A Universal Taxonomy for Natural Hazard and Climate Risk and Resilience Assessments

Infrastructure Edition

September 2026
Version 1.0

This framework provides stakeholders a universal language for risk and resilience assessments so that they can better communicate and align their needs for specific applications. We hope that it will bring much needed consistency and transparency to the growing demand for natural hazard and climate risk assessments around the world and lead to more resilient outcomes. This version is focused on infrastructure and the organizations and people who operate and use them.

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Foreword

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The expansion of Arup's *Universal Taxonomy for Natural Hazard and Climate Risk and Resilience Assessments* to infrastructure is both timely and necessary. The first edition made an important contribution by bringing greater structure and clarity to the way natural hazard and climate risk assessments for buildings are structured, described and evaluated. Since its publication just over two years ago, the taxonomy has already begun to be taken up across academic, public-sector, financial and multi-hazard research contexts, reflecting a clear need for a shared language between both consumers and producers of risk information.

This need is even greater when we turn to infrastructure systems, which are fundamental to ensuring that societies and economies can function. Damage and disruption can cascade through these systems, with both direct and indirect consequences on organisations, individuals, and communities that can extend long after the initial hazard event has passed.

From the perspective of the Global Earthquake Model (GEM) Foundation, this work aligns closely with our broader vision for transparent, consistent and comparable earthquake hazard and risk assessment. While the Arup taxonomy provides a framework for scoping, evaluating and communicating natural hazard and climate risk assessments, GEM's exposure models and taxonomies help describe the assets and vulnerabilities that often underpin such assessments. Emerging multi-hazard work is already beginning to draw these approaches together[1], demonstrating the importance of common taxonomies in linking hazard, exposure, vulnerability and resilience information across disciplines and applications.

This is particularly important as climate and disaster risk assessments are increasingly being used to inform infrastructure investment, adaptation planning, insurance and public policy. The demand for quantitative risk information is growing rapidly, but without common terminology and clear expectations there is a risk that assessments are misunderstood, compared inappropriately, or applied beyond their intended purpose. This report helps address that challenge by using a set of user personas to illustrate how the taxonomy can respond to different needs along a typical resilience journey, depending on each user's role and decision-making context.

I therefore welcome this expansion from buildings to infrastructure. It represents an important step towards more consistent, comparable and actionable risk assessment across the systems on which societies depend.

> "Emerging multi-hazard work is demonstrating the importance of common taxonomies in linking hazard, exposure, vulnerability and resilience information across disciplines and applications.

1 Minority Report Project, funded by the European Union. The harmonised asset taxonomy developed in this project builds on Arup's Universal Taxonomy for Natural Hazard and Climate Risk and Resilience Assessments and the exposure taxonomy maintained by GEM. More information at: https://www.minorityreport-project.eu/en

Preface

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The publication of this Infrastructure Edition of this *Universal Taxonomy for Natural Hazard and Climate Risk and Resilience Assessments* is a significant step forward in our collective effort to strengthen the resilience of the infrastructure systems on which people and economies depend. For the World Bank Group, whose mission is to boost shared prosperity and end extreme poverty on a liveable planet, the integration of climate and disaster risk into infrastructure investment decisions is not optional — it is essential.

Natural hazards and climate change are increasing risks to infrastructure. In low- and lower-middle-income countries, where infrastructure gaps are already significant, limited information about existing assets makes it harder to understand where those risks are greatest. A common taxonomy framework creates the conditions for more consistent risk screening, better targeted investment decisions, and more effective use of limited resources.

Infrastructure owners, investors, development practitioners, insurers, and government planners each bring their own terminology, methods, and expectations to the table. Without a common framework, even well-intentioned risk assessments can be misinterpreted, misapplied, or rendered incomparable. The result is a loss of trust, a loss of efficiency, and ultimately a loss of resilience. This is precisely why the taxonomy introduced in this report matters. By establishing a clear, structured, and universally applicable classification system for natural hazard and climate risk assessments across infrastructure systems, it gives all parties — producers and consumers of risk information alike — a basis for meaningful dialogue. It defines not only what a given level of assessment entails, but what decisions it can and cannot support. That clarity is invaluable when the stakes are high and resources are constrained.

We commend all who are working towards increasing the resilience of our world's infrastructure. We hope these frameworks — now expanded from buildings to include infrastructure systems — are helpful on that journey.

> “By establishing a clear, structured, and universally applicable classification system for natural hazard and climate risk assessments, [the taxonomy] gives all parties a basis for meaningful dialogue.

Applications and uses

Introduction

There is an increasing need to take action on climate adaptation in the built environment. Various stakeholders, from infrastructure professionals to financiers, have been tasked with leading the way. Yet risk and resilience can be highly technical topics and there are limited resources to help non-technical stakeholders navigate the path forward. We often find that we are not talking the same language, causing mis-alignment and unmet expectations between the consumers and providers of risk and resilience information and strategies. Ultimately, this inhibits the speed and quality of enacting resilience and adaptation measures at the scale needed.

There is currently no universal regulatory framework that differentiates between levels or types of risk assessment for natural hazards and climate change for infrastructure systems, and no criteria governing what should be considered adequate or appropriate for the range of situations in which a risk assessment might be required. The Buildings Edition of the Taxonomy, published in 2024, establishes a structured framework to differentiate levels and types of natural hazard and climate risk assessments for buildings, addressing the prior lack of consistent criteria for defining their appropriate application.

The Universal Taxonomy for Infrastructure further builds on this approach, providing a structured framework for establishing what levels of risk assessment should be undertaken, at a minimum, to make resilience-related decisions or take actions with sufficient confidence to increase the resilience of infrastructure systems.

The Risk Class Taxonomy explicitly outlines the risk assessment approaches, data needs, data quality, and typical outputs to achieve a given Risk Class. It also includes detailed taxonomies for a subset of selected hazards (including climate change) and infrastructure systems to supplement the general requirements in the Risk Class Taxonomy. The Resilience Class Taxonomy outlines the types of resilience solutions and maturity level needed to achieve a given Resilience Class.

The section on User Personas outlines how to implement the taxonomies for specific use cases by stakeholders in specific roles within an organization.

The Simplified Risk Class Taxonomy provides a high-level summary for reference and communication purposes.

Simplified Risk Class Taxonomy

	Basic Hazard Screening Class 0	Basic Risk Screening Class 1	Enhanced Risk Assessment Class 2	Advanced Risk Modeling Class 3
Application	Exposure assessment for pre-screening and minimum reporting	Preliminary risk assessment for screening, regulatory disclosures, and low-stakes decisions	Risk assessment for material decisions, preliminary resilience actions, and budgets	Advanced risk assessment to inform high-stakes decisions, resilience-based design, implementable resilience measures, and costs
Assessment approach	Qualitative hazard and exposure assessment (vulnerability not meaningfully captured)	Qualitative or semi-quantitative risk assessment of asset categories and (in some cases) sub-categories	Quantitative risk assessment of asset sub-categories with engineer validation and simplified system considerations	System-level probabilistic risk modeling of all significant assets with explicit consideration of intra- and inter-dependencies
Accuracy and confidence level	Lowest	Low	Medium	Highest
Level of effort	Lowest	Low to Medium	Medium to High	Very High
Typical risk outcomes	• Qualitative hazard ratings • Basic exposure statistics • Spatial visualization of the hazard exposure	• Qualitative risk results for individual assets and/or key system segments • Spatial visualization of risk indicators across asset categories and locations • Qualitative risk narratives of system performance and dependencies	• Quantitative risk results for individual assets and/or key system segments • Spatial visualization of risk indicators across asset sub-categories and locations • Qualitative risk metrics of system performance and dependencies	• Probabilistic risk results for individual assets, components, and/or key system segments • Spatial visualization of risk indicators across individual assets and locations • Quantitative risk metrics of system performance and dependencies

Purpose

The Risk Class Taxonomy addresses natural hazard impacts on infrastructure assets, systems, and their users and operators, while the Resilience Class Taxonomy focuses on integrating resilience solutions at the asset and system level. These taxonomies can be applied together or separately across scales—from individual assets to regional or national infrastructure systems.

The taxonomies are primarily designed for networked infrastructure, enabling the evaluation of interconnected systems (such as utilities and transportation networks), while also supporting assessments of discrete assets (e.g., water treatment facilities) when used alongside the Buildings Edition of the Taxonomy. This hybrid approach accounts for important differences in asset characteristics, dependencies, and system-level behavior across the diverse range of infrastructure systems that can be evaluated.

When to use the taxonomy

For consumers of risk information (e.g. utility providers, transit agencies, multi-lateral development banks, asset managers, investment funds), the taxonomies provide:

- A clear framework for integrating risk assessments into internal project development processes, asset management, enterprise risk management, and/or decision-making cycles
- Guidance for defining appropriate technical requirements in Request for Proposals (RFPs) or Terms of Reference (TORs). A consistent basis for comparing bids or proposals from service providers and consultants offering different levels of risk assessment or resilience solutions for the same RFP

For producers of risk information (e.g. practitioners, consultants, service providers), the taxonomies provide:

- A clear framework to structure, describe, and differentiate service offerings
- A consistent basis for pricing services aligned with defined levels of analysis
- A tool for defining scope of work expectations with project developers, funders, or other stakeholders

Application

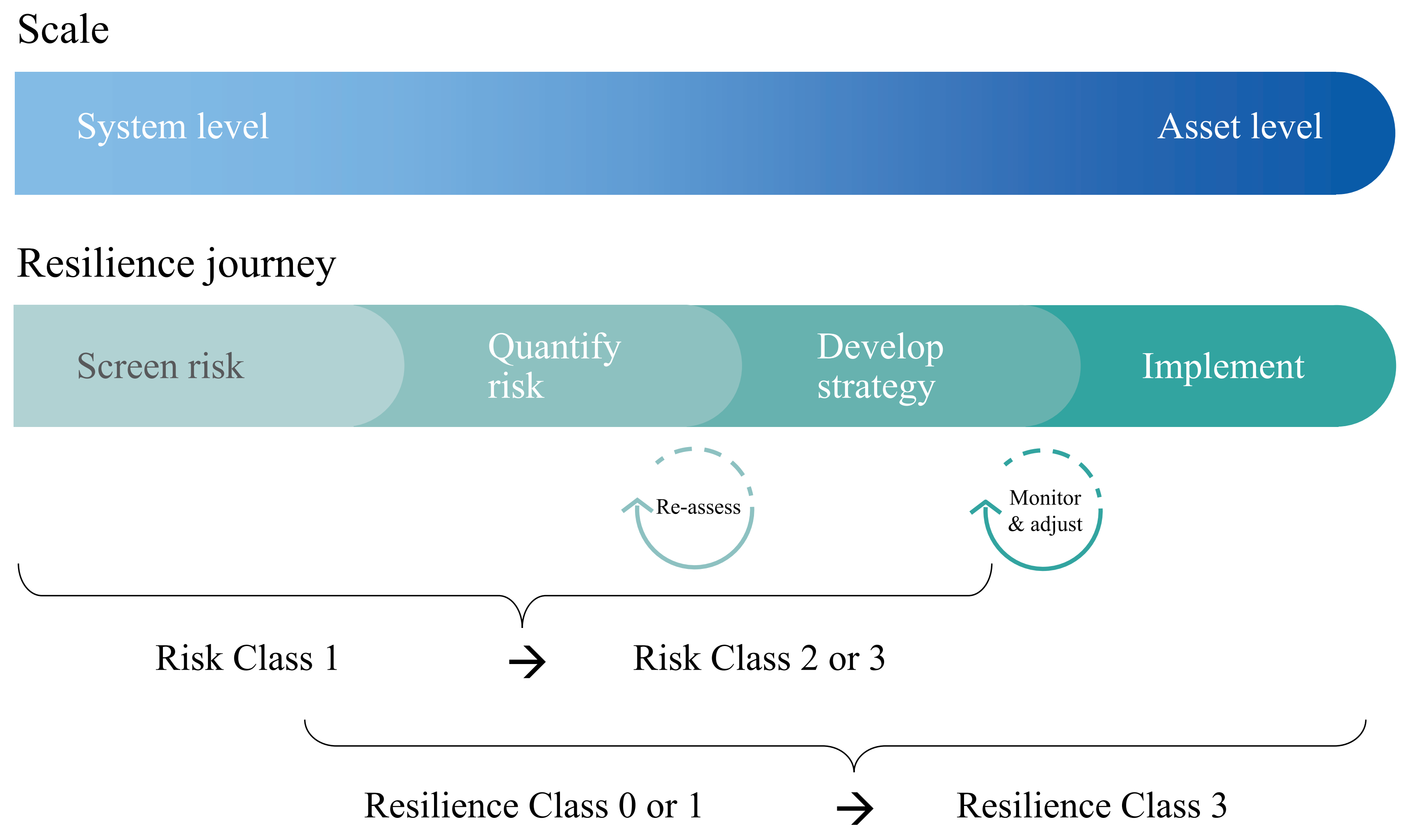
The Risk Class Taxonomy identifies a number of common applications, including decisions or actions, that may be supported by each Risk Class. These applications can lay the foundations for resilience and adaptation plans or projects that align with a given Resilience Class.

This journey can be mapped to the specific organizational workflows and needs of different users to reflect multiple use cases (see User Personas for further details).

Lower Risk Classes are generally intended for awareness, reporting, risk screening, or development of preliminary resilience strategies, while higher Risk Classes are intended to support higher-stakes resilience and adaptation decisions, especially those that may be costly, invasive, or disruptive.

The Risk Class Taxonomy outlines various levels of risk assessment to increase confidence in making progressively more costly or complex decisions as users embark or advance in their journey to resilience.

Figure 1. **Typical user journey**



What is risk and resilience?

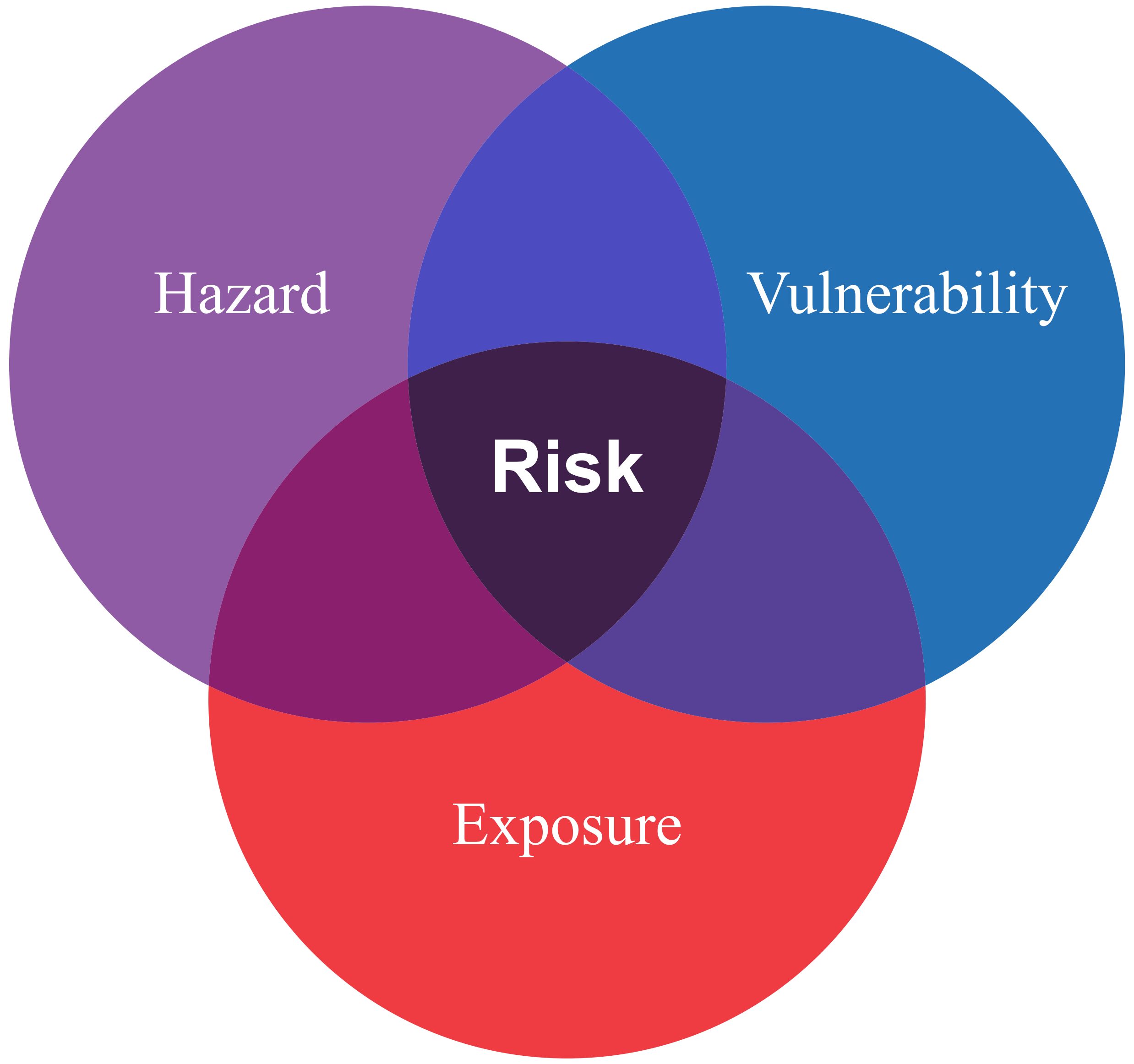
What is risk?

Risk is the probability of incurring a given consequence, where potential consequences for infrastructure systems include damage, downtime, repair costs, casualties, and service disruption. The various methods for assessing risk for infrastructure systems are outlined in the Risk Class Taxonomy.

A risk assessment must integrate the following elements:

Figure 2. Components of a risk assessment

How likely is a hazard event to occur, and what is the intensity? Does the hazard vary across the infrastructure system?



How damageable are the exposed infrastructure assets and how susceptible are users and/or operators?

What are the quantities, locations, and values of exposed assets, users, and/or operators? What services does the system provide to surrounding communities, economies, and/or environments?

What is resilience?

Resilience is the ability to adapt to, withstand, and/or recover rapidly from the effects of a hazard. Infrastructure resilience refers to the role that an infrastructure system plays in supporting an organization in delivering its core mission, services, and functionality, and ensuring safe and accessible conditions for users.

The Resilience Class Taxonomy has been defined to help stakeholders understand the appropriate level of risk awareness needed to plan and design resilience and adaptation solutions for their specific needs, with progressively higher Resilience Classes representing more confidence in the feasibility, risk reduction potential, and cost effectiveness of potential solutions.

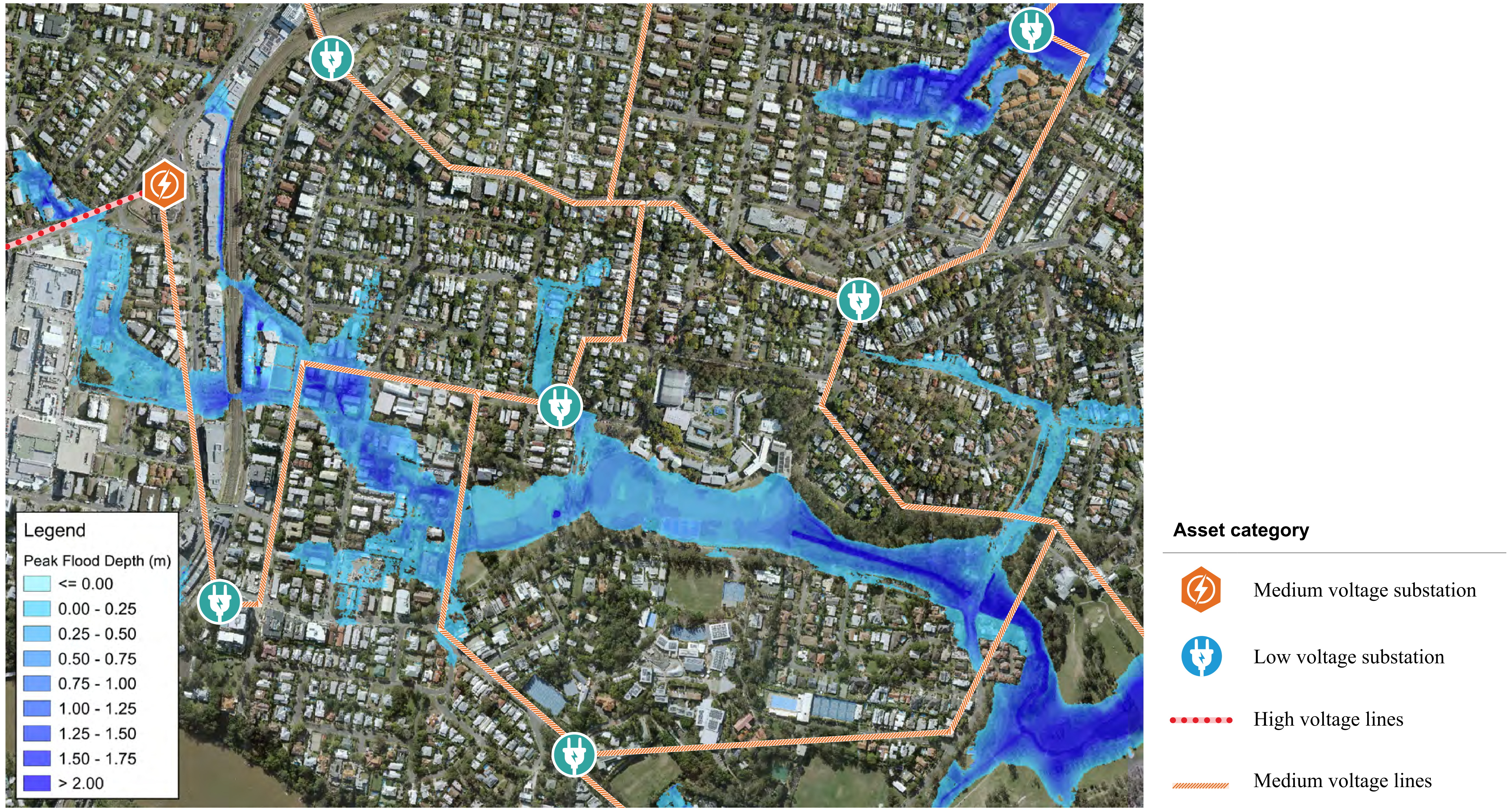
The Resilience Class Taxonomy is aligned with the Risk Class Taxonomy, as resilience and adaptation solutions are typically (though not always) informed by identification of the factors driving risk. Implementation of the most costly or complex resilience solutions requires deep insights into the vulnerable infrastructure assets driving the risk (i.e., Risk Class 2 or 3) so that targeted adaptation measures can be developed and evaluated.

The Resilience Class Taxonomy focuses on physical interventions and operational measures aimed at managing and reducing risk, increasing adaptive capacity, and/or creating redundancy within the infrastructure system. Broader resilience considerations (e.g., environmental degradation, regional economic losses, social cohesiveness) can also be evaluated, but this can be a significant undertaking. Therefore, the Resilience Class Taxonomy outlines differing levels of effort for including these broader resilience considerations.

How do you assess an infrastructure system?

The various methods for assessing risk for infrastructure systems are outlined in the Risk Class Taxonomy. Infrastructure systems typically comprise a diverse hierarchy of horizontal (e.g., pipes, roads) and vertical (e.g., buildings) asset types. These additional factors can add significant complexity to an assessment and make it challenging to establish appropriate system boundaries for the analysis.

Figure 3.
Representation of a Risk Class 2 model of a simplified power network



Infrastructure systems are networks of assets that work together to provide important services (e.g., electricity, potable water, mobility) to a community or region. In an assessment, it is important to capture the relationships between assets to better understand how damage to individual assets can cascade through the system and affect overall performance.

There are two main types of relationships between assets: intra-dependencies and inter-dependencies. Intra-dependencies refer to relationships or dependencies between assets within a single infrastructure system (e.g., a network of distribution pipes depends on an upstream transmission main for delivery of potable water). In contrast, inter-dependencies refer to relationships or dependencies between assets across different infrastructure systems (e.g., a potable water treatment plant depends on power to run filtration systems). The figure to the right shows the different types of inter-dependencies that can be considered.

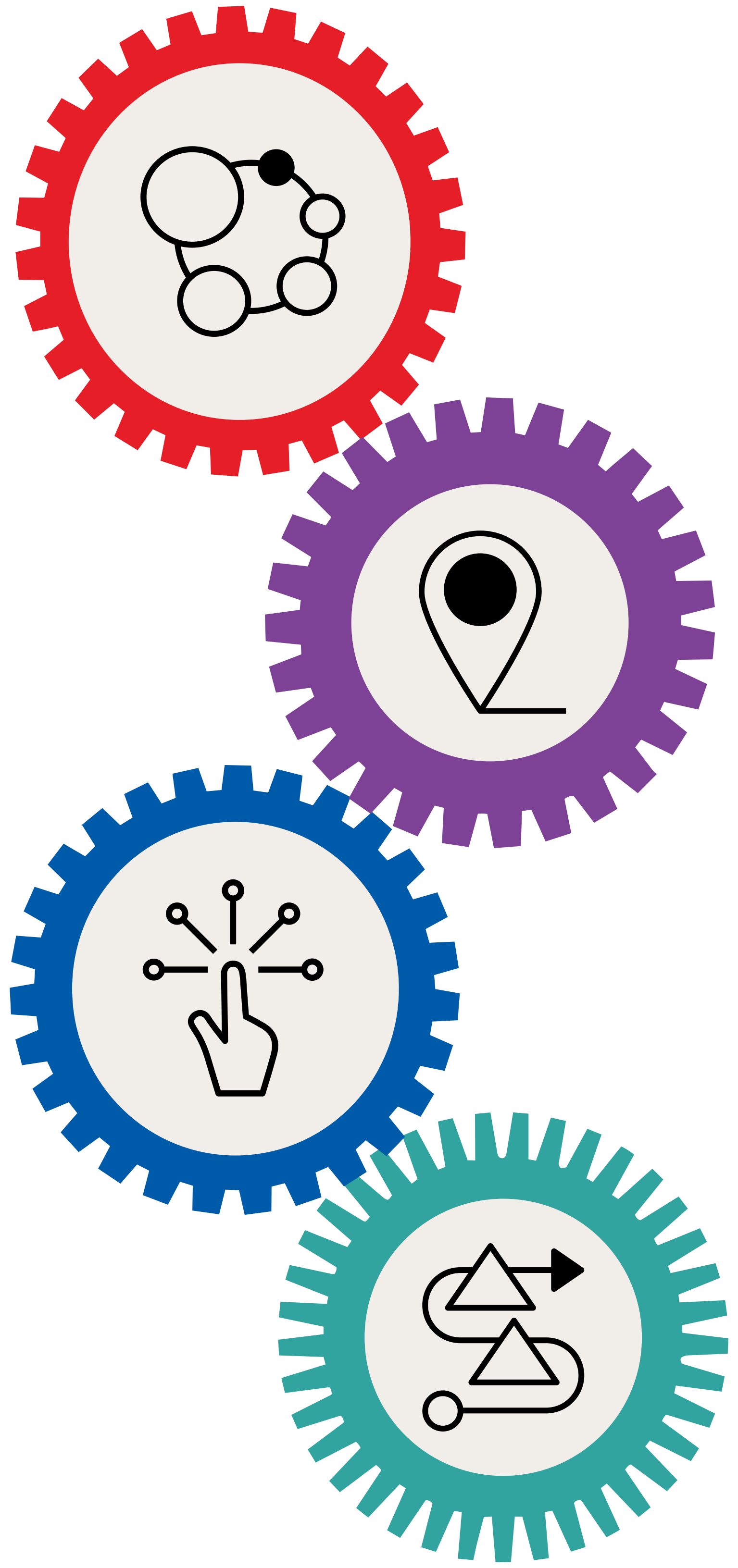
For a regional network of infrastructure assets, an event-based simulation that accounts for the geographic spatial correlation of a given hazard scenario event may be warranted if realistic shared fate risks need to be quantified. This is especially relevant for infrastructure systems, which can have significant geographic footprints and experience different levels of intensity across its network of assets during an event (i.e. storm track of a large hurricane, or epicenter of an earthquake).

Shared fate risks could include the joint probability of simultaneous downtime at two or more critical infrastructure assets, estimates of service loss across a community, or total financial losses across a region. Without an event-based assessment, the aggregated risks across multiple individual assets are likely to be overestimated.

Figure 4. Types of inter-dependencies that can be considered in a risk assessment

Physical

The operation of assets in an infrastructure system depends on the commodities or services provided by another infrastructure system.



Geographic

Assets in an infrastructure system are in close proximity to another infrastructure system and, therefore, are likely to experience simultaneous damage in a hazard event.

Cyber

Assets in an infrastructure system depend on information technology systems (e.g., internet, cell service).

Logical

Disruptions caused by a hazard event cause a chain of impacts across multiple infrastructure systems.

Source: C40 Knowledge Hub

Consequence types and communication of risk

When risks are communicated to stakeholders, they should be intuitive for all audiences and be tied to specific consequence types. Qualitative risk ratings or scores, if used for communication purposes, should be underpinned by quantitative definitions of likelihood and consequences. Narratives and storylines can be effective means of communicating risk, but they should also be underpinned by robust risk assessment.

If risk ratings, scores, or narratives are difficult to interpret, they hold little value for decision makers. In general, the level of confidence desired for these metrics should align with the quantification methods outlined in the corresponding Risk Classes.

The figure to the right lists some potential consequences that can be considered in a risk assessment. Some are the direct consequences of damage to infrastructure assets (e.g., repair costs), while others are more indirect in nature (e.g., regional economic losses). In general, indirect consequences require more effort to evaluate, but they can yield valuable insights that provide a more comprehensive business case for investing in resilience.

Typical consequence types

Organizational impacts

- Downtime
- Repair costs and inventory loss
- Lost revenues or property value
- Reputation damage

Human impacts

- Health and wellness
- Injuries and fatalities
- Population displacement

Community/regional impacts

- Environmental degradation
- Regional or national economic losses

Incorporating climate change effects

Climate change effects

Incorporating climate change effects

It is important to quantify climate-related hazards in terms of both likelihood and intensity for the present-day climate conditions.

Considering the long life span of infrastructure systems, present-day climate-related hazards should also account for climate change effects where attribution science indicates it could be adjusted, but this may depend on stakeholder needs and is not required to satisfy a given Risk Class. The Climate Change Effects Taxonomy provides further guidance if climate change effects are to be included in the risk assessment. In this case, the requirements outlined in the Climate Change Effects Taxonomy can be integrated with the hazard development guidance contained in either the Risk Class Taxonomy or the hazard and system sub-taxonomies, with alignment necessary to achieve the same Risk Class.

The following are key considerations to include climate change effects in the analysis of a hazard:

- Incorporating climate change effects in hazard assessment is typically undertaken using data from Global or Regional Circulation Models (GCMs or RCMs) for discrete scenarios. Scenarios are based on emissions concentration (Representative Concentration Pathways or RCP), shared socioeconomic pathways (SSP) or global degrees of warming (Global Warming Level or GWL), combined with a given time horizon (typically expressed as near-term, medium-term for mid-century, or long-term for the end of century).
- To use climate projections for local climate risk analyses, data should not be taken directly from the GCMs, as these should be validated and downscaled to reflect local climate and weather conditions.
- Climate models provide hindcast and future projections for climate variables such as temperature, precipitation, solar radiation, humidity and others. Thus, in many cases it may be necessary to further post-process these variables by integrating them into a hazard-specific model to obtain the required hazard intensity measures used in a risk assessment. For example, heat variables such as dry bulb temperature must be post-processed from the available time series and extreme value analysis must be undertaken to quantify the return period related to a given temperature. Precipitation data must be used to develop shifted intensity-duration-frequency functions used as input to hydrological and hydraulic models to determine flood depth.
- Including climate change effects introduces another layer of uncertainty to the hazard and risk analysis due to modeling approaches and to the nature of the change, which depends on the evolution of natural processes and human activities into the future. This leads to differing projections across climate models even when forced by the same underlying assumptions. One way to address this may include using multi-model ensembles and examining the differences across the models to quantify the uncertainty. This may be done by using metrics for both the central trend and the extremes, such as percentiles from the median up to more extreme percentiles (e.g., 90th percentile). Additionally, it is also recommended to use the data from a 30-year time slice to represent a selected future time frame, instead of using the specific data reported for a single given year, given the large variability of the projections across individual years.
- The choice of scenarios and future time horizons is related to the desire to reflect business as usual, optimistic or pessimistic trends and to the life span of the infrastructure under study. International and local guidance on best practices and key considerations may be consulted to aid making a selection. Organizations may also consider their own risk appetite (e.g., risk averse organizations may choose more pessimistic emissions scenarios).
- Although climate models and their computational capabilities continuously advance, the spatial resolution of climate models and their modeled hindcast or future projections data may be coarser than the resolution of hazard data

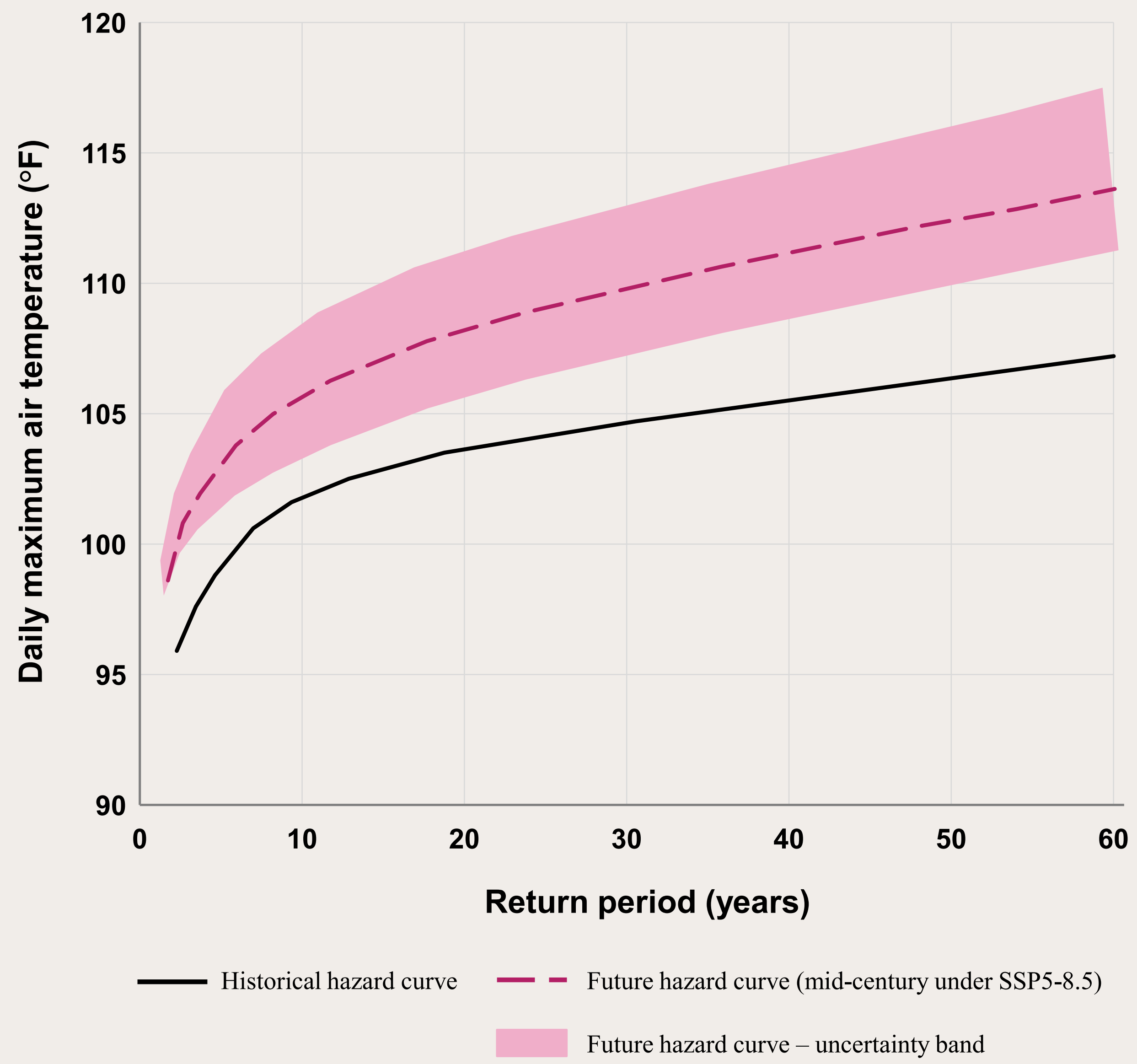
Incorporating climate change effects

used for certain applications of a risk assessment. For an infrastructure risk assessment at a global, national or even sub-national scale, the resolution of climate models may be better matched with the resolution of the hazard data used for the risk assessment. Whereas for a risk assessment conducted for a local sub-set of an infrastructure system or an individual point asset, there may be a large discrepancy in resolution of the climate projections and the local hazard data. It is important to make sure both the climate change and hazard analysis approaches are aligned and allow for a reasonable tolerance of differing resolutions. When needed, bias correction or downscaling approaches are recommended to translate the broader climate change signals to meteorological parameters at a local scale. There are multiple techniques to apply downscaling, ranging from simple morphing to statistical or dynamical downscaling.

- Assessing future climate risk should look beyond climate scenarios and include projections of the changes to the built environment. While climate scenarios modify the hazard component, changes to the built environment can modify the exposure and vulnerability components of the risk definition. These changes may be estimated based on demand projections included in master plans or similar studies.

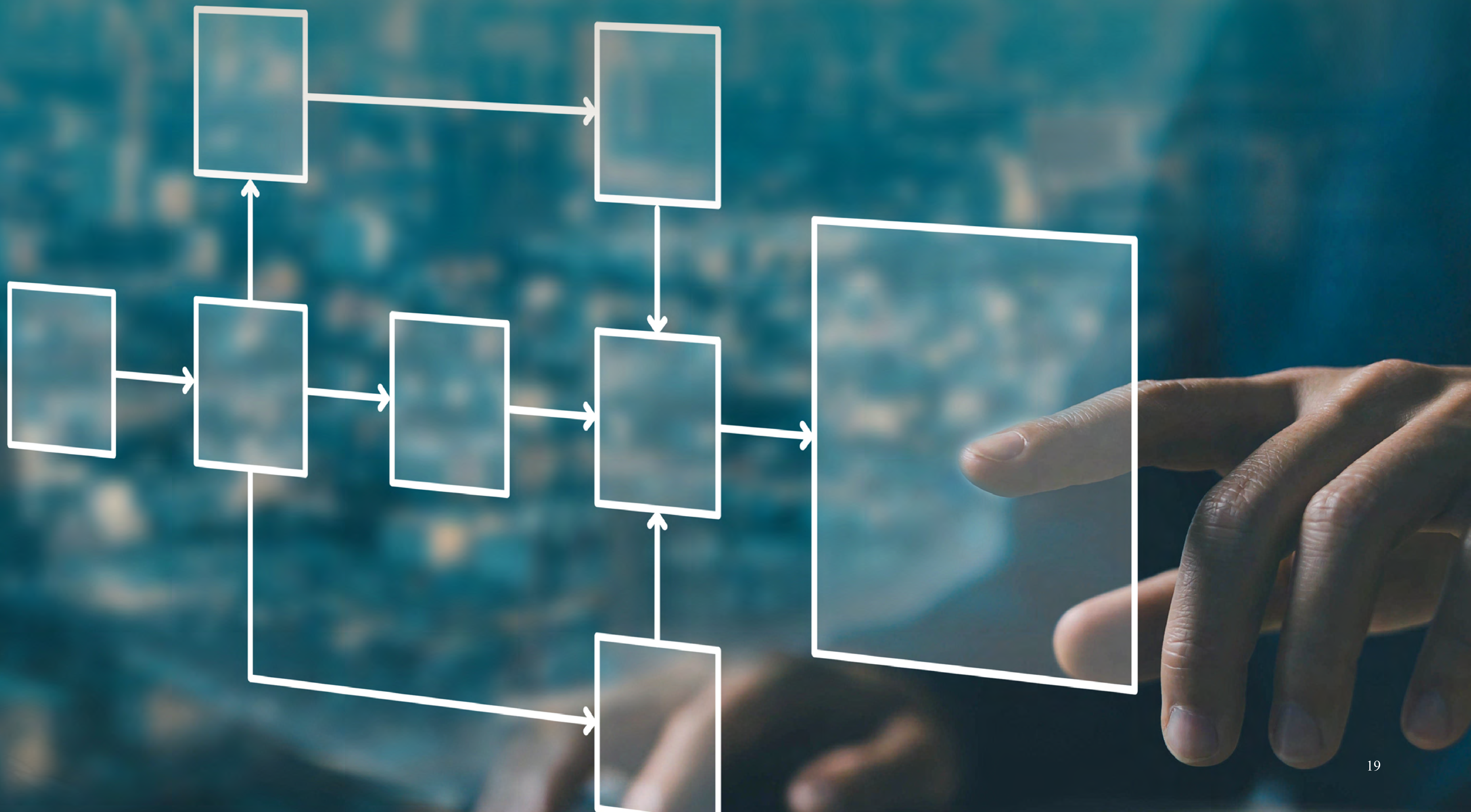
Figure 5. Climate change effects in the risk assessment framework

Figure 6. Example hazard curve showing projected changes in frequency and intensity in air temperature due to climate change effects



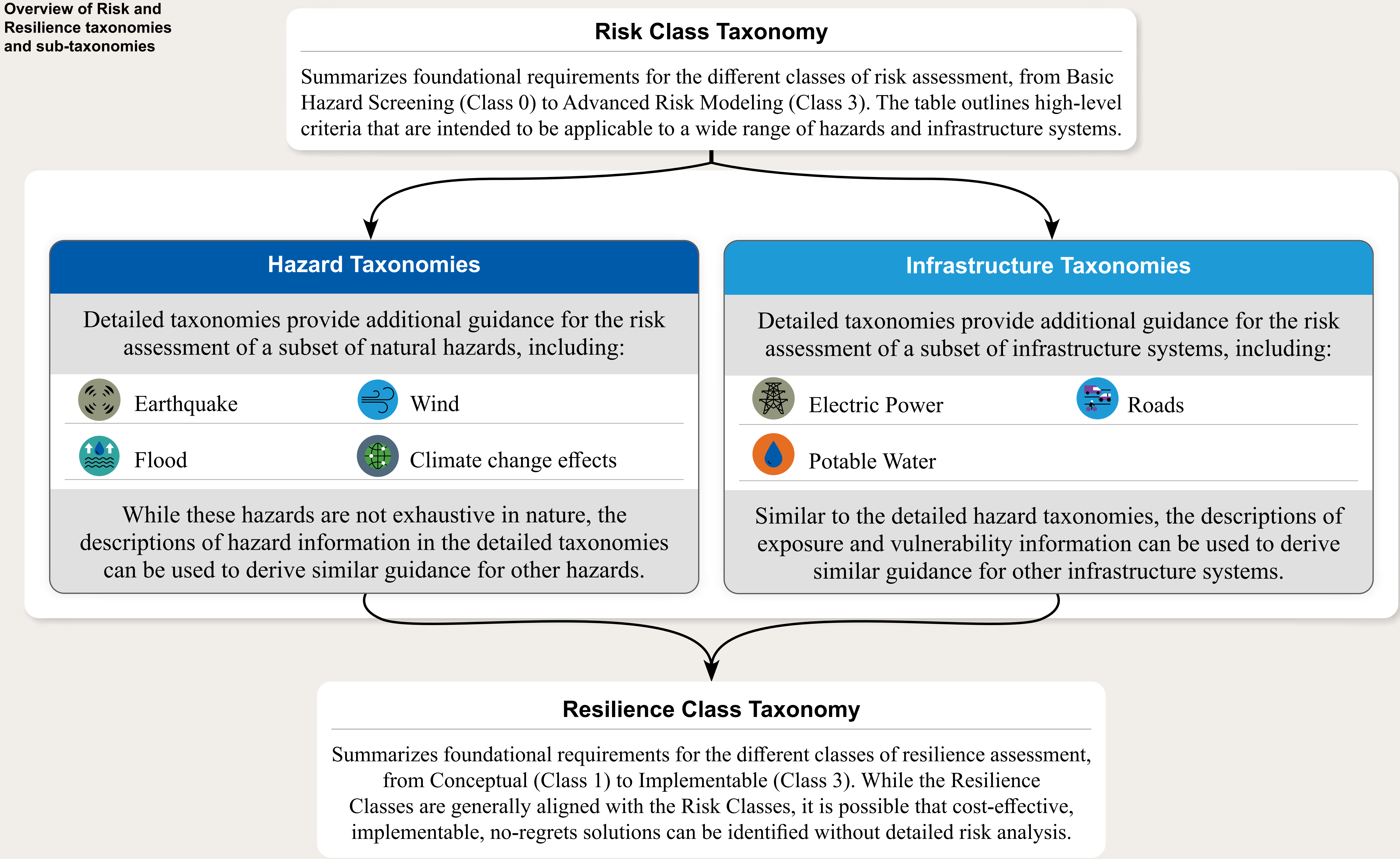
Taxonomy charts

Taxonomies



This section contains a series of taxonomy tables that outline typical minimum requirements and general guidance for conducting varying levels of risk and resilience assessment of infrastructure systems, beginning with the Risk Class Taxonomy. Due to the diverse range of hazards and infrastructure systems that can be evaluated, the general requirements in the Risk Class Taxonomy are supplemented by a series of detailed taxonomies that provide additional guidance for assessing hazard, exposure, and vulnerability for a limited number of hazard and infrastructure systems. Further description of each taxonomy is provided below.

Figure 7.
Overview of Risk and Resilience taxonomies and sub-taxonomies



	Basic Hazard Screening Class 0	Basic Risk Screening Class 1	Enhanced Risk Assessment Class 2	Advanced Risk Modeling Class 3[a]
Application	• Preliminary awareness of asset locations and/or percentage of system exposed to hazards • Pre-screening for higher classes of risk assessment	• Preliminary indication of vulnerable assets and locations • Screening for more advanced risk assessment of smaller subset of high-risk assets • Regulatory disclosures • Rough-order-of-magnitude (ROM) estimates of investment needs	• Indication of vulnerable assets and locations • Preliminary adaptation measures, costs, and cost-benefit analysis • Risk-informed resilience strategy • Preliminary budgets • Preliminary project prioritization	• Identification of vulnerable assets and locations • Asset-specific risk mitigation and shovel-ready adaptations • Cost estimates & cost-benefit analysis • Resilience-based design of new infrastructure • Capital plans • Finalized project selection
Typical scale	Generally suitable for all scales, from national to sub-regional	Generally suitable for all scales, from national to sub-regional	Up to regional or sub-regional scale	Best suited to sub-regional systems or sub-regional-sized sections of larger systems
Assessment approach	Qualitative hazard and exposure assessment (vulnerability not meaningfully captured)	Qualitative or semi-quantative risk assessment of asset categories and (in some cases) sub-categories	Quantitative risk assessment of asset sub-categories with engineer validation and simplified system considerations	System-level probabilistic risk modeling of all significant assets with explicit consideration of intra- and inter-dependencies
Accuracy and confidence level	Lowest	Low	Medium	Highest
Uncertainty quantification	Not considered	Some consideration, but qualitative in nature	Considered in semi-quantitative manner	Explicitly quantified
Risk metrics	• Qualitative hazard ratings • Basic exposure statistics (e.g., total length of roads exposed to a given hazard level) • Spatial visualization of the hazard exposure	• Qualitative risk results for individual assets and/or key system segments (e.g., low/medium/high risk rating per road segment) • Spatial visualization of risk indicators across asset categories and locations • Qualitative risk narratives of system performance	• Quantitative risk results for individual assets and/or key system segments (e.g., average annual downtime per road segment) • Spatial visualization of risk indicators across asset sub-categories and locations • Qualitative risk metrics of system performance (e.g., low/medium/high risk rating for system service disruption)	• Probabilistic risk results for individual assets and/or key system segments (e.g., average annual downtime per road segment) • Spatial visualization of risk indicators across individual assets and locations • Quantitative risk metrics of system performance (e.g., service restoration curves for specific hazard scenarios)
Source data for risk assessment[b]	• Geolocations typically provided by stakeholders or derived from exposure mapping using publicly available maps or satellite imagery. • Data not checked for completeness or accuracy.	Geolocations of asset categories (and sub-categories) provided by stakeholders or publicly available data, with locations subject to limited validation.	• Critical site-specific characteristics for individual assets provided by stakeholders and validated by engineer. • Publicly available satellite or aerial imagery to determine surrounding environment.	• Detailed asset-specific characteristics found in design documents for individual assets provided by stakeholders. • Information validated to ensure it is up-to-date.

The Risk Class Taxonomy outlines minimum criteria to satisfy the given Risk Class. The minimum criteria for a given Risk Class must be satisfied for all categories. It is possible to exceed the minimum criteria in a given category, but this would not constitute assignment of a higher Risk Class. For example, one could use higher resolution flood hazard data than the minimum requirements outlined for Risk Class 0 assessment but if vulnerability is not considered, it remains a Risk Class 0. However, higher resolution hazard data would certainly increase the confidence of the Class 0 assessment and the user can determine how to communicate that to interested stakeholders.

a. It is possible to exceed these requirements for some hazards that impose dynamic loads on assets, such as earthquakes or wind (see hazard-specific taxonomies for more detail).

b. The required exposure and vulnerability data is additive for each risk class.

	Basic Hazard Screening Class 0	Basic Risk Screening Class 1	Enhanced Risk Assessment Class 2	Advanced Risk Modeling Class 3[a]
Hazard	• Deterministic or single return period • Coarse to moderate spatial resolution • Qualitative low-to-high hazard indicators or descriptions (e.g., FEMA flood zones)	• Probabilistic representation of core hazards (e.g., flood, wind, seismic) • Moderate spatial resolution • Quantitative intensity metrics (e.g., flood depth) vs. likelihood for at least one return period	• Probabilistic representation of core hazards (e.g., flood, wind, seismic) • Moderate to high spatial resolution • Quantitative intensity metrics (e.g., flood depth) vs. likelihood at multiple return periods • Validation of hazard data by engineer and region and sub-region-specific adjustments as needed	• Probabilistic and multiple return periods[b] • Highest spatial resolution • Site-specific hazard modeling with quantifiable uncertainty
Exposure	Spatially distributed geolocated assets represented using basic geometry (e.g., points or lines).	Spatially distributed geolocated assets classified by asset category (e.g., power lines, substations).	Spatially distributed geolocated assets differentiated into relevant sub-categories based on characteristics critical to hazard vulnerability (e.g. above-ground vs. below-ground power lines).	Spatially distributed geolocated assets with site-specific attributes required for bespoke assessments (e.g., structural design parameters, construction year, etc. for poles and towers supporting above-ground power lines).
Vulnerability	Not included - hazard and exposure assessment only.	• Assess vulnerability using generic damage and loss functions per asset category (e.g., roads, bridge) and, in some cases, asset sub-categories (e.g., paved vs. unpaved roads). • Qualitative representations of vulnerability may be required for certain asset categories • No differentiation in vulnerability within each asset category. • Vulnerability of users and/or operators captured in qualitative manner.	• Assess vulnerability using using more refined damage and loss functions per asset sub-category (e.g., bridge type, construction year, design level). • Qualitative representations of vulnerability may be required for certain asset categories and sub-categories • Vulnerability of users and/or operators captured in quantitative manner.	• Assess vulnerability using site- and asset-specific damage and loss functions for individual assets (e.g., material properties, age, condition, design parameters). • Vulnerability of users and/or operators explicitly captured in model.
Consequence	Exposure to hazards	Qualitative representations of consequence (e.g., risk ratings for downtime, repair costs, user/operator safety)	• Quantitative representations of certain consequence (e.g., average annual downtime, repair costs). • Semi-quantitative representations of others (e.g., life safety, service disruption, regional economic impact)	• Fully probabilistic representations of certain consequence (e.g., average annual downtime, repair costs). • Quantitative and semi-quantitative representations of others (e.g., life safety, service disruption, regional economic impact)

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a. It is possible to exceed these requirements for some hazards that impose dynamic loads on assets, such as earthquakes or wind (see hazard-specific taxonomies for more detail).

b. Stochastic event sets are recommended for risk assessments of infrastructure systems if realistic aggregate risk metrics are required.

Table continued on next page.

	Basic Hazard Screening Class 0	Basic Risk Screening Class 1	Enhanced Risk Assessment Class 2	Advanced Risk Modeling Class 3[a]
Intra-dependencies[b]	Not included	Provide qualitative narrative regarding any identified critical intra-dependencies and/or redundancies (e.g. the impact of a major road being inundated is reduced if alternative routes remain unflooded during the same event).	Incorporate asset-level intra-dependencies and/or redundancies using criticality factors (or similar) to modify risk results (e.g., a substation may have higher criticality than distribution lines because if a larger number of customers are impacted by its failure).	Develop a network model, ranging from simplified fault trees or impact chains to a full probabilistic model that explicitly captures the intra-dependencies within the system.
Inter-dependencies[c]	Not included	Provide qualitative narrative and/or high-level systems mapping for any identified critical inter-dependencies (e.g., the wastewater system is dependent on the power system for lift station operations).	Measure system-level risk by assigning flags to assets impacted by system inter-dependencies (e.g., a water treatment plant in the potable water system is flagged given it relies on the power system for operation).	Incorporate most relevant components of other systems in network model to capture inter-dependencies (e.g., last mile of supporting infrastructure).

The Risk Class Taxonomy outlines minimum criteria to satisfy the given Risk Class. The minimum criteria for a given Risk Class must be satisfied for all categories. It is possible to exceed the minimum criteria in a given category, but this would not constitute assignment of a higher Risk Class. For example, one could use higher resolution flood hazard data than the minimum requirements outlined for Risk Class 0 assessment but if vulnerability is not considered, it remains a Risk Class 0. However, higher resolution hazard data would certainly increase the confidence of the Class 0 assessment and the user can determine how to communicate that to interested stakeholders.

a. It is possible to exceed these requirements for some hazards that impose dynamic loads on assets, such as earthquakes or wind (see hazard-specific taxonomies for more detail).
b. Relationships or dependencies between assets within a single infrastructure system (e.g., a transmission pipe delivers potable water to a network of distribution pipes).
c. Relationships or dependencies between assets across different infrastructure systems (e.g., a water treatment plant requires power to run filtration systems).

	Basic Hazard Screening Class 0	Basic Risk Screening Class 1	Enhanced Risk Assessment Class 2	Advanced Risk Modeling Class 3
Modeling approach	Probabilistic or deterministic seismic hazard analysis	Probabilitistic seismic hazard analysis	Probabilitistic seismic hazard analysis	Site-specific probabilistic seismic hazard analysis
Spatial resolution	10km	8km	2km	Asset locations
Intensity metrics	MMI or PGA	PGA	PGA and secondary hazard proxies representing liquefaction, ground settlement, and fault rupture (e.g., liquefaction susceptibility levels)	Asset-specific seismic demand parameters, including: • Ground shaking (PGA, PGV, spectral acceleration) • PGD (fault displacement, liquefaction-induced settlement/lateral spread) • Slope instability, where applicable
Likelihood method	Single deterministic or intensity-based scenario (based on single return period)	At least one return period	Multiple return periods	• Multiple return periods and earthquake realizations that capture uncertainty about the median intensity-based hazard values
Hazard-specific requirements	Assumption of rock or soft soil condition	Soil site class augments hazard values or else assume rock or soft soil condition	Soil site class augments hazard values	Site-specific inputs and analyses used to derive seismic demand parameters, including: • Site-specific Vs30 or geotechnical data to adjust ground motion estimates • Use of site-specific models or datasets to characterize permanent ground deformation hazards (e.g., liquefaction, fault rupture, slope instability)

The Earthquake Hazard Taxonomy provides additional guidance for conducting a seismic hazard analysis for each Risk Class. The minimum criteria for a given Risk Class must be satisfied for all categories. It is possible to exceed the minimum criteria in a given category, but this would not constitute assignment of a higher Risk Class.

	Basic Hazard Screening Class 0	Basic Risk Screening Class 1	Enhanced Risk Assessment Class 2	Advanced Risk Modeling Class 3
Modeling approach	Deterministic or probabilistic analysis	Probabilistic and statistical modeling	Probabilistic and statistical modeling (with local validation)	Advanced site-specific modeling including dynamic hydrology and unsteady flow hydraulics and compound flood modeling as necessary.
Spatial resolution	100m and above	30 to 90m [or 100m and above for city-level or larger assessment]	10 to 30m	1 to 3m
Intensity metrics	Inundation classification (in or out of flood zone)	Inundation depth or proxy depths	Inundation depth	Inundation depth, velocity (if near river), duration (for downtime)
Likelihood method	Single deterministic or intensity-based scenario (based on single return period)	At least one return period	Multiple return periods	Multiple return periods and risk realizations that capture uncertainty about the median intensity-based hazard values
Hazard-specific requirements	None	Moderate-resolution topography information and easily accessible rainfall intensity data	• Moderate-resolution topography data, easily accessible rainfall data from local meterological stations, nearby stream gauge data, and basic information about relevant flood defense infrastructure • If included in model, verify adequacy of community-level flood defenses	• High-resolution (e.g., LiDAR) topographic data, detailed land use/cover data, detailed stormwater infrastructure information such as storm drain networks and culverts, rainfall data from local meteorological stations, nearby stream gauge data, and nearby tide gauge data (if coastal). All should represent the current conditions reasonably. • Verify site-specific stormwater conveyance capacity (e.g. size, location, inverts) for inclusion in hazard model

The Flood Hazard Taxonomy provides additional guidance for conducting a flood hazard analysis for each Risk Class. The minimum criteria for a given Risk Class must be satisfied for all categories. It is possible to exceed the minimum criteria in a given category, but this would not constitute assignment of a higher Risk Class.

	Basic Hazard Screening Class 0	Basic Risk Screening Class 1	Enhanced Risk Assessment Class 2	Advanced Risk Modeling Class 3
Modeling approach[a]	• Non-cyclonic: statistical evaluation • Cyclonic: deterministic scenario	• Non-cyclonic: statistical evaluation • Cyclonic: probabilistic intensity-based scenarios	• Non-cyclonic: statistical evaluation • Cyclonic: probabilistic intensity-based scenarios	• Non-cyclonic: statistical evaluation • Cyclonic: probabilistic cyclone event set
Spatial resolution	< 10km	< 2km	< 2km	< 1km
Intensity metrics	Wind speed (typically a 3-second gust, but 10-minute or hourly mean speeds are also possible).	3-second gust wind speed	3-second gust wind speed, adjusted for terrain	3-second gust wind speed, adjusted for terrain
Likelihood method	Single deterministic scenario (e.g., hurricane category) or intensity-based scenario (i.e., based on a single return period).	At least one return period	Multiple return periods	• Non-cyclonic: multiple return periods capturing uncertainty in intensity-based hazard estimates • Cyclonic: probabilistic cyclone event set capturing storm track, intensity, and frequency uncertainty
Hazard-specific requirements	Open terrain unless actual terrain known.	Open terrain unless actual terrain known.	Terrain adjusted based on actual site conditions.	Terrain adjusted based on actual site conditions, wind directionality considered. For cyclonic winds, precipitation should be considered in damage models

The Wind Hazard Taxonomy provides additional guidance for conducting a wind hazard analysis for each Risk Class. The minimum criteria for a given Risk Class must be satisfied for all categories. It is possible to exceed the minimum criteria in a given category, but this would not constitute assignment of a higher Risk Class.

a. Wind hazard data can be obtained from building codes, commercial vendors, or developed by qualified wind engineers, and their models must meet the requirements herein

	Basic Hazard Screening Class 0	Basic Risk Screening Class 1	Enhanced Risk Assessment Class 2	Advanced Risk Modeling Class 3
Typical spatial scale	50km to 100km	25km to 50km	10km to 25km or point analysis (at weather station points)	<10km or point analysis (at weather station points)
Typical temporal scale	Annual, seasonal high-level change factors/indicators	Annual / seasonal / monthly data or daily data	Daily data	Daily or hourly data
Typical climate variables[a]	• Temperature • Precipitation • Wind speed • Sea level (or sea level rise) • Others (if applicable to other climate hazards)	• Temperature (minimum, mean and maximum) • Precipitation • Wind speed • Humidity (relative humidity) • Sea level (or sea level rise) • Others (if applicable to other climate hazards)	• Temperature (minimum, mean and maximum) • Precipitation (daily precipitation) • Wind speed (sustained windspeed) • Humidity (relative humidity) • Sea level (or sea level rise) • Snowfall • Others (if applicable to other climate hazards)	• Temperature (minimum, mean and maximum) • Precipitation (hourly or daily precipitation) • Wind speed (wind gusts, sustained windspeed, wind direction) • Humidity (relative or specific humidity) • Sea level (or sea level rise) • Snowfall • Solar radiation • Others (if applicable to other climate hazards)
Climate change analysis	Long-term trends on mean annual / seasonal / monthly changes	Deterministic analysis of modeled hindcast and future projected data to obtain a single change factor for climate variables from an ensemble of GCMs[b].	Probabilistic analysis of modeled hindcast and future projected daily time series to conduct Extreme Value Analysis on climate variables from an ensemble of GCMs[c] and obtain a set of change factors or absolute values for multiple return periods[d]	Probabilistic analysis of modeled hindcast and future projected daily or hourly time series to conduct Extreme Value Analysis, data resampling or weather generation on climate variables from an ensemble of GCMs[d] and obtain a set of change factors or absolute values for multiple return periods[e].
Climate change downscaling method	No downscaling	Bias correction or simplified statistical downscaling. Delta Change or Morphing approach with a single change factor.	Statistical downscaling and bias correction: Probabilistic Delta Change or Morphing approach with multiple change factors (one for each return period).	• Non-parametric statistical downscaling: resampling or simple weather generators with daily data. • Parametric statistical downscaling model or weather generators with daily or hourly data. • Advanced dynamical downscaling model with daily or hourly data[f].

Table continued on next page.

The Climate Change Taxonomy provides additional guidance for conducting analysis of climate change effects on climate hazards used in a risk assessment, for each Risk Class. The minimum criteria for a given Risk Class must be satisfied for all categories. It is possible to exceed the minimum criteria in a given category, but this would not constitute assignment of a higher Risk Class.

a. These represent common climate variables that are available directly in the Global Climate Models (GCM). As noted in the row below, in many cases it may be necessary to further post-process these variables by integrating them into a hazard-specific model to obtain the required hazard intensity measures used in a risk assessment. Other climate variables or climate change indicators beyond the list included here may be available from GCMs or other sources.

b. Sources may include: published IPCC / International or national GCM aggregated results to obtain single change factors or projected values. Directly use GCM/RCM aggregated data (annual, seasonal, monthly) to obtain single change factors or change values.

c. A sub-set of GCMs may be selected to discard any outlier or erroneous GCMs for the location of interest.

d. Sources may include: published international or national downscaled results for multiple change factors or projected values for different return periods. Use of published international or national downscaled daily time series data to calculate multiple change factors or projected values for different return periods.

e. Sources may include: published national or sub-national downscaled daily or hourly time series data to calculate multiple change factors or projected values for different return periods or exceedance probabilities to get complete hazard curves.

f. Advanced dynamical downscaling using models such as the Weather Research and Forecasting (WRF) model is optional.

	Basic Hazard Screening Class 0	Basic Risk Screening Class 1	Enhanced Risk Assessment Class 2	Advanced Risk Modeling Class 3
Methodology to integrate climate-adjusted variables into climate hazards	Trends for climate variables may be used as a proxy for hazard trends as long as the inherent assumptions made are recognized and caveated.	A deterministic analysis of the climate variables can be used to calculate a single change factor on the inputs for a probabilistic hazard analysis for hazards that are not directly quantified by the climate variables (e.g. flood, wildfire, and sea level rise, drought) OR a single change factor can be applied to the baseline hazard curve in post-processing for hazards that are directly quantifiable by the climate variables (e.g. temperature)	A simplified probabilistic modeling of the climate variables should be done to align with the simplified probabilistic modeling of the hydrometeorological hazards, so that climate-adjusted climate variable curves are directly used as inputs to the standard hazard analyses (i.e., climate-adjusted rain exceedance curves are input into hydrological and hydraulic models to obtain climate-adjusted flood results).	A fully probabilistic modeling of the climate variables should be done to align with the fully probabilistic modeling of the hydrometeorological hazards, so that climate-adjusted variable time series or climate-adjusted climate variable curves are directly used as inputs to the standard hazard models (e.g. rain time series or rain exceedance curves are input into hydrological and hydraulic models where a probabilistic analysis is conducted to obtain probabilistic climate-adjusted flood results).
Typical climate-adjusted hazard outputs	Trend or narrative of increase or decrease.	Hazard intensity metric with and without climate change (e.g. flood depth).	Hazard intensity metric with and without climate change (e.g. flood depth).	Hazard intensity metric with and without climate change (e.g. flood depth).

The Climate Change Taxonomy provides additional guidance for conducting analysis of climate change effects on climate hazards used in a risk assessment, for each Risk Class. The minimum criteria for a given Risk Class must be satisfied for all categories. It is possible to exceed the minimum criteria in a given category, but this would not constitute assignment of a higher Risk Class.

	Basic Hazard Screening Class 0	Basic Risk Screening Class 1	Enhanced Risk Assessment Class 2	Advanced Risk Modeling Class 3
Exposure and Vulnerability	Geolocated assets represented using basic geometries (power lines as polylines; substations and power plants as points).	Geolocated assets differentiated into high-level categories (e.g., transmission lines, distribution lines, transmission towers, power poles, substations, generation facilities) and, where appropriate, sub-categories	Geolocated assets differentiated into relevant sub-categories based on characteristics critical to their vulnerability to natural and climate hazards, as well as overall condition, age, and previous issues/failures. Assess vulnerability using using more refined quantitative damage and loss functions per asset sub-category. Examples of sub-categories include: • Power generation facilities: size (MW), type (wind, solar, hydro, natural gas), and key structural and operational characteristics • Power lines: above-ground or below-ground power lines. • Power poles: wood, steel, or concrete power poles. • Substations: configuration (indoor or outdoor), size (kV), elevation, and layout of critical equipment.	Inclusion of asset-specific information required to conduct bespoke assessments. Examples of asset-specific information include: • Transmission/distribution structures: pole/tower type, structure height, foundation type, and design parameters (e.g., design loads) • Substations: equipment inventory, equipment elevation, enclosure type, and anchorage or foundation details • Surrounding environment: site conditions such as vegetation density, topography, and drainage
Intra-dependencies[a]	Not typically considered	Provide qualitative narratives describing the potential for asset disruptions or failures to impact the broader power network (e.g., ring network provides two feeds to each substation).	Assign criticality ratings/scores to individual assets based on their importance to overall system operations and performance. Example criticality considerations include: • The number of customers potentially affected by asset disruption or loss of function • The level of redundancy (e.g., whether multiple substations serve the same region)	Develop a network model that explicitly captures system configuration and performance, including: • Transmission–substation–distribution connectivity • Redundant feeder availability • Rerouting capability and temporary operational measures that support service continuity and recovery
Inter-dependencies[b]	Not typically considered	Identify assets dependent on external supporting infrastructure systems (e.g., water and communication systems, regional or national power grid) and provide qualitative narratives on the impacts of disruptions or failures in those systems.	Assign scores to individual assets to reflect their level of dependency and sensitivity to disruptions in external supporting infrastructure systems (e.g., water and communication systems, regional or national power grid).	Develop a network model of external supporting infrastructure systems (e.g., water and communication systems, regional or national power grid) serving the system being assessed, focusing on the portions directly connected to it, to incorporate the impact of external system disruptions, degradation, or loss of function into the assessment.

The Electric Power Infrastructure Taxonomy provides additional guidance for characterizing a power system's assets and dependencies for each Risk Class. The minimum criteria for a given Risk Class must be satisfied for all categories. It is possible to exceed the minimum criteria in a given category, but this would not constitute assignment of a higher Risk Class.

a. Relationships or dependencies between assets within a single infrastructure system (e.g., a transmission pipe delivers potable water to a network of distribution pipes).

b. Relationships or dependencies between assets across different infrastructure systems (e.g., a water treatment plant requires power to run filtration systems).

	Basic Hazard Screening Class 0	Basic Risk Screening Class 1	Enhanced Risk Assessment Class 2	Advanced Risk Modeling Class 3
Exposure and Vulnerability	Geolocated assets represented using basic geometries (e.g., water pipes as polylines; water treatment plants and pump stations as points).	Geolocated assets differentiated into high-level categories (e.g., water pipelines, water treatment plants, pump stations, wells, water storage tanks) and, where appropriate, sub-categories.	Geolocated assets differentiated into relevant sub-categories based on characteristics critical to their vulnerability to natural and climate hazards. Assess vulnerability using using more refined quantitative damage and loss functions per asset sub-category. Examples of sub-categories include: • Water pipes: ductile or brittle pipe material, buried or exposed • Water treatment plants: treatment capacity, key system configurations, and elevation of critical equipment • Pump stations: pumping capacity, operational configuration, and elevation of critical equipment • Water storage tanks: at grade vs. buried, material	Inclusion of asset-specific information required to conduct bespoke assessments. Examples of asset-specific information include: • Water pipes: diameter, pipe material, joint type, burial depth, and elevation profile where applicable • Water treatment plants: equipment inventory, equipment anchorage, equipment elevation, foundation and structure type, construction year • Pump stations: equipment inventory, equipment anchorage, equipment elevation, foundation and structure type, construction year • Water storage tanks: material, location, anchorage, foundation type, elevation relative to surrounding grade
Intra-dependencies[a]	Not typically considered	Provide qualitative narratives describing the potential for asset disruptions or failures to impact the broader water network (e.g., loss of water treatment plant would disrupt service to all customers)	Assign criticality ratings/scores to individual assets based on their importance to overall system operations and performance. Example criticality considerations include: • The number of customers potentially affected by asset disruption or loss of function • The level of redundancy (e.g., availability of alternative water sources, parallel transmission mains)	Develop a network model that explicitly captures system configuration and performance, including: • Source–treatment–transmission–distribution connectivity • Redundant supply paths and storage availability/capacity • Rerouting capability, operational flexibility (e.g., valve operations, pump controls), and temporary measures that support service continuity and recovery
Inter-dependencies[b]	Not typically considered	Identify assets dependent on external supporting infrastructure systems (e.g., power systems, upstream municipal or regional water systems) and provide qualitative narratives on the impacts of disruptions or failures in those systems.	Assign scores to individual assets to reflect their level of dependency and sensitivity to external infrastructure systems, with particular emphasis on power supply and upstream water systems.	Develop a network model of external supporting infrastructure systems (e.g., power systems, upstream municipal or regional water systems) serving the system being assessed, focusing on components directly connected to it, to quantify and incorporate the impacts of external system disruptions, degradation, or loss of function into the assessment.

The Water Infrastructure Taxonomy provides additional guidance for characterizing a water system's assets and dependencies for each Risk Class. The minimum criteria for a given Risk Class must be satisfied for all categories. It is possible to exceed the minimum criteria in a given category, but this would not constitute assignment of a higher Risk Class.

a. Relationships or dependencies between assets within a single infrastructure system (e.g., a transmission pipe delivers potable water to a network of distribution pipes).

b. Relationships or dependencies between assets across different infrastructure systems (e.g., a water treatment plant requires power to run filtration systems).

	Basic Hazard Screening Class 0	Basic Risk Screening Class 1	Enhanced Risk Assessment Class 2	Advanced Risk Modeling Class 3
Exposure and Vulnerability	Geographic distribution of assets using basic geometry (roads as polylines; bridges as points; tunnels as polylines, and culverts as points)	Geolocated assets differentiated into high-level categories (e.g., roads, bridges, tunnels, culverts, transit infrastructure) and, where appropriate, sub-categories.	Geolocated assets differentiated into relevant sub-categories based on characteristics critical to their vulnerability to natural and climate hazards. Assess vulnerability using using more refined quantitative damage and loss functions per asset sub-category. Examples of sub-classes include: • Roads: paved or unpaved, number of lanes. • Bridges: material type, structural system, construction year, number of spans. • Tunnels: one lane or multi-lane, construction year. • Culverts: type (box, pipe, open-ended, etc.), material type (concrete, metal, plastic), age of construction.	Inclusion of asset-specific information required to conduct bespoke assessments. Examples of asset-specific information include: • Roads: material, road usage type or class, pavement design parameters, foundation type/condition. • Bridges: material type, structural system, construction year, number of spans, design parameters (e.g., design loads, freeboard). • Tunnels: one lane or multi-lane, construction year, tunnel design parameters, drainage capacity, soil or rock type, presence and location of M&E equipment. • Culverts: type (box, pipe, open-ended, etc.), material type (concrete, metal, plastic), culvert design parameters capacity, or condition of culverts. • Surrounding environment: earthworks neighboring a water body, vegetation density, or potential slope instabilty.
Intra-dependencies[a]	Not typically considered	Provide qualitative narratives describing the potential for asset disruptions or failures to impact the broader road network (e.g. the impact of a major road being inaccessible is reduced if alternative routes remain accessible during the same event).	Assign criticality ratings/scores to individual assets based on their importance to overall system operations and performance. Example criticality considerations include: • Level of connectivity/redundancy • Serving equity-priority communities • Transit routes / evacuation routes • Traffic volume	Develop a network model that explicitly captures system configuration and performance, including: • Road to bridge and tunnel connectivity • Identify how damage to different segments and assets can impact network flow • Explicitly quantify traffic flow and volume • Rerouting capabilities
Inter-dependencies[b]	Not typically considered	Identify assets dependent on external infrastructure systems (e.g., power, communications) and provide qualitative narratives on the impacts of disruptions or failures in those systems.	Assign scores to individual assets to reflect their level of dependency on or sensitivity to external infrastructure systems. Examples include: • Key intersections where traffic lights and cameras are dependent on power • Revenue loss for key road sections dependent on power access to toll station or draw bridges • Importance of culverts on broader drainage systems to ensure hydraulic connectivity where needed and avoidance of drainage disruption	Develop a network model of external infrastructure systems (e.g., power, communications) that support the system being assessed, focusing on the portions directly connected to it, to incorporate the impact of external system disruptions, degradation, or loss of function into the assessment.

The Road Infrastructure Taxonomy provides additional guidance for characterizing a road network's assets and dependencies for each Risk Class. The minimum criteria for a given Risk Class must be satisfied for all categories. It is possible to exceed the minimum criteria in a given category, but this would not constitute assignment of a higher Risk Class.

a. Relationships or dependencies between assets within a single infrastructure system (e.g., a transmission pipe delivers potable water to a network of distribution pipes).

b. Relationships or dependencies between assets across different infrastructure systems (e.g., a water treatment plant requires power to run filtration systems).

	Conceptual - Class 1	Schematic - Class 2	Implementable - Class 3
Resilience/ adaptation solution maturity	Scoping and awareness only	Feasibility and preliminary budgeting only	Implementable and final cost estimates defined
Typical actions and detail	• Physical interventions: High-level concepts for strengthening, upgrading, or relocating infrastructure. • Operational measures: High-level ideation of possible operational solutions such as creating redundant systems, developing business continuity and/or emergency response plans, mitigating impeding factors that delay initiation of repair, or relocating standard functions or people.	• Physical interventions: Schematic level designs for strengthening, upgrading, or relocating infrastructure. Designs may be supported by engineering calculations. • Operational measures: Detailed scoping of operational solutions, including required level of effort and costing, and preliminary development of governance structure, supported by stakeholder engagement.	• Physical interventions: Design documents for strengthening, upgrading, or relocating infrastructure, including drawings and specifications supported by detailed engineering calculations and/or system models. • Operational measures: Governance is defined, and specific champions are identified and assigned to fully develop and implement or complete the operational resilience action or activity.
Applicability to infrastructure or organization	Generic solutions, may not be readily applicable or feasible for specific assets or the infrastructure operator/ organization	Solutions specific to general asset categories or sub-categories may be applicable and feasible for specific assets and/or the infrastructure operator/organization	Solutions are developed specifically for infrastructure assets being designed or retrofitted and the infrastructure operator/organization
Confidence level[a]	Low	Medium	High
Underlying Risk Class[b]	Class 0 or 1	Class 1 to 2	Class 2 to 3
Cost Estimate Class[c]	Class 5	Class 3 to 4	Class 1 to 2
Resilience benefits[d]	Qualitative evaluation of the benefits of resilience solutions in generic terms (e.g., risk reduction potential)	• Quantification of losses at one or more return periods to calculate avoided losses, consideration of asset life extension and discount rate. • Avoided losses include direct costs to repair damage at a minimum, but may also include lost revenues and human impacts (e.g. population/ customers affected).	• Probabilistic quantification of losses at multiple return periods to calculate annualized avoided losses, consideration of asset life extension and discount rate • Avoided losses include direct costs to repair damage, lost revenues, broader economic impacts, and human impacts (e.g. population/customers affected).
Prioritization of actions	Proxy methods considering costs and benefits independently	Semi-quantitative prioritization considering asset-category-level cost-benefit metrics[e] impact to system-level inter- and intra-dependencies, and broader resilience impacts (e.g., projects that serve vulnerable communities)	• Quantitative prioritization criteria considering project-level cost-benefit metrics[e] impact to system-level inter- and intra-dependencies, and broader resilience impacts (e.g., quantification of vulnerable people affected). • May include sensitivity analysis of costs, discount rates, monetized values assigned to revenue loss, asset life extension, and other key inputs.
Typical metrics[e]	Qualitative ratings for mitigation effectiveness and costs	• Benefit-cost ratios at various stages of life cycle at both the individual-asset and system levels. • Net present value of the cumulative discounted benefits over the asset life minus the initial cost/investment in mitigation. • Resilience payback period (i.e. time for investment to break even).	• Benefit-cost ratios at various stages of life cycle at both the individual-asset and system levels. • Net present value of the cumulative discounted benefits over the asset life minus the initial cost/investment in mitigation. • Resilience payback period (i.e. time for investment to break even).

The Resilience Class Taxonomy outlines minimum criteria to satisfy the given Resilience Class. The minimum criteria for a given Resilience Class must be satisfied for all categories. It is possible to exceed the minimum criteria in a given category, but this would not constitute assignment of a higher Resilience Class.

a. The confidence level provides an indication of the applicability of the resilience solution to the specific infrastructure asset that is being designed or retrofitted, the uncertainty in the cost, and the feasibility of implementing it.

b. The Underlying Risk Class provides a general indication of the level of risk assessment typically required to support the development of resilience solutions to the degree outlined in each Resilience Class. It may be possible, however, to arrive at implementable solutions (i.e., Resilience Class 3) via a Risk Class 0 or 1 assessment; in other words, there may exist no regret or low regret physical interventions and/or operational measures (e.g., business continuity and/or emergency response planning, early warning systems, training and development programs) that make sense to pursue even in the absence of advanced risk analysis.

c. The AACE International Cost Estimate Classification System provides guidelines for applying the general principles of estimate classification to project cost estimates, using the maturity level of project definition to map the stages of cost estimating against scope-definition and quality matrix.

d. Due to the potentially significant and widespread impacts of damage and disruption to infrastructure systems, it may be beneficial to include a broader set of resilience considerations when evaluating the benefits of potential solutions and projects, including protection of disadvantaged communities and/or important ecosystems.

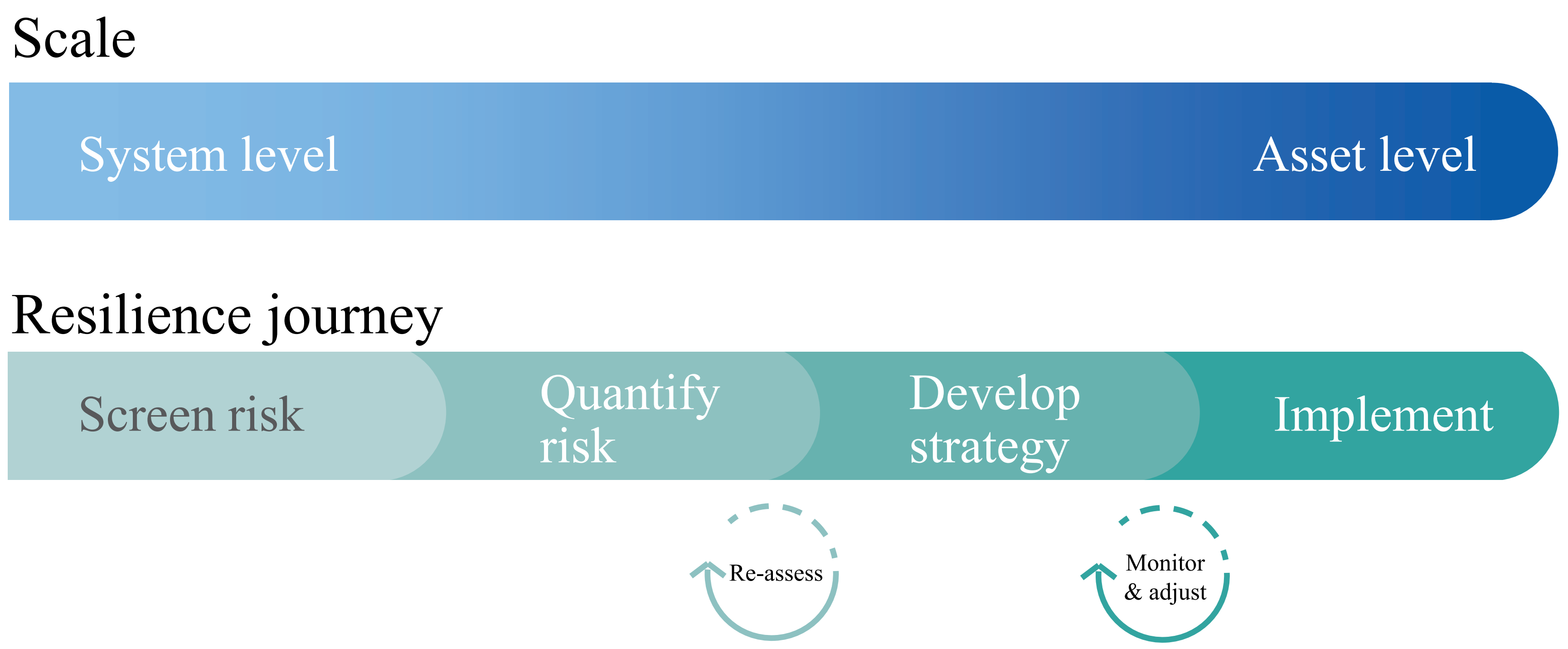
e. Cost-benefit analysis is not required to achieve a Resilience Class but it would support the business case for implementing a solution. Deterministic cost-benefit analysis (i.e., one that assumes the likelihood of occurrence is certain) would overestimate the benefit-cost ratio and is not recommended. For broader consideration of investment prioritization, financial cost-benefit data can be included in multi-criteria decision frameworks that also weigh more qualitative factors such as co-benefits of resilience actions towards sustainability, equity, or policy goals.

User personas

Introduction

User personas are semi-fictional representations of the intended users of this framework. They represent specific roles and responsibilities within an organization that are most likely to find the taxonomies helpful to address their specific needs around risk and resilience topics.

The purpose of this section is to allow readers to align themselves with selected user personas that demonstrate how the taxonomy can support their needs along a typical resilience journey specific to their role.



Multilateral disaster & climate risk specialist

Organization type

Multi-lateral Development Bank (MDB)

Typical titles

Disaster Risk Sector Lead, Climate Risk Sector Lead

Use case

Multi-sector risk assessment at country level to inform the Development Strategy for a Country

> “As a consumer of risk information with subject matter expertise, I want to assess risk for infrastructure at the country or regional (multi-country level) so that I can:
>
> 1. Inform baseline diagnostics to start strategic dialogues with Borrowers to set priorities
> 2. Develop country and/or sector development strategies that consider disaster risk and resilience priorities for investment

Scale

Resilience journey

Example user journey

1. Undertake or procure a **Class 1** Risk Assessment for the infrastructure system(s) that comprise a given sector of interest (e.g., transport, energy, water, telecommunications) at a country or regional level for all hazards that could have a material impact. The assessment should include probabilistic hazard data and the outputs should consist of risk metrics aggregated at the geographic (e.g., sub-regional, for example at province or district level according to the required level of decision making) and sector level.
2. Identify resilience needs and recommendations at geographic and sector level per **Resilience Class 1** to make prioritization, financing, investment or technical cooperation decisions, and to inform the development of a pipeline of programs or projects.
3. Implement the results of the decisions made in Step 2, which may be compiled in a Country Strategy document or a Sector Strategy Document, or hand off specific activities or projects to Project Leads.

Multilateral infrastructure specialist

Organization type

Multi-lateral Development Bank (MDB)

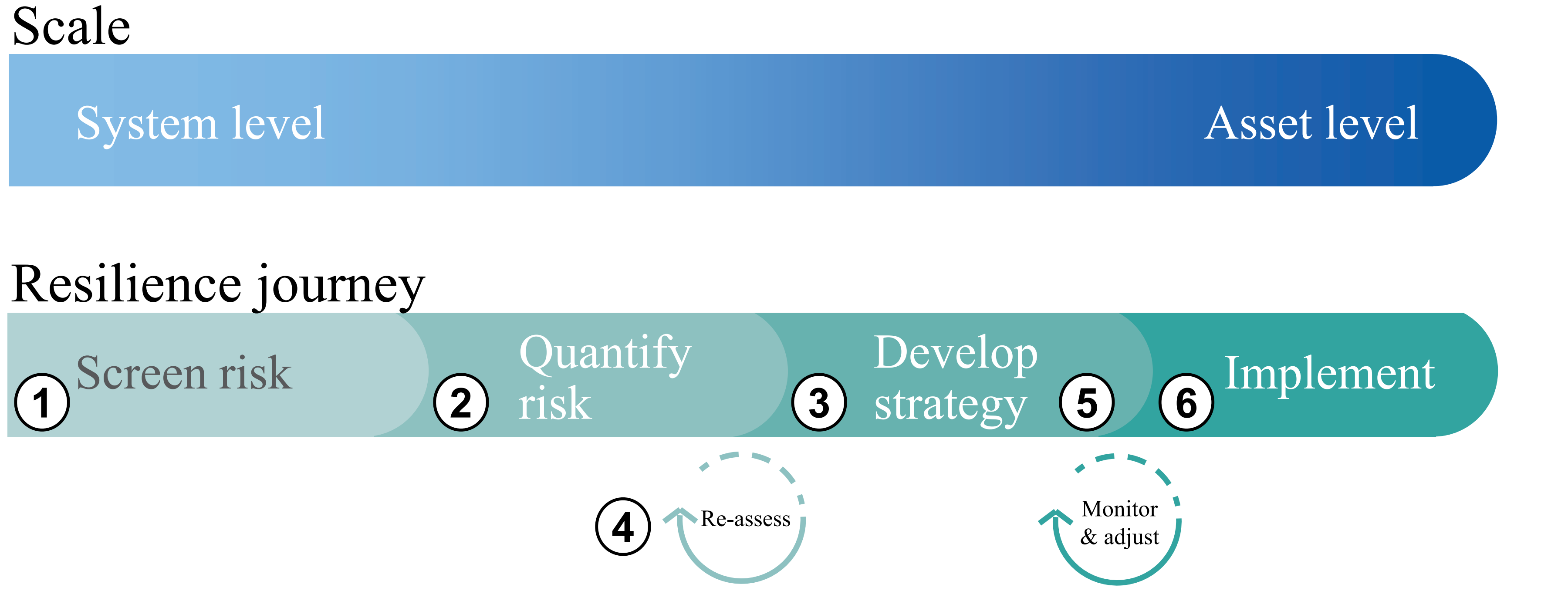
Typical titles

Infrastructure Sector Project Team Leader (e.g., transport, energy, water and sanitation)

Use case

Project or operation-specific (new or existing infrastructure) risk assessment & development of resilience strategy

> "As a layperson consumer of risk information, I want to assess risk for an infrastructure network within a specific geographic area in my project pipeline so that I can:
>
> 1. Align with Bank policies and commitments to unlock project funding
> 2. Inform due diligence during project preparation
> 3. Inform resilient design or retrofit



Example user journey

1. Undertake (led by the Project Team or the ESG/Risk/Climate Division supporting the Project Team) a **Class 0** Hazard Exposure Assessment or a qualitative **Class 1** Risk Assessment as a quick screening of the individual segment / corridor of linear infrastructure or individual infrastructure asset for all hazards that could have a material impact aligned with internal MDB procedures. An initial Risk Category may be assigned to the Project and this will determine the minimum requirements going forward during Project Preparation.
2. If flagged as needing further assessment by Step 1, procure a **Class 1** or **Class 2** Risk Assessment for prioritized hazards identified in Step 1, following the Project Preparation workflow and milestones.
3. For Project Preparation, identify resilience measures and budgets, per **Resilience Class 1** or **2**, and use these to inform Project Preparation documents and requirements.
4. *Optional* – If significant risk was identified that threatens project viability, and major resilience interventions are needed, re-assess risk for each candidate resilience strategy to determine risk reduction effectiveness employing a **Class 2** Risk Assessment (minimum).
5. *Optional* – Use results to make an alternative design or retrofit decision to achieve project viability.
6. During Project Implementation, hand off to design consultants to develop resilience-based design requirements for new construction or retrofit of existing construction to a **Resilience Class 3** level.

Government resilience lead

Organization type

National or sub-national resilience department (risk management, emergency management, climate resilience agencies)

Typical titles

National or City Disaster and Climate Resilience Director / Hazard Mitigation Manager / Sustainability Director

Use case

Multi-sector risk assessment for infrastructure to inform national-level strategy

> "As a consumer of risk information with subject matter expertise, I want to assess risk to key infrastructure systems at the highest level of aggregation for a geographical region (country, state, city) so that I can:
>
> 1. Inform baseline diagnostics to identify institutional capacities and needs
> 2. Inform public policy development

Scale

Resilience journey

Example user journey

1. Undertake or procure a **Class 1** Risk Assessment for the infrastructure system(s) that comprise a given sector of interest (e.g., transport, energy, water and sanitation, telecommunications) at a national, subnational or local level for all hazards that could have a material impact. The assessment should include probabilistic hazard data and the outputs should consist of risk metrics aggregated at the desired geographic and sector level.
2. Identify resilience needs and recommendations at the desired geographic and sector level per **Resilience Class 1** to make planning, financing or investment decisions, and to inform the development of a pipeline of infrastructure programs or projects.
3. Have discussions and advise infrastructure or public works departments / ministries about identified risks. Optionally, this may lead to a more detailed **Class 2 or 3** Risk Assessment, as needed to increase granularity and level of confidence for a specific infrastructure sector or geography.

Public or private infrastructure owner

Organization type

Government or public infrastructure authority owning infrastructure assets, private entity in charge of operating critical infrastructure

Typical titles

Sector Officer (e.g., officer in a transportation, energy or water authority), Infrastructure Operations Lead

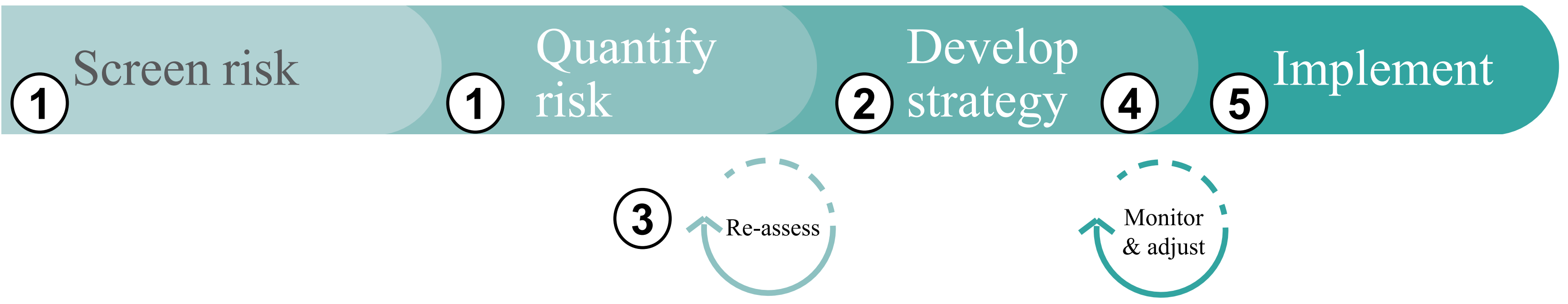
Use case

Project-level (new or existing infrastructure system) risk assessment & development of resilience strategy to minimize service disruptions

> "As a layperson consumer of risk information, I want to assess risk for a specific infrastructure system, project or asset in my portfolio so that I can:
>
> 1. Inform risk management processes / practices
> 2. Inform investment decisions including the need for resilient design or retrofit
> 3. Align with national or local policies to unlock project funding

Scale

Resilience journey



Example user journey

1. Procure a **Class 1** (if there is a long list of hazards to screen out) or **Class 2** (if prioritized hazards have already been identified) Risk Assessment of the infrastructure system(s) and assets for all hazards that could have a material impact aligned with national or local procedures.
2. Identify resilience measures and budgets, per **Resilience Class 2**.
3. Procure a re-assessment of risk for each candidate resilience strategy to determine risk reduction effectiveness employing a **Class 2**.
4. Use results to make decisions on: site selection, alternative design, retrofits, adjusting operational procedures, or new investments.
5. Hand off to design consultants to develop resilience-based design requirements for new construction or retrofit of existing construction, and develop operational resilience procedures to a **Resilience Class 3** level.

Investor resilience lead

Organization type

Enterprise, Financing / Investment Banking, Asset Managers, Pension Funds

Typical titles

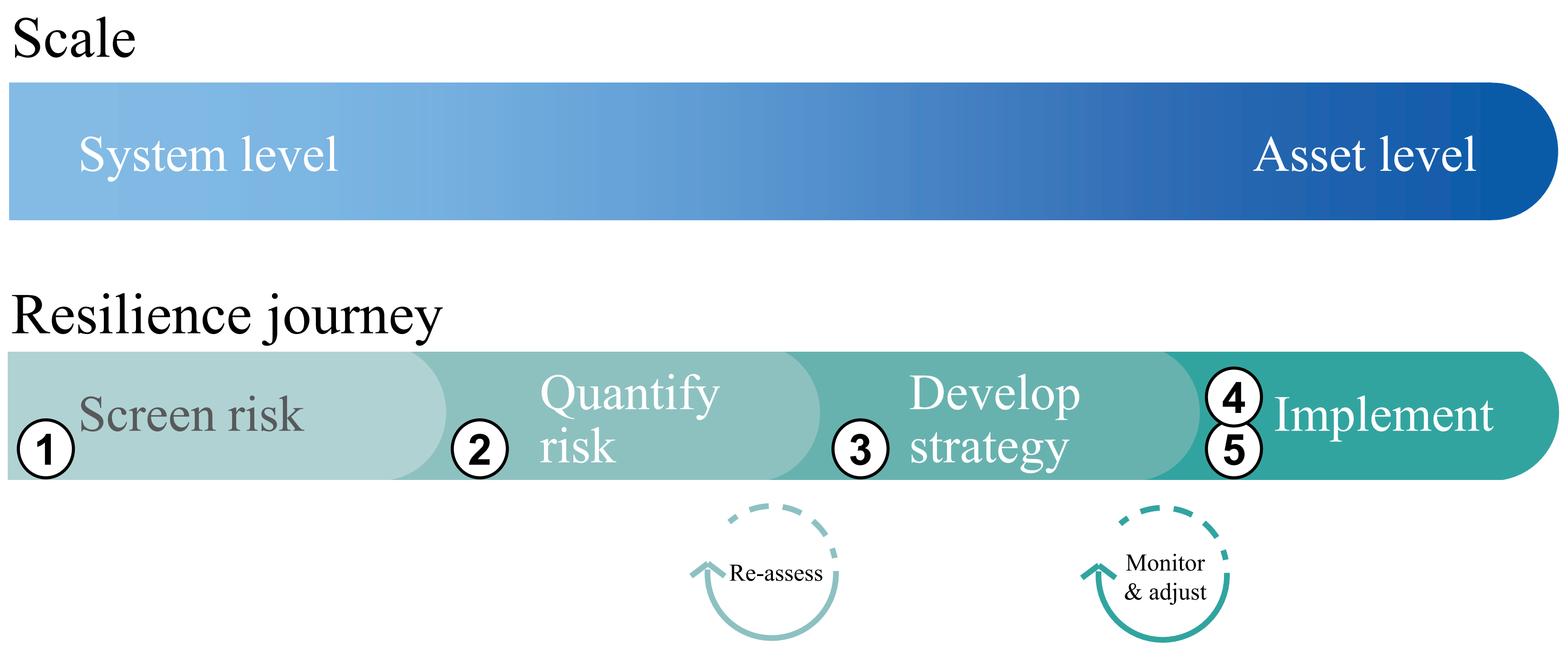
Chief Sustainability Officer, ESG Lead, Climate Adaptation Lead

Use case

Risk assessment for existing infrastructure portfolio

"As a consumer of risk information with subject matter expertise, I want to assess business and safety risks for my organization's portfolio of infrastructure assets so that I can:

1. Identify overall portfolio exposure and risk
2. Communicate risk to leadership
3. Report / disclose



Example user journey

1. Undertake or procure a **Class 1** Risk Assessment of the infrastructure portfolio for all hazards that could have a material impact as a basic screening (skip to Step 2 if top hazards are already known). To satisfy minimum reporting requirements, skip to Step 3.
2. Procure a **Class 2** Risk Assessment for prioritized hazards and/or infrastructure assets identified in Step 1.
3. To satisfy minimum reporting requirements only, identify resilience measures per **Resilience Class 1** and skip to Step 5. Otherwise, identify resilience measures and budgets per **Resilience Class 2 Risk Assessment (at a minimum)**.
4. Implement the strategy from Step 3 and identify measures to manage any residual risk.
5. For reporting only, submit disclosures.

Infrastructure investment manager

Organization type

Enterprise, Financing, Investment Banking, Asset Manager, Pension Funds

Typical titles

Head of Investment, Infrastructure Lead, Investment Manager

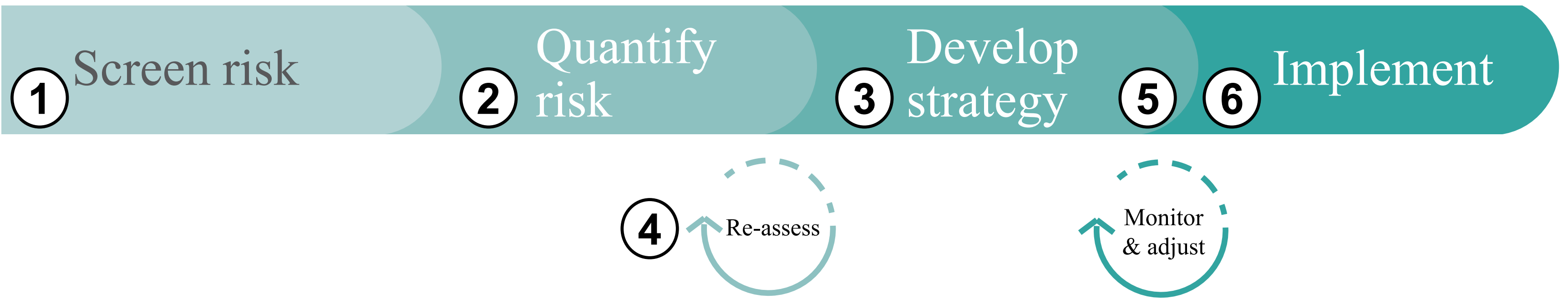
Use case

Risk assessment & identification of required resilience capex for existing or new infrastructure system in a prospective investment deal

> “As a layperson consumer of risk information, I want to assess risk for a specific infrastructure system in my portfolio so that I can:
>
> 1. Inform due diligence during new investment or acquisition transactions
> 2. Inform any need for incremental resilience CapEx and OpEx

Scale

Resilience journey



Example user journey

1. Undertake or procure a **Class 1** Risk Assessment of the individual infrastructure system(s) or individual asset(s) for all hazards that could have a material impact (skip to Step 2 if top hazards are already known).
2. Procure a **Class 2** Risk Assessment for prioritized hazards identified in Step 1.
3. For due diligence, identify resilience measures and estimate any needed resilience costs (CapEx and OpEx), per **Resilience Class 2**.
4. Re-assess risk for each candidate resilience strategy to determine risk reduction effectiveness and estimate benefits (avoided costs) employing a **Class 2** Risk Assessment.
5. Use results to make a divestment, acquisition or additional resilience investment decision.
6. *Optional* – Hand off to design consultants and/or project developer or owner to update resilience-based design requirements for new construction or to design and cost any needed resilience enhancements of existing construction to a **Resilience Class 3** level.

Financial protection and insurance specialist

Organization type

Enterprise, Corporate, Insurance

Typical titles

Chief Financial Officer, Insurance Officer

Use case

Risk assessment & identification of financial protection strategy for existing infrastructure portfolio

> "As an experienced consumer of risk information, I want to assess business and safety risks for my organization's portfolio of infrastructure assets so that I can:
>
> 1. Report / disclose
> 2. Procure optimal financial protection through insurance or other risk retention and risk transfer instruments

Scale

Resilience journey

Example user journey

1. Undertake or procure a **Class 1** Risk Assessment of the infrastructure system(s) for all hazards that could have a material impact across selected sectors as a basic screening (skip to Step 2 if the top hazards are already known).
2. Procure a **Class 2** Risk Assessment for prioritized hazards identified in Step 1. The hazard assessment should include probabilistic hazard data and the outputs should consist of quantitative risk metrics, including quantitative financial losses for the existing conditions.
3. Identify financial risk management, protection and transfer recommendations. Identify residual financial risk for each strategy.
4. Finalize optimized financial risk management strategy based on risk layering, cost-benefit, and financial feasibility analysis of options.
5. Use results to make financing, investment and/or insurance decisions, and to inform the development or update of risk management and transfer instruments and offerings.
6. Monitor and adjust the financial strategy if the portfolio risk profile changes over time.

Introduction
Multilateral disaster & climate risk specialist
Multilateral infrastructure specialist
Government resilience lead
Public / private infrastructure owner
Investor resilience lead
Infrastructure investment manager
Financial & insurance specialist
Risk and resilience practitioner

Risk and resilience practitioner

Organization type

Consultant, Engineering firm, Academia

Typical titles

Risk Analyst, Risk Engineer, Resilience Consultant

Use case

Project-level (new or existing assets) risk assessment & development of resilience strategy

> "As a producer of risk information with subject matter expertise, I want to assess operational, safety and disaster risk for a specific client's infrastructure system so that I can:
>
> 1. Screen out negligible risks
> 2. Evaluate higher risks to identify risk drivers and opportunities
> 3. Develop a set of resilience measures to inform my client's Resilience Strategy

Scale

Resilience journey

Example user journey

1. Undertake a **Class 0 or 1** Risk Assessment of the infrastructure system(s) or individual infrastructure asset for all hazards that could have a material impact as a basic screening (Skip to Step 2 if top hazards are already known).
2. Undertake a **Class 2** Risk Assessment for prioritized hazards and/or assets identified in Step 1. Assess the need for more detailed **Class 3** Risk Assessment.
3. Identify resilience measures and budgets, per Resilience **Class 2** (minimum).
4. Re-assess risk for each candidate resilience strategy (i.e. compilation of measures) to determine risk reduction effectiveness employing a **Class 2** or **Class 3** Risk Assessment.
5. Finalize resilience strategy based on cost-benefit or multi-criteria analysis of each strategy. Develop candidate resilience measures per **Resilience Class 3**.
6. Use results to inform the development or update of the system's or asset's design requirements and to directly influence the design process, and/or to carry out physical protection or correction interventions, retrofit and/or non-structural soft or operational measures to increase adaptive capacity.

Glossary of terms

Adaptation

Actions or measures taken as part of an overarching risk management process (see Risk management) to lessen the physical and/or operational impacts of primarily climate-related hazards.

Adaptive capacity

The ability to adjust to changing conditions, moderate potential damages, take advantage of opportunities, or cope with the consequences of disruptions

Asset category

Describes different groupings of infrastructure assets based on characteristics critical to hazard-specific vulnerability. For a road network, asset categories may include roads, bridges, tunnels, and/or culverts. Asset categories should be consistent with existing taxonomies developed by the infrastructure owner/operator.

Asset sub-category

Describes different sub-groupings of assets within a category. For a road network, asset sub-categories may include unpaved and paved roads, with further breakdown of paved roads possible (based on pavement material, for example).

Climate risk

The likelihood and severity of impacts to people, buildings, infrastructure, organizations, or communities, resulting from the physical effects of climate-related events, such as hurricanes, heatwaves, and wildfires, measured in social and economic terms, and exacerbated by climate change effects.

Climate scenarios

A combination of an emission / concentration / radiative forcing scenario and a selected future time frame. Could also be used to describe current or present-day baseline conditions.

Consequence types

Risks are expressed in relation to a certain consequence type. For infrastructure, these could include downtime, repair costs, lost revenue, and service disruption.

Criticality

Reflects the importance of an individual asset to the successful functioning of the infrastructure system. Criticality can be described qualitatively (e.g., low, medium, high) or can be derived from the relationships defined in an advanced network model.

Downtime

The time required to achieve a defined recovery state for an infrastructure asset or system after a hazard event has occurred.

Extreme Value Analysis

A statistical method used to estimate the probability of rare values of a natural hazard variable by fitting probability distributions to observed or modeled data and extrapolating beyond the historical record. It is used to derive return periods and exceedance probabilities.

Exposure

Any physical element(s) that coincides in time and space with a natural hazard. For infrastructure systems, exposure is characterized by an asset's location, function, physical properties, contents, and replacement value.

Fragility functions

Relate hazard intensity metrics (e.g., 3-sec gust wind speed) to the probability that specific infrastructure asset may incur discrete damage states of increasing severity and/or extent.

Hazard

The potential intensity of a particular natural physical event that can cause physical impacts to infrastructure assets, users, and/or operators. The hazard intensity is measured at the asset location and can be deterministic (i.e., for a single defined event such as a M7 earthquake) or, preferably, probabilistic, such that each intensity magnitude corresponds to a likelihood or probability of occurrence. The latter is typically expressed as return periods or probability of exceedance in a given year or over a specified multi-year or decade time horizon. Hazard data is typically derived from historical observations and extrapolated to estimate future rare events (that may not have previously occurred in the documented history) using extreme value analysis or stochastic event sets. Climate change effects can be incorporated to augment the hazard for a specified emissions scenario and time horizon (e.g., SSP5-8.5, 2070).

Monte Carlo simulations

A widely used method for quantifying uncertainty in risk analysis utilizing probabilistic sampling techniques to capture randomness associated with uncertainty in each variable of the risk assessment.

Glossary of terms

Infrastructure asset

A physical component of an infrastructure system that performs a specific function and supports service delivery. It is the individual unit evaluated in a risk assessment (e.g., a substation, pump station, transmission line segment, or road segment).

Infrastructure system

A network of assets that work together to provide important services (e.g., electricity, potable water) to a community or region.

Intra-dependencies

Relationships or dependencies between assets within a single infrastructure system (e.g., a transmission pipe delivers potable water to a network of distribution pipes).

Inter-dependencies

Relationships or dependencies between assets across different infrastructure systems (e.g., a water treatment plant requires power to run filtration systems).

Resilience

Resilience is the ability to adapt to, withstand, and/or recover rapidly from the effects of a hazard. To the extent that infrastructure systems support communities, institutions, businesses and systems in fulfilling their basic needs, core services, or mission, they perform a crucial role in resilience.

Resilience Class

Defines the level of detail and maturity for resilience and adaptation solutions recommended for planning, budgeting, costing, and implementation purposes.

Risk

Describes the likelihood of incurring a certain magnitude of loss or consequence, derived by integrating hazard, exposure, and vulnerability. When practical and appropriate, it should be underpinned by quantitative analysis and risk metrics, but can be expressed in descriptive terms (e.g., high, medium, or low) or as scores for communication purposes. See Risk metrics.

Risk Class

Defines the level of detail in a risk assessment recommended to support certain decisions with sufficient confidence in consideration of their cost or complexity, primarily around resilience actions.

Risk management

A process that includes risk identification, quantification, prevention, adaptation, and risk transfer for known risks and adaptative capacity to manage both known and unknown risks.

Risk metrics

Risk metrics measure the intensity of the risk to an asset and can be expressed in annualized terms, the probability of exceeding a certain loss threshold (e.g. number of days of downtime) over a given time horizon, or losses corresponding to a given hazard intensity level (with a defined likelihood or return period) or scenario event.

Shared fate risks

The risks determined from impacts of a single hazard event (e.g. Hurricane Sandy) on multiple assets simultaneously, either geo-spatially distributed or generally centralized on a campus or neighborhood.

Stochastic event sets

Typically used in the context of hazard modeling, the development of stochastic event sets using Monte Carlo techniques (or other sampling techniques) to "simulate" hypothetical future hazard events like hurricane/cyclone tracks and corresponding windspeed fields. The results can be used to quantify the hazard at a single site or provide realistic scenarios for assessing shared fate risk (see above).

Vulnerability

The susceptibility of an asset within an infrastructure system to be damaged or impaired by a hazard event. Often quantified through mathematical functions relating hazard or demand parameters to the extent and severity of damage to the asset (see Fragility functions and Vulnerability curves).

Vulnerability curve

Relates hazard intensity metrics to the expected loss in terms of the consequence type, often derived from empirical models or physics-based models.

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