mitigation and Adaptation –** develop strategies to reduce vulnerability for areas identified as high risk within the Risk Analysis.

There is significant room for growth within the area of risk analysis. To date, there is not a clear and comprehensive framework designed to holistically assess and quantify the overall climate risk on current assets and infrastructure within Australia, therefore leaving key stakeholders with an unclear understanding of where is best to invest in infrastructure development.

Within this report OCAM Visionary Alliance address this concern by creating a data driven framework and methodology that aims to assesses and compare the relative hazard risk to infrastructure and assets across Australia. This framework is designed to account for differing spatial and temporal scales and infrastructure sectors, creating a quantitative measure to assist IA in providing coherent advice in this space.

There are significant gaps with the publicly available data that aids this assessment and therefore an assessment of the current available data has been conducted to identify recommendations for future data collection, monitoring and tracking.

Finally, this report will demonstrate the effectiveness of this framework through the application of a proof of concept. An evaluation of this application also led to further advice and recommendations as to where the framework could further be developed to create a more robust and holistic methodology designed to best serve IA and their clients.

Drivers for Action and Project Objectives

Through discussions with Infrastructure Australia, OCAM Visionary has identified 3 key drivers for action in space within IA:

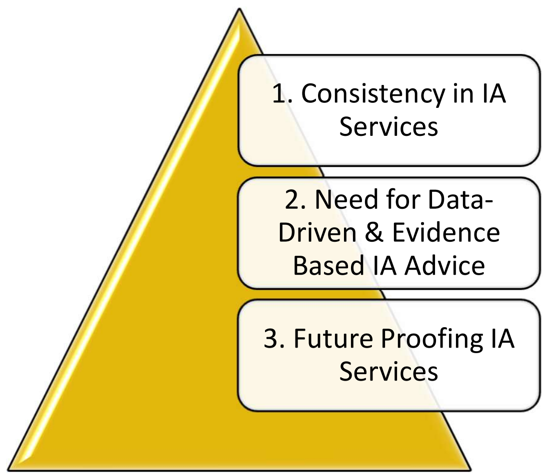


Figure 1: Key Drivers

As a result of these key drivers, the following objectives have been created to ensure these drivers are addressed:

1. Consistency in IA Services
    - Develop a robust risk assessment framework for nationally significant infrastructure assets and networks.
    - Identify and assess relevant data sources to support risk analysis.
2. Need for Data-Driven & Evidence-Based IA Advice
    - Develop a methodology to integrate diverse data sources for comprehensive risk quantification.
    - Demonstrate the framework's practical application through a proof-of-concept in a selected geographic area.
3. Future Proofing IA Services

- Evaluate and assess existing and developed risk assessment frameworks and methodologies to understand gaps in the market and identify opportunities for innovation, collaboration and growth.

Relevant Terminology

Table 1 outlines key terminology that is being used throughout this report.

Table 1: Relevant Terminology

Term	Definition
Impact	Impact is the strong effect or influence that hazards have on assets and networks of interest.
Risk	Risk is the probability of incurring a given consequence as a result of an asset. The risk associated with a particular asset must integrate the following elements: hazard, vulnerability, exposure.
Hazard	Hazard is a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation. *Natural Hazards are predominantly associated with natural processes and phenomena.*
Vulnerability	Vulnerability is the probability that people and assets are harmed and/or damaged to a certain severity given a hazard intensity.
Exposure	Exposure is the situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas.
Resilience	Resilience is the ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.
Climate Change	Climate change refers to long-term shifts in temperatures and weather patterns. Such shifts can be natural, due to changes in the sun's activity or large volcanic eruptions.
Economic Loss	Economic loss is the total financial losses as a result of direct economic loss and indirect economic loss. *Direct economic loss: the monetary value of total or partial destruction of physical assets. Direct economic loss is nearly equivalent to physical damage.*

	Indirect economic loss: a decline in economic value added because of direct economic loss and/or human and environmental impacts.
Environmental Loss	Environmental loss is the environment implications as a result of a significant event or circumstance. This includes any loss, damages, costs, expenses or liabilities caused by the event.
Social Loss	Social loss is the social implications as a result of a significant event or circumstance. This could include impacts in social areas including health and wellness, injuries/fatalities or population displacement.
Assets	Assets are government owned items of property, regarded as having value and available to meet debts, commitments, or legacies.
Networks	Networks are the interconnected assets that rely on each other to provide a service. Removing a particular asset from a network may result in functional failure of the network.
Geographical Location	Geographic location refers to the physical place of the asset and/or network of interest.
Spatial Scale	Spatial scales refer to the land area of which is of interest when conducting the hazard risk assessment.
Risk Framework	The Risk Assessment Framework is the structured approach or set of activities used to evaluate the hazard risks.
Risk Taxonomy	Risk taxonomy is the system of categorization that allows identification and classification of various types of risks.

LITERATURE REVIEW

1. Literature Review

A review of existing literature was undertaken prior to the development of the risk assessment framework and methodology. This review has highlighted key areas of focus and addresses the shortcomings of existing risk assessment frameworks. Refer to Table 2 for an overview of the key findings of the literature review.

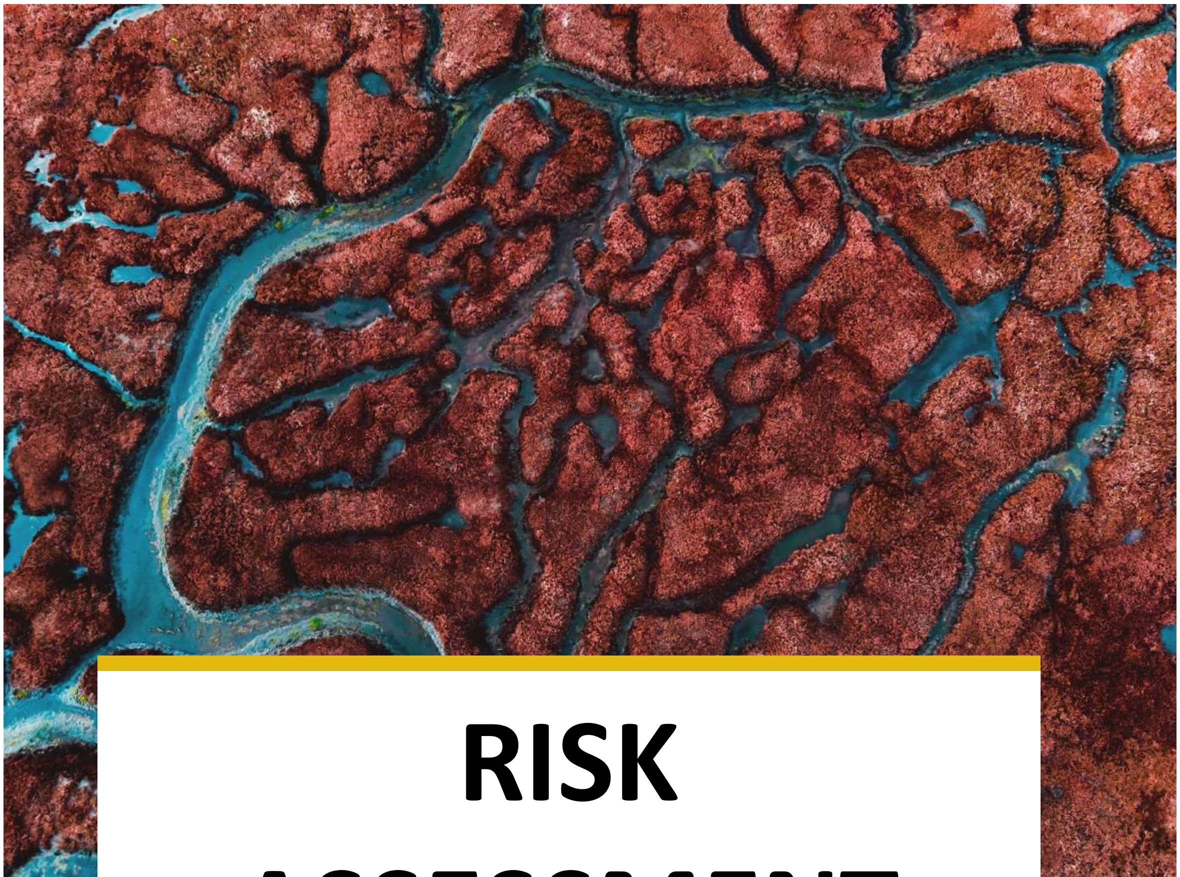
Table 2: Summary of Key Findings of Literature Review

Source	Strengths	Shortcomings
National Climate Risk Assessment - First Pass Assessment Report *(DCCEEW, 2024)*	- Comprehensive overview of 56 nationally significant climate risks. - Identifies 11 priority risks for further analysis. - Robust qualitative framework using expert elicitation workshops.	- Lacks detailed quantitative data integration. - No clear strategy for addressing interdependencies between infrastructure systems.
National Disaster Risk Reduction Framework (*Department of Home Affairs, 2018)*	- Aligns with international frameworks like the Sendai Framework. - Emphasizes resilience building and preparedness across multiple sectors.	- Lacks specific tools and methods tailored to infrastructure-specific vulnerabilities. - Limited direct applicability for targeted infrastructure resilience planning.
UNDRR Sendai Framework Disaster Risk Reduction Terminology *(UNDRR, 2016)*	- Provides standardized terminology and concepts for consistent risk assessments.	- Does not provide detailed guidelines or methodologies for practical application in infrastructure resilience strategies.
Global Methodology for Infrastructure Resilience Review (CDRI) *(UNDRR & CDRI, 2023)*	- Comprehensive assessment methodology including both direct and indirect risks to infrastructure. - Applicable across various countries.	- May not fully consider region-specific climate hazards. - Lacks specific case studies for practical application.
A Universal Taxonomy for Natural Hazard and Climate Risk and Resilience Assessments *(Arup, 2024)*	- Provides a standardized approach to classifying risks and resilience factors. - Useful for developing a common understanding and language.	
Weathering the Storm *(Infrastructure Victoria, 2024)*	- Offers practical insights and best practices in climate resilience strategies for Victoria's infrastructure.	- Limited scalability to other regions with different climate challenges and infrastructure systems.
Profiling Australia's Vulnerability (*National Resilience Taskforce, 2018)*	- Provides a systemic approach to understanding vulnerabilities across sectors. - Considers cascading effects of systemic risks.	- Not fully integrated with dynamic risk models that account for evolving climate conditions and infrastructure changes.
Quantifying Climate Risks to Infrastructure Systems	- Comparative review of quantitative risk analysis developments across infrastructure sectors.	- Limited consideration of multi-hazard scenarios.

(Verschuur, J., et al. ,2024).	- Highlights current methodologies and identifies gaps.	- Lack of cross-sectoral learning and integrative approaches.

As a result of the findings above, OCAM Visionary Alliance has decided to focus on addressing the following limitations throughout the development of the proposed risk assessment framework and methodology:

- *Lacks detailed quantitative data integration:* This is addressed within the proposed methodology. Refer to section 3.
- *No clear strategy for addressing interdependencies between infrastructure systems:* This is addressed within the proposed methodology. Refer to section 3.
- *Lacks specific tools and methods tailored to infrastructure-specific vulnerabilities*: This is addressed within the proposed framework. Refer to section 2.
- *May not fully consider region-specific climate hazards:* This is addressed within the proposed framework. Refer to section 2.
- *Limited scalability to other regions with different climate challenges and infrastructure systems:* This is addressed within the proposed framework. Refer to section 2.
- *Limited consideration of multi-hazard scenarios:* This is addressed within the proposed framework. Refer to section 2.



RISK ASSESSMENT FRAMEWORK

2. Risk Assessment Framework

To achieve the objectives outlined within this report, a clear framework has been created to assess and quantify climate resilience and risk. OCAM Visionary Alliance have developed the following framework which it is believed encompasses a holistic approach for IA to undertake a quantitative and data driven risk assessment.

The risk assessment framework aims to provide a structured process which can be used to assess risk for a given asset and/or network within Australia. The design is rooted in a holistic understanding of risk and analysis of existing frameworks.

OCAM Visionary Alliance understand that risk is a product of the following components:

- **Hazards**: This includes both current and projected future frequencies and severities of climate-related hazard events. Key hazards relevant in this framework are bushfires, floods, cyclones, heatwaves, droughts, and coastal erosion, among others.
- **Exposure**: Represents the presence and distribution of infrastructure assets in hazard-prone areas. For example, transport networks situated in areas historically prone to flooding is at a higher exposure.
- **Vulnerability**: Represents factors that influence how susceptible assets are to damage, including the condition, age, and criticality of the infrastructure.

The framework proposed aims to quantify these three key factors using available data from publicly available sources. The assessment will allow for flexibility in the type, location and magnitude of the assets and networks being assessed, give the selection of a specific climate change scenario and timeframe.

Figure 2: Risk Assessment Framework Proposed by OCAM Visionary Alliance below outlines the key steps within the framework proposed by OCAM Visionary Alliance. Details of each of these phases is outlined within this section.

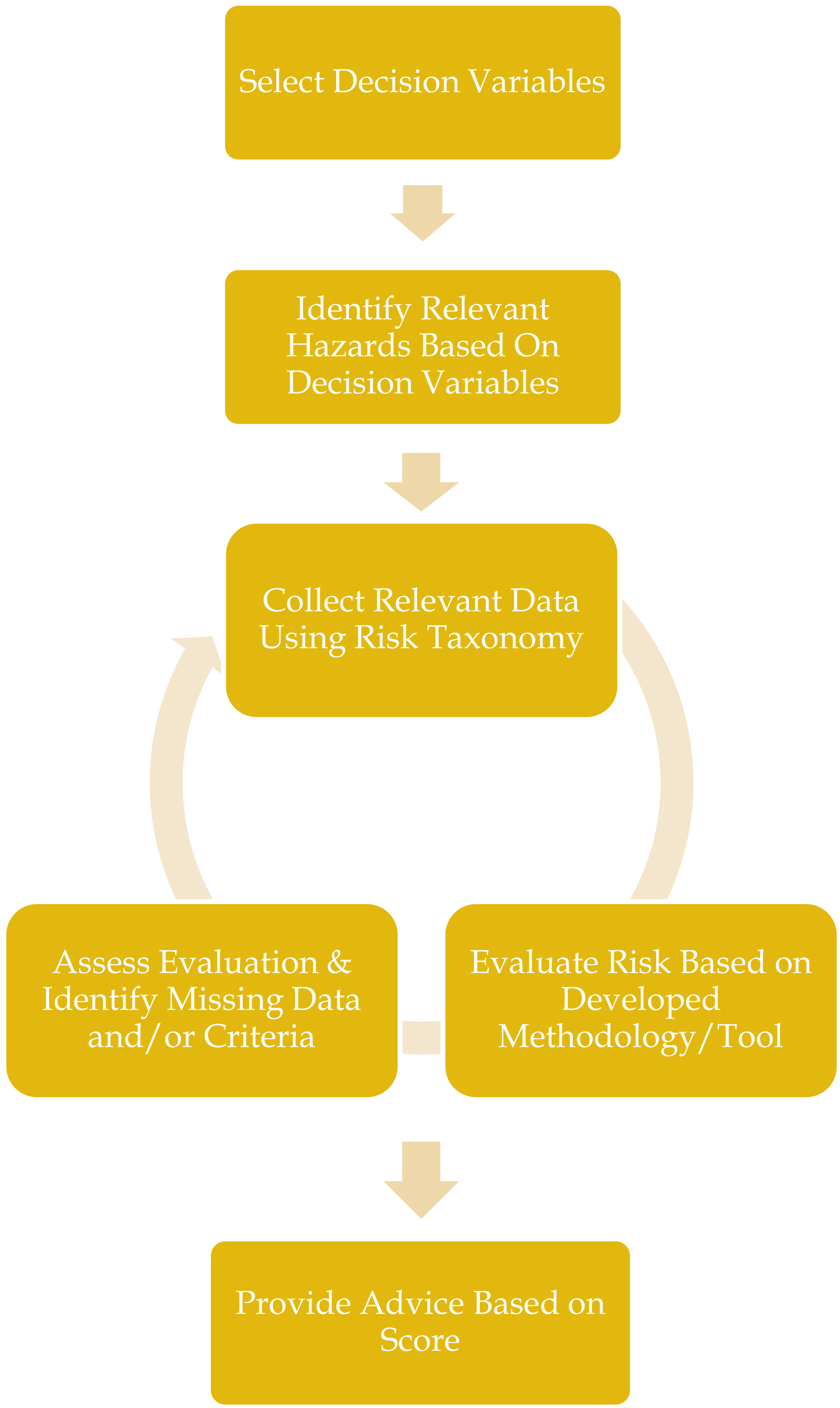


Figure 2: Risk Assessment Framework Proposed by OCAM Visionary Alliance

2.1. Select Decision Variables

To ensure that the framework is scalable across differing sectors, temporal and geographical scales, it is important to understand the key variables that are required to conduct a risk assessment with the available data and are also relevant to stakeholders. Though discussions with IA and the information provided, it was identified that there are 4 key variables in which are required to conduct the risk assessment. Based on the relevant data of interest to IA and their stakeholders to aid decision making, these are: sector, geographical location, spatial scale and temporal scale. The first step in applying the developed framework is to develop a clear understanding and select the decision variables that are relevant to undertake the risk assessment.

2.1.1. Geographical Location

To conduct the required assessment is it important to understand the geographical location of the area of interest. The precise location within Australia is required to conduct a thorough and data driven assessment using the public data available. Most of the data sources identified are based on local government area and it is therefore recommended to utilise LGAs as the location where possible.

2.1.2. Spatial Scale

To conduct the required assessment, it is important to understand the spatial scale of the area of interest. The precise size of the area of interest is required as well as the number of people and assets within the area proposed. This can be found using publicly available data.

2.1.3. Emission Scenario

There are several different emissions scenarios which have been identified within the IPCC's Sixth Assessment Report (2021), these Shared Socioeconomic Pathways (SSPs) are used to model future outcomes based on differing greenhouse gas emissions and changes to the economy, technology and society. The different scenarios are as follows:

1. Low Emissions Pathway – global warming limited to 1.9 to 2°C
2. Medium Emissions Pathway - global warming limited to 2.7 to 3°C
3. High Emissions Pathway – global warming limited to 3 to 5.4°C

Climate change Victoria denotes these as Representative Concentration Pathways (RCP) 2.6, 4.5 and 8.5 respectively for low, median and high emissions pathways. The scenario which is been assessed within the risk assessment must be determined to ensure appropriate hazard predictions are being reviewed.

2.1.4. Relevant Sectors for Assets and Networks

Given the complexity of the assessment, this framework focuses on assessing networks and assets relevant to the advisory services provided by IA. Once the above decision variables have been made, a list of relevant assets within the location of interest can be generated to conduct the risk assessment.

Given IA provide advice on the following sectors, this framework is relevant for the listed networks and assets within these sectors shown below:

- **Transport Infrastructure:** Roads, railways (freight and passenger, lines and stations), airports, ports, freight intermodal terminals, bridges & tunnels.
- **Energy:** Power plants (Coal, Gas, Hydroelectric, Wind Farms, Solar Farms etc.), transmission/ distribution network, Battery Storage facilities, pipelines.
- **Water:** Dams, reservoirs, desalination plants, water treatment plants, water reticulation (utilities).
- **Telecommunications:** Communication towers, data centres.
- **Social Infrastructure:** Schools, hospitals, emergency services, aged care, justice services.

2.2. Identify Potential Hazards

Given the significant array of hazards that occur across the country, it is important to identify the hazards that are relevant within the location and area of interest. The National Climate Risk Assessment written by Department of Climate Change, Energy and the Environment and Water (DCCEEW) has identified the key hazards due to climate change for Australia. The risk assessment looked at numerous hazards and prioritised some of these for further analysis within a future second pass assessment based on the severity of impact, actionability as part of a national adaptation response, clarity of scope for further analysis, and coverage across multiple systems. The document identifies the following priority hazards:

- Bushfires, grass fires and air pollution
- Changes in temperatures including extremes
- Coastal and estuarine flooding
- Coastal erosion and shoreline change
- Convective storms including hail
- Drought and changes in aridity
- Extratropical storms
- Ocean warming and acidification
- Riverine and flash flooding
- Tropical cyclones

To the framework some of these have been identified as difficult to quantify based on the data available and have therefore been disregarded within this framework. As a result, resulting in the following list of key hazards to be assessed within this framework are as follows:

- Bushfires, grass fires and air pollution
- Flooding (coastal and surface water flooding)
- Coastal erosion and shoreline change
- Storms and cyclones

Before moving to the next phase of the framework, it is important to understand which of the above hazards are relevant within the location of interest. Only those that are relevant will be assessed within the risk assessment methodology.

2.3. Collect Relevant Data

Once the key decision variables and hazards of concern are identified, the data collection phase of this framework will then begin. Using the publicly available data, appropriate data will be collected to aid in the risk assessment methodology outlined in section 3 of this report. Section 1.3.1 highlights the risk taxonomy created to categorise the risk and provide a foundation for the risk assessment methodology.

Current available data may be limited to support the risk assessment being proposed by OCAM Visionary Alliance. Therefore, Section 2 of this report highlights areas where information may be lacking and proposes advice as to how this lack of data can be addressed.

2.3.1. Risk Taxonomy

A detailed risk taxonomy is developed to categorise the risk elements and systematically identify all potential climate related risks. Table 3 below highlights the taxonomy created by OCAM Visionary Alliance to support in this risk assessment framework.

Table 3: Taxonomy for proposed risk assessment

MEASURE	INDICATORS	DESCRIPTION
HAZARDS	Likeliness/ Frequency	Frequency of which defined hazard will occur over a year in area of interest.
	Severity	Location based rating based on the density and type of infrastructure in area of interest.
EXPOSURE	Population Affected	Number of people affected by hazard in area of interest.
	Financial Impact	Direct financial losses due to hazard of interest.
	Ecosystem Services	Severity of hazard on ecosystems in area of interest.
	Injury and Fatality Rates	Number of injuries and fatalities based on historical data for relevant hazards in area of interest.
	Population Displacement	Number of people potentially displaced due to hazard impacts.
	Historical Exposure	Records of past events to assess how often the area has been affected.

	Local Growth & Economy Disruption	Duration of disruption on local businesses and economy in area of interest.
VULNERABILITY	Age of Asset	Age of asset relative to design life.
	Condition of Asset	The average Condition ratings (e.g., good, fair, poor) of assets in area of interest.
	Past Investments	The total amount of investment in maintenance and/or upgrades over the past decade.
	Service Dependency	Number of other individuals that rely on the primary asset's functionality.
	Redundancy of Services	Availability of similar assets/services within proximity.
	Repair Costs	Total cost to repair the asset if it is damaged by relevant hazards.

2.4. Evaluate Risk

Following the collection of data, the risk assessment will be conducted using the methodology and tool created as outlined in Section 3 of this report. The objective of this methodology is to create a quantitative and objective way to assess the level of this risk based on the data collected. The output of this methodology will be a quantitative scale in which can be used to aid decision making, support IA advice and compare risk with scenarios of interest having selected different decision variables.

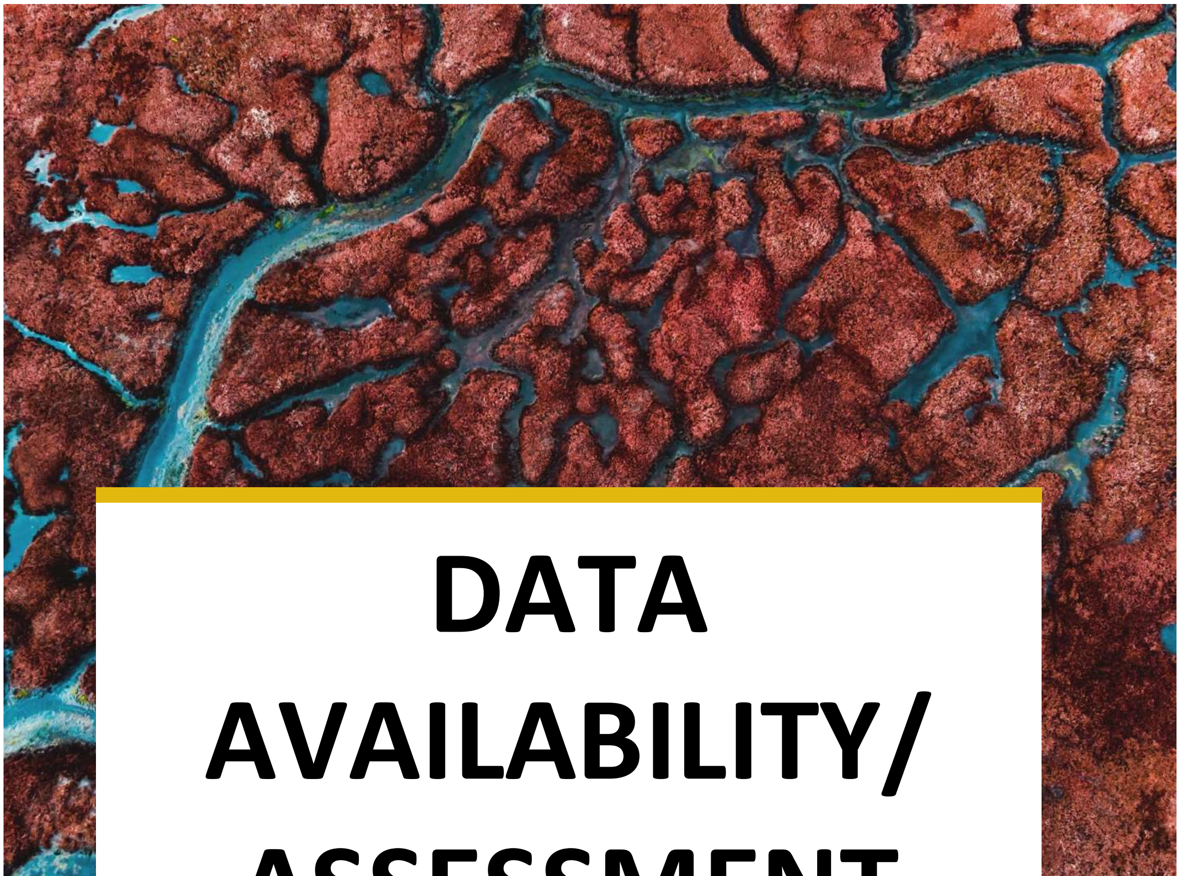
2.5. Assess Methodology and Evaluation

Given the scarcity of data publicly available, it is important for the methodology and evaluation to be assessed. This assessment shall identify if there are any clear and significant gaps within the data and/or if there are any important measures that area relevant to the area that have not been captured within the methodology. This also ensures that the risk assessment being undertaken is specific and relevant to the infrastructure of interest.

If gaps have been identified, it is recommended that amendments are made to the framework such that these factors are considered. In doing so, it is important the unbiased adjustment is made to accurately assess the risk given the selected decision variables.

2.6. Provide Advice

Once the methodology has been assessed and any updates to the methodology have been made, the final output can be used to support IA advice and guide decision making for relevant stakeholders. The outputs of methodology and tool can be further developed and tailored such that it suits the type of advice provided by IA. This is an area for future development of the proposed risk assessment framework and methodology proposed by OCAM Visionary Alliance.



DATA AVAILABILITY/ ASSESSMENT

3. Data Source Identification and Assessment

A vital part of the framework proposed by OCAM Visionary Alliance is the need to rely on publicly available data to evaluate the risk of the asset of interest. The following section identifies the data that is currently available and relevant to the proposed framework, while also assessing the quality of what is available. The objective of this assessment is to demonstrate where public data can be used to support with the risk assessment and identify any critical data gaps within the data. Throughout the assessment, there have been no private data sources reviewed due to availability; however, recommendations have been made where private data sources may be of use.

3.1. Data Review

A comprehensive review of data sources relevant to the framework has been conducted, identifying public and private databases such as:

- Digital Atlas of Australia
- National Exposure Information System (NEXIS)
- Climate Risk Map of Australia
- Australian Disaster Resilience Index
- Geoscience Australia Natural Hazards and Scenarios
- The Australian Disaster Resilience Knowledge Hub
- Australian Emergency Management Knowledge Hub
- Australian Flood Risk Information Portal
- Australian Rainfall & Runoff Data Hub
- Bushfire Boundaries Data
- VicPlan portal / VicMAP
- DTP Traffic Volume Data
- Climate Change Victoria – Climate change predictions
- Victoria's Climate Tool

An assessment has been conducted for each of the above data sources, identifying the relevance of the data to the risk assessment framework and the quality of the data presented. Refer to Table A.1 in Appendix A for an overview of the assessment conducted.

Overall, despite the large variety of data available, there are gaps in the data available to complete the proposed risk assessment framework as outlined in Section 1.

All the data assessed was publicly available meaning that there is no financial investment required for collection of data to complete the risk assessment. In saying that, further exploration into the data that may be available in the private realm may reduce the impact of data gaps on the required risk assessment, which may require commercial investment to improve the quality of the risk assessment conducted.

The quality of the data was found to be adequate, however, it is not always presented in such a way that can be easily fed into the risk taxonomy outlined in Section 2. As a result, there are areas for improvement proposed for the framework to further enhance the efficiency and effectiveness of the framework for the assessor.

The assessment of data sources documented within this report has been limited due to time available for the assessment as well as utilising information predominately within the state of Victoria where OCAM Visionary Alliance is based. It is a key recommendation of this review that more time could be put into reviewing similar data sources through all states and territories. Local and state governments are likely to have much of the data available, if not publicly accessible.

3.2. Data Gaps and Recommendations

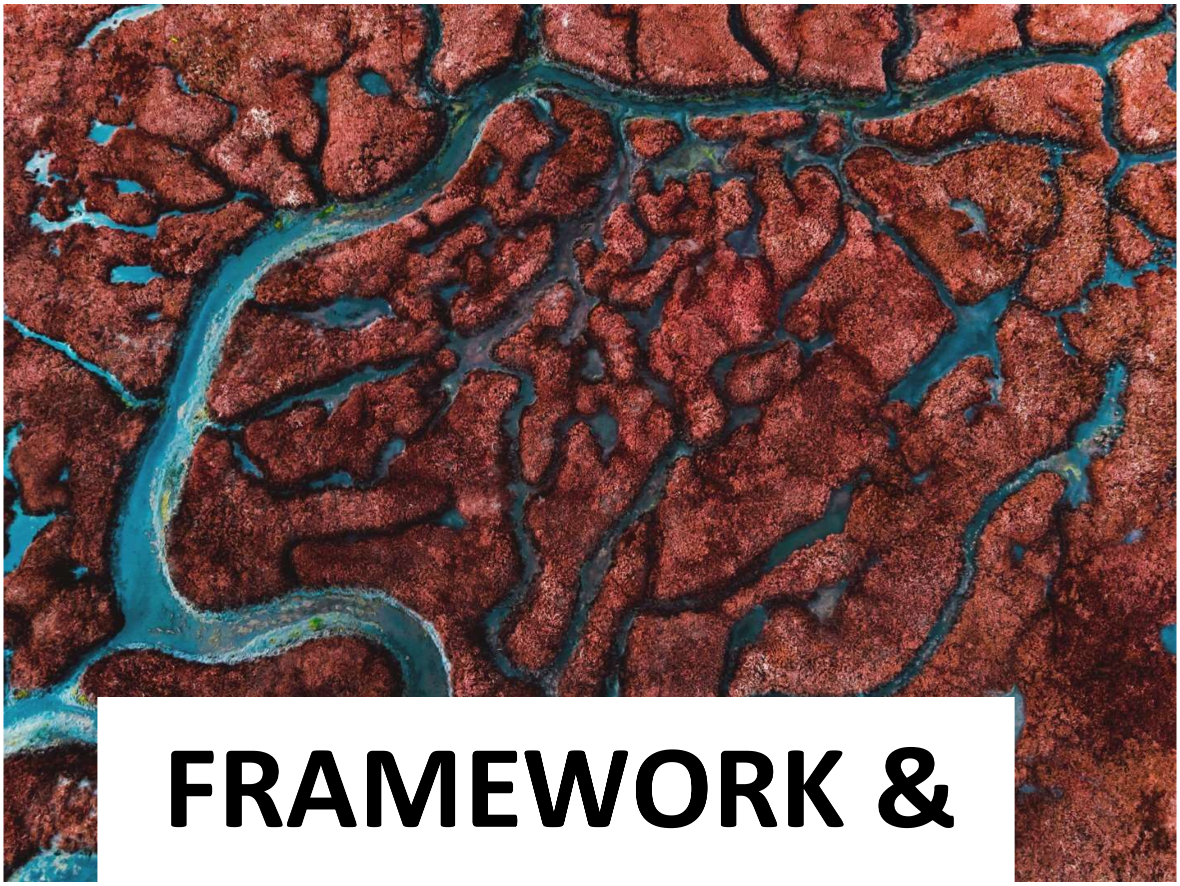
A key takeaway from the data assessment conducted is that there are significant concerns around the availability and quality of data across sources. This is of concern as the risk assessment relies on quality data to produce a quality outcome. Table 4 outlines the key strengths and weaknesses of the data found, identifying key gaps and areas for improvement to enhance the availability of data and ensure high quality risk assessment can be conducted.

Table 4: Strengths, Weaknesses, Areas for Improvement and Key Gaps in the Data Assessed for the Risk Assessment Framework

Strengths	- **Magnitude of Data Available:** There are a large variety of data sources available that provide information relevant to the proposed risk assessment framework. This eliminates the need to create new data extraction processes in which feed into the framework as much of the data is already available. - **Availability to Public:** Much of the data is available and free to the public to use and access. This means that there are no commercial investments required to access all data and complete the required risk assessment.
Weaknesses	- **Frequency of Data Collection and Sharing:** In some cases, the frequency of which data was shared was over a significant period. This means that the assessor is limited as to the timeframe of which an asset or location can be assessed given the available data. - **Data Extraction:** For many of the data sources there was no simple way to extract raw data presented through the relevant user platform. This makes it challenging for data to manipulated and extracted to suit the required inputs for the risk assessment framework. - **Consistency Across Sectors and Regions:** Data availability varies significantly across different sectors and regions. This makes it challenging to complete high quality risk assessment across sectors, specifically when stakeholder decisions require this to be done without data bias. A key challenge is integrating data from

	diverse sources into a coherent, usable format for national-level assessments. - **Ease of Risk Relevant Data:** Although there is a significant amount of data already available, much of it is spread across a large range of sources. There is currently no one stop shop for user to access all data relevant to risk. This makes it more challenging for the assessors to collect all relevant data.
Areas for Improvement	- **Real-Time and Predictive Data:** More emphasis is needed on real-time data for hazard exposure and predictive analytics for climate projections. Many of the data sources used are based on a specific data set or time of collection. As noted in previous sections of this report, climate change predictions are dynamic with constant change based current real time emissions. - **Standardization:** Establishing a national standard for data collection, reporting, and sharing would improve consistency and quality. It has been found that areas where data is mostly available are those which are wealthier – whereas the areas which will be most adversely affected by climate change are those in the poorer or more remote locations. Standardization and expanding the data sets across the full country would aim to reduce this disparity. - **User Friendly Manipulation of Data:** Enabling access of all raw data to the public will allow for further improve the accessibility of data and ability for data manipulation. In doing this, inputs into the risk assessment methodology can easier be tailored to suit the decision variables required by stakeholders. - **Single source for all applicable information**: If all applicable information were available on one GIS based location combining the data sourced and documented within this document it would considerably improve the useability of the methodology and framework for comparing assets and networks for climate resilience. Ensuring that different climate resilience assessments were using a single source of truth. The Victoria's Future Climate Tool is a step in the right direction for this – where several different sources have been used to provide a consolidated GIS based tool which can be used to identify the key hazards for a given region and climate change scenario. VicMap in combination with this also provides a map of key infrastructure which could be used in conjunction with the Climate tool. These are both great tools however only cover the state of Victoria. - **Developing partnerships with research institutions**: This will allow IA to gather more detailed, sector-specific data on areas which are identified as higher risk.

	- **Leveraging technological advancements**, such as remote sensors and AI, for improved data collection and analysis. - **Private Data Integration,** Utility records, insurance claims, and maintenance logs offer valuable insights into asset vulnerability.
Key Gaps	- **Integrated Datasets:** There is a lack of integrated hazard, exposure, and vulnerability datasets. Data from different sectors (e.g., energy, transport) are often specific to the relevant authority or government area. Victoria has been a focus of the review due to existing experience within this state within the OCAM team. The data sets in Victoria are specific to this state and could be expanded further to incorporate other data from other states and territories. - **Asset-Specific Vulnerability Data:** Information on the physical condition of infrastructure (e.g., maintenance history, materials used, or design standards) is often missing from publicly available datasets. This may be available from the asset owners themselves however is likely to historically not be digital data for older assets (such as tunnels, bridges, rail). Non-digital data will be difficult to combine into the overall methodology without significant time input to gather the relevant information.



FRAMEWORK & DATA EVALUATION

4. Framework and Data Evaluation

OCAM Visionary Alliance has conducted an evaluation of the proposed risk assessment framework developed within this report, in addition to the data sources assessed in Section 3.

4.1. Risk Assessment Framework

To conduct a thorough evaluation of the risk assessment framework developed by OCAM Visionary Alliance, the risk assessment framework review process outlined by the Australia Government Department of Finance has been used. This review process is in alignment with the Commonwealth Risk Management Policy and aims to ensure the framework is effective and meets the needs to relevant parties (Department of Finance, 2016).

Within the Department of Finance information sheet for conducting a risk assessment framework evaluation, there are a series of questions that have been outlined to aid the evaluation. These have been used to aid the evaluation of the risk assessment framework created by OCAM Visionary Alliance. Refer to Table 5 for an overview of this evaluation.

Table 5: Evaluation of risk assessment framework based on questions outlined by the Department of Finance

Is a common definition of risk, which addresses both threats and opportunities, used consistently throughout the entity?	OCAM visionary alliance have adopted a definition of risk that is commonly used globally across multiple organisations. This model has been recommended by the Intergovernmental Panel on Climate Change and has been put forth by IA as an appropriate model to use to define and assess risk.
Are the key roles, responsibilities and authorities relating to risk management clearly articulated and followed within the entity?	Key roles, responsibilities and authorities relating to risk management have not been clearly articulated within the proposed framework. This is an opportunity for further development if IA find this to be an appropriate framework to adopt. These roles will be influenced by IA internal systems and will therefore require IA input to be articulated.
Do the governing bodies (e.g., Boards, Audit Committees, Risk Committees, Management Committees) have appropriate transparency and visibility into the entity's risk management practices to discharge their responsibilities for oversight?	It is assumed that if this framework is to be adopted by IA, there will be an adequate level of transparency and visibility into the risk management practices of clients and stakeholders. If this is not the case, the framework can be developed such that it is appropriate to suit the level of transparency that is available.

Does the risk function's position in the entity enable direct access to the executive management team?	If the proposed risk assessment framework is to be adopted, this would be a key criterion that shall be considered for IA and their clients and stakeholders.
Has your entity defined relevant risk categories which enable risks to be aggregated, analysed and reported upon?	The proposed framework has categorised risk using the definition of risk as recommended by the Intergovernmental Panel on Climate Change and IA. This definition allows risk to be categorised based on hazard, exposure, and vulnerability. Adopting this categorisation allows for risk and relevant data to be aggregated, analysed and reported in such a way that is recognised across the globe and within the organisation.
Do your entity's risks align to its organisational objectives?	The main objective of Infrastructure Australia is to advise governments, industry and the community on the investments and reforms needed to deliver better infrastructure for all Australians. Within the risk assessment framework, the taxonomy adopted ensure that both financial and social aspects are considered such that the assessment aligns with this objective for IA.
Does your entity have a clear approach for analysing and evaluating risk?	The methodology outlined in this section of the report aims to create a clear approach for analysed and evaluating risk based on the proposed framework. A step-by-step methodology has been provided.
Has your entity defined its risk appetite? Does its risk appetite enable decisions to be made that reflect the entity's attitude towards risk, that is, what is acceptable and unacceptable?	The risk assessment framework does not consider the risk appetite of IA nor their clients and stakeholders. This could be later be assessed to determine if this could be accounted for within the framework.
Does your entity have a regular reporting cycle where risk information is incorporated for management review and attention?	The proposed framework does not outline any reporting, information management and/or review process guidelines. This is an area in which could be incorporated into the framework in future development.
Is there a process which identifies, assesses and treats risks for all key activities (e.g. projects,	The process includes identifying and assessing risks; however, the framework does not include the treatment of those risks. The relevant activities in which the risk is being assessed for has not be accounted for within the

programs, policy development and business processes)?	proposed risk assessment framework. Further development of the framework could account for this.

Based on the evaluation above, the following are key areas for further development of the risk assessment framework:

- Assign key roles and responsibilities within the risk assessment framework that align with IA's advisory role with clients and ensuring that executive management teams of relevant parties have direct access to risk function.
- Understand the level of visibility and transparency IA have in relation to client's risk management practices, and update framework to suit.
- Consider role of risk appetite of both IA and their clients to understand if accounting for this within the framework will enable a more effective and reliable assessment.
- Framework could be further developed to outline reporting, information management and review processes.
- Framework could be further developed to account for activity of interest to be considered when assessing risk.

4.2. Data Sources

To conduct an effective evaluation of the available data sources, OCAM Visionary Alliance have adopted an evaluation approach proposed by DAS42, an American data consultancy that strive to create effective data centric environments. DAS42 has generated a list of questions in which aim to deepen the understanding of data and develop effective strategies to manage and handle the data (Kovich, 2024). Refer to Table 6 for an overview of this evaluation.

Table 6: Evaluation of data sources based on questions outlined by the DAS42.

What Objectives Does the Data Serve?	The data sources assessed serve as quantitative measures of which can be used to assess risk of assets and networks within Australia.
What Manual Steps Does the Data Require?	There is a large amount of manual labour required to find, sort, manipulate and manage the data available. To find the relevant data, the reviewer must manually find the relevant data, extract the data point and input into the created tool to complete the assessment. This must be repeated for all measures within the risk taxonomy. Given this is quite a taxing and time-consuming process, there is opportunity for further atomisation of this process if this tool is to be adopted.
Where Does the Data Come From?	All data is from respected government and or private bodies, organisations, and agencies.

How Reliable and Complete is the Data?	Given all data is from trusted bodies, the reliability of the data is adequate. The completeness of the data varies across sources. The location and areas of which data is represented varies across sources and therefore creates limitations within data collection.
How is the Data Organized and Stored?	Currently the data is organised and stored across multiple platforms run and operated by separate entities across Australia. Collection and storing of this data into a single location will improve efficiency of the risk assessment.
Which Key Concepts Transcend the Tools, and Which Ones Are Siloed?	Currently all data, tools and platforms are siloed creating a disconnect between data sources creating further challenges to observe correlations between data.
What Correlations Do We Want to Explore?	This question can be further explored with experts within the industry and key representatives within IA. OCAM Visionary Alliances assumes that there would be value in exploring correlations between categories of risks and the locations of interests to identify if there are additional factors that influence the measures identified or if the hazard alone results in the measurable data. This may improve efficiency of assessment.
How Do We Comply with Data Privacy and Security Regulations?	It is assumed that all bodies and organisations are collecting and sharing data in alignment with the data privacy and security regulations.
How Do We Turn Data Insights into Action?	The risk assessment framework and methodology created outlines how IA can leverage their influence and network within the industry to create desirable action with the data being collected.
What relevance does the data have with the risk assessment framework?	Although there is a large amount of data available within the public realm, much of it is not relevant to the taxonomy and risk assessment framework being created. This creates further challenges around the availability of data in conducted the proposed risk assessment. Further assessment of the available data is conducted later in this report.
What is your organisation's capacity to collect data? Who will manage, collect, analyse, and interpret the data?	It is not well understood as to the level of sources, capacity and commitment that IA are willing to invest into the collection and management of data. Further discussions with IA around this could lead to clearer, more efficient and effective processes in which can be used to collect data for the risk assessment being proposed.

Based on the evaluation above, the following are key areas for further development (in addition to what is proposed in Section 3) of the data sources. Note that some of the evaluation above supports the recommendations made in Section 3 of this report.

- Potential further development of risk assessment tool to include automation in the collection of data. This could be an extension of the single source of information tool as previously recommended, such that this single source could extract the relevant data required for the risk assessment.
- In addition to the standardisation recommendation made in Section 3, a further consideration of this approach could consider the precision of this data and the scale of areas in which are being assessed.
- Further discussion with IA and industry experts around expected correlations with data inputs and location could be explored. It is important to understand the key drivers of the data collected and ensure that it is directly related to hazards and no other factors within the area of interest. This will ensure appropriate solutions are adopted that directly related to the issue at hand.
- Further discussions with IA to understand the commitment and resources available to invest into the collection, management, analysis and interpretation of data. This will ensure that any processes and procedures being proposed in this area are most effective and efficient for IA.

RISK ASSESSMENT METHODOLGY

5. Risk Assessment Methodology

A core component of the risk assessment framework is a detailed process designed to evaluate the climate resilience risk of specific assets or networks. The objective of this methodology is to leverage available data to create a standardised scoring system, supporting Infrastructure Australia (IA) in its reporting and advisory functions for clients and stakeholders.

This section outlines the risk assessment methodology developed by OCAM Visionary Alliance. The methodology is applicable across various sectors, scales, and asset types, ensuring consistency in risk evaluation using available data sources. The methodology integrates diverse data inputs through a unified scoring system. This system enables comparative analysis and aggregation of risk ratings, providing a quantitative assessment of risks based on severity and likelihood. The methodology accounts for different time horizons and climate scenarios, allowing for a dynamic and forward-looking risk evaluation.

This matrix is an essential tool, working alongside the risk framework to generate an overall climate resilience score. These scores enable direct comparisons between regions, assets, and infrastructure, facilitating informed decision-making.

Successful implementation of this methodology will produce objective, data-driven risk assessments. The quantitative outputs will guide actionable recommendations, helping IA clients and stakeholders prioritise investments and develop strategies to enhance infrastructure resilience.

For detailed scoring criteria and risk matrix structure, refer to Appendix B.

5.1. Methodology Overview

The risk assessment methodology aims to evaluate climate resilience risks for infrastructure by addressing three core components: Hazard, Exposure, and Vulnerability. Each component is assessed using specific criteria and quantitative measures to produce a comprehensive risk profile. This standardised approach ensures consistency and enables comparative analysis across different regions and asset types.

The methodology has been designed with adaptability in mind, allowing Infrastructure Australia (IA) to apply the framework to a broad range of infrastructure sectors. By integrating available data into a scoring system, this framework provides actionable insights to support IA's advisory and reporting functions. The overall objective is to generate a robust, data-driven measure of risk that informs decision-making and prioritisation of investments.

This section outlines the framework's key steps, from data collection to scoring and interpretation. The detailed risk matrix, found in Appendix B, serves as the foundation for evaluating hazards, exposure, and vulnerability.

5.1.1. Methodology Phases

In combination with the framework outlined in Section 2, the methodology follows a structured, step-by-step process to evaluate climate risks for multiple hazards and assets within a given region. The steps outlined below align with the process flowchart illustrated in Figure 3.

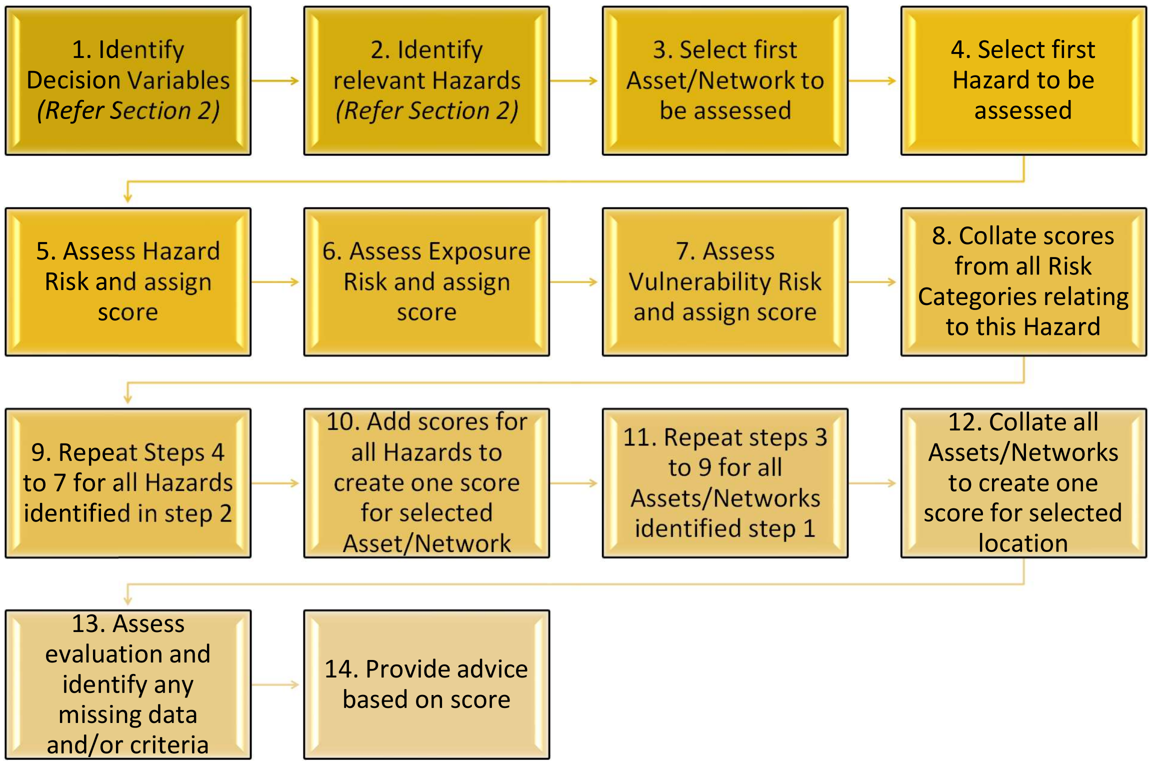


Figure 3: Risk Assessment Methodology Process

Step 1: Identify Decision Variables

This initial step defines the scope of the assessment, including the geographic region, time horizon, and infrastructure types. The variables ensure the risk assessment aligns with broader strategic objectives. *(Refer to Section 2 for more details on decision variables.)*

Step 2: Identify Relevant Hazards

Based on the region and asset type, climate hazards such as flooding, bushfires, or heatwaves are identified. This step leverages historical climate data and projections to determine which hazards are most relevant. *(Refer to Section 2 for hazard identification criteria.)*

Step 3: Select First Asset/Network to Be Assessed

An asset or network within the region is selected for risk evaluation. This ensures a focused and systematic analysis of each critical infrastructure component.

Step 4: Select First Hazard to Be Assessed

The first identified hazard is applied to the selected asset. This hazard will form the basis for scoring the subsequent risk dimensions.

Step 5: Assess Hazard Risk and Assign Score

The likelihood and severity of the selected hazard are evaluated and scored based on predefined criteria in Appendix B, Table B1 and available data for the given region. This establishes the potential impact of the hazard on the asset.

Step 6: Assess Exposure Risk and Assign Score

Exposure is assessed by evaluating how much of the asset or surrounding population is at risk from the hazard. Scoring criteria, as outlined in Appendix B, Table B2, include population density, asset importance, and economic dependency.

Step 7: Assess Vulnerability Risk and Assign Score

The vulnerability of the asset is assessed by examining its structural condition, maintenance history, and redundancy. Scoring guidance is provided in Appendix B, Table B3.

Step 8: Collate Scores for the Hazard

Scores from the Hazard, Exposure, and Vulnerability assessments are combined to generate a comprehensive risk score for the specific hazard impacting the asset. Refer to section 5.1.2 for further details on the scoring and weighting of each of the scores for Hazard, Exposure and Vulnerability.

Step 9: Repeat Steps 4 to 7 for All Hazards

For the selected asset, repeat the scoring process for each remaining hazard identified in Step 2.

Step 10: Calculate Asset Risk Score Across Hazards

Aggregate the risk scores from all assessed hazards to produce an overall risk score for the selected asset or network.

Step 11: Repeat Steps 3 to 9 for All Assets

The process is repeated for all assets or networks identified in Step 1, ensuring that each critical infrastructure component is thoroughly evaluated.

Step 12: Collate Regional Risk Score

Finally, the aggregated risk scores from all assets and hazards are combined to produce a single risk score for the entire region. This regional score provides a high-level view of climate resilience and highlights priority areas for intervention.

Step 13: Assess evaluation and identify any missing data and/or criteria

Review and assess evaluation to ensure all critical criteria has been captured and correctly assessed. If assessor feels that there are critical criteria that has not been captured, methodology can be captured to suit *(Refer to Section 2 for more details.)*

Step 14: Provide advice based on score

Use score to provide advice to clients and stakeholders. *(Refer to Section 2 for more details.)*

5.1.2. Scoring and Aggregation

The scoring and aggregation process forms the backbone of the risk assessment, translating raw data into actionable risk profiles. Each dimension of risk—Hazard, Exposure, and

Vulnerability—is assigned a numerical score based on predefined criteria outlined in the risk matrix (Appendices B, Table B1, B2, and B3).

Step 1: Scoring Each Dimension

Hazard: Assessed on likelihood and severity, using historical and projected climate data. Scores range from 1 (low risk) to 5 (high risk).

Exposure: Evaluates the extent of the impact, including population density, asset value, and critical ecosystem services. Each of these exposure criteria are assigned a score from 1 to 5 depending on the applicable consequence of the criteria. These scores are then averaged over the number of applicable categories.

Vulnerability: Factors in the physical state of assets, redundancy, and historical maintenance records. As with the exposure, these are assigned scores of 1 to 5 depending on the magnitude of the vulnerability, and the scores averaged to provide a vulnerability rating.

Where data is unavailable or not applicable, a 'not applicable' (N/A) score is assigned. This N/A score is excluded from the final weighted average to ensure the accuracy of the aggregate risk rating.

Step 2: Weighted Aggregation

Each dimension is weighted according to its significance:

Hazard: 40%

Exposure: 30%

Vulnerability: 30%

These weightings can be adjusted based on stakeholder priorities or specific asset requirements. The aggregated score represents the overall climate risk for an asset or network, providing a comprehensive and comparative risk profile.

Step 3: Risk Classification

The final scores are categorised using a traffic light system for visualisation, refer to *Table 7*:

Insignificant (0–1): Light Green

Low (1–2): Green

Medium (2–3): Yellow

High (3–4): Orange

Extreme (4–5): Red

This system enables rapid identification of high-risk assets, streamlining decision-making process.

Enhancing Interpretation

The scoring framework is designed for adaptability and clarity. By providing an overarching score alongside detailed sub-scores for each dimension, stakeholders can pinpoint specific areas of concern and tailor resilience strategies accordingly.

Table 7: Risk Matrix Traffic Light Scoring System

Risk Matrix Traffic Light Final Scoring System					
	Severity				
Probability	Insignificant	Minor	Moderate	Major	Severe
Almost Certain	Low	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	High	Extreme
Possible	Insignificant	Low	Medium	High	High
Unlikely	Insignificant	Low	Low	Medium	Medium
Rare	Insignificant	Insignificant	Insignificant	Low	Low

5.2. Assumptions

The risk assessment framework developed by OCAM Visionary Alliance incorporates several assumptions to address data gaps, ensure methodological consistency, and facilitate effective decision-making. These assumptions underpin the entire assessment process and are detailed as follows:

5.2.1. Data Accessibility and Reliability

The framework assumes that reliable data sources are available for all relevant inputs, including historical climate events, asset condition, and socio-economic factors.

- **Example:** It is assumed that public climate datasets (e.g., Bureau of Meteorology) accurately capture the frequency and intensity of past hazard events. Where gaps exist, alternative data, such as third-party climate models, are used.

5.2.2. Scoring Criteria Uniformity

The scoring system assumes that hazard, exposure, and vulnerability criteria apply uniformly across all asset types and geographic regions.

- **Example:** The same scoring system is applied to evaluate flood risks for both urban transport networks and rural water treatment facilities, despite differences in operational contexts.

5.2.3. Static Asset Conditions

The assessment assumes that the current physical state of an asset (e.g., structural condition) remains constant throughout the evaluation period unless specific data indicates recent or planned changes.

- **Example:** A bridge that had repairs in the past year is evaluated based on its current state. However, if repairs / works are planned but not yet implemented, it is assumed to be in its pre-upgrade condition.

5.2.4. Independent Hazard Events

Hazards are assessed as independent events unless there is clear evidence of cascading or compounding risks.

- **Example:** Flooding and landslides are assessed separately unless data indicates that flooding is likely to trigger landslides in the region under review.

5.2.5. Socio-Economic Stability

The socio-economic factors influencing exposure, such as population density and economic reliance on infrastructure, are assumed to remain stable during the assessment period.

- **Example:** A commuter rail network is assessed based on current ridership levels, assuming no significant changes in population distribution or commuting patterns over the next five years.

5.2.6. Hazard Frequency Projections

It is assumed that the likelihood of future hazard events can be estimated based on historical data and climate model predictions.

- **Example:** The probability of a flooding event causing damage to the asset is projected based on historical records and climate projections for increasing precipitation intensity. Refer Figure 4: Extract from Climate Council for an example of the data set available from the Climate Risk Map of Australia.

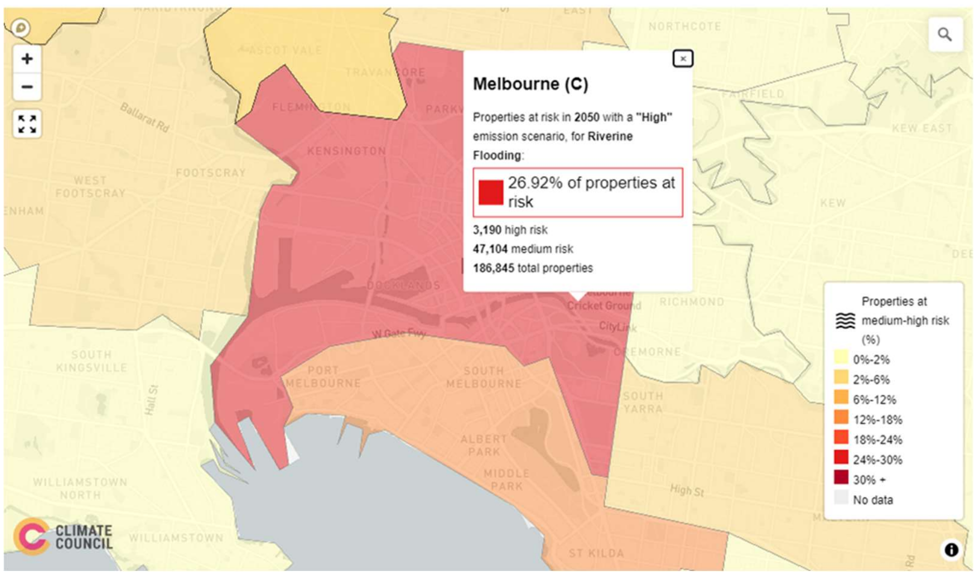


Figure 4: Extract from Climate Council (Climate Risk Map of Australia, 2024)

5.2.7. Proxy Data for Exposure and Vulnerability

In cases where direct data is unavailable, proxy indicators are used to estimate exposure and vulnerability.

- **Example:** If traffic data for a particular road is unavailable, population density in the surrounding area is used as a proxy to estimate exposure levels. Figure 5 shows an extract from the DTP (Department of Transport and Planning) open traffic data platform which shows AADT for each DTP road.

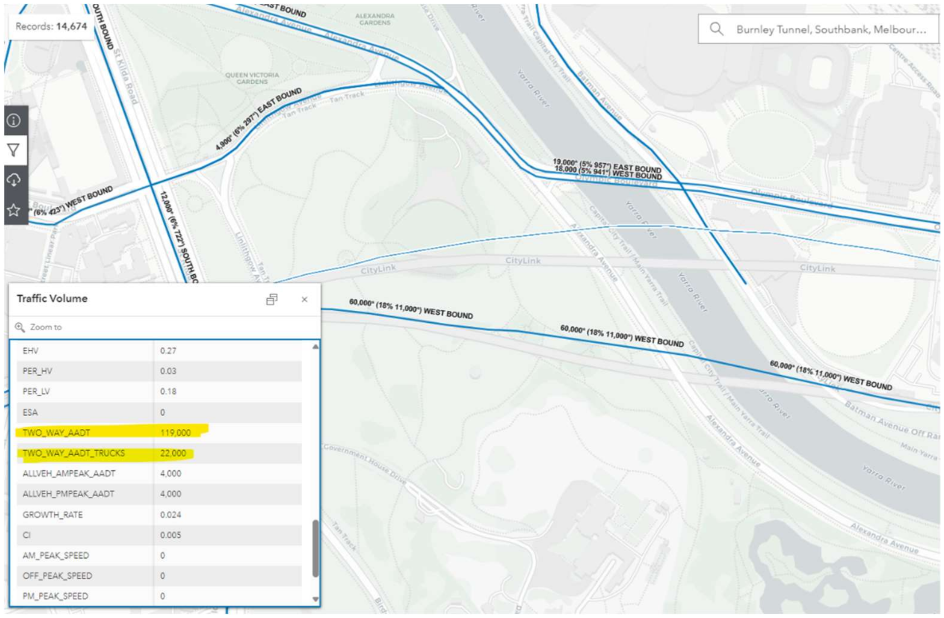


Figure 5: Traffic AADT (DTP open data traffic volume, 2024)

5.2.8. Redundancy of Critical Systems

The framework assumes that data on system redundancy (e.g., availability of alternative routes or backup systems) is accurate and comprehensive.

- **Example:** An electricity substation is evaluated based on the assumption that nearby substations can handle excess load in the event of a failure.

5.2.9. Weighting Flexibility

The default weighting of Hazard (40%), Exposure (30%), and Vulnerability (30%) is assumed to reflect stakeholder priorities but can be adjusted for specific projects.

5.2.10. Temporal Scope of Risk Assessments

Risk assessments are conducted for a defined timeframe, depending on the asset's operational lifespan and climate data projections. The tool includes options for 2030, 2050, and 2100 only as these are the most common evaluated years among the data sources available.

Conclusion

These assumptions underpin the robustness and flexibility of the risk assessment framework. While they help simplify complex assessments, periodic reviews and updates of data and assumptions are essential to maintain accuracy and relevance.

5.3. Assessment Tool

To implement the proposed risk assessment methodology, a customised assessment tool was developed. This tool automates the process of assigning scores for each dimension—Hazard, Exposure, and Vulnerability—using predefined criteria detailed in Appendix B, Table B1, B2, and B3.

Features and Functionality

The tool integrates multiple functions designed to simplify data input, scoring, and aggregation:

1. *Data Input Automation*

Users input specific data points (e.g., population density, asset condition) into highlighted fields, and the tool automatically assigns corresponding scores based on predefined criteria.

2. *Dynamic Scoring*

The tool dynamically calculates scores for each risk component using a weighted system. Scores are adjusted based on hazard likelihood, exposure factors, and asset vulnerability.

3. *Traffic Light System for Visualisation*

The final aggregated scores are presented using a traffic light system for visualisation.

4. *Multi-Hazard and Multi-Asset Evaluation*

The tool allows for simultaneous assessment of multiple hazards affecting a single asset and vice versa, as illustrated in the methodology flowchart in Figure 2.

Workflow and Scoring Calculation

1. *Input Data Collection*

Users input available data into highlighted fields (e.g., hazard frequency, infrastructure density).

2. *Criteria-Based Scoring*

The tool applies standardised criteria from the risk matrix to assign scores for each input. For example, a highly exposed area with dense infrastructure might score a 5 under exposure.

3. *Aggregation and Weighted Calculation*

The scores for Hazard, Exposure, and Vulnerability are weighted at 40%, 30%, and 30%, respectively. The tool computes an overall risk score for each asset or region.

Benefits and Recommendations

The assessment tool offers the following benefits:

- Consistency: Ensures uniform scoring across different regions and assets.
- Efficiency: Reduces the time and effort required for manual scoring.
- Comparability: Allows for easy comparison of risk levels across assets, helping stakeholders prioritise interventions.

Further development could include advanced automation features, such as integration with real-time data sources and GIS mapping for enhanced visualisation.

Recommendation: For optimal results, regular updates and calibration of the tool should be conducted as new data becomes available, ensuring its long-term applicability and accuracy.

5.4. Data Availability

The effectiveness of the risk assessment framework is heavily reliant on the availability, quality, and consistency of data. This section outlines the current data landscape, identifies key gaps, and highlights opportunities for improvement.

1. *Key Data Sources*

The framework utilises publicly accessible datasets as its primary input to ensure transparency and scalability. Key data sources are documented within Section 3 of this report.

2. *Data Gaps and Limitations*

Despite the availability of public data, several limitations exist:

- *Infrequent Updates:* Many datasets lack real-time updates, reducing accuracy for rapidly changing conditions such as urban growth or climate shifts.
- *Coverage Gaps:* Rural and remote areas often lack detailed hazard and asset data.
- *Limited Asset-Specific Data:* Critical information on asset condition, maintenance history, and repair costs is typically unavailable or scattered across different stakeholders.

3. *Enhancing Data Availability*

To address these gaps, integrating additional data sources and improving data accessibility are essential. Potential improvements include:

- *Private Data Integration:* Utility records, insurance claims, and maintenance logs offer valuable insights into asset vulnerability.
- *Data Standardisation:* Harmonising data formats across public and private sources to streamline analysis.
- *Centralised Data Hub:* Establishing a unified platform for data storage and access to enhance consistency and ease of use.

Further detail on data availability and recommendations can be found in Section 3 of this report.

4. *Future Directions*

Advancements in technology, such as real-time monitoring and predictive analytics, will play an essential role in improving how we assess and respond to climate risks. For example, sensors and monitoring devices can collect data about infrastructure conditions and hazards, like flooding or extreme heat, as they happen. These tools, often referred to as IoT (Internet of Things) devices, provide up-to-date information that makes risk assessments more accurate and timely.

Additionally, using predictive models powered by advanced analytics can help anticipate future risks based on this real-time data. These developments will enhance the accuracy of our framework, ensuring Infrastructure Australia has clear and actionable insights to prioritise investments and build resilience in the face of climate change.

PROOF OF CONCEPT

6. Proof-of-Concept Application

OCAM Visionary Alliance has complete the following proof of concept using the developed framework and methodology to assess and demonstrate how it is to be applied in practice.

6.1. Application in Selected Geographic Area

A proof-of-concept was conducted in a sub-region within a Victoria. The assessment has been based on a single transport infrastructure asset, identifying key recommendations and future developments to enhance the developed tool enhancing utilisation for networks and multiple interconnecting assets as a future expansion on the concept.

The asset chosen was the Burnley Tunnel, in Melbourne. This was chosen as it is a key piece of transport infrastructure within the state of Victoria which is heavily relied upon for the population of Melbourne.

Refer to Appendix C for a summary of the numerical risk scores calculated using the proposed methodology.

6.1.1. Step One: Identify Decision Variables

Geographical Location: City of Melbourne

Spatial Scale: 20km^2

Assessment year: 2050,

Emissions scenario: High

6.1.2. Step Two: Identifying relevant Hazards

Numerous data sources were utilised to identify the following Hazards as being of concern in the location of interest:

- The Geoscience Australia Natural Hazard Scenarios tool highlighted that cyclones are not expected in the location of the asset. (Geoscience Australia Natural Hazards Scenarios Tool, 2024)
- The Australian Disaster Resilience Knowledge Hub was used to identify any past hazards and disasters which may impact the Burnley Tunnel. Past events included a Tunnel fire, bus accident, and water ingress into the tunnel. Leaks were reported on the tunnel in 2001 and 2007.
- City of Melbourne has documented an expected 18.5% increase in rainfall intensity and 0.8m increase in sea levels by the year 2100, highlighting a risk of rainfall intensities exceeding design. (City of Melbourne, 2023).
- Historical data and previous knowledge of the nominated area recorded that storms would also affect this asset and be relevant to the area. Although this was identified as a potential hazard of interest, a lack of data led to an inability to evaluate.

Three key hazards were identified for further evaluation:

- Flooding (surface water)
- Riverine Flooding
- Storms

6.1.3. Step Three: Select first Asset/Network to be assessed

Asset Choice: Burnley Tunnel

6.1.4. Step Four: Select first Hazard to be assessed

Hazard Choice: Flood

6.1.5. Step Five: Assess Hazard Risk and assign score

In the case of a flood event, it was identified that a critical flood event would be one where the floodwater levels exceed that of which is accounted for in the tunnel design. As a result, the following hazard scores were identified:

Likelihood – It is understood that tunnels are designed for a 1% Annual Exceedance Period (AEP) flood event, therefore, there is a less than 5% probability that a flood event that exceeds design flood levels will occur in a year. As a result, this allocates a likelihood score of 1.

Severity – Given the Burnley Tunnel is in a densely populated location with critical infrastructure, it was allocated a severity score of 5.

Averaging the likelihood and severity scores provides a hazard score of 3.

6.1.6. Step Six: Assess Exposure Risk and assign score

Exposure measures were assessed using data sources as shown in Appendix C. The assessed exposure measures are documented in Table 8, where the values of all criteria were averaged to provide an exposure score of 2.14.

Table 8: Proof of Concept: Burnley Tunnel - Exposure Assessment

Exposure Category	Assessed Impact	Exposure Score	Source
Population Affected	>100,000 people impacted	5	Traffic data confirmed the number of vehicles using the tunnel per day exceeds 100,000 people per day. (DTP open data traffic volume, 2024).
Financial Impact	>$200Mil	5	DTP traffic data shows 22,000 trucks use the tunnel per day. If the tunnel were to be closed, this would affect the national supply chain because of delays and increased traffic on alternative routes, therefore it was assumed that the impact of tunnel closure would be greater than $200mil. *This item has been identified as an area for improvement as is it challenging to*

			define a simple, objective and/or definitive way to find the value of the impact of the hazard on the asset.
Ecosystem Services	Negligible impact on ecosystem services	1	Using the VicPlan portal the area of where the Burnley Tunnel sits was reviewed against the key environmental overlays and no areas of environmental significance, or other overlays were identified therefore resulting in a score associated with negligible impact on ecosystem services. (Mapshare VicPlan,
Injury and Fatality	No fatalities and no severe injuries, Minor first-aid level injuries affecting fewer than 10 people.	1	Historical data was used to identify if previous flood events of similar magnitude have resulted in injuries and fatalities. It was found that it is not expected that fatalities will occur as the tunnel would be closed as soon as any emergency was detected. It was also noted during the review that safety precautions are put in place when designing and building tunnels to reduce the risk of flooding. *There was no specific historical data used for this item within the proof of concept however the intention was to use historical data for similar events to predict fatalities and injury numbers.*
Population Displacement	<100 people	1	Due to the nature of the asset, it is not expected that there would be any displacement of people as a direct result of the hazard.
Historical Exposure	No significant historical events in the past 100 years.	1	Using historical data, it was found that there are no significant flood events which have affected the Burnley Tunnel. (Disaster Map, 2024)
Local Growth and Economy	Impacted for less than 1-day, localised partial disruption for a day/days	1	The impact of tunnel closure was identified as low impact. The reason for this is that it is expected that closure of the asset for flooding will not result in permanent damage and therefore can be

			repaired and resume operation quickly. This is based on the use of historical data on the closure times for the tunnel for repairs.
Exposure Score:		2.14	

6.1.7. Step Seven: Assess Vulnerability Risk and assign score

Vulnerability of the asset was then assessed using the identified measures noted within the risk matrix, these are documented in Table 9 below. The averaged vulnerability score was calculated to be 3.20.

Table 9: Proof of Concept: Burnley Tunnel - Vulnerability Assessment

Vulnerability Category	Assessed Impact	Score	Source
Age of Asset	0-25% of its design life	1	Publicly available data was used to determine the date of construction to be the year 2000. Given the standard design life of tunnels of 100 years, the age of asset measure was given a score of 1. *It is expected that IA will have access to the design life of specific assets and/or will be able to request this information from the asset owner.*
Condition of Asset	N/A	0	This information was not available to OCAM Visionary Alliance, it is expected that IA will be able to access this information from asset owners who are expected to perform regular assessments of their infrastructure assets. As no information was available for this category, it was removed from this assessment.
Past Investments	Investment range (over past 10 years) in the range of $500,000 - $1 million	4	This was determined through publicly available information and research into news articles.
Service Dependency	Number of People	5	This was estimated based on traffic data, truck numbers, and estimated impact on supply chains.

	Dependent: >1 million people		
Redundancy of Services	Redundancy: More than 5 similar assets within a 5 km radius	1	There are several different routes both road and rail which could be used if the Burnley Tunnel was not operational. Using maps, it was apparent that if the tunnel were to be flooded, alternative transport routes exist. However, it would cause traffic and delays in the local road networks.
Repair Cost	Repair costs >75% of TCC (NPV-adjusted)	5	This assessed the total cost if the tunnel were to fail. *It is recommended that this be determined based on the repairs of the asset under certain circumstances and for different required repairs for the different hazard scenario.*
Vulnerability score		3.2	

6.1.8. Step Eight: Collate scores from all Risk Categories relating to this Hazard

The overall risk for a flood event for the Burnley Tunnel is calculated using the risk ratings for the hazard, exposure and vulnerability and weightings of 0.3, 0.3, 0.4 respectively. For the Burnley Tunnel under a proposed flood hazard, using the High Emissions scenario in 2050 the risk score was identified as **2.8, a moderate score.**

This was calculated using a weighted average of Hazard (3), Exposure (2.14) and Vulnerability (3.2).

6.1.9. Step Nine and Ten: Asset Risk Score

When utilising the risk assessment framework, it is expected that this assessment as documented above would be completed for each hazard identified and the risk scores combined to provide an overall risk rating for the network or asset.

Refer to Appendix C for a full summary of the Burnley tunnel assessment against all hazards. Accounting for all potential hazard events. The tunnel is given an average risk score of **3.0, a moderate score.**

6.1.10. Step Eleven and Twelve: Regional Risk Score

If the entire City of Melbourne were to be assessed, the above process would be completed for all key assets within the location. The risk ratings of all assets would them be combined to identify a risk score for the entire location. This could then be used to identify which areas are at high risk to climate impacts and would therefore require additional investment.

6.1.11. Step Thirteen: Assess evaluation and identify any missing data and/or criteria

Throughout the application of the methodology, there were no additional criteria that were identified to be of significance that were not already captured. One measure was however noted to be neglected in this assessment as a result of limited data.

If an additional measure were identified throughout this process, the methodology scoring would be recalculated to account for this additional measure, creating room for flexibility and adaptability within the framework.

6.2. Insights from the Risk Framework

The proof of concept for the risk framework and methodology outlined within this report has allowed OCAM Visionary Alliance to identify key areas of improvement and future works to enable the proposed framework to be utilised over a more varied scale and asset types.

6.2.1. Key Findings

The framework identified critical gaps in data availability and highlighting areas where investment in data collection and processing could yield the most significant benefits, particularly in enhancing the robustness of transport and energy networks against anticipated climate impacts.

Throughout the assessment it was also identified that some of the measures were challenging to quantify given the number of variables required to generate the quantitative measure that was allocated. Identifying a single, tangible value to assess each measure creates more consistency of the assessment across assessors, minimising subjectivity and bias.

It is also noted that the assessment was only completed for a single asset and is therefore limited in its ability to provide a comprehensive overview of the framework and methodology.

6.2.2. Opportunities for Improvement

In completing the risk assessment, the following were identified as key areas for improvement and opportunities for future development:

- Further development of the framework can include refining the risk taxonomy and expanding the integration of real-time data for dynamic risk assessment.
- The proof-of-concept assessment was completed based on a specific transport infrastructure asset, extending the framework to other infrastructure sectors such as telecommunications and water management can provide a more comprehensive national risk overview. The proof of concept was not used on these different areas of interest, and it is expected that additional risk criteria may be more suitable to these different asset types.
- The assessment completed used data from 2024 to determine the number of people affected by the hazards and does not consider the future population. It's recommended if this were to be taken forward that estimated future population information be used.

- The framework has been assessed using a specific climate change scenario. As climate change is an ongoing and evolving based on predictions and real time emissions, the use of dynamic data for climate predictions and identification of hazards for a given area would allow for more accurate risk assessments in future.
- A key area identified for improvement was the applicability of all the criteria to each specific assessment. It is therefore recommended at the start of the assessment that the reviewer identify the areas of interest / applicability to the specific asset or network. The risk matrix allows for some of the categories to be marked as 'not applicable' and these items are then not used to calculate the risk score for the vulnerability or exposure.
- A future opportunity for the framework would be to provide a single source where all data can be combined into one user friendly platform. This would require the data from all the identified sources to be available in one location. A map-based GIS system where current data is provided for each of the assessment criteria would prevent differing sources of truth and allow for a more uniform assessment when completed by different assessors.
- The risk assessment matrix could be automated fully, where data is extracted from the relevant sources and the tool identifies the required figures from the data supplied. Based on the collected data it would automatically score based on our risk matrix criterion This would remove the human error from the tool, reduce manual effort and ensure consistence in results. It would also make it more user friendly for application by people without expertise in the required area.
- Due to the recommendation above to incorporate a 'one stop shop' with a centralised GIS platform for efficiency it could be linked to dynamic updates at which all data was linked to be real time data and could track past events and historical data which would give an understanding on predictive analytics for evolving climate scenarios occurring over time and their frequencies/severity.

7. Conclusion

The development of the risk assessment framework presented in this report represents a significant step toward enhancing the resilience of Australia's infrastructure to climate-related hazards. Through a data-driven and standardised methodology, the framework provides a robust approach to evaluate and quantify risk associated with climate change. The framework not only integrates key risk components – Hazards, Exposure, and Vulnerability – but also offers scalability across infrastructure sectors and geographic regions.

The proof-of-concept application on the Burnley Tunnel demonstrates the practical utility of the framework. It highlights the tool's capability to generate actionable insight, such as identifying priority areas for investment and resilience-building. The outcomes reinforce the framework's adaptability and its potential to support Infrastructure Australia's advisory functions.

Key Takeaways:

- The comprehensive approach ensures that risks are assessed holistically, providing a clear understanding of infrastructure vulnerabilities.
- The standardised scoring and weighting system facilitate consistent risk evaluation across multiple assets and regions.
- The use of publicly available data allows the framework to remain cost-effective while maintaining transparency.

Recommendations for further development:

1- **Data Integration and accessibility:** Future iterations of the framework could focus on integrating private datasets, including asset-specific maintenance records, insurance claims, and real-time monitoring system to improve data accuracy and depth. Real-time data collection of asset usage through IoT and GIS mapping tool could significantly enhance the spatial and temporal precision of risk evaluations.

2- **Framework Refinement and customisation:** Expanding the framework to include sector-specific customisation options would allow for greater alignment with stakeholder priorities and regional challenges. Custom scoring systems and weight adjustments could be developed to accommodate unique risk profile.

3- **Automation and Efficiency Improvements:** Incorporating automation features into the assessment tool, such as pre-filled data inputs and dynamic visualisation dashboards, would streamline the evaluation process and enhance user experience. This would also ensure quicker turnaround times for large-scale assessments.

This report lays the groundwork for a systematic, scalable, and adaptable climate risk assessment framework. The methodology's strength in standardisation and flexibility makes it an indispensable tool for addressing the evolving challenges of climate change. By continuously refining and applying this framework, Infrastructure Australia can lead the way in safeguarding the nation's infrastructure, ensuring its long-term sustainability, and supporting its communities against future climate uncertainties.

References

- Climate Council. (2024a). *Earth's hottest year signals urgent need for climate action*. [online] Available at: https://www.climatecouncil.org.au/resources/earths-hottest-year-signals-urgent-need-climate-action/.
- Council, C. (2024b). 2024's Climate Crisis: Extreme Weather Around the Globe Signals the Urgent need for Action. [online] Climate Council. Available at: https://www.climatecouncil.org.au/2024s-climate-crisis-extreme-weather-around-the-globe/.
- IPCC Emissions Scenarios (2021). https://www.ipcc.ch/site/assets/uploads/2018/03/sres-en.pdf
- Government of Australia. Department of Finance. (2016) Reviewing a Risk Management Framework COM COVER INFORMATION SHEET FRAMEWORK. [online] Available at: https://www.finance.gov.au/sites/default/files/2019-11/Reviewing-a-RM-framework.pdf.
- Kovich, T. (2024). *10 Questions You Should Ask About Your Data*. [online] DAS42 | Data Consultancy | Data & Analytics Strategy. Available at: https://das42.com/thought-leadership/ten-questions-you-should-ask-about-your-data/ [Accessed 17 Nov. 2024].
- City of Melbourne. (2023). *Stormwater Drainage Design Guidelines.*
- *Climate Risk Map of Australia*. (2024).
- Department of Finance. (2016). Commonwealth Risk Management Policy. *Risk Management Services*.
- *Disaster Map*. (2024). Retrieved from Australian Disaster Resilience Knowledge Hub: https://knowledge.aidr.org.au/
- *DTP open data traffic volume*. (2024). Retrieved from DTP Open Data Hub.
- *Geoscience Australia Natural Hazards Scenarios Tool*. (2024).
- *Mapshare VicPlan*. (2024). Retrieved from VicPlan: https://mapshare.vic.gov.au/vicplan/
- Arup. (2024). *A Universal Taxonomy for Natural Hazard and Climate Risk and Resilience Assessments: Version 1.0 – Buildings Edition*. Retrieved from https://www.arup.com/insights/a-universal-taxonomy-for-natural-hazard-and-climate-risk-and-resilience-assessments/
- Department of Climate Change, Energy, the Environment and Water (DCCEEW). (2024). *National Climate Risk Assessment: First Pass Assessment Report*. Canberra: Commonwealth of Australia. Retrieved from https://www.dcceew.gov.au/climate-change/publications/ncra-first-pass-risk-assessment
- Department of Home Affairs. (2018). *National Disaster Risk Reduction Framework*. Canberra: Commonwealth of Australia.
- National Resilience Taskforce. (2018). *Profiling Australia's Vulnerability: The interconnected causes and cascading effects of systemic disaster risk*. Canberra:

Department of Home Affairs. Retrieved from https://knowledge.aidr.org.au/resources/profiling-australias-vulnerability/

- Verschuur, J., et al. (2024). *Quantifying Climate Risks to Infrastructure Systems: A Comparative Review of Developments Across Infrastructure Sectors*. PLOS Climate, 3(4), e0000331. DOI: https://doi.org/10.1371/journal.pclm.0000331
- United Nations Office for Disaster Risk Reduction (UNDRR) & Coalition for Disaster Resilient Infrastructure (CDRI). (2023). *Global Methodology for Infrastructure Resilience Review*. Retrieved from https://www.undrr.org/media/91939/download?startDownload=20241118
- Infrastructure Victoria. (2024). *Weathering the Storm: Adapting Victoria's Infrastructure to Climate Change*. Retrieved from https://www.infrastructurevictoria.com.au/resources/weathering-the-storm

Appendices

Appendix A: Review of Data Sources

Table A.1: Overview of Assessment of Data Sources

Data Source	Measure Application	Measure Description	Measure Value/Relevance	Ease of Use	Public
Digital Atlas Australia **https://digital.atlas.gov.au/**	*Digital Atlas Australia provides various datasets and GIS maps, including information on transport networks, climate risks, infrastructure, and geographical data. Can use it to create your own map and include any data source they have on the website. Can use this to include your own data or date provided by the site.*			Easy to use, basic tool or advanced tool, basic tool can be used to add layers to the map from the website data only, whereas advanced can be used to add your own datasets.	Yes
	Identify Risk area	Locate areas with high exposure to climate hazards, such as flood zones, bushfire-prone areas	Flood Area - Water Bodies Bushfire Prone Area		
	Infrastructure assets	Location of infrastructure assets across Australia.	N/A		
	Any data available on the website can be added to the map created.				
National Exposure Information System (NEXIS) **Australian Exposure Information Portal** **https://www.aeip.ga.gov.au/**	*NEXIS is a database that offers comprehensive information on the exposure of assets, population, and infrastructure to natural hazards. It's designed to support risk assessments and disaster management.*			Easy to extract relevant data from the website for specific exposure to specific hazards. To use the data however the user needs to know what they are looking for.	Yes
	Asset Location	Geographic coordinates and physical placement.			
	Asset Characteristics	Information about building types, construction materials, age, and other relevant attributes that contribute to vulnerability. Includes exposure of different business and environmental types.	Building counts, infrastructure assets, Reconstruction values,		
	Population Data	Demographic and socioeconomic data that can help identify the exposure of communities surrounding the assets.	Socio-economic data		
				Easy to use, colour coded map to provide percentage risk of an area	Yes

Climate Risk Map of Australia **https://www.climatecouncil.org.au/resources/climate-risk-map/**	The Climate Council's Climate Risk Map of Australia is an interactive map of climate vulnerable places in Australia			for given hazards under different year scenarios.	
	Geography / location	Risk to properties within a geography depending on differing climate emission scenarios. (riverine flooding, bushfire, surface water flooding, coastal inundation, extreme wind).	% of properties at risk		
The Australian Disaster Resilience Index **https://adri.bnhcrc.com.au/#!/maps**	The Australian Disaster Resilience Index shows the capacities for disaster resilience in Australian communities based on several factors. Disaster resilience is the capacity for communities to prepare for, absorb and recover from natural hazard events and to learn, adapt and transform in the face of future events.			Easy to use map platform, however understanding the meaning of the terminology and basis of the factors shown takes expertise in the field.	Yes
	Disaster resilience An overall measure of disaster resilience formed from coping and adaptive capacity.	Based on location, factors of disaster resilience based on factors such as social character, social and community engagement, governance and leadership. information access, yes community capital, emergency services, economic capital, planning and the built environment and social character.	low to high capacity for disaster resilience (value e.g. 0.6762)		
	Coping capacity	Coping Capacity is how communities or organisations can use available resources and abilities to face adverse consequences.	low to high capacity for coping capacity (value e.g. 0.6762)		
	Adaptive Capacity	Adaptive Capacity is the arrangements and processes that enable adjustment through learning, adaptation and transformation.	low to high capacity for adaptive capacity (value e.g. 0.6762)		
Geoscience Australia Natural Hazards and Scenarios **https://portal.ga.gov.au/persona/hazards**	The data includes hazard, exposure and vulnerability data on a national scale. The aim to ensure the country is prepared for responding to the consequences of hazards including earthquakes and cyclones. The data is location based, with the user identifying the location which will be analyses for hypothetical events providing an estimated reoccurrence and magnitude of each hazard.			Difficult to use website, non-user friendly and hard to figure out how to get the information out of the interactive map.	Yes
	Earthquake scenario selection	realistic and represent "worst-case" or hypothetical events that may impact population centres around Australia. Based on 160 sites.	Estimated reoccurrence and magnitude of earthquake		
	Tropical Cyclone Scenario Selection		Estimates wind speed and category of cyclone		

The Australian Disaster Resilience Knowledge Hub **https://knowledge.aidr.org.au/** **https://knowledge.aidr.org.au/resources/2019-bushfire-vic-eastern-victorian-bushfires/**	National hub to support decision making and good practice disaster resilience. Includes sources of information for disaster risk reduction including documentation on the national disaster risk reduction framework, national action plan for disaster risk reduction and the Sendai Framework for Disaster Risk Reduction. It includes a disaster map which shows past historic disasters across Australia and their details.			Easy to use map, zoom into the location and click on the disasters which are identified. Provides easy to understand information on each historical event with key data points.	Yes
	Disaster Map identifying historic disasters from 1874 to present day.	Includes disasters in the following categories: Fire, Cyclone, Earthquake, Flood, Health, Storm, Tornado, and transport. This can be used to predict magnitude of future events by looking at previous examples of how many people were affected in each area.	Number of lives lost, Insurance Cost, Number of homes lost,		
Australian Flood Risk Information Portal Floods	The hub provides historical data on previous flood modelling and studies for an identified area. Includes data on previous flood mapping which would show information on the area you nominate.			Easy to find the data, would require expertise to determine how to use the downloaded flood studies (not all information is available to be downloaded).	Yes
	Flood Studies	Flood studies conducted across Australia. Information varies across studies.	NA		
	Waterways (regional) Catchments				
	Waterways (national)				
	River Region	Name, division and number of river region for location.			
Australian Rainfall & Runoff Data Hub: **https://data.arr-software.org/**	The Australian Rainfall and Runoff Data Hub is a tool that allows for easy access to the design inputs required to undertake flood estimation in Australia (enter location to retrieve data).			Portal best suited to stormwater drainage, flooding and hydrology engineers. Provides raw data on all items listed to be used as required.	Yes
	ARF Parameter	Areal reduction factors (ARFs) convert a point estimate of extreme precipitation to an estimate of extreme precipitation over a spatial domain and are commonly used in flood risk estimation. Areal reduction factor (ARF) is the ratio between the area-average rainfall intensity over a duration D with return period T and the point rainfall intensity for the same D and T.	NA		

	Temporal Patterns	Burst patterns over time.	NA		
	Area Temporal Patterns	Burst patterns over space and time.	NA		
	BOM IFD Depths	Rainfall depth for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP). Intensity-Frequency-Duration (IFD) design rainfall intensities.	Depth (mm)		
	Climate Change Factors for increased rainfall intensity				
	Baseflow Factors	Baseflow (also called drought flow, groundwater recession flow, low flow, low-water flow, low-water discharge and sustained or fair-weather runoff) is the portion of the streamflow that is sustained between precipitation events, fed to streams by delayed pathways.	NA		
	Probable Maximum Precipitation (PMP)	Probable Maximum Precipitation (PMP) is termed as “theoretically the greatest depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographic location at a given time of the year. (need to be calculated)	Depth (mm)		
VicMap Planning Portal **VicPlan (mapshare.vic.gov.au)**	Vic planning portal - includes areas subject to inundation, environmental sensitive areas, other environmental overlays			Easy to use map format with general GIS functionality, adding layers as required to identify different data to be shown on the map.	Yes
Home | VicTraffic (transport.vic.gov.au)	Current traffic disruptions / works Site can be used for network analysis to determine the impact of an asset being down on the overall network.			Typical GIS interface.	Yes
Traffic Volume | Department of Transport (arcgis.com)	Traffic volume data in Victoria - actual vehicle counts for VicRoads roads including current data. Can be utilised for predicting impacts if transport infrastructure were to be affected by hazard, number of vehicles per day / AADT.			Typical GIS interface.	Yes
https://www.csiro.au/en/research/environmental-impacts/climate-	Climate predictions for Australia – Feeds into hazard identification within the risk assessment.				Yes

change/climate-change-information			
Climate change Australia	Climate predictions for Australia – Feeds into hazard identification within the risk assessment. Look at specific location to determine the predicted hazards for that area.		Yes
Vic Future Climate Tool	The tool combines multiple different data sources, including different prediction / emissions scenarios and different prediction horizon years (2030s, 2050s, 2070s, 2090s). Looks at predicted data for rainfall, temperature extremes, sea level rise. It includes overlays for road and rail infrastructure. Specific to Victoria – hazards.	Typical GIS interface. Not straightforward unless you know what each of the data sources to add to the map are. Some expertise required.	Yes

Appendix B: Risk Matrix

TABLE B1. HAZARDS

Likelihood/Frequency Definitions			HAZARDS	Consequence
Likelihood	**Description**	**SCORE**	**Severity**	
Almost certain	Frequency: Hazard occurs multiple times per year, or there is a greater than 90% chance of the hazard occurring in any given year. Likelihood: The hazard is almost inevitable in the location due to environmental conditions, historical patterns, or geographical vulnerability.	5	**Highly vulnerable location with dense, critical infrastructure. This includes major metropolitan areas (e.g., CBDs) with a high concentration of interdependent systems (transport, utilities, communications), where any disruption could cascade across sectors.**	**Severe**
Likely	**Frequency:** Hazard occurs once a year or every 1 to 3 years, with a 50-90% chance of occurrence in any given year. Likelihood: There is a high probability of the hazard occurring due to regular environmental factors, but some mitigation measures may reduce its impact.	4	**Moderate to high infrastructure density in a location with some vulnerability, such as industrial hubs or large suburban areas. The infrastructure is relatively concentrated, and while some mitigation measures are in place, they may not be sufficient to handle large-scale hazards.**	**Major**
Possible	**Frequency:** Hazard occurs once every 3 to 10 years, with a 20-50% chance of occurrence in any given year. Likelihood: The hazard is possible but not predictable. Environmental factors or occasional extreme weather conditions may trigger the hazard, but it is not an annual occurrence.	3	**Moderate infrastructure density in a partially vulnerable location. This could be a smaller town or outer suburban area where infrastructure systems are present but less dense and interdependent.**	**Moderate**
Unlikely	Frequency: Hazard occurs once every 10 to 50 years, with a 5-20% chance of occurrence in any given year. Likelihood: The hazard is unlikely due to geographic resilience or effective mitigation measures, and only occurs under unusual environmental conditions.	2	**Low infrastructure density in a relatively resilient location, such as rural areas or small towns with limited critical infrastructure. The area is less vulnerable to hazards due to its low population density and less complex infrastructure. Any failures are unlikely to have wide-reaching impacts.**	**Minor**
Rare	Frequency: Hazard occurs less than once every 50 years, with a less than 5% chance of occurrence in any given year. Likelihood: The hazard is very rare, occurring only in highly unusual or unprecedented circumstances.	1	**Very low infrastructure density in a highly resilient location. The location is sparsely populated, with little critical infrastructure and strong natural or engineered protections against hazards**	**Insignificant**

TABLE B2. EXPOSURE

SCORE	Consequence	Population Affected	Financial Impact	Ecosystem Services	Injury and Fatality Rates	Population Displacement	Historical Exposure	Local Growth & Economy Disruption
5	Severe	Widespread and severe impact on a large population. Could include fatalities, significant injuries, or displacement. Major disruptions to essential services (e.g., power, water, transportation) affecting a major urban area. More than 100,000 people affected.	Direct loss or opportunity cost of more than $200Mil	Destruction or irreversible damage to key ecosystems (e.g., wetlands, forests, coral reefs) that provide essential services such as water purification, carbon sequestration, flood protection, and biodiversity. This would result in widespread environmental, social, and economic consequences, potentially leading to long-term harm to both ecosystems and human populations. Severe degradation or complete loss of critical ecosystem services, not repairable	Severe adverse human health effects - leading to multiple events of total disability or fatalities. More than 10 fatalities or permanent disability for more than 20 people, Over 100 severe injuries.	Extensive displacement, likely requiring large-scale evacuation and long-term relocation. Emergency shelters, temporary housing, and significant social services would be needed. This could have a major economic and social impact on both the displaced population and the host communities. Population dispalaced more than a million people within a city.	The asset or region has been exposed to a high frequency of major events (e.g., natural disasters, large-scale infrastructure failures) in the past, each causing widespread destruction or disruption. There is a strong historical precedent that suggests a very high probability of recurrence with severe consequences. More than 5 significant events in the past 50 years.	Full service or business performance disruption > 1 year, partial disruption (months)
4	Major	Significant impact on a large community or region. May result in long-term disruptions to public services, temporary displacement of residents, or a notable number of injuries. Extensive emergency response required. More than 50,000 and 100,000 people affected.	Direct loss or opportunity cost of between $50Mil-200Mil	Major impacts on critical ecosystems that substantially reduce their ability to provide essential services (e.g., coastal mangroves that protect against storm surges or forests that maintain air quality). Restoration is possible but would require significant time, resources, and intervention. Disruption could lead to loss of biodiversity and increased vulnerability to natural disasters. Significant degradation of key ecosystem services, requires a repair/maintenace plan over years.	Permanent physical injuraies and fatalities may occur from an indvidual event. Between 3 and 10 fatalities or permanent disability for 5-20 people, Between 20 and 100 severe injuries.	Large displacement requiring significant temporary housing solutions and major government response. Displaced population may need support for several months. The event could disrupt local economies and put pressure on surrounding regions. Population displaced hundreds of thousands of people a large urban area.	The area has experienced multiple large events in recent history. The recurrence of similar events poses significant risks to infrastructure or operations, with a high potential for substantial damage or disruption. Between 3 and 5 significant events in the past 50 years	Full service or business performance disruption >6months, sustained partial disruption (weeks)
3	Moderate	Moderate disruption to a local community. Could involve temporary closures of critical services (schools, hospitals), limited evacuations, or significant but manageable health and safety risks. Requires coordinated local response. Between 10,000 and 50,000 people affected.	Direct loss or opportunity cost of between $10Mil-50Mil	Some degradation of ecosystems (e.g., partial loss of wetlands, deforestation) that impacts the ability to provide services such as water regulation, pollination, or soil stabilization. While there may be adverse effects on local biodiversity and ecosystem health, they are manageable and potentially reversible with medium-term intervention and restoration efforts. Moderate degradation of ecosystem services, require resources and attention to repair.	Adverse human health effect including mental health impacts. Between 1 and 3 fatalities or permanent disability for fewer than 5 people, Between 10 and 20 severe injuries.	Moderate-scale displacement, requiring temporary accommodation (e.g., hotels, shelters) and some social services. Displacement is typically for a few weeks to months. This level of displacement would stress local resources but would not require a national response. Population displaced between tens of thousands of people.	The area or asset has been impacted by some historical events, though with less frequency. While the occurrence of such events is less frequent, there is still a reasonable likelihood of future risks, based on past exposure. Between 1 and 2 significant events in the past 50 years.	Full service or business performance disruption less than a month, consistent partial disruption (weeks)
2	Minor	Minor but noticeable impact on a local population. May include temporary inconvenience, such as limited access to services or transportation. Could involve minor injuries but no fatalities. Local authorities can manage without external assistance. Between 1,000 and 10,000 people. affected.	Direct loss or opportunity cost of between $2Mil-10Mil	Localized, short-term disruption to specific ecosystem services, such as temporary reduction in air or water quality, minor habitat loss, or slight changes to ecosystem functions. The ecosystem remains mostly intact, and services can be restored with limited effort. Minor impact on ecosystem services quite easily naturally repaired.	Slight adverse human health effects or general amenity issues. Minor mental health impacts. No fatalities, but some serious injuries (fewer than 10 severe injuries, Minor injuries affecting 10 or fewer people.	Localized displacement, likely short-term (a few days to weeks). Requires some temporary relocation and could cause limited disruption community. Typically managed by local authorities with minimal external aid. Population displaced between 100 and 1,000 people.	There has been minimal historical exposure, with only one notable event in the past century. This suggests that similar events are rare, though possible, but any future occurrences are expected to have a minor impact. 1 event in the past 100 years.	Part service or business performance disruption less than a week, limited partial disruption (days)
1	Insignificant	Minimal impact on a small group of people. Likely limited to short-term inconvenience or disruptions (e.g., road closures, power outages). No injuries or long-term effects. Easily manageable at the local level. Fewer than 1,000 people affected	Direct loss or opportunity cost of between less than 2Mil	Minimal or no measurable impact on natural ecosystems or the services they provide. Any disturbance is temporary or reversible without the need for significant intervention. Ecosystems continue to function normally, and their capacity to provide services is unaffected. Negligible impact on ecosystem services.	No adverse human effects or complaint. No fatalities and no severe injuries, Minor first-aid level injuries affecting fewer than 10 people.	Minimal displacement, likely restricted to individual households or a small group of people. No significant long-term impact on the community. Easily managed with very limited resources and short-term relocations. Fewer than 100 people	No significant exposure to major historical events. The risk of similar events occurring is considered very low, with no precedent to suggest substantial future risk. No significant historical events in the past 100 years.	Partial closure of service or bussiness performance for less than 1 day, localised partial disruption for a day/days
	Relevant Reources	- National Exposure Information System (NEXIS) - Australian Exposure Information System - Traffic Volume | Department of Transport (arcgis.com)	- National Exposure Information System (NEXIS) - Australian Exposure Information System - Traffic Volume | Department of Transport (arcgis.com) - Digital Atlas Australia	- VicMap Planning Portal	- The Australian Disaster Resilience Knowledge Hub	- National Exposure Information System (NEXIS) - Australian Exposure Information System - Traffic Volume | Department of Transport (arcgis.com)	- The Australian Disaster Resilience Knowledge Hub - Australian Flood Risk Information Portal - Digital Atlas Australia	- The Australian Disaster Resilience Knowledge Hub - Historical records

TABLE B3. VULNERABILITY

SCORE	Consequence	Age of Asset	Condition of Asset	Past Investments
5	Severe	Asset exceeds its designed lifespan by a significant margin, with no major upgrades or retrofits. The asset is outdated and does not meet modern safety or performance standards. The risk of failure is high, and maintenance is costly and frequent. Asset exceeds its design life by 10+ years or 10% over its original design life span.	Inspection Report: Repeatedly fails inspections, with severe structural issues identified. Maintenance Expenditure: Extremely high maintenance costs, indicating significant, ongoing issues that can't be fully resolved. Repair Costs: Extensive repairs required repeatedly, with costs close to or exceeding replacement value. The asset is highly vulnerable to failure in the near term. EG. A 70-year-old pipeline with persistent leaks and high repair costs, continually flagged for replacement in inspection reports.	No significant investment made in maintenance or upgrades over the past 10 years. The asset is outdated and increasingly vulnerable to failure under stress or hazards due to lack of modernization. High likelihood of performance issues or catastrophic failure. Investment range (over past 10 years) less than <$500,000
4	Major	Asset is close to its designed lifespan, with limited upgrades or only minor retrofits. Maintenance demands are increasing, and the asset does not fully comply with current safety codes or environmental standards, increasing its vulnerability to hazards. Asset exceeds its design life by less than 2 years or 5% over its original design life span.	Inspection Report: Significant issues noted, including moderate structural degradation or outdated components. Maintenance Expenditure: High, with several major repairs completed in recent years, but further repairs are needed. Repair Costs: Repair costs are high but still manageable, though they continue to increase each year. The asset is vulnerable to moderate to severe hazards and may not withstand high-stress events. EG. A rail bridge inspected with moderate corrosion on primary supports and some outdated load-bearing components.	Minimal investment has been made, with only small repairs or patch fixes applied in the past 10 years. Essential systems are not upgraded, leaving the asset vulnerable to hazards. Investment range (over past 10 years) in the range of $500,000 - $1 million
3	Moderate	Asset is middle-aged within 50-75% of its design life, but it has received some upgrades or retrofits to meet current standards. Maintenance is still manageable, but signs of wear are starting to appear. EG. A 30-year-old highway bridge with a design life of 50 years, which has undergone routine maintenance but no significant structural updates.	Inspection Report: Issues present but manageable, with signs of wear on non-critical components; however, major systems remain intact. Maintenance Expenditure: Moderate, with occasional high-cost repairs, but regular maintenance has kept the asset generally functional. Repair Costs: Repairs have been moderate but are increasing; the asset is functional but requires planned upgrades to maintain resilience. EG. A road overpass with worn expansion joints and surface wear on the deck, showing early signs of structural aging. Or a sewage treatment plant with aging pumps that have required several mid-cost repairs, with recommendations for replacement within the next few years.	Moderate investment made in key areas, addressing some vulnerabilities but not all. Significant systems remain outdated, though repairs have been made on critical components. The asset remains functional but would benefit from further upgrades. Investment range $1 million - $5 million spent on maintenance over the past 10 years.
2	Minor	Asset is relatively new 25-50% through its design life and has received routine maintenance. It largely meets current standards and performs well under normal conditions, but it may lack advanced resilience features found in newer assets. EG. A recently constructed road designed for modern traffic loads, with minor wear but no serious vulnerabilities.	Inspection Report: Passes inspections with minor findings; small issues found that are not critical to overall function. Maintenance Expenditure: Low, with most costs associated with regular maintenance rather than significant repairs. Repair Costs: Minor repair costs incurred occasionally; the asset shows normal wear and tear and is in stable condition. EG. A 15-year-old tunnel with minor water infiltration at joints, which has been easily managed with routine maintenance.	Consistent investment made over the past decade, including targeted upgrades on critical components, keeping the asset in good condition. While some areas may still require future investment, the asset is generally resilient. Investment range $5 million - $15 million spent on maintenance of infrastructure. EG. A tunnel where regular investments in drainage and ventilation systems have been made, extending its lifespan.
1	Insignificant	Asset is new or recently constructed 0-25% through its design life. Built to current standards, it incorporates modern technology and is fully compliant with updated codes. The asset is highly resilient to hazards, and maintenance needs are minimal. EG. A 5-year-old tunnel with advanced flood defenses, ventilation, and drainage systems.	Inspection Report: Consistently passes inspections with no significant findings; the asset is in excellent condition. Maintenance Expenditure: Minimal, primarily preventative maintenance with no need for repairs. Repair Costs: Negligible repair costs, with no significant repairs required to date. The asset is fully resilient against expected hazards. EG. A water pipeline with no leakage or structural issues, well-maintained with no repair costs incurred beyond minor preventative tasks.	Significant investment in comprehensive upgrades, retrofits, and maintenance, bringing the asset up to modern standards. The asset is highly resilient and well-prepared to withstand hazards. Investment spent on asset >$15 million over the past 10 years. EG. A recently upgraded transportation hub with comprehensive retrofits and state-of-the-art technology. The investment has brought the asset up to modern standards, making it highly resilient to anticipated hazards.
	Relevant Reources	- National Exposure Information System (NEXIS) - Australian Exposure Information System - Asset owners / local councils - local news or information on asset build	- National Exposure Information System (NEXIS) - Australian Exposure Information System - Asset owners / local councils	- National Exposure Information System (NEXIS) - Australian Exposure Information System - Asset owners / local councils

TABLE B3. VULNERABILITY (Cont.)

SCORE	Consequence	Service Dependency	Redundancy of Services	Repair Costs
5	Severe	The asset provides essential services (e.g., power, water, transportation) to a very large population. Its failure would lead to catastrophic impacts across multiple sectors, including emergency services and essential daily functions. Number of People Dependent: >1 million people EG. A tunnel in a major city that serves as the main route for commuters, emergency vehicles, and public transportation, connecting critical business and healthcare hubs. The failure of this tunnel would severely impact the entire urban area.	The asset has no redundancy and is the sole provider of essential services in a large area. Its failure would result in severe disruptions, as there are no alternative assets or backup options within a practical distance. Redundancy: 0 similar assets within a 50 km radius. EG. A critical power substation that supplies electricity to a major city, with no alternative substations or backup sources within a 50 km radius. Its failure would lead to widespread blackouts and economic disruption.	Repair costs are extremely high, close to or exceeding the total construction cost (TCC) of the asset when adjusted to NPV. The asset is extremely vulnerable, and ongoing repair costs may not be financially sustainable, potentially necessitating replacement. Repair costs >75% of TCC (NPV-adjusted) EG. A bridge with severe corrosion requiring constant repairs, where accumulated repair costs over time approach or exceed 75% of the bridge's original TCC (NPV-adjusted), indicating it may be more cost-effective to replace it.
4	Major	The asset serves critical functions to a large population, including business districts and essential services, but some alternative options exist. Failure would cause severe disruptions and major inconveniences across many sectors. Number of People Dependent: 100,000 - 1 million people. EG. A large regional wastewater treatment plant serving multiple neighborhoods in a metropolitan area. Disruption of this facility would impact public health and environmental quality, with only limited backup options available.	The asset has limited redundancy, with only one or two similar assets nearby, but they lack the capacity to handle the full demand if this asset fails. Disruption would cause significant delays and congestion. Redundancy: 1-2 similar assets within a 20-50 km radius. EG. A large water treatment plant serving multiple neighborhoods, with only one smaller backup facility 25 km away. The alternative lacks the capacity to handle full demand, leading to potential shortages.	Repair costs are high and consume a significant portion of the asset's adjusted TCC, indicating substantial financial vulnerability. Continual repairs are costly, and more efficient solutions should be considered. Repair costs 50-75% of TCC (NPV-adjusted)
3	Moderate	The asset is important for daily operations for a moderate population and businesses, with some dependencies on essential services. While its failure would disrupt daily life, alternative services or routes are available. Number of People Dependent: 10,000 - 100,000 people. EG.A key bridge in a medium-sized town, used by local businesses and residents to access the main shopping and business district. There are alternative routes, but they are less direct and could lead to congestion during peak times.	The asset has some redundancy, with a few similar assets nearby that can handle moderate demand, but disruption would still cause delays and inconveniences. Redundancy: 2-3 similar assets within a 10-20 km radius EG. A highway bridge in a suburban area, with two alternative routes within a 15 km radius. The alternatives can handle moderate traffic but could become congested during peak times.	Repair costs are moderate relative to the TCC, adjusted to NPV. The asset is financially manageable, but ongoing repairs may increase over time, suggesting future investment may be needed. Repair costs 25-50% of TCC (NPV-adjusted)
2	Minor	The asset supports non-essential services or provides services to a smaller population. Disruption would be inconvenient but manageable, as alternative routes or facilities are readily available. Number of People Dependent: 1,000 - 10,000 people. EG. A local community center that provides resources and activities for a neighborhood. Its closure would be inconvenient but would not affect essential services, as nearby facilities are available.	The asset has adequate redundancy, with multiple similar assets nearby capable of handling demand in case of failure, though some minor delays may occur. Redundancy: 3-5 similar assets within a 5-10 km radius EG. A water pumping station in a city with several nearby stations capable of handling demand if one station fails. Minor delays may occur, but the overall service remains intact.	Repair costs are low compared to the TCC, adjusted to NPV. The asset's maintenance costs are financially manageable, and repair requirements are minimal, indicating resilience.EG. Repair costs 10-25% of TCC (NPV-adjusted)
1	Insignificant	The asset has minimal dependency, primarily serving a very small population or niche functions. Its failure would have a negligible impact on the population, and there are ample alternatives available. Number of People Dependent: <1,000 people. EG. A small pedestrian bridge in a park that serves a few hundred people daily. Its closure would have minimal impact as there are nearby paths and alternative access points.	The asset has high redundancy, with numerous similar assets within a small radius, ensuring minimal impact if the asset fails. Traffic or service can be easily rerouted with no major disruption. Redundancy: More than 5 similar assets within a 5 km radius EG. A minor local road segment in an urban grid where multiple alternative routes exist nearby. Failure of this segment has minimal impact, as traffic can easily be rerouted.	Repair costs are negligible relative to the TCC, adjusted to NPV. The asset incurs minimal repair costs, reflecting strong durability and low vulnerability. Repair costs <10% of TCC (NPV-adjusted) EG. A newly constructed pedestrian bridge with minimal wear and tear, where repair costs amount to less than 10% of TCC (NPV-adjusted). The asset requires only basic
	Relevant Reources	- National Exposure Information System (NEXIS) - Australian Exposure Information System -Traffic Volume | Department of Transport (arcgis.com)	- National Exposure Information System (NEXIS) - Australian Exposure Information System -Traffic Volume | Department of Transport (arcgis.com) - Digital Atlas Australia - Geoscience Australia	- Asset owners / local councils

Appendix C: Proof-of-Concept Analysis Result

Risk Matrix Assessment Platform - Burnley Tunnel

Step 1- Select Decision Variables

Geographical Location	City of Melbourne
Region	Melbourne
Spatial Scale (km2)	20
Emission Year	2050
Emission Scenario	High

Step 2 - Identify Potential Hazards

using inputs identify if there is a greater than 0 risk of the hazaed

Step 2 - Identify Potential Hazards	Applicable	Source	Notes
Fires (Bushfires, grass fires and air pollution)	No	https://www.climatecouncil.org.au/resources/climate-risk-map/	
Flooding (Coastal and Surface Water)	Yes	https://www.climatecouncil.org.au/res	Evidence of flooding from cracking within tunnel and water leakage https://en.wikipedia.org/wiki/Burnley_Tunnel
Coastal erosion and shoreline change	No	https://www.climatecouncil.org.au/resources/climate-risk-map/	
Storms and cyclones	Yes	BOM/Australian Rainfall and runoff	

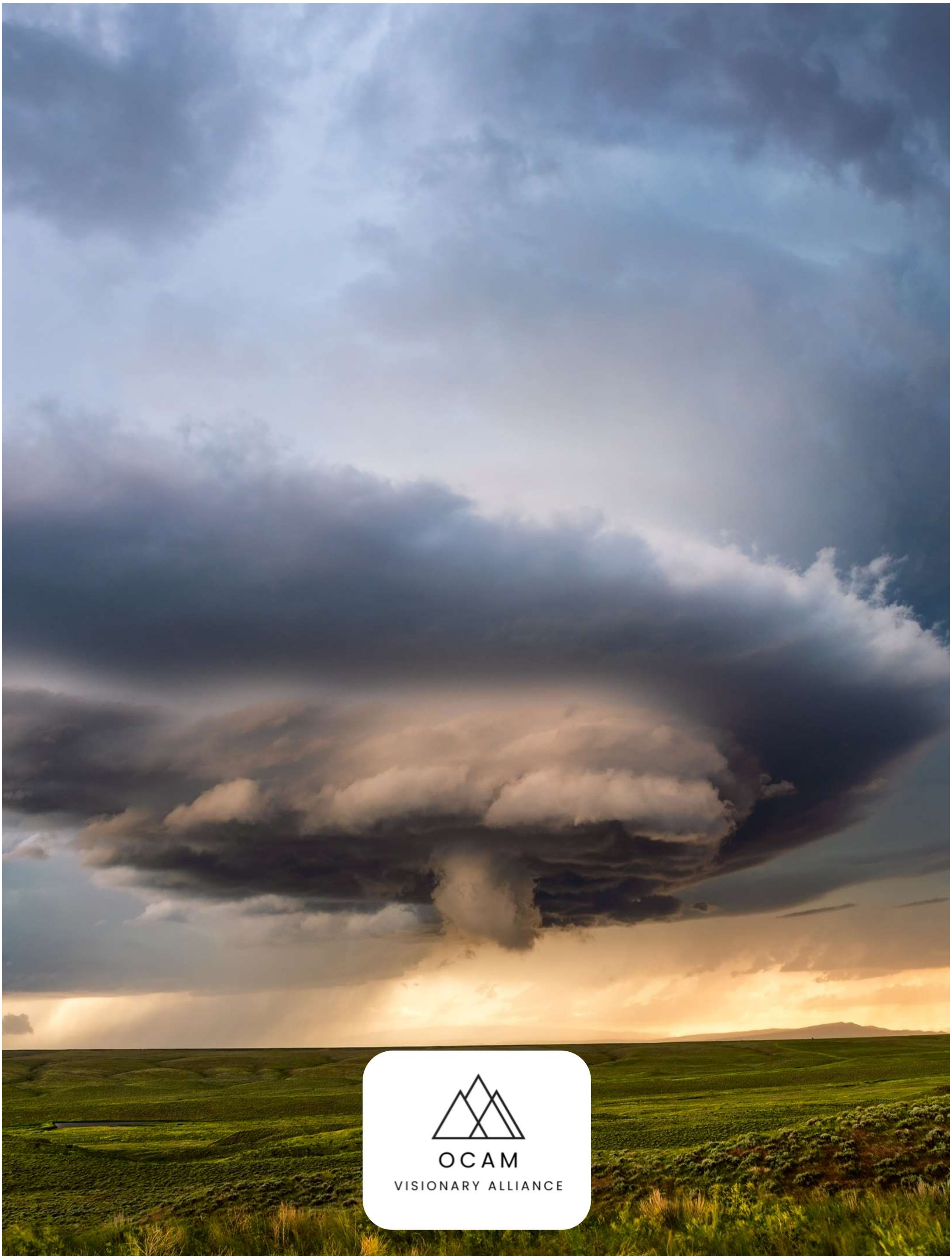
Step 3- Select Decision Variables

Asset(s)	Road Tunnel	*Burnley Tunnel*

STEP 4 TO 8 - Collect Relevant Data

REFER TABLE B1, B2 AND B3 FOR CRITERIA COMMENTARY

Hazards (30%)	Flooding (coastal and otherwise)	Score	Storms and cyclones	Score	Bushfires, grass fires and air pollution	N/A	Coastal erosion and shoreline change	N/A	Source
Likelyhood	Rare	1	Likely	4	Unlikely	0	Likely	0	
Severity	Severe	5	Major	4	Insignificant	0	Major	0	
Hazard Score		3		4		0		0	
Exposure (30%)									
Population Affected	>100,000 people	5	<1,000 people	1	<1,000 people	0	<1,000 people	0	https://vicroadsopendata-vicroadsmaps.opendata.arcgis.com/datasets/traffic-volume/explore or https://www.aeip.ga.gov.au/
Financial Impact	> $200Mil	5	> $200Mil	5	> $200Mil	0	> $200Mil	0	https://vicroadsopendata-vicroadsmaps.opendata.arcgis.com/datasets/traffic-volume/explore
Ecosystem Services	Negligible impact on ecosystem services.	1	NOT APPLICABLE	0	Negligible impact on ecosystem services.	0	Negligible impact on ecosystem services.	0	Vicplan
Injury and Fatality Rates	No fatalities and no severe injuries, Minor first-aid level injuries affecting fewer than 10 people.	1	NOT APPLICABLE	0	No fatalities and no severe injuries, Minor first-aid level injuries affecting fewer than 10 people.	0	No fatalities and no severe injuries, Minor first-aid level injuries affecting fewer than 10 people.	0	
Population Displacement	<100 people	1	NOT APPLICABLE	0	NOT APPLICABLE	0	NOT APPLICABLE	0	
Historical Exposure	No significant historical events in the past 100 years.	1	No significant historical events in the past 100 years.	1	No significant historical events in the past 100 years.	0	No significant historical events in the past 100 years.	0	https://knowledge.aidr.org.au/
Local Growth & Economy	for less than 1 day, localised partial disruption for a day/days	1	for less than 1 day, localised partial disruption for a day/days	1	for less than 1 day, localised partial disruption for a day/days	0	for less than 1 day, localised partial disruption for a day/days	0	
Exposure Score		2.14		2.00		0.00		0.00	
Vulnerability (40%)									https://digital.atlas.gov.au/apps/5c4072d5c8664b719384844f1333584e/explore
Age of Asset	0-25% through its design life	1	0-25% through its design life	1	0-25% through its design life	0	0-25% through its design life	0	
Condition of Asset	NOT APPLICABLE	0	NOT APPLICABLE	0	NOT APPLICABLE	0	NOT APPLICABLE	0	
Past Investments	Investment range (over past 10 years) in the range of $500,000 - $1 million	4	Investment range (over past 10 years) in the range of $500,000 - $1 million	4	Investment range (over past 10 years) in the range of $500,000 - $1 million	0	Investment range (over past 10 years) in the range of $500,000 - $1 million	0	
Service Dependency	Number of People Dependent: >1 million people	5	Number of People Dependent: >1 million people	5	Number of People Dependent: >1 million people	0	Number of People Dependent: >1 million people	0	
Redundancy of Services	Redundancy: More than 5 similar assets within a 5 km radius	1	Redundancy: More than 5 similar assets within a 5 km radius	1	Redundancy: More than 5 similar assets within a 5 km radius	0	Redundancy: More than 5 similar assets within a 5 km radius	0	
Repair Costs	Repair costs >75% of TCC (NPV-adjusted)	5	Repair costs >75% of TCC (NPV-adjusted)	5	Repair costs >75% of TCC (NPV-adjusted)	0	Repair costs >75% of TCC (NPV-adjusted)	0	
Vulnerability Score		3.20		3.20		0.00		0.00	
OVERALL SCORE		2.8		3.1		0.0		0.0	
FINAL COMBINED RATING				3.0					


OCAM
VISIONARY ALLIANCE