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# REFINEMENT OF PIARC'S INTERNATIONAL CLIMATE CHANGE ADAPTATION FRAMEWORK FOR ROAD INFRASTRUCTURE

TECHNICAL COMMITTEE E.1 *ADAPTATION STRATEGIES AND RESILIENCY*

WORLD ROAD ASSOCIATION
MONDIALE DE LA ROUTE

# STATEMENTS

*The World Road Association (PIARC) is a nonprofit organisation established in 1909 to improve international co-operation and to foster progress in the field of roads and road transport.*

*The study that is the subject of this report was defined in the PIARC Strategic Plan 2016– 2019and approved by the Council of the World Road Association, whose members are representatives of the member national governments. The members of the Technical Committee responsible for this report were nominated by the member national governments for their special competences.*

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# EXECUTIVE SUMMARY

2019R30EN

# REFINEMENT OF PIARC'S INTERNATIONAL CLIMATE CHANGE ADAPTATION FRAMEWORK FOR ROAD INFRASTRUCTURE

Climate change is anticipated to have a significant impact on the design, construction, maintenance and operation of global road infrastructure. The IPCC Climate Change projections[1] indiciate that the earth will become warmer, some regions will become wetter and some will become drier, sea levels will rise and storm surge height will increase, snow cover and extent of sea ice will reduce, and the frequency and severity of extreme weather events will increase. This in turn will result in significant global and regional challenges related to climate change in both the short and long-term.

The *PIARC International Climate Change Adaptation Framework for Road Infrastructures*[2] guides road authorities through the process of increasing the resilience to climate change of their networks and assets. It takes users through four stages: Identifying scope, variables, risks and data (Stage 1); Assessing and prioritising risks (Stage 2); Developing and selecting adaptation responses and strategies (Stage 3); Integrating findings into decision-making processes (Stage 4).

Within PIARC Technical Committee E.1, two Working Groups were established.

**Working Group 1 (WG1)** had the task to undertake a state-of-the-art case study analysis of adaptation strategies to increase the resilience of road infrastructure at the policy, strategic, system level and project specific level. This includes consideration of:

- data requirements regarding climate change adaptation of road infrastructure
- assessment of the vulnerability and criticality of road infrastructure
- adaptation measures with regard to possible threats resulting from climate change; and
- cost-benefit analysis of climate change adaptation.

The WG1 Report provides the methodological detail supporting each stage of the refined PIARC International Climate Change Adaptation Framework for Road Infrastructure, by referring to state-of-the-art case study examples.

**Working Group 2 (WG2) had the task** to review the collected case studies and other relevant experience and propose refinements of the original edition of the International Climate Change Adaptation Framework for Road Infrastructure. The Framework has systematically been implemented in only two places, Mexico and Queensland, Australia. The experience from this implementation (e.g. in Mexico), together with a comparison with other existing frameworks, provided input to the contents of the steps of the Framework, and how they can be clarified.

In addition, WG2 investigated possibilities for adjusting the Framework to broaden its applicability. One reason for this was that the Framework appears to be demanding for countries that have not

[1] IPCC Intergovernmental Panel on Climate Change, www.ippcc.ch
[2] World Road Association PIARC (2015) "International Climate Change Adaptation Framework for Road Infrastructure"

already carried out some adaptation work. A number of short-cuts in the procedures are, therefore, proposed to accommodate an initial vulnerability assessment, and a risk assessment in the planning phase of a road project.

Another reason for wanting to broaden the applicability of the Framework is the fact that some countries already apply a methodology for risk assessment, which is different from the one incorporated in the Framework. Some adjustments are, therefore, proposed so that countries can benefit from the structure of the Framework and combine it with their own established methodologies for risk assessment.

The WG1 Report provides the methodological detail supporting each stage of the refined PIARC International Climate Change Adaptation Framework for Road Infrastructure, by referring to state-of-the-art case study examples. The WG2 Report investigates possible applications of the Framework and discusses needs and options for its refinement.

The work on the two WG tasks was based on 59 collected and classified case studies that were analysed and classified by a dedicated Technical Committee (TC) internal Task Force. Further to this, by making available more than 100 case studies in total, the work of TC E.1 represents a comprehensive consolidation of state-of-the-art concepts applicable to climate change adaptation for roads. These detailed references can also be used as reference points for other world-wide projects being undertaken. It is crucial that PIARC's products represent significant added value for owners and operators of road infrastructure and have a unique selling point. This is achieved by making available a wide range of case studies of state-of-the-art practice world-wide.

There is capacity to extend the work developed by TC E.1 into formulating a new edition of the PIARC Framework. It is acknowledged that the work of TC E.1 is highly interrelated between cycles whereby it builds from the previous cycle and can be extended to the next PIARC cycle for 2020-2023. Therefore, there is a need for consistency in transferring knowledge across three consecutive cycles.

# CONTENTS

# 1. INTRODUCTION

The International Climate Change Adaptation Framework for Road Infrastructure **Erreur ! Source du renvoi introuvable.** was initiated during the Strategic Plan Cycle 2012-2015 [2] of the World Road Association. At its meeting in Bali, Indonesia, TC1.3 "Climate Change and Sustainability" developed a proposal for a 'special project' with the aim to create an international framework for climate change adaptation.

In May 2014, the World Road Association launched a call for proposals for PIARC special projects. The idea of developing a framework to address climate change adaptation, which would be of practical use for road assets owners and managers, was supported. A tender was sent out for consultants to respond to and the task was given to the British Consultant URS (now AECOM). The first draft was published in January 2015. The final version was released in July 2015. The Framework was published and disseminated during the World Congress in Seoul, November 2015.

After the publication, the Framework was translated into Spanish and French, and was applied in Mexico and Australia. In the same period, the World Road Association established in its Strategic Plan 2016-2019 [3] a project to refine the Framework, to ensure its applicability and investigate the potential for further updates.

In the 2016-2019 cycle, tasks related to adaptation to climate change were assigned to Technical Committee E.1 Adaptation Strategies/Resilience. The TC organised its work in two working groups. The objective of Working Group 1 was to undertake a state-of-the-art case study analysis of adaptation strategies to increase the resilience of road infrastructure at the policy, strategic, system level and project specific level [4].

Working Group 2 had the task to formulate proposals for the refinement of the International Climate Change Adaptation Framework for Road Infrastructure, based on the case studies analysed by Working Group 1 and on findings from direct implementation of the Framework. Both working groups were assisted by a special Task Force, which was organised to collect and systemise case studies from country members.

This report summarises the results of the work on the refinement of the Framework (WG2). It provides examples of implementation, discusses the applicability of the Framework for various purposes, reports on feedback from countries comparing the Framework to their own ongoing adaptation work. It also reports the results of a benchmarking exercise, where the Framework was compared to other approaches for adaptation of roads to climate change.

The report concludes with a list of proposed options for the refinement of the current PIARC Framework (2015) **Erreur ! Source du renvoi introuvable.**.

# 2. PURPOSE OF THE REPORT

The purpose of the report is to:

- Present and discuss the rationale supporting the refinement of the Framework
- Within that: illustrate various applications of the Framework, and explore the adjustments they motivate
- Propose refinements that enable simple and more targeted application of the Framework.

In this PIARC cycle (2016-2019) [3] the refinement itself is not carried out. If decided so by PIARC, the development of a new edition of the Framework will be the task for a TC in the following cycle.

It is recommended that this report be read together with the report of WG1 [4].

As will be explained in Section 5, one of the TC's aims is to distinguish between the "system aspect" of the Framework and the "methodology aspect" of the Framework. The present report concentrates on the system aspect, whereas the methodologies underpinning each stage of the Framework are the subject of WG1-report [4].

# 3. STRUCTURE OF THE REPORT

This report provides an overview of PIARC's Adaptation Framework, in Section 0.

Section 5 describes how the Committee addressed the task of identifying refinements of the framework, describes the methods of work, and some observations that motivated the direction of work: applicability of the Framework, the contents or scope and use of terminology.

Section 6 gives three examples of implementation of the PIARC Framework: in Mexico (also Appendix 1), Queensland /Australia and Paraguay.

Section 7 deals with findings from comparisons of PIARCs Framework with other relevant frameworks or adaptation strategies of national road agencies reported among the case studies. An exercise of benchmarking was performed for these chosen frameworks, identifying their main differences and similarities with the PIARC Framework. Major information about each framework included in the benchmarking exercise is given in text boxes throughout the report. Appendix 2 provides more detailed information about the benchmarking exercise.

In Section 8, how the adaptation work of the country members fits into the steps of the PIARC Framework is evaluated. This is a way of checking the applicability of the structure that the Framework provides. This can also be a way of identifying the points that individual frameworks for adaptation are missing.

Section 0 collects experience and feedback from workshops that were organised for potential users who need to implement a strategy to adapt their road infrastructure to climate change and extreme weather.

Section 0 presents the proposals for refinement and discusses their function. The main points are:

- applicability of the Framework
- the risk assessment methodology incorporated in the Framework
- introducing the aspect of criticality
- modifying the calculation of the risk score
- proposing a more concrete stakeholder network; and
- expanding the framework with new knowledge.

Section [illegible] summarises the proposals and defines some goals for future work.

# 4. OVERVIEW OF PIARC'S INTERNATIONAL CLIMATE CHANGE ADAPTATION FRAMEWORK FOR ROAD INFRASTRUCTURE"

PIARC's "International Climate Change Adaptation Framework for Road Infrastructure" **Erreur ! Source du renvoi introuvable.** was a result of extensive research and consultation with road authorities globally and was thus a synthesis of best practice and knowledge available internationally. The intention was to develop a direct effective and useable tool for use by any road authority, irrespective of geographical, climatic, economic, environmental or climatic condition. It was to be applicable to any scale, such as national, regional, local or asset specific.

The PIARC Framework guides road authorities through the process of increasing the resilience of their networks and assets through the following stages:

- Stage 1 - Identifying scope, variables, risks and data;
- Stage 2 - Assessing and prioritising risks;
- Stage 3 - Developing and selecting adaptation responses and strategies;
- Stage 4 – Integrating findings into decision-making processes.

Stage 1 has the following main components: establishing assessment scope, aims, tasks and a delivery plan; assessing vulnerability and adaptive capacity; and assessing climate change projections and scenarios. Typically, the key aim of any type of climate impact assessment is to ensure and enhance the resilience of the road network, asset, operation or service to the effects of climate change and extreme weather. This will be achieved by assessing climate change projections and scenarios, assessing exposure and sensitivity, assessing vulnerability levels and adaptive capacity. The road authorities will need to define the scope, aims, tasks for this assessment and a plan for delivery. The outcome is that the road agency will have identified which assets, locations and operations are most vulnerable, determined key climate effects and will have knowledge on how to apply climate change scenarios and projections. See Figure 1.

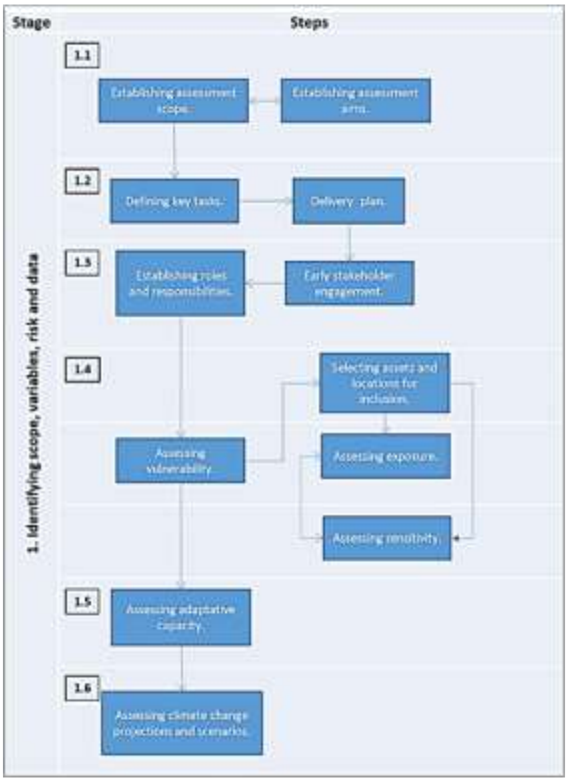



*Figure 1: Diagram of Stage 1 of the Framework*

Stage 2 has the following main components: assessing impact probability, assessing impact severity, establishing risk scores and risk register. This stage will enable authorities to understand and, where possible, to quantify the risks posed to their networks and assets in a simplistic, accessible, iterative and yet robust and holistic way following risk assessment principles. Road authorities will be able to rank their assets, locations and operations according to the level of risk probability and/or severity associated with climate change and extreme weather. For this framework, risk is considered to be a function of probability and severity. The outcome of Stage 2 is that the road authorities will have developed a ranked list of risks (with corresponding locations on the road network) according to their probability of occurrence and their severity. The highest scoring risks should be taken forward to stage 3, which outlines how adaptation responses to address these risks can be identified, selected and prioritised. See Figure 2.

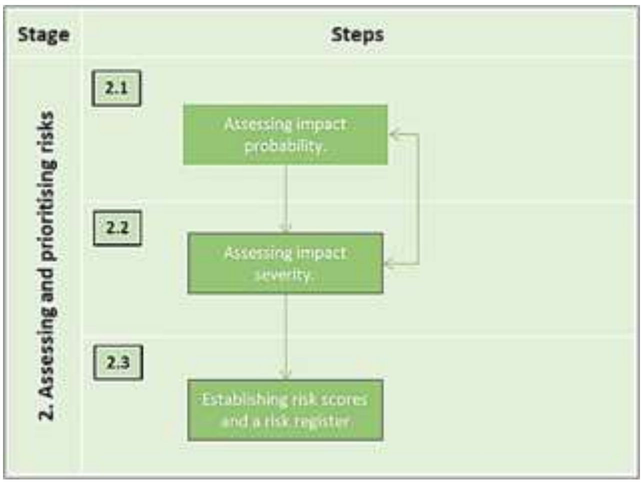



*Figure 2: Diagram of Stage 2 of the Framework*

Stage 3 includes identification of adaptation responses and strategies, selection and prioritization of adaptation responses and strategies, and the development of an adaptation action plan or strategy. Identification of adaptation responses and opportunities occurs through professional judgment, expertise and knowledge of the road network. Authorities should be able to produce a list of potential adaptation responses suited to their assessment and their road network. Selection and prioritization of adaptation responses and opportunities occurs through two common methods: cost-benefit analyses (CBA) and multi-criteria analysis (MCA). At this stage of the assessment, road authorities will have a list of potential adaption responses to the main risks on their road networks, assets and operations. The outcome of this stage is that road authorities will be able to develop a prioritised list of adaptation responses, which can be accompanied by an Action Plan to facilitate the delivery of these activities. See Figure 3.

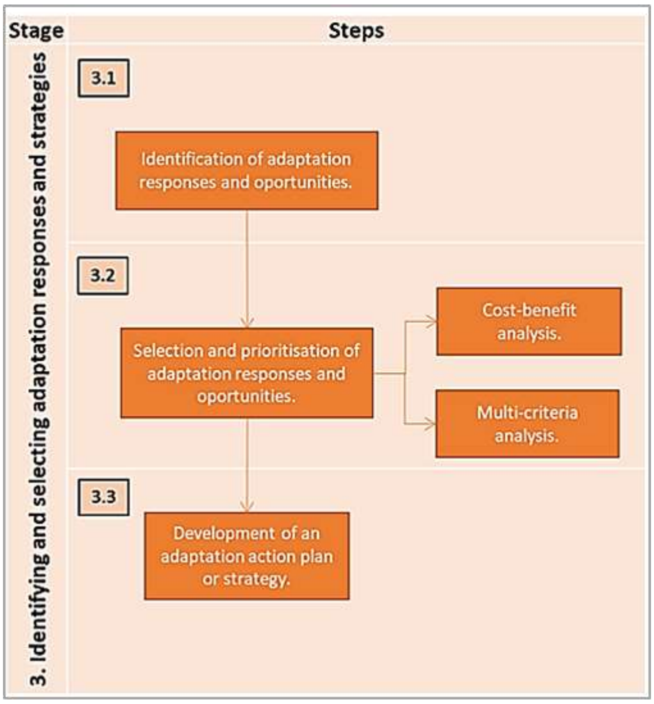



*Figure 3: Diagram of Stage 3 of the Framework*

Stage 4 includes incorporating recommendations into decision-making processes, education, awareness training, and effective communication, developing a business case and future planning and monitoring. Climate change must be considered as one of the many risks requiring attention in decision-making, rather than as a separate standalone issue. Road authorities may be able to incorporate climate change vulnerability assessment results into: asset management plans, inventories and policies, land use strategies, traffic management strategies, investment plans, design standards and specifications, emergency and risk management processes, hazard mitigation plans, transportation planning project selection criteria, or environmental reviews and strategies. The outcome of this stage is effective integration of assessment findings into decision-making activities, communication plans, business case activities and ongoing planning and operational procedures. See Figure 4.


*Figure 4: Diagram of Stage 4 of the Framework*

# 5. REFINEMENT OF THE PIARC FRAMEWORK – TASKS AND AIMS

PIARC identified the need to evaluate the Framework's application and sought to identify possible improvements through the detailed exercises conducted in this WG2 report. The task of TC E.1 was to collect examples of implementation of the framework and propose refinement options based on these experiences. In addition, case studies of adaptation measures and strategies, which are the subject of the report [4], were expected to provide valuable input for undertaking adjustments to the Framework. The development process adopted to undertake these tasks is shown in Figure 5. This work provides a basis for the development of a revised Framework in a future PIARC cycle.

The method of work adopted by WG2 was as follows:

- **Collecting experience from implementation of the Framework**

To the authors' knowledge, there are only three examples of systematic implementation of the Framework: regional roads of the Mexican National Roads (see Section 6.1 and App 1), in Queensland (see Section 6.2) and the road network in Paraguay (see Section 6.3).

- **Collecting examples of general adaptation measures /adaptation strategies**

The TC collected several examples of adaptation frameworks (case studies) at the national road administration level. Some of these examples were called "strategies for adaptation to climate change"; others were named "adaptation frameworks". Regardless of the term used, the TC's focus was on examples of holistic approaches, describing the work of the road administration as a whole. In addition, WG2 identified big differences in ways of carrying out systematic vulnerability assessments (see Section 7.1).

Some of these relevant case studies of existing frameworks were used to make a systematic comparison based on the "Benchmarking" method (see Section 7.2 and Appendix 2).

- **Fitting ongoing adaptation work in member countries into the PIARC framework**

Most of the countries involved in the work of TC E.1 have done *some* work on adaptation to adverse climate conditions and climate change. From this analysis, it was possible to place all valuable pieces of adaptation work within a Framework for adaptation. Vice versa: an adaptation framework should ideally provide a structure that can be overlaid over any ongoing adaptation work. The exercise of overlaying the PIARC Framework on ongoing adaptation work helped WG2 recognise the missing parts, how they can be provided and what should be prioritised. See Section 7.3.

- **Workshops on the PIARC framework**

Another strategy was to review the practicality of using the Framework with other potential users who do not have experience using this tool, and who need to implement a strategy to adapt their road infrastructure to climate change and extreme weather, through workshops. Feedback was obtained from these workshops in some countries, and the findings are shown in section 0.

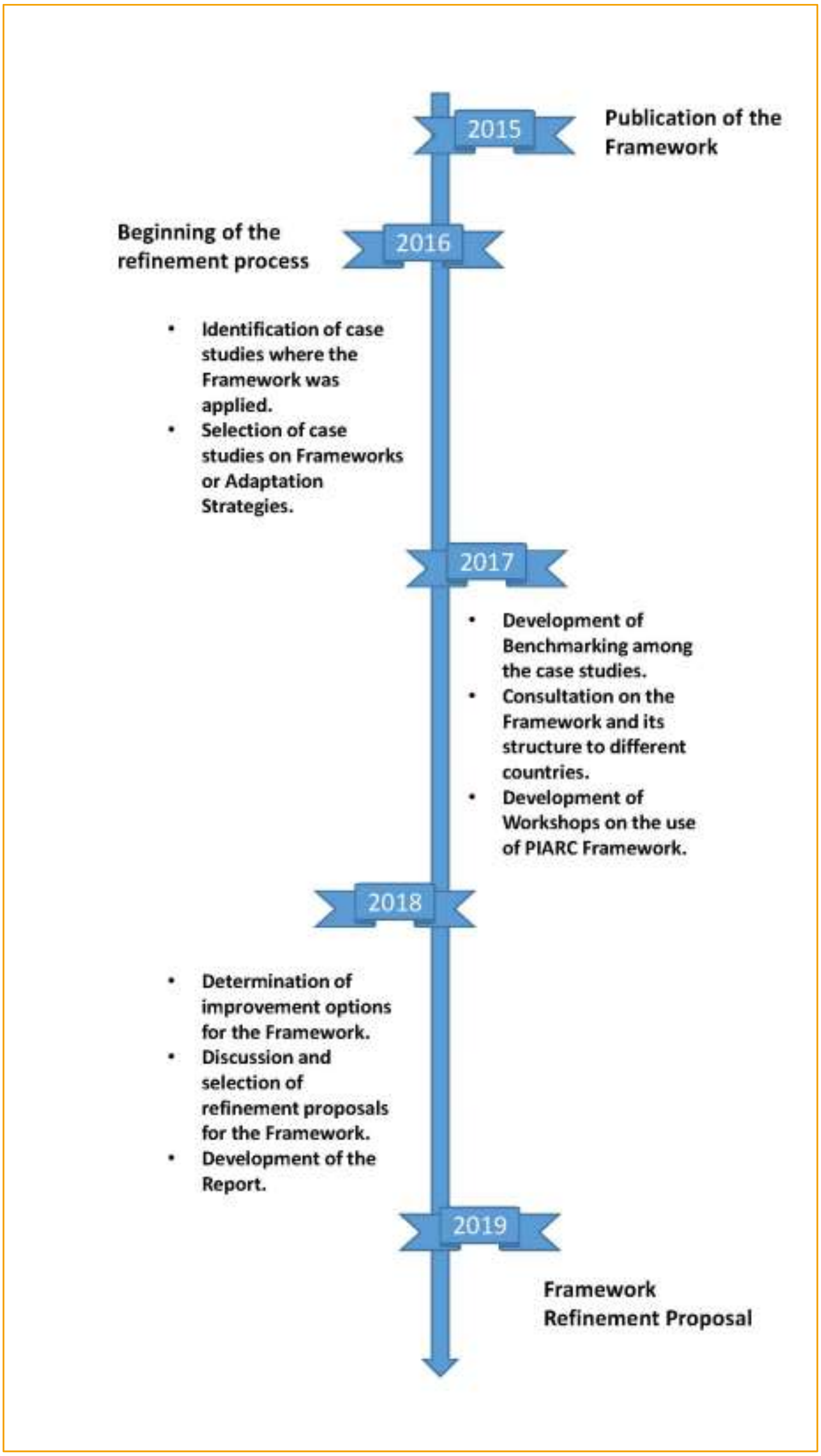



*Figure 5. Time line of the refinement development process of PIARC's Framework*

**Preliminary observations**

Some observations regarding the applicability and the contents of the Framework were made before any of the described analyses were carried out.

- **Framework or methodology, or both?**

Definitions[3]:

- *Framework:* a basic conceptual structure (as of ideas)
- *Methodology:* a body of methods, rules, employed by a discipline, a particular procedure or set of procedures
- *Strategy:* a careful plan or method (or the art of devising or employing one) toward a goal.

The PIARC Framework guides the user through a systematic assessment of challenges, risks, methods of response and methods of implementing the results into a management context. In this way, in its present shape, the Framework provides a methodology *within* a conceptual structure of tasks to enable adaptation to climate change. The risk assessment method chosen is one of many possible methods. The choice of parameters of the risk assessment and the algorithm for calculating the total risk could have been different depending on the particular scenario. There is a whole variety of methodologies, as is shown in [4].

*Do we need a framework or a methodology?*

- Some road agencies will require a *methodology*– a step-by-step explanation of what to do and how. However, as will be shown later in the report, applying a full methodology requires a good knowledge base. It is not easy to apply a whole methodology as the first thing one does.

- Other road agencies have already started on adaptation work, which in many cases consists of making small adjustments to established systems or routines. These agencies will rather need the *framework aspect*, as a structure where the pieces of ongoing work can be placed, in that way revealing the missing parts or highlighting alternatives.

As identified in the case studies collected by the Task Force and further assessed by WG1, road agencies often refer to *strategies,* describing work the work that others may call a "framework". The cases considered interesting for the present report include descriptions of *holistic* approaches to managing climate adaptation efforts, which include both frameworks and strategies.

- **Scope of the framework**

The Framework is mostly suitable for road agencies that have not done much adaptation work yet, but:

- have enough *basic knowledge* for carrying out a climate impact assessment and implementing adaptation measures, and
- have established *contacts with partners* /stakeholders.

[3] Merriam Webster Dictionary

If they, in addition, are interested in addressing *particular* parts of the road network and the corresponding assets, the present edition of the Framework will provide good and systematic guidance.

However, in many cases a road administration may be interested only in a part of the scope of the Framework. An agency may only want to obtain an overview of the challenges and work to be done; perform a climate impact assessment or a vulnerability assessment of the roads or types of road assets. In such cases, the PIARC Framework will be somewhat demanding and too detailed.

Report [4] Section 9, provides examples of different levels of detail of the risk assessment.

- **Terminology**

An overview of other countries' ways of organising adaptation work has revealed differences in definition and the use of established terms. This causes difficulties in recognising similarities and relations between existing frameworks.

TC E.1 uses the definitions according to ISO: 31000 Risk management and ISO 14090 Adaptation to climate change. These are also referred to in Section 13.

# 6. EXAMPLES OF IMPLEMENTATION OF THE PIARC FRAMEWORK

## 6.1. IMPLEMENTING THE PIARC FRAMEWORK IN MEXICO

In 2016, the Ministry of Communications and Transportation of Mexico took action to apply the International Climate Change Adaptation Framework for Road Infrastructure. The motivation for this were the observed impacts on the road structure from hydro-meteorological phenomena associated with climate change. This has involved large economic investments to replace the affected infrastructure, as well as economic losses due to the interruption of the service.

For the implementation of the Framework, the road network of the states of Nayarit and Colima were chosen in the first phase of the work. Later, in the second phase, the road networks of Baja California Sur, Hidalgo and Tabasco were chosen. The complete results of the application of the Framework are shown in Appendix 1.

The application of the Framework at the network level required information on roads, climate change impacts that have affected the networks under study (heavy rains, hurricanes, floods, etc.), as well as road condition data, traffic data (AADT) and population data.

**In Stage 1**, following the structure of the Framework, the objective and scope of the assessment were defined; and the activities and deliverables were specified. The deliverables included technical reports of each road network and the database of the vulnerable sites. These actions comprised the *planning* phase of the Framework.

The project was based on the available historical information of the hydro-meteorological threats that occurred in Mexico. However, the agencies that provided this information were not necessarily involved in this particular project and could therefore not contribute with additional input on road impacts.

An element that had to be developed separately was the identification of sites that were assumed vulnerable to climate change, which is a part of Stage 1 of the Framework. This involved additional steps, such as forming a team of specialists, development of a work procedure, and a registration scheme.

With the information from those sites, the vulnerability could be evaluated, through the assessment of exposure and sensitivity. To assess the exposure, historical information on weather related impacts on the road network was required. To evaluate the sensitivity, a physical on-field assessment of the state of the road assets was undertaken, including how the areas surrounding the road can increase sensitivity of the road. In this way, a list of vulnerabilities of the road network was obtained, which could be prioritised according to their vulnerability level.

Stage 1 of the Framework also requires an assessment of the adaptative capacity of the road or network asset. This implies that, if there is redundancy or a high recovery capacity, it is not necessary to continue with the adaptation process in this moment for that network or asset. Additionally, in cases when one has climatic scenarios, the possible impacts that they would have on the road network can be evaluated. However, this step was not applied to the case study of Mexico.

The sites in the studied road networks that were marked with a 'very high' and 'high' vulnerability level, were studied further in **Stage 2**, following the PIARC Framework. In this situation, the risk level was assessed according to the probability and severity of the hazards i.e. possible unwanted events. The probability was evaluated through the national risk atlas, which specifies the level of probability that a hazard will materialise, such as tropical cyclones, heavy rains, etc. The severity was evaluated using the criteria established by the Framework, which were found to be easy to apply. However, the specified thresholds of, for example, population data, traffic volume, the costs in the national currency, etc., must be adapted to be consistent with the road network being assessed in the study.

With the probability and the severity index determined, a risk score was obtained. This allowed a prioritised list of risks to be obtained. Only the sites identified with a 'high' or 'very high' risk level were then chosen to be considered further for Stage 3. This depuration of sites does not imply that the previous ones were abandoned, but that they are postponed for future evaluations.

In **Stage 3**, for each site identified with a 'high' risk or greater, an adaptation measure was designed, to reduce or minimise the risk that could arise from anticipated hydro-meteorological phenomena. These adaptation measures were evaluated through a Multi-Criteria Analysis (MCA), which involved determining the cost of the adaptation response, its feasibility, its adaptive capacity, and other variables suggested by the Framework.

Additionally, in Stage 3, a prioritised list of risks, with the corresponding road sections /assets, and their adaptation responses to climate change was obtained. These were then incorporated into a working plan /an action plan or program. In the case of Mexico, adaptation actions are included in the regular road maintenance and conservation programs.

The knowledge of the experienced field engineers responsible for maintenance of the road assets under study often includes knowledge and information about the measure that are necessary for each site. Therefore, the main task is to ensure that climate change considerations are present when defining the threats that need to be taken into account.

**Stage 4** of the Framework is not implemented in Mexico yet, although it is intended to be in the future. The chosen adaptation actions will be implemented, monitored and communicated. Meanwhile, training and education continue so that the entire Ministry of Communications and Transportation, both maintenance engineers, as well as construction and road planning engineers, know the risks associated with climate change and that these are incorporated in the daily work within the sector.

The results lead to the conclusion that the application of the Framework (including its methodology) is feasible for developing countries, although information that is required may not always be available. The systematic process of the Framework allows assessment of the vulnerability of road networks and assets, and identifying, evaluating and prioritising the risks associated with climate change.

The continuous application of the Framework would ensure that preventive actions are implemented to timely adapt the road network in Mexico. However, the road network in Mexico is very large, so it is necessary to simplify the process of site selection, so that sites exposed to hazards with a higher probability of occurrence are attended first. Therefore, the future study areas will be selected through a geospatial analysis of climate change. The selection of exposed assets, such as bridges, can also be done through a geospatial analysis, which is then followed by analyses each asset following the Framework's methodology.

The effects of climate change on Mexico's road transport systems are increasingly obvious. Hence the recognition of the authorities and the application of the Framework is an important first step towards the resilience of the country's road network regarding climate change.

**Next steps in Mexico**

It was very useful for the road engineers to learn how to include climate change in the assessment of road infrastructure risks. It is commonly understood how climate variables are part of the road design. However, now the road authority is beginning to rethink the approach with a broader vision, which helps ensure resilience of roads under different climate stressors.

For the first time in Mexico, climatic risk maps were used to evaluate the impact on the road network. This implied linking with other agencies and managing information on the impacts of the different phenomena associated with climate change on roads. In this way, the inspection procedure in the management of road assets, included climate change as a variable that can affect the performance of the road.

The steps of the Framework were easy to follow. The greatest challenge was gathering all the necessary information, such as the road network data, the condition of the road network, the risk maps associated with climate change, etc. Having all the information in compatible formats and temporalities is not a simple task. Agencies that wish to implement the framework need to review the available information first.

Some suggested changes that could improve the Framework were identified:

- The application of Framework required making some adjustments to assess the severity of the impact. This is because each country and region have different thresholds to evaluate the level of impact that climate change could have on a road asset. In addition, the criteria applied in the multi-criteria analysis had to be adjusted to the local conditions of the country.
- The "adaptive capacity" as expressed in the Framework should be considered and revised to enable correct interpretation and application in the vulnerability assessment.
- Effective communication is a step in Stage 4 of the Framework. However, it must be used transversally throughout the whole assessment process, especially in Stage 1, where it is a major force for interrelating all the stakeholders.
- The identification of risks in Stage 1 in the Framework should be reinforced based on different case studies. Report [4] provides a good basis and includes possible ways to perform this activity, in order to identify the risks correctly and their relationships with climate change. For example, based on statistics, risk inventory in asset management, field visits, geospatial analysis of climate change and roads, etc.
- It must be ensured that the experience of local road engineers included in the identification of risks and the establishment of adaptation measures.

## 6.2. IMPLEMENTING THE PIARC FRAMEWORK IN QUEENSLAND, AUSTRALIA

A project was undertaken by the Department of Transport and Main Roads (TMR), Queensland under a National Asset Centre of Excellence (NACoE) program together with the Australian Road Research Board (ARRB), relating to the implementation of the PIARC Framework. This project emerged from the PIARC International Workshop on Climate Change Adaptation, hosted by TMR in Brisbane in May 2017, where the PIARC Framework was presented.

The purpose of this project was to develop a consistent resilience framework for TMR (which is also applicable to industry) based on the findings of existing projects. This involved integrating the existing PIARC International Climate Change Adaptation Framework for Road Infrastructure, and other approaches into current TMR practice.

Additionally, this project was connected to PIARC TC E.1 by integration of Queensland case studies into [4]. It also contributes to this report, because it provides an example of how the PIARC Framework can be applicable in Australia and elsewhere.

## 6.3. Implementing the PIARC framework in Paraguay

In the process of updating of its Road Design Manual, the Paraguayan Road Association decided to include adaptation to climate change as part of the design criteria and standards for its future roads. To support that, through the World Road Association and the Mexican Institute of Transportation, a workshop was held on the experience of Mexico in the application of the Framework.

The workshop included terminology for adaptation to climate change, an overview of the impacts of climate change on roads, adaptation best practices, as well as the use of tools that can help to identify the impacts of climate change and select possible adaptation responses.

The Paraguayan Road Association will include in its new manual an annex guide on the PIARC Framework, so that users can apply it in the design and conservation of roads in Paraguay.

# 7. INPUT FROM CASE STUDIES AND BENCHMARKING

## 7.1. Collected Examples of Adaptation Frameworks from Case Studies (TC E.1 Task Force)

The Task Force within TC E.1 gathered almost 100 case studies, which covered a vast range of topics. For the present report, the cases considered most relevant were examples of holistic approaches to vulnerability assessment of roads, i.e. whole adaptation frameworks.

To provide input into further work towards refining the Framework, the following questions are considered:

- How does the example of a strategic approach fit into the PIARC framework? Are there issues that are not included in the Framework, but are important for adaptation?
- Are some tasks done differently and cannot be found /recognised in the Framework?
- Other differences: The terminology used? Another sequence? Differences in the scope (making some steps of the PIARC Framework irrelevant)? Aspects of criticality? Ways of calculating the final risk?
- How does the knowledge base in a case study relate to the knowledge base necessary to carry out a full implementation of the PIARC Framework?

These references provided insight into the similarities and differences between various ways of defining scope, identifying threats, assessing vulnerability, criticality, risks, and identifying adaptation responses. The main features of such case study framework examples are presented in text boxes throughout the report.

**Box 1: Ministère des Transports, de la Mobilité durable et de l'Électrification des transports, Quebec**

In Quebec, transportation plays a major role in supporting the vitality of regions, the distribution of goods and services, and the exploitation of natural resources. The size of the province, and the remote nature of certain Quebec communities in the regions affected by climate change, are factors that increase its vulnerability.

For nearly 20 years, the Quebec government has been making greater efforts to adapt transport systems to climate change and thus strengthen their resilience. These efforts have enhanced knowledge about the impacts and potential solutions to improve the management of transport infrastructure. Quebec's Ministère des Transports, de la Mobilité durable et de l'Électrification des transports (MTMDET) plays a central role in the management and sharing of responsibilities for transport infrastructure. Highways; national, regional and collector roads; and some access roads to remote resources and communities fall under Quebec's jurisdiction.

Québec's large territory and varied topography help to create different climates. These range from a cold and humid continental climate in the southern and eastern parts of the province to a sub-polar continental climate in the central regions, a polar tundra climate in the north and a maritime climate in the coastal areas towards the Gulf of the Saint-Lawrence. All of Québec is affected by climate change and certain trends are already being observed. Climate change will modify the natural environment in all areas of Quebec. Most of Quebec's coastal areas will experience an increase in erosion, in addition to submersion in areas that were minimally affected until now.

The MTMDET has dedicated considerable efforts over the last two decades to better understanding the impact of climate change on the natural environment as well as on transport infrastructure and mobility. The challenges related to coastal erosion and permafrost thaw are particularly well documented. Strategies to develop solutions to these problems are becoming better understood. On the basis of this work, in Québec concrete actions to increase infrastructure resilience have started to be implemented. Nevertheless, transport adaptation continues to be a subject requiring further research.

*Source: Corina Nicorici, Ministère des Transports, de la Mobilité durable et de l'Électrification des transports, Quebec*

**Box 2: Norwegian Public Roads Administration (NPRA)**

NPRA's «Strategy for civil protection» (published in 2017) recognises adaptation to climate change as one of the three main challenges for maintaining mobility. NPRA does not have an official framework for the adaptation to climate change. However, during the years of work on adaptation, existing systems, tools, reporting routines etc. have been expanded by introducing climate considerations and adaptation measures.

The Norwegian national framework for adaptation (political guidelines, the availability of climate projections etc) is helpful. The Norwegian Centre for Climate Services provides data, climate projections and interpretations of climate research for practical applications in other sectors.

Over recent years, the NPRA has performed a range of general vulnerability assessments, estimating the exposure and sensitivity of *types* of assets and geographical areas. Vulnerabilities were mapped and remedial measures proposed – all on a *general level*. Cost-benefit analyses were not carried out at this level, but an assessment of feasibility was made and an evaluation of the knowledge-base and the data quality. The remedial measures identifed were: adapting design rules (from planning to maintenance), improving climate data accessibility through collaboration with meteorological and hydrological agencies and improving road data quality in the National road databank, introducing climate aspects into the risk assessment method and increasing awareness for better preparedness and emergency management with respect to natural hazards. These general adaptation measures ensure that all new activities will move the roads towards higher resilience. They also provide a better framework for adaptation on the road section or the asset level.

In the *planning phase* of a project, assessing risks from natural hazards is a part of the obligatory general risk assessment. For the e*xisting road network*, "rough" risk assessments have been carried out annually, from the aspect of mobility and security. Climate considerations have recently been included in this work, so that the vulnerable points identified also include those vulnerable to climate hazards. Procedures for more detailed analysis of assets are being developed. The main goals are to further improve the work being undertaken related to overviews of costs and benefits, and better sharing of experience and knowledge.

*Source: Gordana Petkovic, NPRA*

**Box 3: Secretariat of Communications and Transportation in México (SCT)**

In Mexico, derived from the General Law of Climate Change in 2012, the actions of the federal public administrations in mitigation and adaptation to climate change were strengthened. The Mexican goverment recognises the need to act to reduce greenhouse gases, as well as the need to adapt infrastructure and ecosystems to climate change, in order to reduce future economic impacts.

In this way, the National Climate Change Strategy 2013-2018 was developed, in which adaptation issues were established to strengthen the existing strategic infrastructure (communications, transport, energy, among others) considering climate scenarios. Additionally, the government has a Special Climate Change Programme, where activities are held annually to maintain and increase the levels of resilience in the communications infrastructure.

For the transport sector, particularly roads, the International Climate Change Adaptation Framework for Road Infrastructure has been implemented since 2015 in México. The application of the Framework was applied at the road network level in different States, including Nayarit, Colima, Hidalgo, Tabasco and Baja California Sur.

The use of the PIARC Framework enabled the development of a prioritised list of risks according to their level of vulnerability and existing danger, and adaptation actions in the road network.

Currently, studies continue in the adaptation of the road network and in the implementation of the identified measures. The SCT is supporting actions to have better climate information, better adaptation information, and simplifying the process of identification of risk sites, etc.

*Source: Juan Fernando Mendoza Sánchez, Mexican Institute of Transportation*

**Box 4: General Directorate for National Roads and Motorways - GDDKiA**

GDDKiA will conduct the construction of more than 1100 km of motorways and expressways in the near future. Due to the large impact of climate change and expected increase in frequency of extreme weather events. A "Strategy of climate change adaptation for roads managed by GDDKiA" was developed.

The work started in 2016, by collecting and analysing information of previous climate related events, in the period 2004-2016. A number of sensitivity analyses were performed, regarding disturbances in traffic flow, damages and defects in infrastructure (according to European Investment Bank model: sensitivity + exposure = vulnerability).

The studied weather events were divided into four classes:

- Class I (damages and defects of road or road infrastructure);
- Class II (obstacles in traffic flow, but no damages and defects of road and road infrastructure);
- Class III (total block of traffic flow, but no damages and defects of road and road infrastructure);
- Class 0 (no damages and no obstacles, but maintenance team action needed). A particular event may belong to more than 1 class.

Data received from GDDKIA's regional offices consisted of about 3300 weather events. Preliminary results showed that the most common events were Class I and II. 20 % of all events were classified into Class 0. Events from Class III accounted for about 8.5 % of all noted events in total. They will be analysed in detail in the next stage of this work.

The next steps are to perform vulnerability analyses (using available meteorological data from Polish Meteorology Hydrology and Water Management, Polish Railway Authority data, severe weather events data and other relevant data sets). A comparison of methodology with other countries and consultation of the results with other areas of expertise within the organisation (bridge engineers, maintenance teams, designers etc.) will be performed. The expected results are an assessment of the current state and current needs and recommendations on measures (when and where), which should be applied to adapt road infrastructure to climate change.

*Source: Jacek Wojtowicz, Anna Stańczak – Jażdżyk, GDDKiA*

**Box 5: CEREMA /France**

To support transport managers and operators to improve the resilience of their networks, Cerema, a French agency in charge of risk, environment, mobility and land and country planning, has published in 2015 an innovative framework to assess the risks incurred by climate change on transport infrastructures and services.

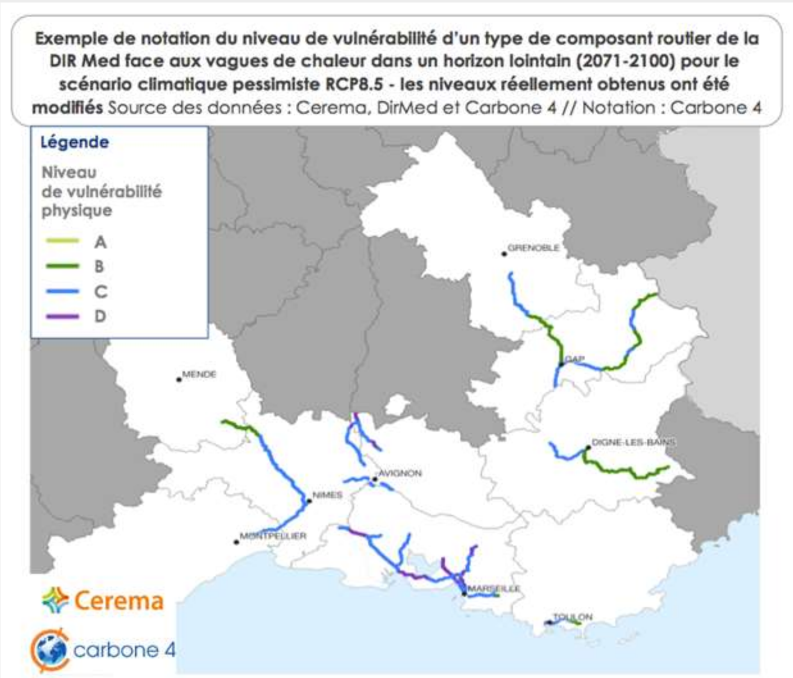
The framework has been applied on a 750 km section of the French national road network, operated by the Mediterranean Interdepartmental Road Directorate (DIR). The Cerema, in association with Carbone 4, a leading consulting firm, have assessed:

- its exposure to current and future climate conditions
- the possible extent of the damage to different types of infrastructure: road surface, bridges, drainage structures for example; according to their characteristics: materials, current condition, and other parameters
- the possible extent of the impact on travel, which depends on the traffic flow, the economic importance of a road section, and other parameters.

As a result, a set of maps of the exposure, vulnerability and criticality of each road component and the travel functionality as a result of various hazards for the current period and with a forward-looking vision including different climate change scenarios have been produced. These results are useful to improve transport management policies and strategies, more particularly within budgetary constraints.

This approach may be useful to assess the sensitivity, vulnerability and criticality of transport networks to other future pressures such as changes in traffic flow, development of new transport technologies, etc., and the results are useful in the prioritisation of works, adaptation of technical solutions to climate change, and thus optimisation of expenditures in the mid-term horizon.

Cerema has also develop a set of communication tools to share knowledge with transport operators, for example: information on tools and methodologies on the issue of asset management are regularly shared with the twitter account: @CeremaRoute.




*Source: Marie Colin, CEREMA*

**Box 6: Swedish Transport Administration (STA)**

The STA adopted a climate change adaptation strategy in 2014. It is based on the Danish Road Administration´s strategy. The strategy is divided into three parts; how to work with climate change adaptation, how to build a robust infrastructure and how to react when an incident happens. The strategy was followed by an action plan in 2016. In 2018, the actions were completed, and a new action plan developed. The actions deal with issues such as creating an internal organisation that can work with climate change adaption especially on a regional level, creating financial opportunites for climate related adaptation actions, supporting related research, and developing a system for identifying climate related risks.

STA has not performed a general vulnerability assessment of the road network and no cost benefit analyses on an aggregate scale has been carried out. This is due to lack of available data for use in the economic models and a lack of directives at a governmental level (Sweden initiated a national climate change adaptation strategy as late as 2018). However, vulnerabilities and needs have been addressed in several of the actions within the action plan, mentioned above. Some basic cost benefit analyses has been carried out and a research project has recently started that aims at filling in the lack of data in cost benefit analyses.

In the planning phase of a project, assessing risks from natural hazards is a part of the obligatory general risk assessment. For existing road network, a general risk assessment method called "Chosen Road Stretch" has been developed and it was revised in 2018. Major roads have been scanned and the risks classified. The focus is on risk related to landslides, rock fall, erosion, flooding and mudflows. During the plan period of 2018-2029. It is estimated that about 1.5 billion Swedish kronor will be set aside for climate change adaptation actions.

*Source: Eva Liljegren, Swedish Transport Administration*

**Box 7: The Danish Road Directorate**

Providing roads suited for the climate is a well-known problem for the Danish Road Directorate but this has taken on new meaning because of the challenges presented by climate change, especially in the last decade. For this reason, the Danish Road Directorate has been implementing additional safety dimensions across the road network and is well-prepared for the future. Relevant research and the development of climate prediction models show that over the next century, Denmark should expect significant changes in climatic conditions. For this reason, the Danish Road Directorate has prepared a strategy for managing climate change that can affect the national road network.

The Danish Road Directorate has opted for a three-pronged strategy with regard to increased rainfall and water on roads - we manage, we improve, and we prevent.

The Danish Road Directorate protects road surfaces and equipment against increased temperatures and stronger winds. Temperature and wind mainly affect road furniture with a short lifetime (<20 years), e.g. road surfaces, signage, signage structures, barriers and noise reduction screens. The Danish Road Directorate continually replaces worn road surfaces and evaluates the dimensioning of road-sign structures in relation to relevant climatic models. Adaptation takes place through the amendments of road regulations and as such, climatic adaptation is already incorporated into the system.

*Source: Christian Axelsen, Danish Road Directorate*

**Box 8: Australia - Framework to address the climate change impacts on road infrastructure assets and operations**

In 2008 a Climate Change Adaptation Framework was developed for Department of Transport and Main Roads (TMR) (Evans et al. 2009) [19]. The purpose was to provide principles and techniques for adapting to the impacts of climate change on road transport and infrastructure in the context of temperature changes, changes in precipitation (increases/decreases), rising sea levels, and increased storm activity. It outlines the potential climate change effects, impacts of extreme events on Queensland's transport infrastructure, possible adaptation strategies, and planning and project evaluation.

Since this work was undertaken, Australian Transport Agencies, such as TMR are needing to update adaptation planning to transport assets given the continued global heating and the range of risks it poses to infrastructure construction, maintenance and network operations. As outlined in Section 6.2, TMR is currently developing a project, under a National Asset Centre of Excellence (NACoE) program combining input from the above report with the subsequently published PIARC Framework to provide an implementation framework specific to a Queensland context.

*Source: Evans et al. (2009)*

**Box 9: Australia - Vulnerability Analysis for Transportation Networks (Taylor 2017)** [20]

This work involves the development of a series of assessments for the transport sector, which integrates different vulnerability assessment methodologies across the areas of inventory, topology, serviceability and accessibility.

Methods and decision-support tools (such as those outlined in this document) enable decision makers to make rational assessments of the threats to facilities, and consequences of network degradation and failure at various locations under different circumstances and solutions for these. Social and economic benefits then flow from the ability to plan and manage the impacts of transport network degradation to minimise wider consequences e.g. employment, trade, and social activities.

The key components of the integrated framework are as follows:

1. Definition of scope and determination of planning and management objectives. Identification of key factors allows for a wider range of influences and focuses on relevant components of a network.

2. Vulnerability assessment including the options for inventory, topology, serviceability and accessibility approaches to be adopted, separately or jointly, and including the five steps of:

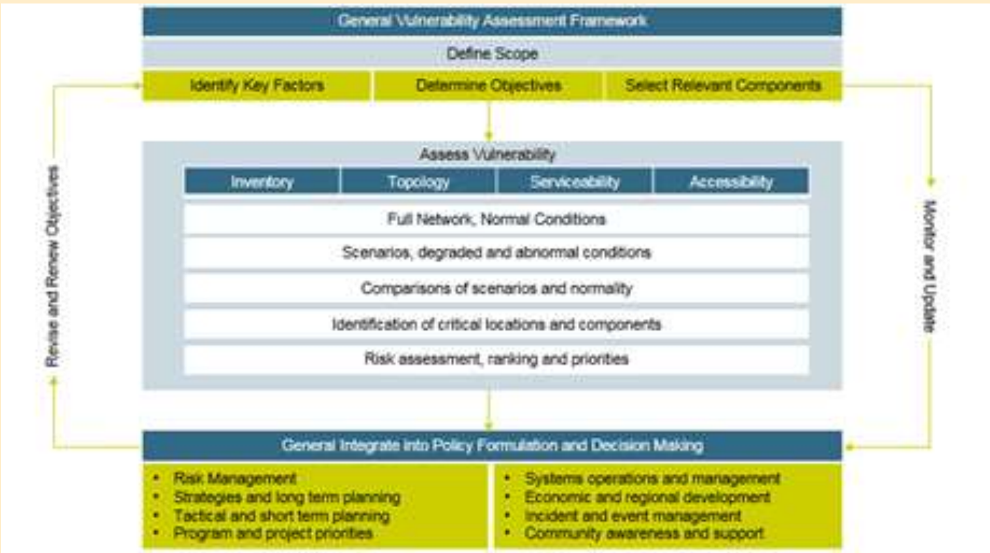
a) Assessment of normal operating conditions in the full, intact network
b) Development of scenarios covering network degradations and abnormal conditions
c) Comparisons of the scenarios with normal operating conditions, and the computation of vulnerability metrics
d) Identification of critical locations and components
e) Risk assessment of identified features, with ranking and priority determination

3. Integration of the vulnerability analysis results in policy formation and decision-making for the network, including initiatives in:

f) Risk management
g) Strategy determination and long-term planning
h) Programme and project priority determination
i) Systems operation and management
j) Wider considerations of economic and regional development
k) Incident and event management
l) Community awareness, opinion and support.

4. Monitoring and update of network assets, operations and usage
5. Revision and renewal of planning objectives in line with system developments over time.

A general framework for vulnerability analysis and its incorporation into transportation-systems planning



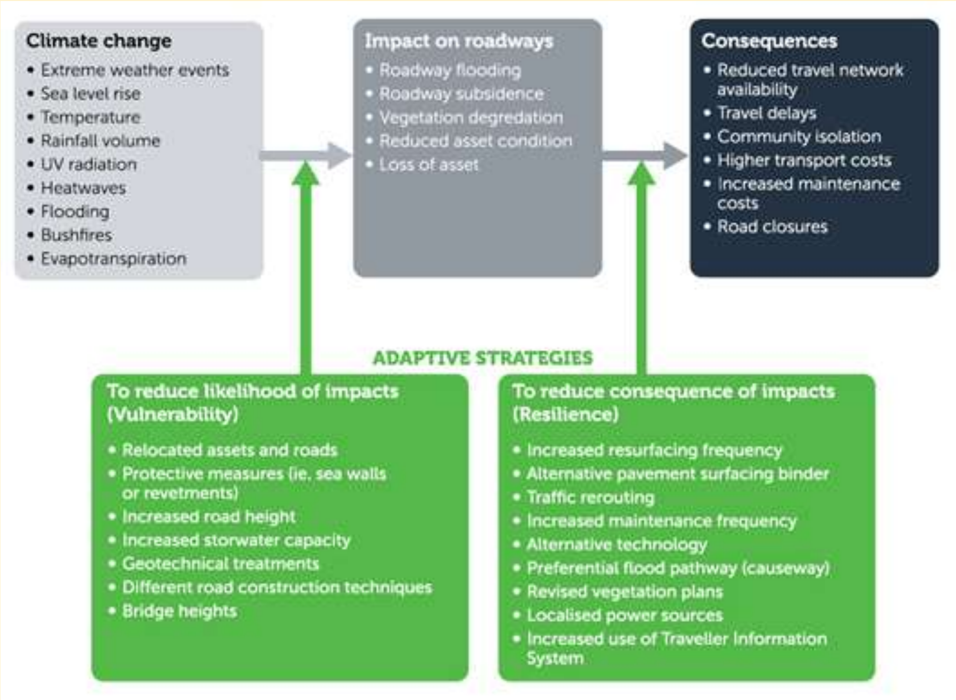
**Box 10: Australia – VicRoads Climate Change Risk Assessment (VicRoads 2015)**

The VicRoads (2015) Climate Risk Assessment is a summary of work undertaken by VicRoads (Victorian Transport Resources) to assess risks to infrastructure associated with climate change parameters, as well as some appreciation of the time frame and potential directions for climate change adaptation. The document provides:

- An overview of climate change adaptation;
- Strategic context in which the project was undertaken;
- Climate change projections used in assessment;
- Detailed overview of the climate change risk assessment undertaken and associated asset information
- Detailed breakdown of risk assessments undertaken for the prioritisation of specific climate change risks including sea level risk, temperature, rainfall, UV level, and extreme weather events;
- Detailed summary of the development of adaptation responses and long-term asset responses for, and the organisation of these responses.

The appendices of this report provide case studies for climate change adaptation and adaptation measures in different regions of Victoria.

Illustration of how activities to decrease likelihood and consequence fit together and influence the impacts and consequences of climate change




*Source: Adapted from Melillo, Richmond & Yohe 2014 (Cited in VicRoads 2015)*

## 7.2. The Benchmarking Exercise

Ten frameworks and methodologies were included in a benchmarking exercise, where they were systematically compared to the PIARC Framework. These frameworks are also presented by short descriptions in text boxes throughout the report. Table 1 lists the frameworks /methodologies that were included in the benchmarking. The detailed description of benchmarking exercise, frameworks and findings, is given in Appendix 2.

*Table 1. Frameworks included in the benchmarking exercise*

| | |
|---|---|
| ADB | Asian Development Bank: "Guidelines for Climate Proofing Investment in the Transport Sector: Road Infrastructure Projects" [5] |
| HE UK | Highways England (formerly Highways Agency) (United Kingdom): "Climate Change Adaptation Strategy and Framework" [6] |
| FHWA | Federal Highway Administration "Climate Change & Extreme Weather Vulnerability Assessment Framework" [7] |
| NZL | NZL: Ministry for the Environment, New Zealand, "Climate Change Effects and Impacts Assessment: A Guidance Manual for Local Government in New Zealand" [8] |
| UKCIP | UK Climate Impacts Programme: Climate adaptation: Risk, uncertainty and decision-making [9] |
| USAID | USAID Climate-Resilient Development [10] |
| RIMAROCC | ERA-NET Road, Transnational R&D programme [11] |
| US D.O.T. | "Vulnerability Assessment and Adaptation Framework" [12] |
| Additional frameworks, which were studied, but not included in the benchmarking process. | |
| ROADAPT | Roads of Today adapted for tomorrow, CEDR transnational R&D project [13] |
| ID | Climate Services: A Tool for Adaptation to Climate Change in Latin America and the Caribbean. [14] |

This section provides a summary of the frameworks/methodologies highlighted above.

**Box 11: Climate Change Adaptation Strategy and Framework: Highways England (United Kingdom) [6]**

Highways England (formerly the Highways Agency) is committed to understanding and assessing the risks posed to the strategic road network from a changing climate and taking appropriate management action to mitigate these risks.

The reason of the adaptation framework is to allow Highways England to develop and implement a system for the challenge of climate change, for its responses for the delivery of their corporate objectives. The adaptation framework provides:

- A decision maker platform, to examine their individual business areas, including standards, specifications, maintenance, development and operation of the Highways England network.
- The process to identify the activities that will be affected by a climate change.
- Determining associated risks, opportunities and some options to manage the risks.

**Box 12: Guidelines for Climate Proofing Investment in the Transport Sector: Road Infrastructure Projects (Asian Development Bank) [5]**

These Guidelines aim to present a step-by-step methodological approach to assist project teams to incorporate climate change adaptation measures into transport sector investment projects. While the focus of the Guidelines is on the project level, an improved understanding of climate change impacts should also be used in the design of infrastructure planning and development policies and strategies to ensure appropriate resource allocation. Through the transport sector includes roads, waterways, rails, and airborne transport, this Guidelines focuses solely on road infrastructure.

The methodological approach presented in this Guideline for building adaptation into road investment projects is divided into six different sets of activities. The process begins with scoping the project and defining the assessment and its objectives. The core activities related to project design fall under impact assessment, vulnerability assessment, and adaptation assessment. Finally, the process ends with defining implementation arrangements and monitoring frameworks. To facilitate the implementation of the methodological approach, these six sets of activities are broken into 20 steps.

**Box 13: Climate-Resilient Development (United State Agency International Development, USAID) [10]**

This framework facilitates the systematic inclusion of climate considerations in development decision-making.

The framework's objective is to support the development process by assisting practitioners in identifying, evaluating, selecting, implementing, and adjusting actions to reduce climate vulnerabilities and improve development outcomes. The climate-resilient development framework described here is designed to promote actions that ensure progress toward development goals by including climate stressors, both climate variability and climate change.

The framework focuses on how climate can be incorporated into existing planning and decision-making processes (also known as mainstreaming). The climate-resilient development framework provides a five-stage, systematic process for understanding and prioritising current and projected climate-related vulnerabilities.

**Box 14: Vulnerability Assessment and Adaptation Framework (US Department of Transportation) [12]**

This vulnerability assessment framework is a manual to help transportation agencies and their partners assess the vulnerability of transport infrastructure and systems to extreme weather and climate effects. It also can help agencies integrate climate adaptation considerations into transportation decision-making. The Framework provides an in-depth and structured process for conducting a vulnerability assessment.

The background of this Framework was the Climate Change & Extreme Weather Vulnerability Assessment Framework (US Department of Transportation, 2012). The updated Framework provides further examples from assessments conducted nationwide and a more structured process for conducting vulnerability assessments. This document identifies key considerations, components, and resources to help agencies design and implement vulnerability assessments and climate change adaptation strategies.

**Box 15: Decision-making framework: UKCIP (United Kingdom) [9]**

UK Climate Impacts Programme (UKCIP) developed a structured framework and associated guidance to promote good decision making to the management of the risk and uncertainty about the future impacts of climate change.

This framework enables decision-makers to recognise and evaluate the risks posed by a changing climate, making the best use of available information about climate change, its impacts and appropriate adaptive responses.

**Box 16: Climate Change Effects and Impacts Assessment (Local Government in New Zealand) [8]**

This guidance manual is focused on helping the local governments to identify and quantify opportunities and hazards that climate change poses for their functions, responsibilities and infrastructure.

Risk assessment is central to the approach promoted in this Guidance Manual. It draws particularly on AS/NZS4360:2004 (Risk Assessment) (Standards New Zealand 2004).

These procedures are already well known within local government and allow the effects of climate change to be considered as part of existing planning, assessment and regulatory activities.

**Box 17: Risk Management for Roads in a Changing Climate: RIMAROCC (EU) [11]**

The Guidebook has the objective to develop a common method for risk analysis and risk management, with regard to climate change, for Europe.

This Guidebook is intended to be a concise methodological guide to risk management for roads with regards to climate change. The proposed method should enable the user to identify the climatic risks and to implement optimal action plans that maximise the economic return to the road owner taking into account construction cost, maintenance and environment.

The RIMAROCC method is designed to be general and to meet the common needs of road owners and road administrators in Europe. The method intends to present a framework and an overall approach to adaptation to climate change.

The comparison of the chosen frameworks showed that there are many similarities in the various processes of adaptation of the road infrastructure to climate change.

A step-by-step analysis of the approaches was undertaken (presented in Appendix 2). It revealed that the PIARC Framework omitted some aspects that could be relevant for the adaptation process. Some of the missing aspects are implicitly included in the PIARC process but are not established as separate stages or steps.

WG2 identified the following aspects as interesting for comparison:

a) The initial stage (from the start of the work in Step 1.1, to the initiation of the vulnerability assessment in 1.4) outlines the plan for the assessment. It could be strengthened if following aspect were included:
   - Step 1.2 Criteria for the selection of preferred adaptation (HE, UK) [6]; The road administrations must also define their criteria with which they will evaluate the results of the adaptation.
   - Step 1.2 Establish a specific context for a scale of analysis (RIMAROCC); Adjusting the context to the scale of analysis makes it easier to identify the optimal adaptation responses, according to the capacity of adaptation of the area.
   - Step 1.3 Establish risk criteria and indicators adapted to each particular scale of analysis (RIMAROCC); 4.3 Determine which risks are acceptable (RIMAROCC); 4.2 Compare climate risk to other kinds of risk (RIMAROCC). Organisations must have their risk criteria for each region in particular.

b) In Stage 1 of the Framework, when assessing the vulnerability of the asset or the road network, one should identify the threats that will be included. However, it could be more useful to distinguish between current and future climate threats and then evaluate the vulnerability of the system or the road assets. Some adaptation frameworks suggest doing so. Examples are: 2.1 Primary climatic variables and secondary climatic impacts (HE, UK); 1.1 Screen the project exposure to climate change (ADB); 1.4 Identify key climate variables to study (FHWA); 1.3 Define the climate change risk assessment context (NZL).

c) Some adaptation frameworks suggest that the required data and the methodologies to obtain them must be explicitly defined in the initial stage: 1.5 Identify methodology and the data needs (ADB); 2.2 Selects methods (USAID); 2. Obtaining asset data for the vulnerability assessment; 2.4 Provide actionable information (USAID); 2.2 Identify hazard type based on current and historical information (NZL).

   The methodologies for vulnerability assessment vary between the adaptation frameworks. On can indeed chose an adequate methodology, the choice can depend on the available data /information.

   The PIARC Framework also sets a requirement on necessary information, but it is not a separate step in the Framework. Since this information is crucial for further application of the Framework, it is suggested to establish a separate step, within the initial stage, called "obtaining /collecting data".

d) As part of the benchmarking exercise, WG2 identified the importance of including the experience of the local engineers in the team set to carry out the assessment, see Step 1.6 Identify the required expertise in ADB.

e) The working group suggests that the social acceptance of the adaptation project is important, as shown in 4.2 Conduct consultations (ADB).

f) The road organisations need to know their technical capacity and resources at the initiation of the adaptation process, as suggested in ADB, 5.2 Identify needs for technical support and capacity building.

g) Some frameworks place special emphasis on the identification of aspects of sensitivity, which influence the vulnerability of roads. Examples are: 1.2 Climate and non-climate stressors (USAID); 2.1 Identify localities by land use, natural resources, development and services provided (NZL).
Including some aspects for judging sensitivity in the PIARC Framework could result in a more effective sensitivity analysis.

h) An aspect that is not considered in the PIARC Framework and is suggested by TC E.1 for possible inclusion in a forthcoming update of the Framework, is 1.4 Assessing asset critically (as highlighted by FHWA).

i) WG2 also suggested that it is important to identify the capacity of the organisation, such as: decision making criteria, risk tolerance, internal process, as shown: 2.1 Understand the organisation procedures (UKCIP);

j) The working group believes 'identifying examples', although implicitly included in PIARC Framework in Step 3.1, should rather be an explicit step in the process, as shown in 5.5 Identify examples in UKCIP;

k) Adaptation is considered to be a process, where some frameworks include considerations of future aspects of the threats and their consequences. This is shown in: 2.3 Identify long-term changes in hazard due to climate change or other processes (NZL); and 2.3 Identify possible consequences (RIMAROCC).

*The points described will be considered as ideas for modifying the present version of the PIARC Framework.*

Table 2 shows the comparison between the steps of the frameworks identified at the beginning of this Section.

*Table 2. Comparison of the steps of the frameworks included in the benchmarking exercise*

| PIARC | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| No. | Stage | Steps | Highways England UK | ADB | US AID | US FHWA | UK CIP | NZ Gob | RIMAROCC |
| 1 | Identifying Scope, Variables, Risks and Data | 1.1 Establishing assessment scope and aims | 1.1 | 1.2 | 1.1 | 1.1 | | 1.1 | 1.1, 1.2 |
| | | 1.2 Defining key tasks and delivery plan | | | | | | | |
| | | 1.3 Early stakeholder engagement and establishing roles and responsibilities | | 1.4 | | 4.1 | 1.1, 1.2 | 1.2 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1.4 Assessing vulnerability | 3.3 | 3.1 | 2.3 | 4.2 | 3.1 | | 2.1-2.3 |
| | | 1.5 Assessing adaptive capacity | 3.3 | | | 4.2 | | | |
| | | 1.6 Assessing climate change projections and scenarios | 2.2 | 2.1 | 1.2 | 3.1 | 3.2 | 2.4 | 3.1 |
| 2 | Assessing and Prioritising Risks | 2.1 Assessing impact probability | 4.1 | 2.3 | | 4.4 | | 3.2 | 3.3 |
| | | 2.2 Assessing impact severity | 4.1 | | | 1.4 | | 3.1 | 3.2 |
| | | 2.3 Establishing Risk Scores | 4.3 | | 5.3 | | | 4.1 | |
| 3 | Identifying and selecting adaptation responses and strategies | 3.1 Identification of adaptation responses and strategies | 5.1 | 4.1 | 3.1 | | 3.3, 4.1 | 5.1 | 5.1 |
| | | 3.2 Selection of adaptation responses and opportunities | 5.3 | 4.3, 4.4 | 3.2, 3.3, 3.4 | 5.1, 5.2 | 4.2, 4.3 | 5.1 | 4.1 |
| | | 3.3 Development of an Adaptation Action Plan or Strategy | 5.2 | | 4.1 | | 4.4 | | 5.4 |
| 4 | Integrating findings into decision-making processes | 4.1 Incorporating recommendations and requirements into programs, processes and investments | 6.1 | 5.1 | | 6.1-6.5 | | | 6.1-6.2 |
| | | 4.2 Education, awareness and training | 7.2 | | | | | | |
| | | 4.3 Effective communication | | | | | | 6.1 | 8 |
| | | 4.4 Developing a business case | 7.6 | | | | | | 7.3 |
| | | 4.5 Future planning and monitoring | 7.4 | 6.1 | 5.1, 5.2 | 6.6 | 5.1-5.4, 5.7 | 6.1 | 7.1 |

## 7.3. OTHER INPUT FROM CASE STUDIES (WG1)

The WG1 report on case studies [4] provides information relating to possible approaches for expanding the Framework on to issues where there is more knowledge and experience. The information provided can be used to expand the stages in the PIARC Framework, either by modifying the contents of each Stage of the Framework, or by including the most relevant examples for each stage.

Combining adaptation strategies into adaptation pathways may also add a dimension to the *structure* of the Framework. The idea of adaptation pathways is to introduce flexible adaptation measures, allowing several rounds of implementation, depending on certainty and economy.

Measures that respond to the more certain challenges can be implemented first. Measures that respond to less certain or more long-term challenges can be postponed. This way of dealing with risk and risk management can introduce a loop in the structure or the "flow" of the Framework.

Table 3 gives an overview of some main points that need to be considered for a new edition of the Framework, with reference to the case study report [4].

*Table 3. Findings from case studies and [4] to include in the future version of the PIARC Framework*

| **Section in** [4] | **Additional Information for the Framework** | **Relevant for step** |
|---|---|---|
| 6.3 | Advice on expertise required for carrying out risk assessment | 1.3 |
| | Example of establishing large-scale stakeholder networks – consisting of other state agencies, municipalities etc. | 1.3 (4.3) |
| 7.3 | Exposure assessment /Selection of the climate hazards.<br>Questions that help identify the most important challenges, so that the risk assessment concentrates on prioritised hazards. | 2.1 |
| 7.4 | Advice on choosing climate change scenarios. The transport authority will have to decide which climate model(s), and which scenarios of socio-economic conditions and greenhouse gas emissions, will be used as the basis for risk assessment. Relevant for Stage 1.4 (Assessing exposure) and 1.6 (Assessing climate change projections and scenarios). | 1.4<br>1.6 |
| 7.5 | Exposure scoring on a larger scale – in cases one wants to perform comparisons within a larger area of the road network. | 1.4 |
| 8.1 | Examples and advice concerning assessment of sensitivity<br>- general sensitivity, and aggravating factors<br>- qualitative, semi-quantitative and quantitative sensitivity assessment. | 1.4 |
| 8.2 | Criticality is an important feature; it must be included in the Framework. The Section gives an overview of criteria and possibilities for assessing criticality. | New Stage 1.7 |
| 9 | How is the risk assessment performed?<br>Qualitative to quantitative assessment – the PIARC Framework should be able to allow for all types of assessment. | all |
| 10 | Adaptation measures – classes and types, hard and soft measures, general level and specific measures on the asset level.<br>Educational measures, Management … | 3.1<br>4.2, 4.3 |
| 11 | Prioritising adaptation measures – including adaptation in appraisal<br>Description of methods for evaluating the effectiveness of various adaptation measures. Adaptation pathways may require a "loop" in the structure of the framework, i.e. on the sequence of assessments done. | 3.2 |

# 8. COMMENTS ON THE FRAMEWORK FROM COUNTRY MEMBERS

Following the work undertaken by the Task Force, it was identified that most of the countries involved in the work of TC E.1 have already carried out some work on climate resilience and adaptation to climate change. This section involves retrofitting the work already done by the road agency into the Framework. The aim of this is to help recognise the missing parts, how these can be provided, and which aspects should be prioritised.

The member countries were asked to perform a check of how the PIARC Framework relates to the work already being done in their agencies. The main questions were:

- Does your NRA do some work that is not included in the Framework, but you find important for adaptation?
- Are there things you do differently and that do not "fit" in the Framework? Do you find some of the steps in the PIARC Framework irrelevant or unnecessary for adaptation?
- Does terminology in itself cause trouble and confusion?

In this section, some main points of the input are presented. The comments are related to the relevant steps in the PIARC Framework. An overview of full responses is given in Appendix 3.

**Canada /Quebec**

| **Comment** | **Relevant for step** |
|---|---|
| Other types of climate impact assessment are a good "introduction" to the assessing the climate impact of roads. E.g. maps of coastal erosion and submersion - as a basis for vulnerability assessment of coastal roads. | 1.4<br>maps |
| Introducing climate change in manuals, best management practices, etc., provides advice on future structures. This is an important administrative adaptation measure. | 1.2 |
| It is important to forecast the return period of extreme weather events to assess the likelihood of impact. The likelihood is necessary for carrying out a standard risk analysis. | 2.1 |
| It is important to consider whether the closure of a road causes the isolation of cities or a region. In Quebec, this scenario is possible. When there are no alternative routes, the consequences of a road closures are more important. | 2.2 |
| Thresholds of risk should be defined, as a part of the basis for risk management. | 2.3 |
| Adaptation measures may be defined on a general level, not only on the asset level. For example, development of decision support tools - good practice guides, management and intervention methods, decision trees, etc. | 3.1 |
| The results of a risk assessment are input to The Civil Security Risk Management Policy. This will consider climate change and its influence on natural hazards. | 4.1 |

**Mexico**

| **Comment** | **Relevant for step** |
|---|---|
| A challenge is that the institutions that generate climate and meteorological information work independently without achieving a close link between sectors. This is possibly a challenge in other countries as well. | 1.1<br>1.6 |
| Climate projections are done on a coarse scale and the scenarios are not specific for roads. | 1.6 |
| The Ministry of Communications and Transportation has defined a process, whereby each year it selects one of the 32 States of the Mexican Republic giving it the responsibility for carrying out studies to identify vulnerable sites in the road network, training within the sector, and the implementation of adaptation actions.<br>The proposed process is a response of the Ministry to the challenges of effective communication within the road agency. | 1.1<br>4.1 |
| Hazard maps are completed for all sectors. Specific maps of road exposure are being developed. In addition, there are national maps for assessing adaptive capacity for a whole region, and national hazard maps, although not specific for roads.<br>The agencies responsible for the elaboration of climate change hazard models must specifically consider the variables that put the elements of the roads at risk. | 1.4 |
| There are no defined policies to select critical network assets, except for research papers, so the vulnerability assessment has been carried out throughout the network.<br>One approach would be to base the adaptation process on geospatial hazard maps of the specific extreme climatic phenomena that were identified as a threat. In this way, the exposed road network would be identified, and several would probably satisfy predefined criteria for "critical infrastructure".<br>Then, prioritising the roads and assets can also be done according to the criteria for adaptive capacity in the Framework. If the adaptive capacity is low or medium, one can proceed and assess their vulnerability (exposure and sensitivity), and finally their level of risk (probability and severity). | 1.4 |
| Assessing sensitivity requires information about original design levels of state. This is probably lacking many places. | 1.4 |
| Adaptive capacity is sometimes understood as the strength of the region or population to cope with a climatic phenomenon. This is an additional aspect to the Framework's definition of adaptive capacity, to be considered. | 1.5 |
| For assessing severity, it is useful to have information on the resources used from the national fund for disasters. | 2.2 |
| Risk thresholds are difficult to establish.<br>In Mexico, the design criteria for drainage works and bridges (the design return periods for precipitation, runoff, etc) are defined by the national water commission. | 2.3 |
| All investment projects require a cost-benefit analysis, but the maintenance programs do not. In Mexico, adaptation actions are incorporated into road conservation plans, so cost-benefit analyses are not necessarily carried out. | 3.2 |

### Norway

| Comment | Relevant for step |
|---|---|
| An early development of contacts between the road agency and providers of climate data and climate projections; developing mutual understanding of needs and possibilities. This is a precondition for adaptation. | 1.1 or 1.2<br>1.6 |
| The possibility should be given for carrying out a climate impact assessment on a more general scale. This can be done for chosen types of structures (e.g. bridges), or for chosen phenomena (e.g. heavy rain). No scoring, no particular structures or stretches. | 1.4 |
| The vulnerability assessment on existing roads in the tool used in NPRA is differently composed, however consisting of almost the same elements. | 1.4-1.5 |
| Vulnerability (NO) = Adaptive capacity (PIARC)<br>Vulnerability (NO) is calculated as the sum of factored scores of the redundancy and the preparedness of the road agency to handle the specific weather-related challenge. | 1.5 |
| It is useful to decide upon, and list, a limited number of threats for assessing risk. | 2.1 |
| "Importance of the road" (NO) is not adequately covered in the PIARC Framework. It corresponds to criticality. | 2.2 |
| The calculation of total risk is performed differently – other parameters and another algorithm. The method is described in [4]. | 2.1-2.2 |
| The Framework should give a possibility for defining adaptation measures only on a general level, not for particular assets. Examples: revision of design rules, inspection routines etc. | 3.1 |
| Action plan or strategy may also be defined on a more general level. | 3.3 |

### USA

| Comment | Relevant for step |
|---|---|
| Criticality, as an expression of the importance of the road, is included in the criteria for choosing the scope of the assessment. Criticality is not scored in the calculation of total risk. | 1.1<br>1.2 |
| The importance of collecting relevant maps is emphasised – e.g. information on the flood plain for being able to assess exposure. | 1.4 |
| Importance of including diverse staff in the vulnerability assessment: local maintenance and district personnel (included in "others" or "key individuals".) In addition, in the list of working staff, GIS specialist, climate science partner, universities. | 1.3 |
| Another way of limiting the scope of the investigation is choosing a representative sample of assets. An agency interested in understanding the range of climate variables that might affect its system could select a small number of assets that represent the different types of infrastructure and assets found within its transport system. | 1.4 |
| Redundancy is an element of severity /consequences.<br>(In the PIARC Framework, it is an aspect of adaptive capacity.) | 2.2 |
| In design or design-build contracts, require contractors to evaluate climate impacts and develop adaptation solutions. | 4.1 |
| Choose flexible adaptation strategies or pathways that allow for changing course as new information emerges. (This would happen in stage 3 and carry through to stage 4.) | 3.1-4.5 |

# 9. FINDINGS FROM WORKSHOPS

The Technical Committee carried out several workshops during its cycle to provide the participants with knowledge about the "International Climate Change Adaptation Framework for Road Infrastructure". In 2017, three workshops were held: in Querétaro, México; Asunción, Paraguay; and Havana, Cuba.

Engineers from the transport organisations, construction companies, consultants and universities learned how to use the Framework, and also provided feedback concerning the Framework's applicability in the local context.

**General findings**

- Road professionals understand that they have a problem associated with climate change, but do not know how to deal with it.
- Involving adaptation responses outside the transport sector is complicated because they belong to different ministries with different objectives.
- If possible, countries should implement strategies with geospatial analysis of climate change, to optimise the risk identification process of the road network.
- Most countries do not have downscaled regional climate change projections and scenarios and rely on projections from the IPCC.
- The local knowledge of the field engineers is important for the success of the adaptation and implementation of appropriate measures
- Developing countries face difficulties with risks associated with climate change. These must be addressed together with all the other important needs, such as non-existing or inadequate transport routes, security problems, poor condition of assets, poor data availability, etc.

**Framework findings**

In terms of the application of the Framework, these are the main findings:

- No difficulties were identified. The Framework was easy to use.
- The Framework gives a detailed description of how to identify risk sites. However, without prior knowledge, the user can not undertake this task.
- Introductory training on adaptation to climate change is required. This includes providing a closer description of all the necessary steps within the Framework.
- Countries need to build databases, collect information necessary for the vulnerability assessment. As previously mentioned, geospatial analyses of the impacts of climate change facilitates the assessment of exposure.
- There is lack of information about the condition of the assets and the area surrounding the road, to assess sensitivity.
- According to the PIARC Framework, "severity of impact" should be evaluated as the potential impact that the loss of road would have. Whereas in practice the severity is often judged by the expenses of the repair of the damage or the loss of the physical infrastructure.
- The assessment of "adaptive capacity" is included in Stage 1. However, it is not clear how this concept should be used in the continuation. It can be understood that, if the asset has a high capacity for adaptation, the Framework process should stop here.

- In addition, the "adaptation capacity" is applied with another scale and another focus in Stage 3, and MCA is suggested as a method to prioritise adaptation actions. This should be harmonised in both Stages of the PIARC Framework.
- Steps: 4.2 "Education, awareness and training" and 4.3 "Effective communication" have no sequence in the Framework process. They should be linear throughout the process, and with greater force in Stage 1.

# 10. POSSIBILITIES FOR REFINEMENT

Based on the input from the previous sections in the report, some possible refinements to the Framework can be proposed.

To illustrate the proposed refinements, a "flow chart" of the steps of the PIARC Framework has been put together. This is shown in Figure 6.

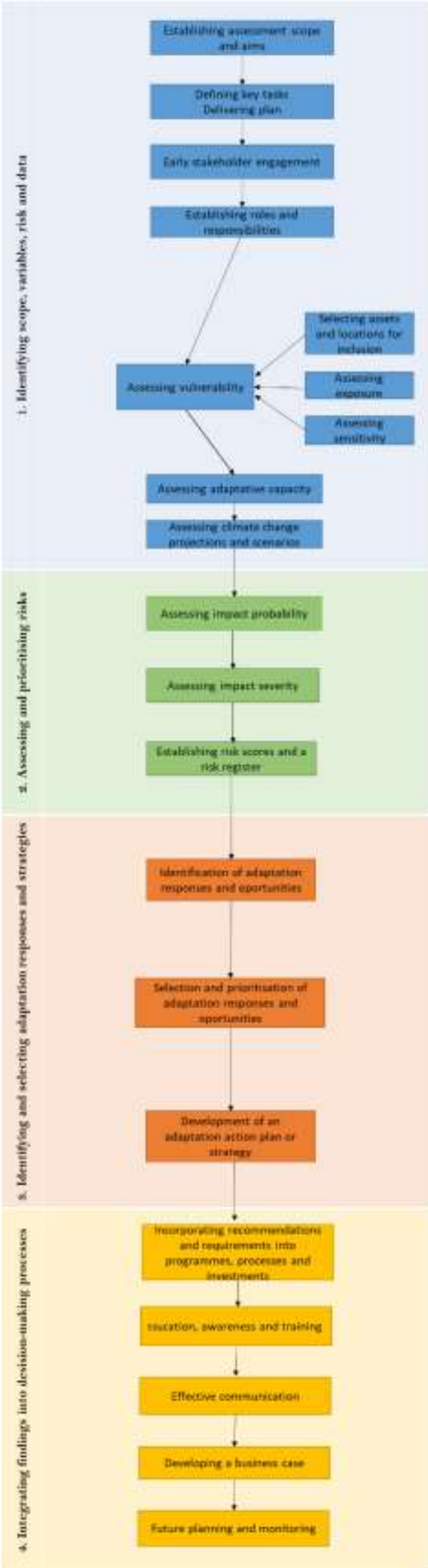



*Figure 6. A «flow chart » showing the process contained by the PIARC Framework*

## 10.1. APPLICABILITY OF THE FRAMEWORK

As noted in Section 5, the Framework is found to be mostly applicable for countries that understand the possible impacts of climate change, have a reasonably good basis in data, and that wish to perform a risk assessment on chosen, particular roads or networks. For such applications, the Framework provides a set of preliminary conditions and a methodology – a practical sequence of stages, with a good description of aims and procedures in each step. This methodology for risk assessment is only one of many possible methodologies that have been developed internationally, as is shown in Section 10.2 and in [4]. It provides a sound basis for application by developed and developing countries.

However, it is acknowledged that the starting points of adaptation work can vary extensively between countries and regions. Road agencies that have not started any systematic work on adaptation to climate change may not see the challenge in a holistic manner – both within the transport sector and across sectors.

Experience shows that the cross-disciplinary nature of this work often reveals questions and challenges throughout the analysis. The original premises for the work are often found insufficient, the data incomplete or inadequate etc. The draft version of ISO 14090 "Adaptation to climate change - Principles, requirements and guidelines" suggests organisations adopt the method of assessing climate change impacts that suits their needs [15]. Depending on the starting point, available data and overall aims, it may be better to perform a vulnerability assessment before a full risk assessment. Therefore, one of the proposed modifications of the PIARC Framework will be introducing a "short-cut" that enables the use of the framework as a tool for vulnerability assessment.

Another proposed modification will be to include the considerations and possible actions that are necessary to implement in the *planning phase* of a road project. This phase is very important for increasing climate resilience. The Framework needs a "short-cut" to accommodate the need to include the planning phase.

### 10.1.1. Performing a vulnerability assessment

A road agency just starting to investigate the impacts of climate change on its road network may first want to obtain an overview of challenges, to investigate the potential threats and vulnerabilities, and consider the capacity of the organisation to cope with these hazards and adapt. As a result of such an assessment, a new strategy or action plan, or a set of educational measures can be formulated.

For example, the road agency may seek answers to the following questions:

- What are the challenges in maintaining traffic mobility, safety and the environment of the road network in the future climate?
- In which areas of the country are the roads most exposed to the impacts of climate change?
- What type of assets are most sensitive to the climate parameters expected to change? Which of the climate related threats could be most critical?
- Based on exposure and sensitivity – what are the vulnerable aspects/parts of the road network? Does our organisation have the capacity to cope with them and how?

- What should we generally do to organise and start the work in a good way, how shall we estimate and allocate resources and how should we integrate this work in our management?

One may also want to concentrate on one type of asset only, for example bridges, and want to know:

- Exposure: Which aspects of climate change will affect bridges in the country? Which climate parameters do we need to know more about? Which areas of the country will these parameters change the most?
- Sensitivity: What types of bridge structures are most vulnerable to the expected climate impacts /to climate change?

Other possibilities:

- How vulnerable are the drainage structures for a future climate? Can we adopt a plan for coping with the problems?
- How will the bearing capacity of roads be affected by climate change?

This vulnerability analysis does not address specific road stretches and does not include scoring. Nevertheless, it describes the challenges the road agency has to face and helps define measures that should be implemented. Many of the adaptation measures may be of the organisational, administrative or educational type.

The idea of starting the adaptation work by performing a vulnerability assessment and an assessment of adaptive capacity is supported by the findings from the workshops, where the Framework was systematically implemented on specific parts of the road network (Section 0). The road agency should prepare for adaptation work by an introductory education, i.e. learning to understand the uncertainties. The systematic mapping and collection of available data and information (required in Stage 1) may change the scope and ambitions of the assessment. It can also define the methodology that can be used.

As a start it may be useful to perform an assessment of exposure and sensitivity to historical climate trends and climate events. It is nevertheless our suggestion that the projections of climate change are required early in the process.

In the structure of the Framework, the proposed refinement would be a short-cut between Step 1 and 3. Figure 7 illustrates this adjustment in the flowchart.

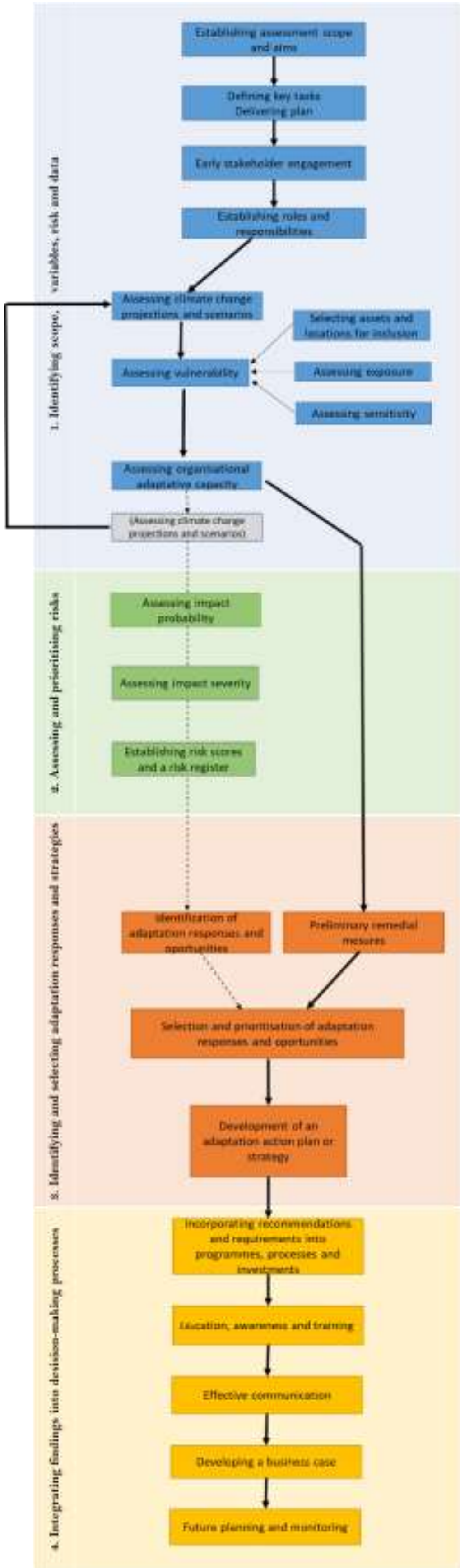



*Figure 7. A schematic presentation of the use of the Framework for a general assessment of risks*

### 10.1.2. Addressing the planning phase of a road construction project

It is a well-established experience that the planning phase is important for good resilience to climate change. Small mistakes in the early phase of a project can cause serious challenges in the operation phase, for example by intensifying the maintenance need and expenses. Vice versa, small early additional investments may provide substantial benefits in the operation phase. For these reasons, the planning phase is proposed to be presented in the Framework in a clearer way.

The PIARC Framework is mostly applicable to *existing road stretches*. The need may, however, be to estimate the risks in an *area* assigned for road construction. In addition, one may want to compare the risks for several alignment options.

As design criteria is often predefined, a new road aims to minimise the risk and ensure that the quality requirements are given by national standards and in the most economically efficient way. The remaining factor is to assess is exposure to climate related effects. The task is to:

- assess exposure in the planned alignment (or possibly in several alignments)
- estimate the probability of relevant unwanted events
- estimate the consequences.

The estimates of probability and consequences may be done roughly or in more detaile and are dependent on the specific phase in the planning process and the available data /knowledge base.

If the alignment of the new road is close to an existing road, where one has available data on frequency of events and documented consequences, the estimates of probability and consequences will be easier to carry out. If this is not the case, one will have to judge based on hazard maps, knowledge about ground conditions etc, and estimate the probability and consequences using a coarser scale (low – medium – high).

The estimate of potential threats for different route options must be carried out for the climate that will be valid during the service life of the road. That is why it is advisable to move the step "Assessing climate change projections and scenarios" earlier in the process. This will also be discussed in Section 10.2.

Figure 8 presents graphically this type of application of the Framework.

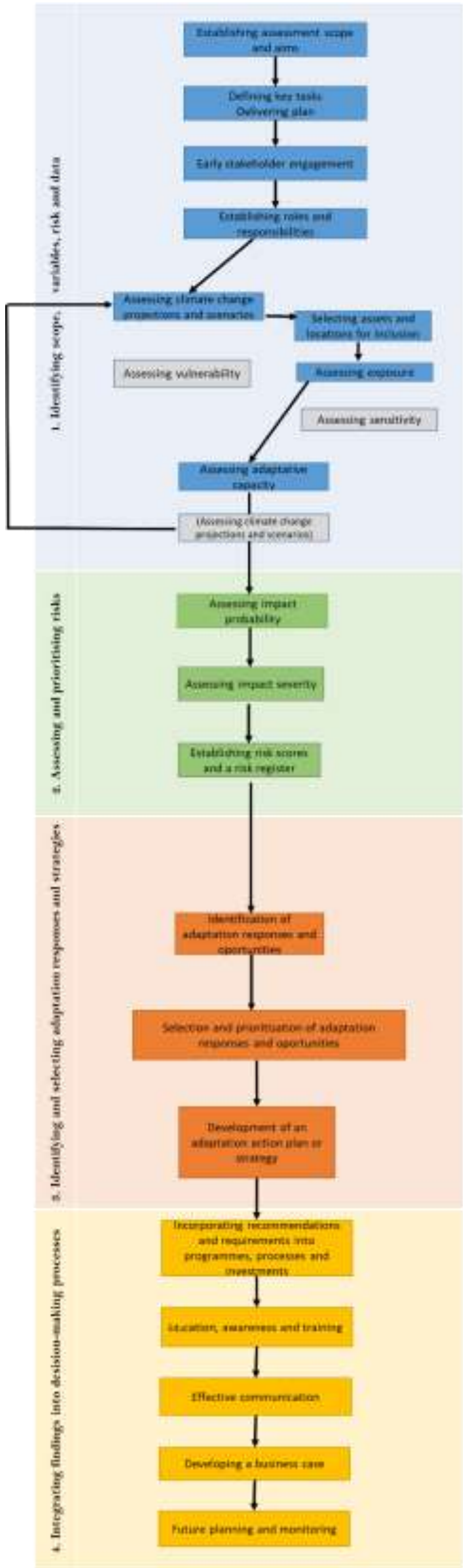



*Figure 8. A schematic presentation of the use of the Framework for assessment of risks in the planning phase*

### 10.2. COMBINING THE COMPONENTS OF RISK

A road agency may not yet be aware of the need to address climate change. It may nevertheless have a method for risk assessment of roads or assets. In such cases, it is only reasonable to expand the existing methodology by introducing aspects of climate change, instead of developing a new method for risk assessment. In other words, even if the road agency's system for risk assessment does *not* include aspects of climate change, it should be possible to place it within the climate change adaptation framework.

According to the definition used in PIARC, "risk" is a combination of the probability of an event occurring and the consequences of the event. The difficulty concerning risk assessment of weather-related events, climate change and extreme events is that information on probabilities is limited. There is a discrepancy between the probability for a certain climate phenomenon and the probability of an unwanted event caused by this phenomenon. For example, a 1 in 100-year precipitation event will not cause a 1 in 100-year drainage failure.

In its present version, the PIARC Framework shows one of many possible ways of assessing vulnerability and calculating the risk. However, as shown in [4] and in Section 7.2, components such as exposure, sensitivity, redundancy, adaptive capacity etc. are both defined and used in various ways, with the same aim – to calculate risk. Examples include:

- "vulnerability" is in the PIARC Framework composed of "exposure" and "sensitivity".
- "adaptive capacity" is – in some frameworks - composed of "redundancy" and "preparedness to tackle the event". In other frameworks, redundancy is a parameter of its own, or even included in the scoring of severity (consequences).

It is important to recognise the individual components of risk assessment, to be able to compare *ongoing* adaptation work with the present version of the Framework. The aim is to make use of established procedures and apply the Framework as a "corrective".

Tasks that usually comprise risk assessment methodologies (see Section 7.2 and [4]) are to:

- estimate the exposure of the road /road assets to the key climate variables – the ones already causing problems for the road network and/or expected to change;
- estimate the sensitivity of the road /road assets to the key climate parameters; describe the features that determine if the climate parameter in question poses any risk to the road /road assets.
- determine which unwanted events are likely to happen on the road or road assets;
- for exposed locations, describe the probability of the event happening – if possible. (For weather related events, probability may be very difficult to assume);
- describe the consequences or severity of the chosen studied event. Here the criteria can be anything the road agency chooses. These may vary from simple road closure yes/no, to an elaborate table of various aspects of consequences;
- describe the road agency's ability to handle a certain event. Does the road agency have the equipment and the know-how?
- estimate the level of redundancy: existing or not, adequate /not adequate for the type of traffic that uses the road;
- describe the criticality of the road, through estimating the size of the area affected by the road being taken out of function. What is the original function of the road?

- estimate the importance of the road by the help of established classifications, or through factors such as annual daily traffic, share of freight traffic, etc.

These points are by no means a complete list of tasks that comprise a risk assessment! However, if the road agency has any of these points already established as regular tasks, they may be the start of a risk assessment, and through that of adaptation to climate change.

Examples of risk assessment in [4] show the variation in methodologies, although many similarities exist. A suggestion is to extract the methodology component from the structure of the Framework. Figure 9 illustrates this point, by drawing the risk assessment part as a separate task.

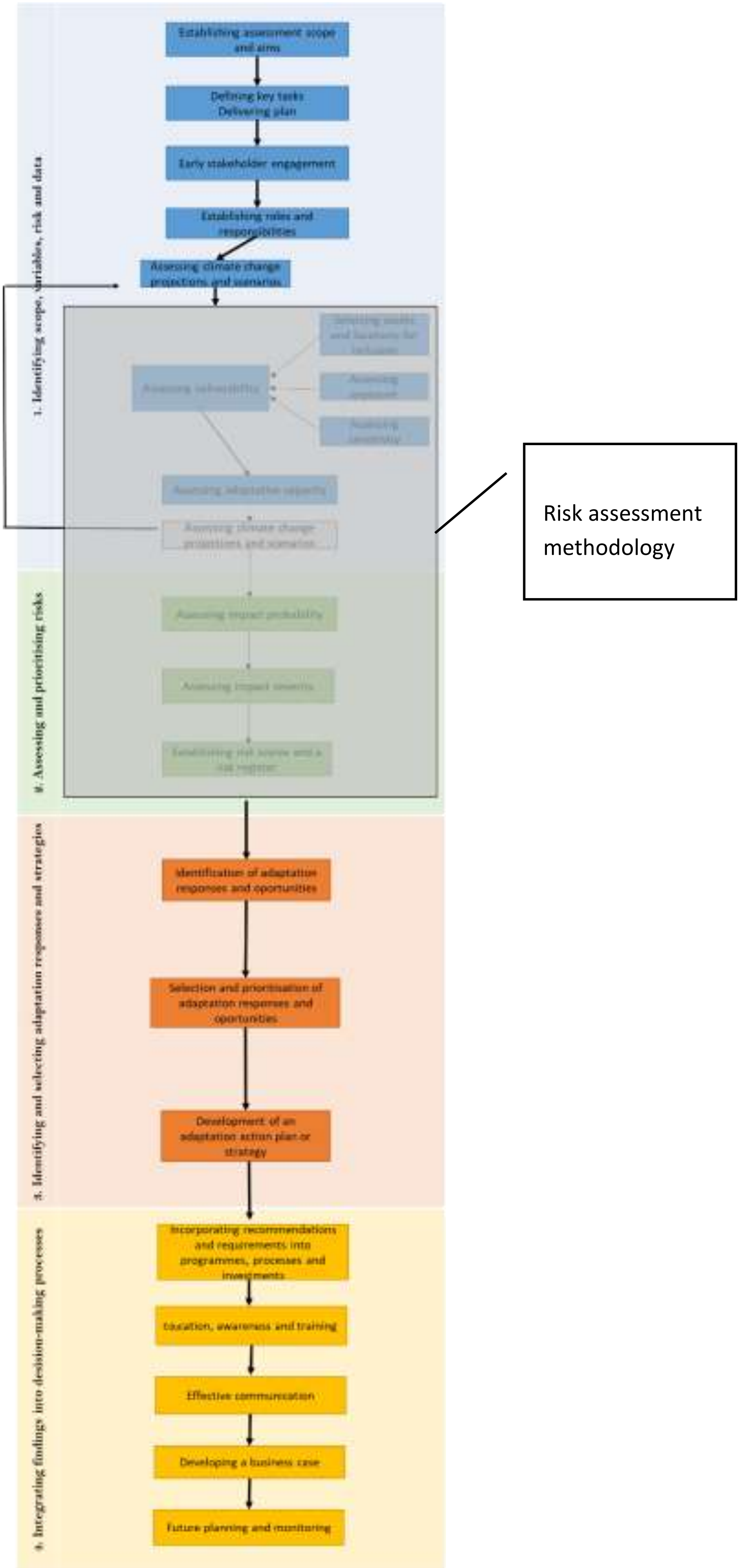



*Figure 9. Illustration of the risk assessment as a separate task that gives a final risk score*

These considerations lead to another possible adjustment. The steps taken before the "frame" called 'risk assessment methodology' should be recognised as the preparation stage. The steps comprising this preparation stage provide the conditions for carrying out the work; can help users decide on the methodology to use and help make adjustments according to the objectives and outcomes of a project. The climate projections should be available already in this stage.

This is in line with the conclusions from the implementation of the PIARC Framework in Mexico, where a "preparation phase" in Stage 1 was recognised, see 6.1.

## 10.3. INTRODUCING THE ASPECT OF CRITICALITY

The present PIARC Framework does not distinguish between road sections/structures that are crucial for the transport services in a community or region, and roads that are not. In some frameworks such issues are covered by the term "criticality", other call it "importance" of the road or "road value".

There are numerous ways of defining and expressing criticality, as shown in [4]. Criticality does not depend on a specific hazard. It is a value connected to the functionality of the road, i.e. to the services provided by the road. Several frameworks include the aspect of criticality, as shown in Section 7. In most cases, criticality is an element of the risk assessment, and a factor in the calculation of risk score.

This report focuses on the *system* aspect the PIARC Framework rather that the *methodology* part (as described in Section 10.2). However, since criticality has not been included in the PIARC Framework up to now, some options for its inclusion are described in the following.

- <u>Criticality can be one of the initial criteria for defining the scope of the risk assessment</u>. In the present version of the PIARC Framework, this belongs to Step 1.4, "Selecting assets and locations for inclusion". One of the tasks in Step 1.4 is to "evaluate critical assets of great value for the transport", with the aim of prioritising, or limiting the scope of the assessment, at the very start. FHWA framework [7] applies the assessment of criticality in this way.
  However, if the scope is defined by a geographic area and comprises roads of various importance, it is necessary to define /score criticality as an element of its own.
- <u>'Criticality' can be assessed and scored as an element of its own, in a risk analysis and when calculating the total risk</u>. This interpretation is most in line with the contents and conclusions of the present report. This would apply to an analysed road or road segment, whereas the other factors are mostly estimated per point. This way of defining criticality can come in addition to the previous point. In the PIARC Framework, this would mean adding a step between 2.2 and 2.3.
  This way of treating criticality is suitable in cases when one wishes to compare the risk scores on several road stretches within a road network. The score of total risk, defined in the PIARC Framework as "probability x severity", would in that case get 'criticality' as an additional element. Please see [4] for examples.
- <u>Criticality can be combined with other criteria into more complex parameters of the risk assessment methodology</u>. Some frameworks /methodologies add the notion of criticality to the criteria for judging the sensitivity of a road section, or the severity of an event. In the PIARC Framework, this would belong to Step 1.3 and 2.2, respectively.

RIMAROCC methodology describes traffic intensity or economic impacts as aspects of both vulnerability or consequences. The ROADAPT methodology has a sub-step where the aim is to provide an allocation of different road importance categories to different road stretches. In the ROADAPT method, this is called sensitivity. The suggested criteria are traffic intensity and the economic importance of the area surrounding the road (which correspond to what the present report describes as criticality), but also redundancy (which the present report handles as a part of adaptive capacity).

## 10.4. Using the Score of Adaptive Capacity

Step 1.5 of the PIARC Framework estimates the *adaptive capacity* of the road or road agency with respect to the specific event studied. The following criteria are suggested applied:

- the ability of the road agency to respond to the particular threat and repair damages (repair);
- existence and adequacy of alternative transport routes (redundancy); and
- ability to readily adjust to short term climatic events (resilience).

Adaptive capacity is not an aspect of increasing or reducing the probability or the severity of the studied event. Adaptive capacity is rather an expression of how quickly normal conditions can be re-established, though temporarily. Therefore, it is logical to define adaptive capacity as a factor of its own.

In the present version of the PIARC Framework, the score of adaptive capacity is not used in the continuation of the calculation of risk. This should be taken care of in the next edition of the Framework.

## 10.5. Algorithm for the Calculation of Total Risk

Base on the contents of the previous sections, there are two main reasons for making adjustments to the algorithm for calculating the total score of risk in the Framework:

- *adaptive capacity* is scored in Stage 1.5, and this score needs to be included in the calculation of the total risk. In the present edition of the Framework, this is not the case.
- *criticality* or *importance of the road*, is proposed to be introduced in the risk assessment and should also be taken into consideration in the calculation of total risk.

It is proposed that these two aspects be elements of their own. Several examples of how criticality and adaptive capacity are made use of in the calculation of the final score are presented in [4].

## 10.6. The Importance of the Stakeholder Network

Adaptation to climate change is cross-disciplinary work. In many road agencies, new contacts and cooperation channels need to be established. The most important for adaptation of roads to climate change are stakeholders/partners who provide data or maps, for example meteorological offices, hydrological institutes, or partners for collaboration in emergencies, for example civil protection agencies.

Many road agencies lack expertise in hydrology and might not yet have established cooperation with agencies that have that expertise. An important part of the work is getting in place such connections, and to establish good communication:

- Road agencies need to refine their requirements, describe their needs in an efficient way. For example: the available climate projections, provided by the professional agencies, may be done on a coarse scale and the scenarios may be inadequate for roads.
- The collaborating agencies need to understand the road owners' needs and respond with adequate information, containing information about uncertainty and applicability of data or procedures that they can supply.

Learning to communicate needs and possibilities may take time but is important for ensuring the success of any adaptation work. It is, therefore, necessary to emphasise the importance of establishing a good stakeholder network early in the process.

Here are some examples of elements in a knowledge base for adaptation, where participation of other agencies /partners is important:

- Achieving access to climate data – meteorological and hydrological data.
  - Accessibility: Is climate data easily available?
  - Relevance: Is data relevant for the case, e.g. coming from climate stations placed at relevant places with respect to the road?
  - Format: Is the knowledge /data provided by other agencies applicable for road owners?
  - Compatibility: Do the road agency own their own climate stations? Are they compatible with stations owned by a met-office (or other data provider)?
- Communicating needs for adjustments or improvements. Are the needs of the road agency clear and understandable to the agencies providing the data or knowledge? Are the possibilities of the partner agencies clear and understandable to the road agency? How should the inevitable uncertainty be handled?
- Acquiring the adequate climate projections. If climate projections exist – are they presented in a way that is suitable for practical purposes?
- Collecting maps for adaptation to climate change. Does the road agency have adequate flood (risk) maps, maps of landslide risk? Communicating needs, communicating possibilities and managing uncertainty are essential issues for collaboration.

Even if climate projections are provided, it is necessary to interpret these results for easier practical application. The need to collaborate is present in all phases of adaptation work.

It should also be mentioned that collaboration between the institutions that generate climate and meteorological information is a great benefit for all sectors working on adaptation to climate change. In cases when the knowledge providers work independently, the knowledge base they provide is difficult to implement.

Several R&D projects belonging to CEDR Transnational road research programme [16] [1], address issues of interpreting climate knowledge for road engineers, and interpreting needs of road engineers for climate experts. Some relevant documents are:

- "Guideline on the use of data for the current and future climate for road infrastructure" of the RoadApt project [16]
- "Design guideline for a transnational database of downscaled climate projection data for road impact models" of the CliPDaR project [17]
- "Climate and climate change: protocol for use and generation of statistics on rainfall extremes" of the WATCH project [18].

# 11. SUMMARY OF PROPOSALS FOR REFINING THE FRAMEWORK

This section summarises the types of adjustments put forward for discussion and decisions when developing a new edition of the PIARC Framework.

## 11.1. STRUCTURAL CHANGES

- Short-cut, from step 1.4 to 3.1, tailored for carrying out a vulnerability assessment, omitting the risk assessment of specific road stretches and assets.
- Short-cut tailored for addressing the planning phase of a road project, e.g. when alternative alignments are compared. The emphasis is on exposure, omitting the issues of sensitivity and vulnerability.
- Recognising the initial steps 1.1 – 1.3 as the "Preparation phase" or the "Project planning and scanning" phase.
- Recognising steps 1.4, 1.5 and the whole of Stage 2 as the "Risk assessment" stage, where methodologies can vary. This is a separate task, which can be extracted from the Framework and performed in different ways.
- Identifying examples is important for better understanding the application of the Framework.

## 11.2. ADDED STEPS AND SUB-STEPS

- Reviewing (regional) projections of climate change, which are an important part of the knowledge base for adaptation, should be carried out earlier in the process. They can determine ambitions for the whole assessment, the methodology to use, etc.
- More advice on choosing appropriate climate scenarios is needed. Cooperation with stakeholders are important for achieving this. This is proposed to be included early in the process, already in the "preparation stage".
- Advice is needed for limiting the challenges /unwanted events/ to the most important ones.
- Criticality needs to be introduced as a parameter.
- Adaptive capacity needs to be inserted in the sequence of tasks, as a part of the risk assessment (Stage 1.5) and an element in the calculation of the total risk score (Step 2.3). However, this belongs to the methodology aspect of the Framework, and not to the framework as a structure of work.
- Stage 3 should start with "identification of the type of risk assessment, its chronology and scenarios".
- The road agency must know their technical capacity and resources at the commencement of the overall adaptation work.
- The road agency needs to make some important decisions at the initiation of the work, such as defining criteria for risk tolerance, the limits of feasibility of adaptation measures, criteria for evaluating the results of adaptation.
- 'Effective communication' should be present throughout the stages of the Framework.

### 11.3. ADDED CONTENTS

- It is important to include in a clearer way the necessary revision of technical specifications. This is a response strategy, affecting the decision-making process and costs.
- More emphasis on road owners' need to obtain data as the basis for risk assessment.
    - Road data, traffic data, redundancy, supply chains, traffic freight transport;
    - Information about existing structures: design levels, condition;
    - Information about historic events, damage, costs, etc.
- Adaptation pathways should be included – stepwise implementation of adaptation measures, dependent on their benefits and costs.
- Life-cycle costing analysis to assess and prioritise adaptation measures can be included.
- Observation /suggestions regarding methodology:

- distinguish between the scale of analysis, define risk criteria and indicators adapted to each scale of analysis;
- some advice is needed concerning adjusting the evaluation of the severity of impact, and definition of threshold values;
- emphasise on local knowledge, and other advice concerning expertise is required at all stages;
- add advice concerning evaluating sensitivity: general sensitivity, aggravating factors, qualitative /quantitative assessment;
- add exposure scoring on a larger scale – in cases one wants to perform comparisons within a larger area of the road network;
- include social acceptance of the adaptation measures, as included in one of the frameworks in the benchmarking section (ADB); and
- distinguish between current and future climate threats and then evaluate the vulnerability of the system or the road assets.

## 12. CONCLUSIONS

PIARC's International Climate Change Adaptation Framework has been implemented in three cases worldwide and presented in selected workshops in some road administrations. In this report, the Framework has been subjected to an investigation of applicability for various purposes, comparison with other adaptation frameworks and compliance with ongoing adaptation work. Based on this assessment, some proposals for refinement of the Framework have been formulated. A summary of proposals is given in Section ▯.

The PIARC Framework is most suitable for road agencies that have enough basic knowledge for carrying out a climate impact assessment and implementing adaptation measures, that already have good communication with other stakeholders, but that have not done much adaptation work yet. Therefore, some simplifications (short-cuts) in the procedure are proposed in order to satisfy different levels of analysis or scope.

The Framework provides a combination of a structure of tasks for adaptation to climate change and a methodology for risk assessment. It is proposed that these two aspects are separated. The structural aspect is important because it sets out the various tasks in relation to each other. The methodology aspect is not less important but *is* variable and *needs to be* variable to suit the different existing practices of road administrations.

The aspect of criticality needs to be included in the assessment of risks and decisions on adaptation measures.

All the proposals from this report, together with examples of adaptation measures reported in [4] provide a basis for developing a new edition of the Framework in a future PIARC cycle.

# 13. GLOSSARY

| Term | Definition |
|---|---|
| **Adaptation** | Adaptation is adjustment within natural or human systems in response to actual or projected climatic stimuli or their effects, which aims to moderate harm or exploit beneficial opportunities (PIARC Framework, 2015). |
| **Adaptive Capacity** | The ability or potential of a system to respond successfully to climate variability and change, and includes adjustments in both behaviour and in resources and technologies (PIARC Framework, 2015). |
| **Consequence** | Outcome of an event affecting objectives. An event can lead to a range of consequences. A consequence can be certain or uncertain and can have positive or negative effects on objectives (ISO, 2009). |
| **Critical Assets** | Critical assets are those that are essential for supporting the social and business needs of both the local and national economy (PIARC, Asset Management Manual, 2017). |
| **Criticality** | The relevance of an infrastructure element or section to the availability of a road infrastructure system.<br><br>Note: Based on All-Hazard Guide for Transport Infrastructure, 2015. |
| **Exposure** | The presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected (Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, IPCC, 2012). |
| **Frequency** | Measure of the likelihood of an event expressed as a number of events or outcomes per defined unit of time (ISO, 2009). |
| **Likelihood** | Chance of something happening (ISO, 2009).<br><br>ISO uses the word "likelihood" is used to refer to the chance of something happening, whether defined, measured or determined objectively, subjectively, qualitatively or quantitatively, and described using general terms or mathematically (such as probability or a frequency). |
| **Mitigation** | A human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs).<br><br>Note: Based on IPCC Fourth Assessment Report: Climate Change 2007 |
| **Probability** | Impact probability relates to the likelihood of an impact occurring within a given timeframe (PIARC Framework, 2015). Measure of the chance of occurrence expressed as a number between 0 and 1, where 0 is impossibility and 1 is absolute certainty (ISO, 2009). |
| **Resilience** | The ability to prepare and plan for, absorb, recover from, or more successfully adapt to actual or potential adverse events.<br><br>Note: Definition developed by the study committee based on the extant literature and is consistent with the international disaster policy community (UNISDR, 2011), U.S. governmental agency definitions (SDR, 2005; DHS Risk Steering Committee, 2008; PPD-8, 2011), and NRC (2011). |
| **Risk** | Effect of uncertainty on objectives. Risk is often characterized by reference to potential events, consequences, or a combination of these and how they can affect the achievement of objectives. Risk is often expressed in terms of a combination of the consequences of an event or a change in circumstances, and the associated likelihood of occurrence (ISO, 2009). |

| | |
|---|---|
| **Risk Analysis** | Process to comprehend the nature of risk and to determine the level of risk. Risk analysis provides the basis for risk evaluation and decisions about risk treatment (ISO, 2009). |
| **Risk Assessment** | Overall process of risk identification, risk analysis and risk evaluation (ISO, 2009). |
| **Risk Evaluation** | Process of comparing the results of risk analysis against risk criteria to determine whether the level of risk is acceptable or tolerable (ISO, 2009). |
| **Risk Management** | Coordinated activities to direct and control an organization with regard to risk (ISO, 2009). |
| **Risk Treatment** | Process of developing, selecting and implementing controls (ISO, 2009). |
| **Sensitivity** | The degree to which a system is affected, either adversely or beneficially, by climate-related stimuli (PIARC Framework, 2015). |
| **Vulnerability** | The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes (PIARC Framework, 2015). |

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