The World Bank Group

Incorporating Climate Risk in PBC

Risk Management Framework

Task 3 Report

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WORLD BANK GROUP

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1 Executive Summary

Climate change is directly affecting the transportation industry through reduced functionality of access pathways for people, goods and services. Loss of access to critical human services severely impacts economic development in the regions that most need growth, and consequently are often the most exposed to climatic shocks and stresses. As the climate models continue to show greater extremes, there is greater uncertainty and greater risk to roadways investments, especially within the performance-based contracting (PBC) model, which relies on successful results.

Managing these uncertainties is key to development successful, resilient roadways through the PBC model. In order to effectively protect the essential investments being made in World Bank client countries, it is necessary to accurately predict and value climate impact such that adaptation measures can be integrated into contracting terms. Further understanding these critical points allows for reallocation of risk to the stakeholder parties best suited for handling the impacts. If these issues can be addressed, it will significantly aid in the establishment of a more resilient infrastructure development community.

Climate Risk Management Framework

In order to organize these questions, the World Bank and its partners have developed a five-step stress test approach that aims to provide guidance for considering the uncertainty of climate change in PBCs. The framework has been laid out to drive roadway resilience in a responsible and cost effective manner based not only on future climate projections, but also on prioritization of investment to meet the many demands transport agencies are facing globally.

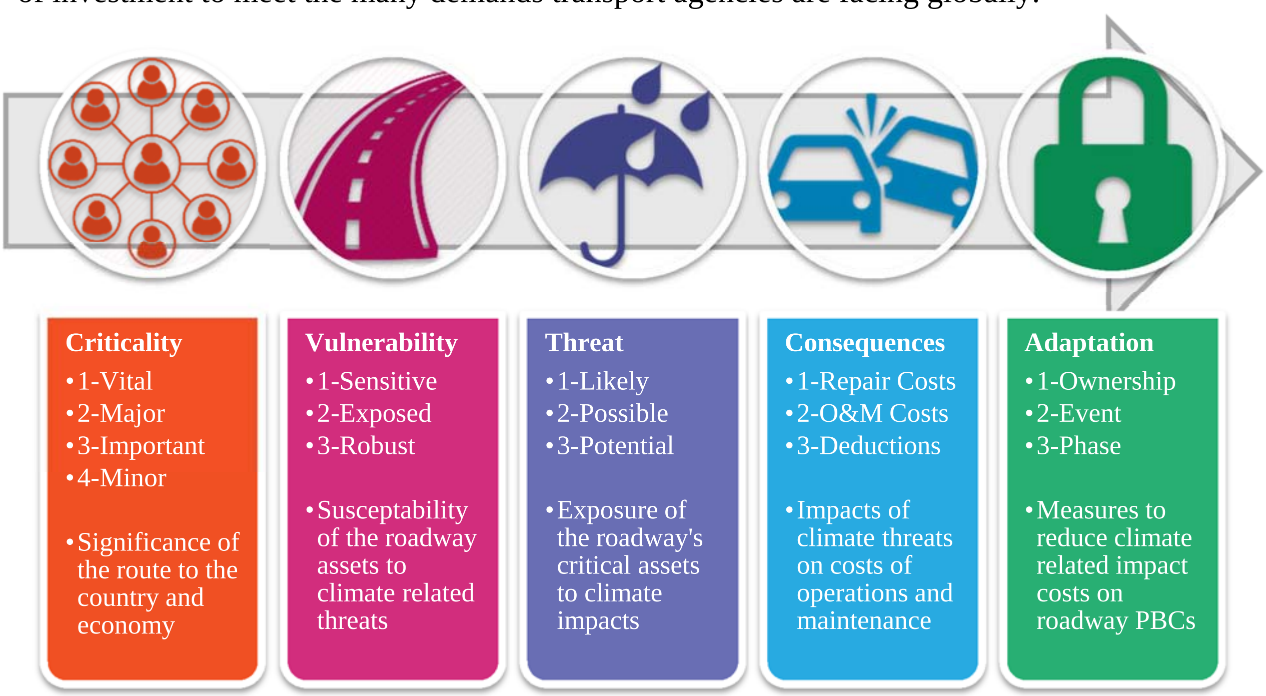


Figure 1 Overview of Risk Assessment Framework

2 Framework Background

The risk management framework has been developed in order to rate roadways on their vulnerability to climate impacts, their overall criticality to the larger transport system and their potential exposure to climate change. The consequences of those impacts and recommended risk mitigations are generated using a stress test decision tree assessment methodology inclusive of the outputs from each section of the five-step analysis process.

The stress test process considers key input information related to the roadway assets to determine which resilience measures should be incorporated into the design and contracting documents of the project. Asset owners (client countries and transportation ministries) will need to fill in the relevant information in each section in order to calculate potential consequences and recommended contract adaptation measures pertinent to that specific roadway asset or set of assets. The overall approach and anticipated outcomes are detailed below.

2.1 Stress Test Decision Tree

Each step of the process provides framework users with information to determine the scaled ranking of risk input data. These statistics feed into the risk assessment methodology following standard risk quantification practices of probability and consequence collation. The risk assessment logic used in this tool is detailed on the following page.

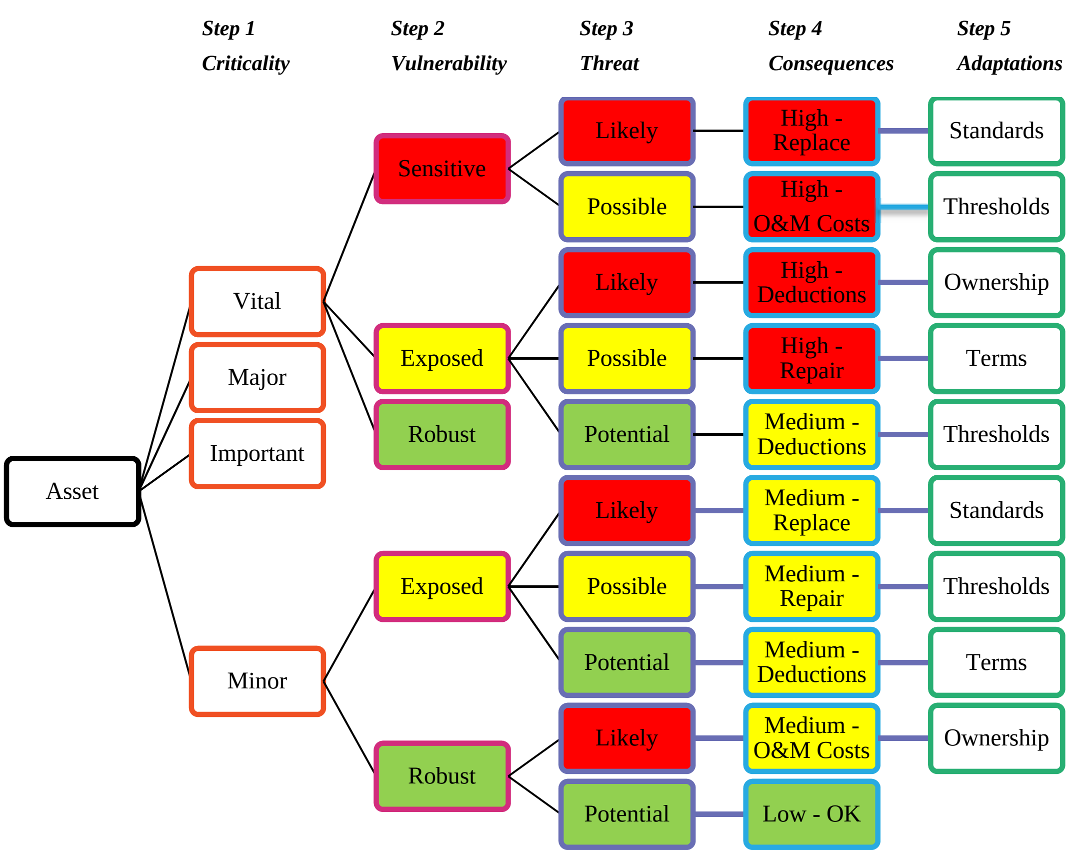


Figure 2 Stress Test Decision Tree Example

3 Risk Assessment Methodology

Climate related risk is particularly hard to estimate due to the vast uncertainty associated with climate change. There is uncertainty associated with what **Global Climate Model (GCM)** to use in any particular location, what **Representative Concentration Pathway (RCP)** is most likely occur at each time horizon and what confidence interval is reasonable to design to. In order to provide practical contracting recommendations, the proposed methodology attempts to link decisions around these uncertainties to asset specific data.

Since GCMs and RCPs changes vary around the globe, they need to be determined based on location of the project and an indicative point along the time horizon. To simplify this complicated projection process, the methodology uses expected asset life to determine time horizon (10 years, 20 years, 50 years) and regional criticality of the route to set a reasonable confidence interval (95th, 75th , 50th , 25th) for data.

GPS locations indicate which specific threats (temperature, precipitation, wind, SLR) are applicable along the route. GIS and risk modeling will inform the probability of shock and stress events (as well as compounding smaller events) occurring for each of these threats, in the geographic region.

3.1 Risk Determination

The proposed methodology follows three key PBC industry themes of risk understanding:

a) identification,
b) valuation and
c) allocation,

…through a multi stakeholder information gathering process. Inputs gathered during steps 1 – 3 are combined to identify risks, during step 4 to quantify the consequences and during step 5 to recommend adaptation measures.

The framework links the pertinent pieces of information associated with the asset using a traditional risk identification matrix. The criticality of the roadway route is determined based on its social and economic functions in the region (detailed on page 5) and its vulnerability is based on location and expected material performance life (detailed on page 7). The expected probability of threat exposure is informed using proximity factors (detailed on page 9) along with confidence (guided by route criticality), and time horizon selection (guided by material vulnerability).

Actual quantification of risk is determined in Step 4 using cost input data associated with probable losses such as replacement material costs, repair labor costs, increased operational costs and KPI deduction rates.

Figure 3 Risk Identification Matrix

Climate Change Threat Probability (Step 3)	Likely	**Medium**	**Medium**	**High**	**High**
	Possible	**Low**	**Medium**	**Medium**	**High**
	Potential	**Low**	**Low**	**Medium**	**Medium**
		Minor (use 25th)	Important (use 50th)	Major (use 75th)	Vital (use 95th)
		Route Criticality (Step 1)			

4 Evaluation Process

The five-step process requires gathering a concise quantity of data correlated with each roadway sub-asset to diminish the uncertainty associated with climate change and calculate a reasonable risk exposure. These inputs have been simplified to allow for efficient assessment of climate related natural hazards and disaster risks that are appropriate in the context of global roadways. Individual data input parameters have been collected from published tools to assess the vulnerability of road assets and routes to current and future climate and geological events as well as determining the adequacy of existing and future road assets to resist and adapt to these climate related impacts.

The process has been designed to be feasible for replication globally and allow for quick prioritization of threats and associated cost implications. The objective is to develop reasonable loss projections as a result of climate events and use these to inform region appropriate contractual adaptation measures (threshold definition, project phase specifics, risk ownership).

Data Needs

- Socio-economic metrics
- GIS-based maps
- Areas with higher hazards and exposure/vulnerability along the selected routes.
- Areas that are more vulnerable to natural hazard in terms of likelihood of occurrence and consequences.

The step by step inputs to the framework are designed to quantify risk for better allocation and are described in detail on the following pages. The factors with greater weight are indicated with

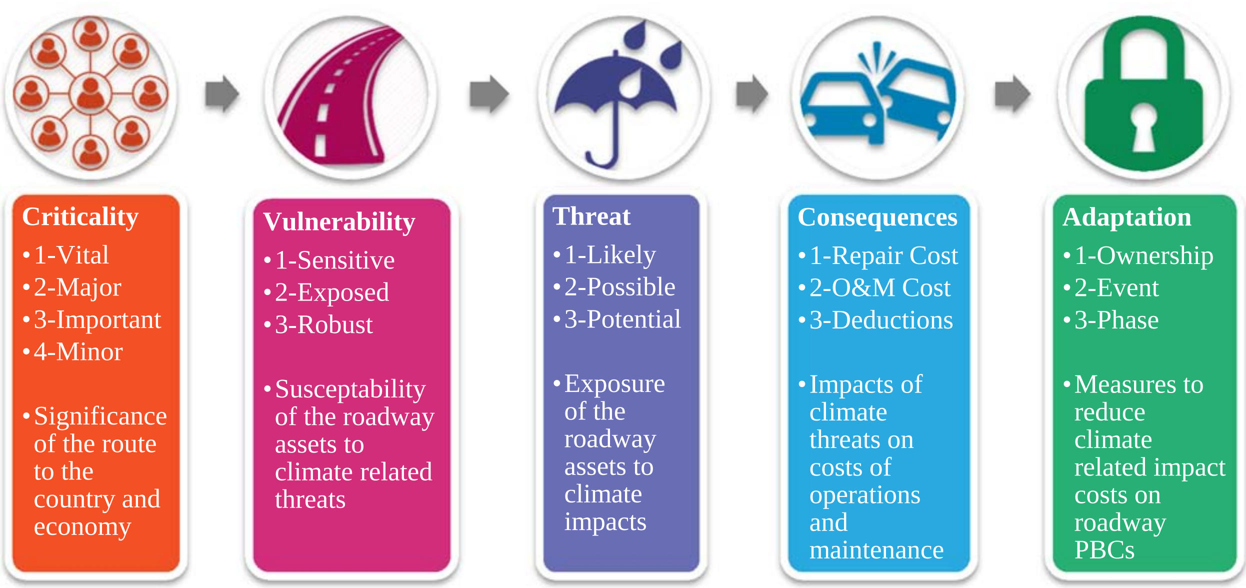


Figure 4 Risk Assessment Process

Each step description is followed by an **Example** of how that step of the management framework would be applied to a typical route

4.1 Step 1: Determine Asset Criticality

A roadway criticality determination should be made using relevant route specific data provided by the client country with consideration of trans border trade, regional emergency planning, long range planning and humanitarian needs.

The key factor in determining asset criticality is the roadway classification but this value can be upgraded or downgraded by other important roles the route may serve. These may include utilities that run in the route or access to key infrastructure assets that may be cut off by route disruption. It should also take into account what social needs will be impacted by service interruption of the roadway. It is important to consider the effect of these outages on both human life and economics.

Figure 5 provides an overview of the various considerations and prompt questions that the client country can reference to assist in making the criticality determination. The criticality determination will be translated into future climate projections by designating a confidence interval for identifying the applicable climate projections under both the RCP4.5 and RCP8.5 emissions pathways.

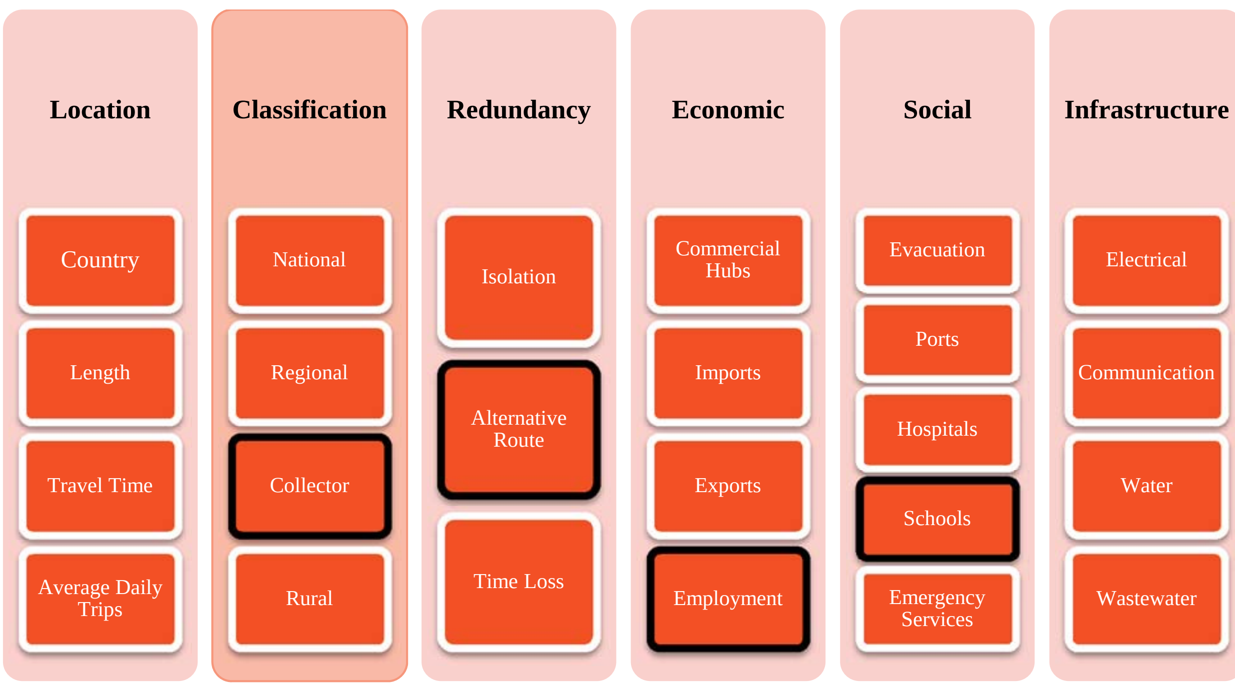


Figure 5 Criticality Considerations

Example: *A 60km collector roadway in Tonga provides access to employment and local schools. There is another 80km alternative route that takes 30 minutes longer, but all of the water and communication lines that supply the community are in route A.*

*The route should be upgraded from important (collector routes) to **Major** based on utilities*

Table 1 Criticality Inputs

	**Determine overall criticality of roadway - the more critical the roadway, the higher the confidence percentile to be used**			
	Vital	**Major**	**Important**	**Minor**
Usage Definition				
Location:	*Country*			
Begin/ End	*GPS*			
Length	*Km*			
Travel Time	*Hours*			
Average Speed	*KPH*			
Average Daily Trips	*#*			
Classification:	*National*	*Regional*	*Connector*	*Rural*
Redundancy:	*0*	*1*	*2*	*more*
Is there another road/alternative route nearby?	*Yes*	*No*		
Time on alternative route	*NA*	*Hours*		
Number of people isolated by road loss?	*NA*	*#*		
Economic:				
Does this road connect commercial hubs?	*Yes*	*No*		
Does this road serve as a route for import goods? (food/products)	*Yes*	*No*		
Does this road serve as a route for export goods? (agriculture/raw materials)	*Yes*	*No*		
Does this road provide access to employment?	*Yes*	*No*		
Social: Does this road provide direct access to:				
- Evacuation Routes?	*Yes*	*No*		
- Ports (air/or marine)?	*Yes*	*No*		
- Schools or childcare?	*Yes*	*No*		
- Hospitals or eldercare?	*Yes*	*No*		
- Police stations or military facilities?	*Yes*	*No*		
- Fire stations or Emergency facilities?	*Yes*	*No*		
Infrastructure: Does this road provide direct access to or contain:				
- Water utilities?	*Yes*	*No*		
- Energy utilities (e.g., substations)?	*Yes*	*No*		
- Telecomm utilities?	*Yes*	*No*		
- Wastewater utilities?	*Yes*	*No*		

4.2 Step 2: Determine Asset Vulnerability

The physical vulnerability of the roadway will help determine which climate related threats are most likely to negatively affect the asset components and which adaptation measures will provide the most value and risk mitigation over time.

Roadway vulnerability is based on physical conditions of the roadway assets. Some of these may be intrinsic to the location such as terrain and geology but elements of the design such as geometry, drainage and surface material selections may drastically improve the assets resilience.

Roadways designed and constructed in a manner that indicates a longer physical life expectancy will be assessed using longer time horizons for climate change. Routes that are constructed of materials that are expected to be replaced in 10 years such as gravel surfacing or temporary paving will be planned in the manner that fits their expected usefulness. These routes can be upgraded later based on planning at that time which reduces overdesign and inefficient spending

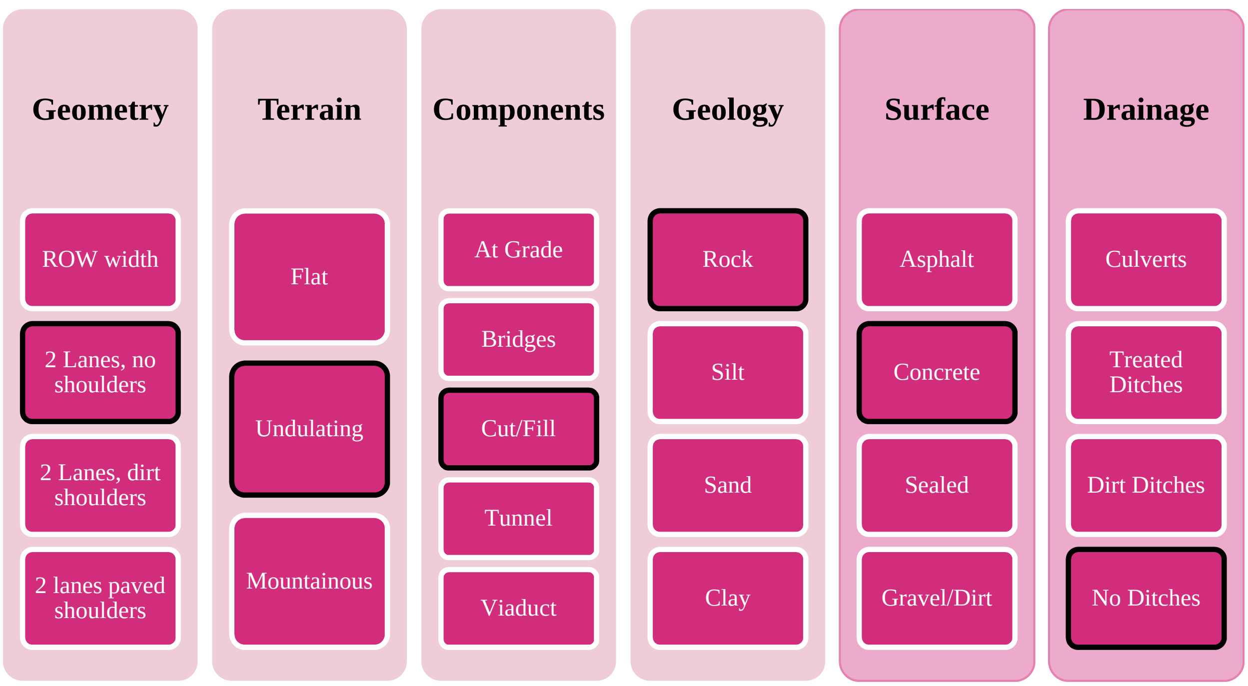


Figure 6 Vulnerability Considerations

Example: *The 2 lane roadway is paved with concrete and set in a rocky, undulating terrain. The design combines at grade and cut and fill sections with very few dirt ditches.*

The roadway should be downgraded from robust (concrete), to ***Exposed*** *based on poor drainage conditions.*

Table 2 Vulnerability Inputs

	Identify materials and other parameters of the roadway that indicate performance		
	Sensitive	**Exposed**	**Robust**
Physical Definition			
Design:	A	B	C
Width of ROW	*Meters*		
Lanes	*#*		
Shoulders	*no shoulders*	*dirt shoulders*	*paved shoulders*
Terrain per standard design guidelines:	*Flat*	*Undulating (rolling)*	*Mountainous*
Asset Components:	*Km*	*Sub areas add granularity*	
- At Grade	*meters*		
- Bridge	*meters*		
- Cut	*meters*		
- Fill	*meters*		
- Tunnel	*meters*		
- Viaduct	*meters*		
Geology Soil condition:			
- Rock	*meters*		
- Silt	*meters*		
- Sand	*meters*		
- Clay	*meters*		
Surface Materials:			
- Asphalt Paved	*Cubic meters*		
- Concrete Paved	*Cubic meters*		
- Gravel	*Cubic meters*		
- Sealed	*Cubic meters*		
- Dirt	*Cubic meters*		
Drainage:			
- No ditches	*meters*		
- Ditches – dirt	*meters*		
- Ditches – treated	*meters*		
- Culverts	*meters*		

4.3 Step 3: Determine Climate Threat

Once the roadway criticality level and asset vulnerability have been determined, this information can be used to identify an appropriate planning horizon (based on life cycle of asset materials). Applicable climate impacts can be designated by leveraging data from the climate models within the IFC Climate and Disaster Risk Screening tool, using GPS coordinates. These can in turn help to determine the future climate exposure and the associated design inputs required for the roadway.

The confidence intervals are based on the criticality determination, as follows:

- Vital = 95th percentile
- Major = 75th percentile
- Important = 50th percentile
- Minor = 25th percentile

Therefore, a "vital" roadway determination will be required to use the 95th percentile climate projections under any emissions pathways (based on worst case planning horizon). The criticality determination and threat projections will be identified by the client country data and incorporated into the bidding documents in order to inform the contractor of the requirements that will be integrated into the performance standards for the roadway.

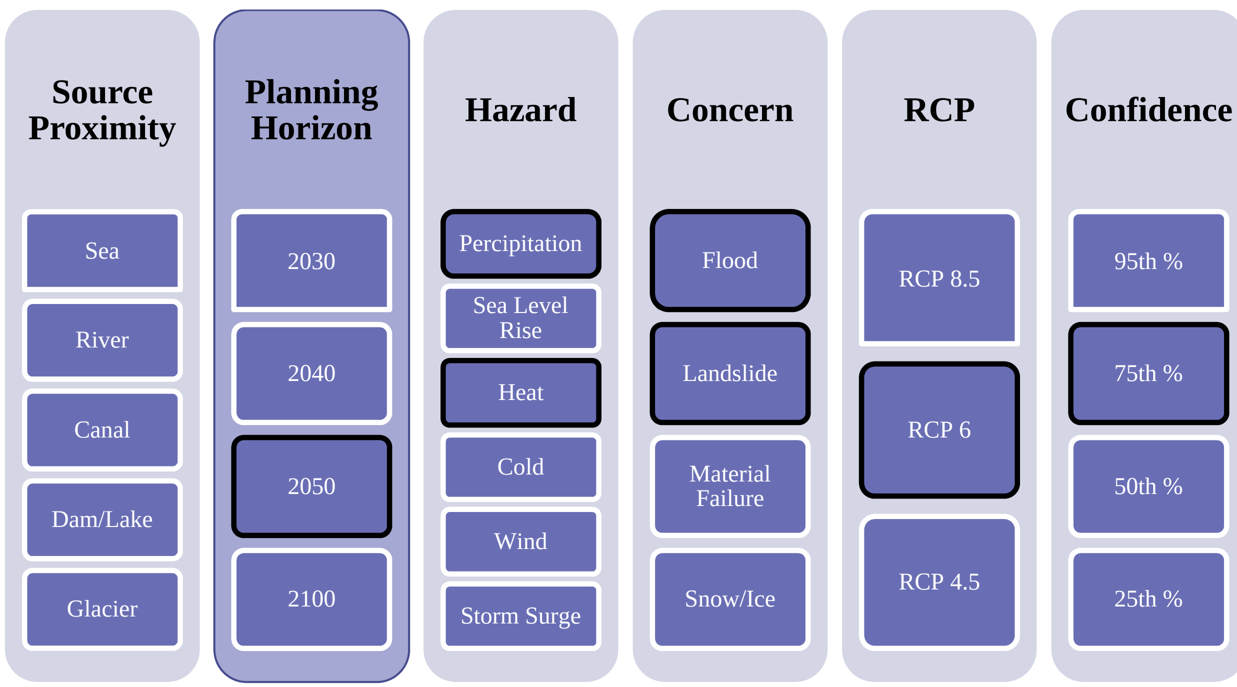


Figure 7 Threat Considerations

Example: *A paved roadway base along a river in Tonga will last 30 years, deeming a 2050 planning horizon when the precipitation and heat from the RCP 6 model will be most severe.*

This Major roadway will use the 75th percentile to predict that floods and landslides are ***likely***

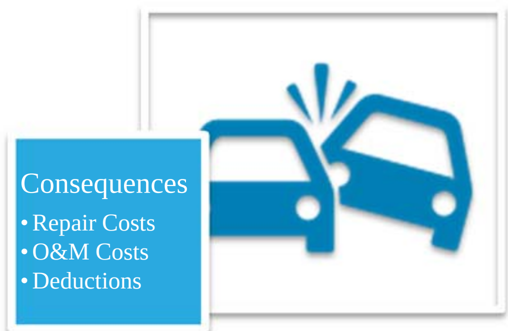
The level of climate exposure requires set planning horizons, emission scenarios and confidence intervals, based on data already entered as part of Step 1 and 2.

Table 3 Climate Threat Inputs

	Identify the applicable climate impacts associated with the planning horizon, emissions scenario and confidence			
	Likely	Probable		Possible
Hazard Definition* (set from step 1 and 2)				
Source: *Distance from:*				
- Sea	*meters*			
- River	*meters*			
- Canal	*meters*			
- Dam/Lake	*meters*			
- Glacier	*meters*			
Planning Horizon:	*2030*	*2040*	*2050*	*2100*
Emission Scenario:	*RCP 8.5*	*RCP 6.0*	*RCP 4.5*	
Confidence Percentile:	*95th*	*75th*	*50th*	*25th*
Hazard Models:				
- Precipitation	*mm/hour*			
- Sea Level Rise	*meters*			
- Heat	*Degrees*			
- Cold	*Degrees*			
- Wind	*Km/hour*			
- Storm Surge	*meters*			
Concerns:				
- Flood	*meters*			
- Landslide	*Cubic meters*			
- Erosion	*Cubic meters*			
- Scour	*meters*			
- Material Melting	*Square meters*			
- Material Cracking	*Square meters*			
- Ice / snow	*Days*			
- Fire	*Days*			
- Dead Vegetation	*#*			
- Dust	*Days*			

4.4 Step 4: Determine Consequences

Consequences include projected repair costs, operational costs and KPI deductions based on the risk level determined during step 1, 2, and 3. The criticality determination, asset vulnerability and climate threat assessments are the responsibility of the client country, and will influence the consequences used to determine design and performance standards for the project.



The contractor will be required to adhere to the designated inputs for future climate in designing physical adaptation measures and estimating project costs. The project will be evaluated based on whether it effectively meets the design standards and KPIs when held to these more stringent climate thresholds.

As a result, the contractor will need to evaluate the sensitivities and physical components of the roadway design to understand how the future climate design standards will impact the overall design and construction. **Figure 8 Consequence Considerations** details some of the project components the contractor will need in order to understand the overall sensitivity of the roadway to the projected climate impacts.

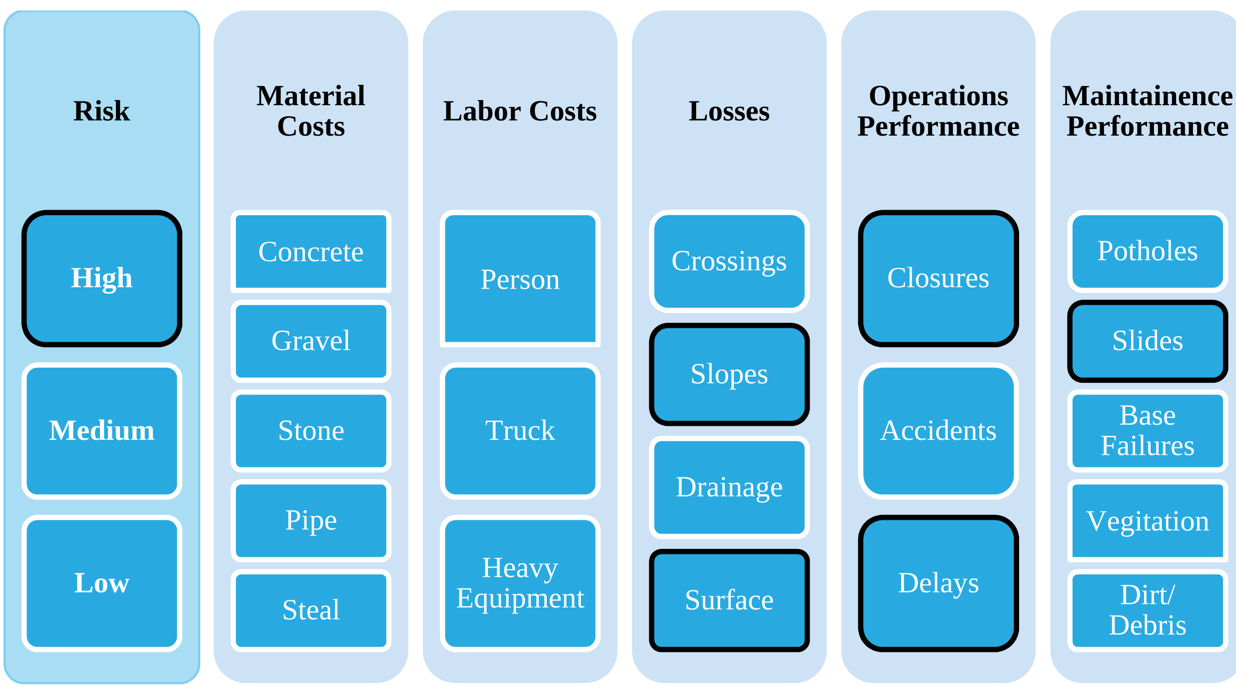


Figure 8 Consequence Considerations

Example: *There is a high risk the roadway will experience slope and surface failures as a result of over saturation and flooding, leading to closures, delays and failure to meet KPI s.*

***Deductions** are possible and additional labor to repair damage will increase **O&M costs**.*

Table 4 Consequence Inputs

	**Identify the applicable failures and costs associated with climate impacts**		
	Repair Costs	**O&M Costs**	**Deductions**
Consequence Definition			
Risk Level:	*High*	*Medium*	*Low*
Material Costs: *Unit Price:*			
- Concrete	*$/cm*		
- Gravel	*$/cm*		
- Stone	*$/cm*		
- Pipe	*$/meters*		
- Steal	*$/cm*		
Labor Costs:			
- Person	*$/hour*		
- Truck	*$/hour*		
- Heavy Equipment	*$/hour*		
Losses:			
Crossings	*meters*		
Slopes	*Cb. m*		
Drainage	*meters*	Drainage off roadway functional (no standing water in lanes)	
Surface	*Sq. m*	Roughness coefficient meets contractual requirements	
KPIs:			
Closures	*#*		
Accidents	*#*		
Delays	*hours*		
Potholes	*#/km*		
Slides	*#/km*		
Base Failure	*m/km*		
Mechanical Failures	*#/km*		
Electrical Failures	*#/km*	Lighting levels meet standards and contract specifications	
Vegetation	*Days*	Roadside vegetation doesn’t impair designed sight distance	
Debris	*Days*	Roadway is free of Debris (Trash, sand, dead vegetation)	

4.5 Step 5: Determine Adaptations

Based on the established design standards, physical components and sensitivities of the roadway, the asset owner will be able to determine the mitigation measures that will be most applicable to their roadway contract. Inputs into the design standards are based on the projected future climate risk per the GCMs.

It is important to consider what events will realistically and reasonably occur during both the contract period and the asset life cycle. Contract languages should clearly spell out which event patterns are considered as climate change so that proper standards can be used during each phase of development.

Overall, the recommendation of this study is that the key performance indicators (KPIs) do not change, but rather the requirements for the design of the roadway will change based on the future climate projections, as determined by these first two steps in the process. However, there is a targeted list of KPIs that the client country may want to consider modifying based on the most pressing climate exposure of the roadway (see **Figure 9**).

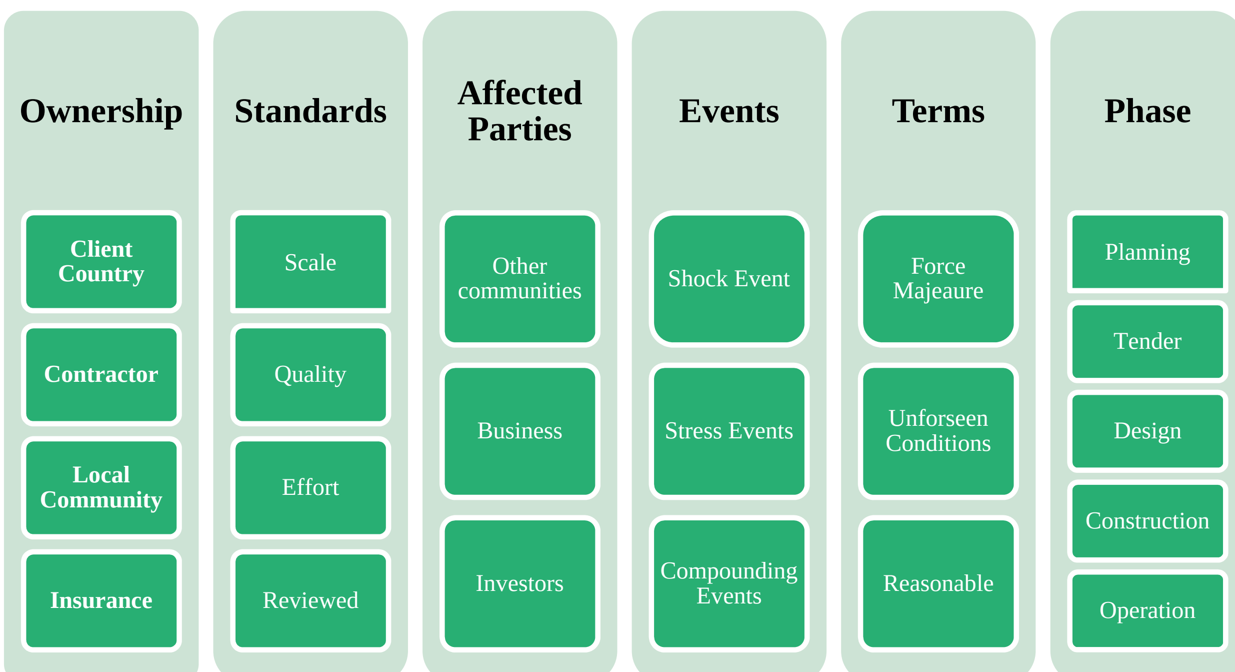


Figure 9 Adaptation Considerations

Example: *To reduce O&M cost overruns the contract should include language around Stress Event and Shock event thresholds as well as transfer of design risk to the Contractor.*

Table 5 Adaptation Outputs

	Identify the applicable adaptation measures and contract augmentations to include in the project documents		
	Ownership	**Event**	**Phase**
Contract Definition			
Ownership:			
Client Country	*Ability to control policy*		
Contractor	*Ability to control quality*		
Local Community	*Vested interest*		
Insurer	*Financial incentives*		
Affected Parties:			
Other communities	*Upstream/ downstream*		
Businesses	*Downtime consequences*		
Investors	*Revenue loss*		
Event:			
Shock	*Maximum Expected*		
Stress	*Daily/ Annual Change*		
Compounding	*Cumulative*		
Standards:			
Scale			
Quality			
Effort			
Review			
Project Lifecycle:			
Systems Planning	*Connectivity*		
Tender	*Risk/ Funding*		
Engineering and Design	*Adaptation*		
Construction	*Material Selection*		
Operations Maintenance	*Schedule/ Budget*		
Terms:			
Force Majeure			
Unforeseen Conditions			
Reasonable			

5 Adaptation Drivers

It is necessary that projects include amplified measures of value to offset increased contractor costs. These opportunities can be gains for the developer, the community or the local government. In order to better calculate true value of opportunities and impacts, there needs to be better quantifiable understanding of potential business and social impact losses. Investment decisions will be calculated inappropriately until this holistic understanding of climatic impact is calculated.

There are several key drivers which motivate each of the stakeholders within a performance based roadway operations contract, but these are different for the specific parties involved. With regards to the impact of climate on roadway operations, we consider the Stakeholders with their associated concerns.

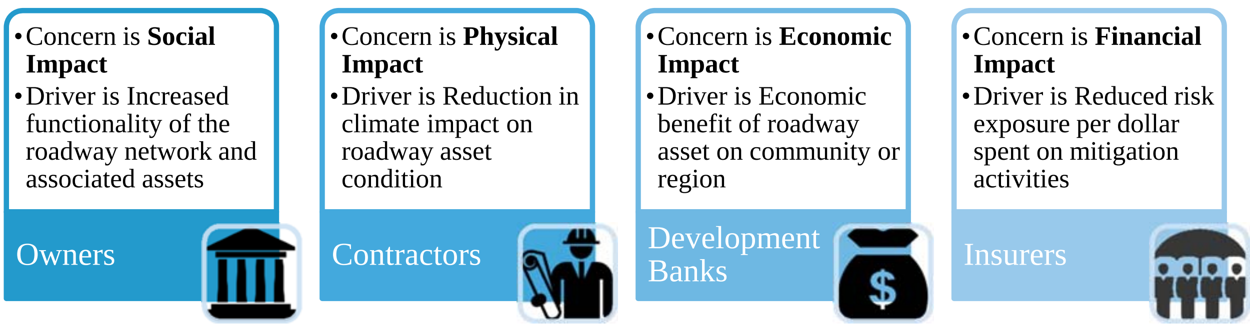


Figure 10 Climate Change Impacts

5.1 Adaptation Metrics

The Performance Criteria and economic drivers of each stakeholder come with measurable KPIs that play directly into quantification of those associated drivers. The following shows some of these potential areas of measurement to achieve each stakeholder's objectives.

Social Impact	**Asset Functionality**	Availability Performance Service Performance
Physical Impact	**Damage Reduction**	Physical Damage Environmental Damage
Economic Impact	**Value for Money**	Business Generation Business Downtime
Financial Impact	**Loss Reduction**	Asset Values Repair Cost Estimates

5.2 Contract Document Changes

The following list includes a few recommended changes to World Bank Bidding Documents to better allocate risk between project stakeholders. The objective of the changes are to reduce language ambiguity that often results in asset owners left with full responsibility for the impacts of climate, yet no control of the choice to improve adaptive capacity. The process of contract document modification should include a rigorous cross checking process to ensure that risk is fully understood by all parties involved and that all risks are captured within the allocation framework.

Citations are based on:

Sample Bidding Docs from Procurement of Works and Services under Output- and Performance-based Road Contracts and Sample Specifications – Oct. 2006; revised 2017

- p. vi, 10 (c) – Management Performance Measures – "Requirements should include…Maintenance History (so subsequent tenderers can price the work")

  This information could be used to identify trends in increasing losses as a result of climate risk and a need to more proactively include resilience considerations into future bids.

- p. v, 7 – the terms "short term, medium term and long term" *should be further defined to indicate the actual length of time over which this is assessed since it directly impacts the planning horizons to be used to determine climate projections.*

- p. vii, 13 – "The users will be able to know the Service Level they can expect in return for the payments they make for the use of infrastructure…"

  We feel that a positive ROI will only be recognized if climate risk is adequately accounted and planned for in the overall design of the project and its maintenance needs. Likewise, there is a question as to whether or not the associated "bail outs" provided in the Emergency Works funding are included in this ROI. We would argue that they would need to be to truly provide an adequate assessment of value.

- p. viii, 19 – Maintenance Services, Rehabilitation Works, Improvement Works

  We believe that a case could be made for adequately including budgets/contingencies/performance metrics for climate risk and resilience in all of these types of funding sources.

- p. ix – "There should also be a price adjustment clause applicable to all prices and activities in order to compensate for increases in cost indices."

  It may be advisable to have a climate resilience index built into this. In terms of cost escalation, a Stanford-led study has shown that an increase in fortification for climate resilience (especially with respect to coastal barriers and port fortification) will necessarily lead to a global shortage of concrete with the potential to completely deplete the market. This is just one example of how climate change could directly impact the costs of construction and maintenance.

- p. 42 – 2.2.1 History of non-performing contracts

  The definition of this could be expanded to include excessive cost overruns associated with recovery from climate-induced extreme events.

- p. 44 – 2.2.3 Declaration: Environmental, Social, Health and Safety (EHS) Past Performance

  This definition could be expanded to include adequately accounting for climate change.

- p.47 - 2.3.3 Financial Resources

  While it does not address it directly, there may be an opportunity to ask the bidder to disclose potential financial risks of its firm as they relate to climate change, in the spirit of the disclosure criteria that were outlined in the Task Force on Climate-Related Financial Disclosures.

- p. 51 – 2.5 Key Personnel

  Selection criteria inherently assume that there is adequate accounting for these risks in the bids. For example, in Part 1, Section 3, Subsection 2.5 (p. 51) of the OPRC, the contractor must ensure that they have qualified personnel to cover identified specifications and in Part 3, Section IX criteria are stipulated to assess capacity for ensuring environmental, social, health and safety performance security. In these instances, the World Bank has set a standard for identifying the particular areas of need that it feels are necessary to deliver a successful project.

  The bidder must ensure that they have qualified personnel for specific specifications. Climate adaptation expertise could be expressly required in this section.

- p. 54 – Letter of Bid

  In evaluating the bid, the Bank could choose to incentivize proactive resilience measures by providing extra points or some other type of weighting which would tip to the advantage towards those bids that are more climate resilient. From an economic perspective, the more resilient projects should result in fewer Emergency Works claims. However, we would not encourage a lower bid for Emergency Works in itself to be an adequate proxy for resilience since it could also represent an underestimation and/or uninformed assessment of the project's climate risk.

- p. 107 Section VI. Specifications

  In general, we would recommend that performance metrics remain the same. However, the change would be to emphasize the need to use climate projections to inform the development of design storms and temperature fluctuations and their impact on the final performance of the facility.

- p. 109-110 Suggested Content for an Environmental and Social Policy

  We would recommend adding a policy that speaks to reasonably and explicitly considering how climate risks could impact the overall health and longevity of the project and how those risks are mitigated within the proposal.

Risk Management Framework Overview

The provided climate risk management framework for roadways outlines a multi – criteria analysis methodology to consider the threat of climate change to roadway assets from a social and financial point of view. The tool provides simplified climate projection scenarios to proactively quantify the uncertainty associated with climate change for design and contracting purposes. Contract adaptation recommendations are correlated to specific climatic threats found in different parts of the globe and the tool has been designed to be easily usable across a variety of exposure typologies including:

- low lying island states,
- mountainous regions affected by glacial melting,
- densely populated inland water ways,
- geologically vulnerable and
- drought prone areas.

The framework explores central questions about benefit cost analysis and total risk exposure which require gathering key data useful in informing stakeholders and decision makers. In line with research conducted around climate impacts on PBC, output information from steps 1, 2 and 3 allows for risk identification, followed by risk valuation in step 4 and risk allocation in step 5.

[1] Route Uses
[2] Material Durability
[3] Asset Location
[4] Recovery Costs
[5] Contractual Issues

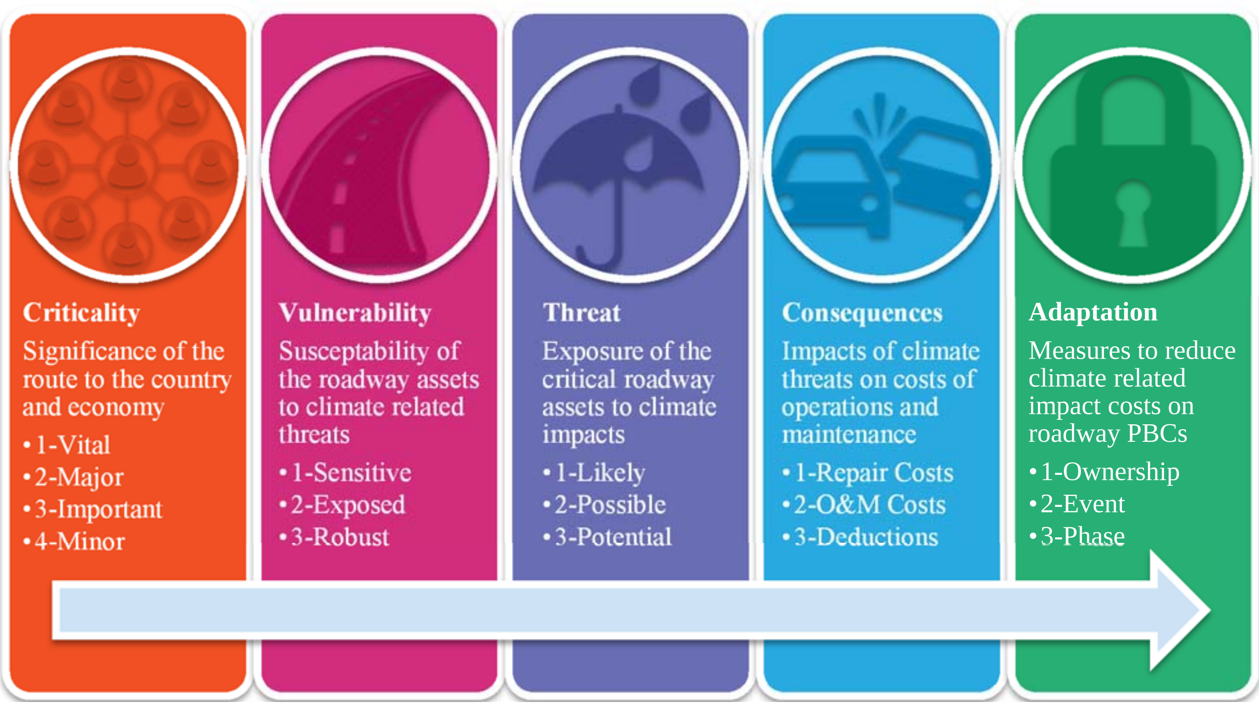


Figure 11 Key Considerations