



Best-practice guidelines for the adaptation of roads to climate change

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1. Background

The Intergovernmental Group on Climate Change (IPCC), the world's leading scientific body in this field, repeatedly points out the need to adapt infrastructures to reduce vulnerability to climate variability and change. Changes affect the social and productive infrastructure of the countries, their investments and their sustainability, so it is important to take into account all possible considerations to shield them from those transformations.

Although adaptation mechanisms are being developed around the world, the progress made is not homogeneous. IPCC identifies that regions such as North America and Europe are working on transversal adaptation policies in all areas of government, as well as protecting transportation and energy infrastructures, while in other regions, such as Latin America (for which these Guidelines have been developed) are still taking their first steps.

It was estimated that the effect of "El Niño" in 1997 had an impact of USD 1,700 million on transport in Latin America. "La Niña" in 2010 and 2011 in Colombia significantly affected the country's road infrastructure; more than 31,600 kilometres of roads were affected, 10% of them part of the primary road network. The total economic impact of the damage caused to the infrastructure exceeded 3.2 billion Colombian pesos (Ministerio de Transportes 2014). In Paraguay, "El Niño" 2015-2016 and its extraordinary rains caused the destruction of 40 bridges and the need to rehabilitate more than 11,000 kilometres of local roads; the damages and losses exceeded USD 220 million USD and the reconstruction needs exceeded USD 150 million (Ministerio de Obras Públicas y Comunicaciones 2016). These are just some examples of the impact that the weather has had on the road network recently.

Approximately 25% of the losses from natural disasters in the Latin-American region fall upon the transport sector. The adaptation of roads to climate change aims to anticipate the adverse effects of climate and take appropriate measures to avoid or minimize the damage they may cause, in order to reduce future costs and maximize investment profitability. These adaptation measures should be focused in the short, medium and long term, and complemented with environmental management, planning and disaster risk management components.

There has always been a close relationship between climate and road infrastructure; however, the accelerated changes that have happened recently mean that the historical climate data used to date is not sufficient for an adequate management of the current infrastructure. If the planning and design of roads are still carried out only in accordance with the usual engineering practices and with the existing historical data, they will probably not be able to respond to the climatic events of recent years which, predictably, will continue in the

future. As a consequence, the sustainability of the infrastructure and the economic efficiency of the investments could be questioned.

The current situation in the Latin America and the Caribbean region is heterogeneous; while there are some countries which are developing adaptation plans, there are others in a very early stage; however, it is widely recognized that there is a need to act in this area in all nations.

Multilateral entities are deploying ambitious programs to help countries in their policies of adaptation to climate change; in spite of this, the application of adaptation actions to roads is relatively recent and existing experiences are limited. At a national level, there is a lack of coordination between the different authorities of the countries' governments, usually between those responsible for public works and transport and those responsible for the environment - likewise, the lack of coordination is transferred to subnational relationships. This will undoubtedly be one of the great challenges in the coming years, together with the transfer of information in the region.

The following references and best practices should be highlighted in the region, in terms of adaptation of road infrastructure to climate change:

- Plan for the adaptation of federal highways to recurrent natural disasters (Brazil) (Ministerio de Medio Ambiente 2016).
- Inclusion of criteria for adaptation to climate change in the Handbook of highways (Chile).
- Plan Vías-CC: roads compatible with the climate. Adaptation plan for the primary road network (Colombia) (Gobierno de Colombia 2014).
- Study of climate risk for Colombia's primary road network at the national level (Colombia) (Ministerio de Transporte. Ministerio de Ambiente. INVIAS. ANI 2015).
- Creation of a specific unit for adaptation to climate change within the Ministry of Public Works, Transport, Housing and Urban Development of El Salvador: Directorate of Adaptation to Climate Change and Strategic Risk Management (DACGER). (Ministerio de Medio Ambiente y Recursos Naturales 2015).
- Climate change policies in infrastructure (El Salvador).
- Climate change adaptation plans for roads (Mexico).
- Evaluation of the impact of El Niño 2015-2016 in the transport and communication sector (Paraguay). (Ministerio de Obras Públicas y Comunicaciones 2016).
- Assessment of vulnerability and adaptation to climate change in the transport sector (Peru). (Ministerio del Ambiente 2011).

In the current situation, it is time to act to adapt the road infrastructure to the effects of climate change; thus, it is necessary to promote comprehensive approaches, with the participation

of all government departments in the countries of Latin America and the Caribbean, as well as the collaboration of multilateral entities, so that one of the great challenges of the region can be effectively addressed: the sustainability of road infrastructure and its economic and social impact in the countries.

The "Best-Practice Guidelines for the Adaptation of Roads to Climate Change", published by CAF - development bank of Latin America, and developed by the Ibero-American Road Institute (IVIA) and the Spanish Road Association (AEC), aim to generate knowledge about the importance of defining infrastructure adapted to the climate throughout its life cycle, as well as to show examples, actions and measures of good practices that could be useful for its application to road projects. The Guidelines consider not only new construction of roads, but also existing road networks¹.

2. Objectives

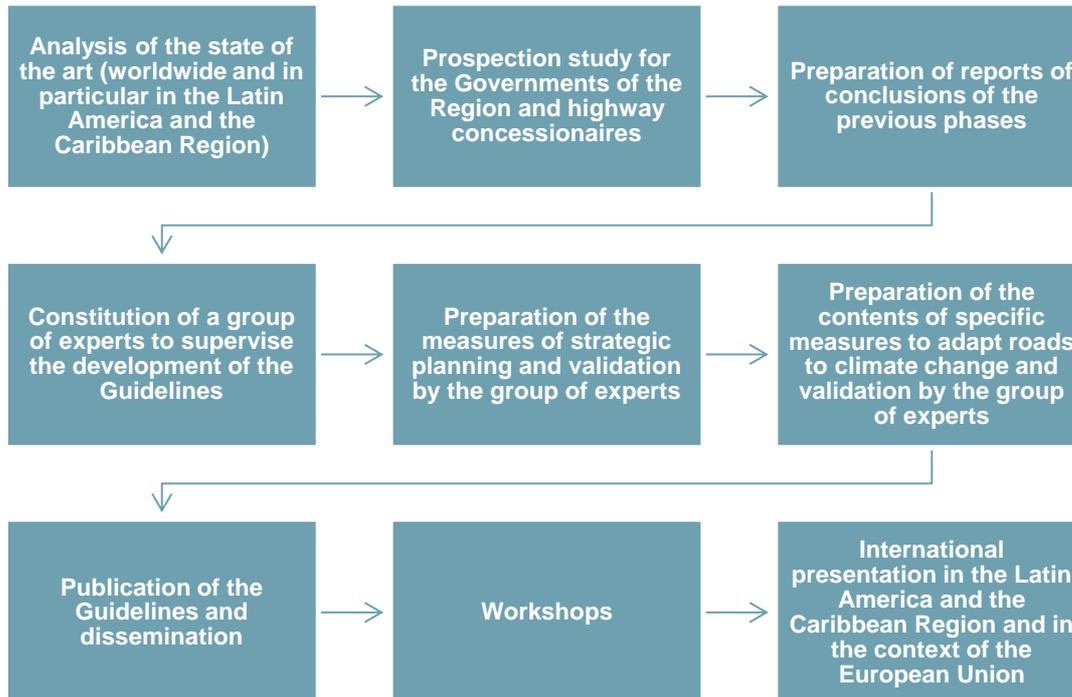
The "Best-Practice Guidelines for the Adaptation of Roads to Climate Change" have been developed according to the following objectives:

- Provide an answer to basic questions about the importance of incorporating climate adaptation measures in highway projects.
- Guide public policymakers to identify measures that can be applied to highway projects, from strategic planning to technical and environmental components.
- Identify specific measures that can be implemented in road projects and in the road network(s) in service, throughout its life cycle.

¹ The Guidelines can be downloaded from <http://scioteca.caf.com/handle/123456789/1221>.

3. Process followed for the development of the guidelines

The following steps have been taken for the development of the Guidelines:



Graph 1: Process for the development of Guidelines (own sources)

The analysis of the state of the art was the starting point for the development of the Guidelines, through the knowledge of the situation of countries in the fighting against the effects of the climate change, adaptation strategies and specific initiatives in road infrastructure. To this end, works and policies of international organizations present in the region (such as World Bank, Inter-American Development Bank, CAF - development bank of Latin America, United Nations, IPCC, World Road Association, etc.) were considered. Additionally, the initiatives of other reference entities were assessed, even though their geographic scope of action is not Latin America and the Caribbean region.

Regarding the study of prospection to the public sector, it should be noted that its objective was to collect information on existing policies and plans in the field of adaptation of roads to climate change, as well as specific measures and available results on their effectiveness, implementation difficulties, budget range, financing mechanisms, etc. The questionnaire was distributed among many public entities of the road and environmental sector that are involved in this field. The answers received were analysed and their main results and conclusions are presented below:

- Difficulties for obtaining information on adaptation of roads to climate change.
- Greater willingness to participate by the highway authorities.

- Limitations of coordination between different authorities of the countries' governments.
- Heterogeneity in terms of the level of readiness to face climate change.
- Recognition of the challenge of adaptation of roads to climate change.
- Need for greater information and knowledge transfer and establishment of contacts in the region.

4. Description of guidelines.

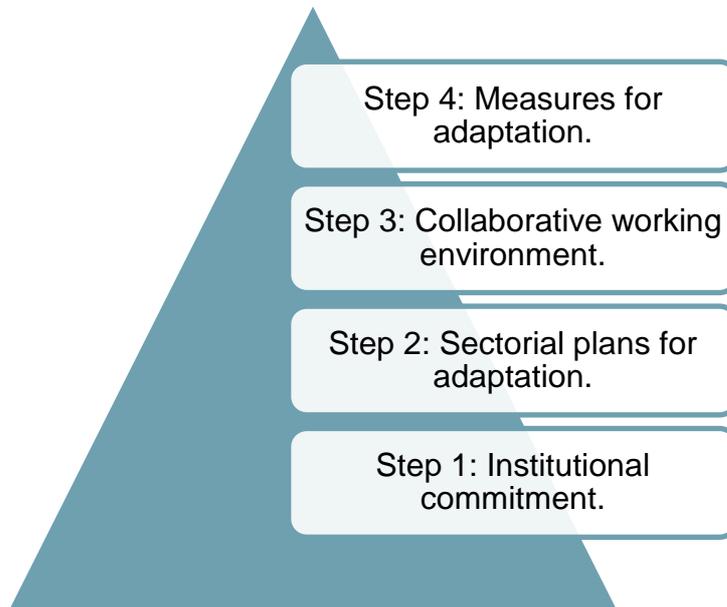
The Guidelines have been structured in four differentiated blocks, including conclusions and annexes:

- An initial part includes the introduction, the background and the objectives.
- There is a conceptual chapter including the principles for adaptation of roads to climate variability and change.
- Following, there is a description of strategic planning actions for adapting roads to climate variability and change.
- Set of specific technical measures for adaptation throughout roads life cycle.
- Conclusions.
- Annexes including the state-of-the-art of the adaptation of roads to climate variability and change in Latin America and the Caribbean, as conclusions of a survey study conducted in the region, furthermore including a glossary of the most frequent terms.

A brief summary of the main chapters and contents of the Guidelines is included in this paper.

4.1. Strategic planning actions for adaptation of roads to climate change

Strategic planning actions are the first step for the implementation of measures to adapt roads to the climate change in the context of a government or a territory. The following graph introduces the concept of the "Strategic pyramid of adaptation to climate change", which encloses the vision of these Guidelines, from a global perspective:



Graph 2: Strategic pyramid of adaptation to climate change (CAF - banco de desarrollo de América Latina 2018)

In addition to this global scheme of work, which implies the creation of an appropriate institutional framework (steps 1, 2 and 3), the Guidelines also contemplate the implementation of adaptation measures in new road projects and existing roads (step 4), regardless of previous steps.

As shown in the graph, the strategic pyramid of adaptation to climate change allows the setting up of the following priorities:

- The first step for roads adaptation to climate change is a real institutional commitment, in order to define policies, plans and budget for this purpose, as well as institutional strengthening actions to be ready for the necessary change.

This commitment should be out of any political sign of governments, and should be included in the political compromises of the country regarding climate change policy.

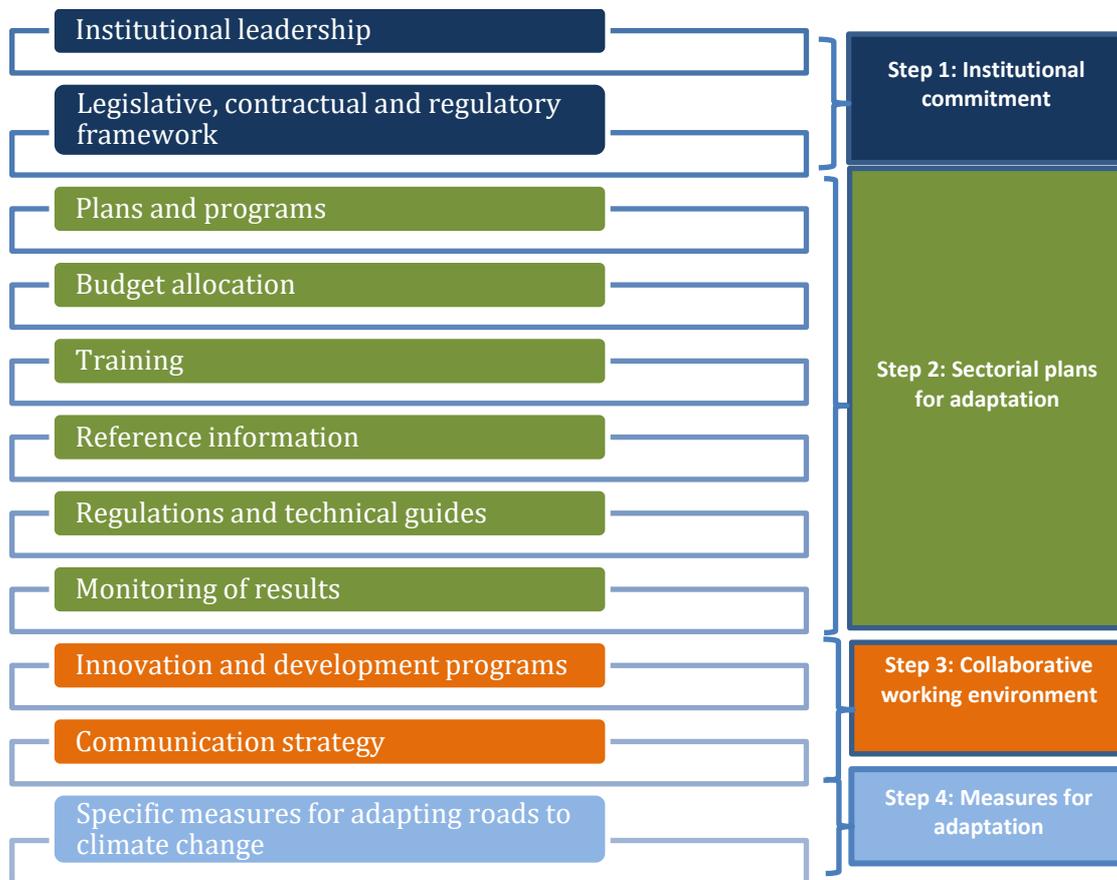
- Once there is a policy for adaptation to climate change, it is the moment to generate specific plans for adaptation of roads to climate.

These plans should include specific actions, clear objectives to achieve and a definition of stakeholders, as well as indicators for follow-up and corresponding budgets.

- As soon as previous steps have been taken, it is important to promote the creation of a collaborative working environment for adaptation; this concept compiles the willingness to cooperate from the public and private sector, as well as media, academia and society as a whole.

- The implementation and monitoring of climate adaptation measures should ideally be carried out on the basis of the previous steps of the pyramid, in order to guarantee the sustainability of the actions carried out. However, they can be developed independently to these steps.

The steps to progress in the Strategic Pyramid of adaptation to climate change are detailed in the following sections; they have been categorized according to the step to which they refer:



Graph 2: Steps to advance in the strategic pyramid of adaptation of roads to climate change (CAF - banco de desarrollo de América Latina 2018)

The following table summarizes the actions considered in the different steps:

FIELD	ACTION	CHARACTER	HORIZON	LEVEL OF DIFFICULTY
Institutional leadership	1.A. Assign responsibility for adaptation of roads to climate change.	ESSENTIAL	IMMEDIATE	Low
Legislative, contractual and regulatory framework	2.A. Develop legal framework for the adaptation of roads to climate change.	ESSENTIAL	IMMEDIATE	Medium
	2.B. Improve terms of references or contracts in projects.	RECOMMENDED	MEDIUM TERM (5 YEARS)	Medium

FIELD	ACTION	CHARACTER	HORIZON	LEVEL OF DIFFICULTY
Plans and programs	2.C. Enhance standardization for adaptation to climate change.	RECOMMENDED	LONG TERM (>5 YEARS)	Medium
	3.A. Develop specific plans for adaptation of existing road networks to climate change.	ESSENTIAL	SHORT TERM (2 YEARS)	High
	3.B. Support the implantation of climate shielding for new roads.	RECOMMENDED	MEDIUM TERM (5 YEARS)	High
Budget allocation	4.A. Develop an economic assessment of the impact of climate natural disasters in roads.	RECOMMENDED	SHORT TERM (2 YEARS)	Medium
	4.B. Assess and allocate budget for adaptation actions.	ESSENTIAL	IMMEDIATE	Medium
Training	5.A. Incorporate professional profiles suitable for adaptation of roads to climate change.	ESSENTIAL	MEDIUM TERM (5 YEARS)	Medium
	5.B. Create training programs for fighting against variability and climate change.	RECOMMENDED	MEDIUM TERM (5 YEARS)	Medium
Reference information	6.A. Collect, analyse and systematize the available climate information, considering a regional approach.	ESSENTIAL	IMMEDIATE	High
	6.B. Analyse climate risk in road networks.	ESSENTIAL	SHORT TERM (2 YEARS)	Medium
Regulations and technical guides	7.A. Develop regulations and guidelines for the adaptation of roads to climate change.	ESSENTIAL	SHORT TERM (2 YEARS)	Medium
Monitoring of results	8.A. Implement follow-up actions.	ESSENTIAL	SHORT TERM (2 YEARS)	Medium
	8.B. Set-up feedback processes after extreme climate events.	RECOMMENDED	SHORT TERM (2 YEARS)	Medium
Innovation and development programs	9.A. Promote innovation and development in the field of adaptation to climate change.	RECOMMENDED	LONG TERM (>5 YEARS)	Medium
	9.B. Create national networks for knowledge transfer.	RECOMMENDED	MEDIUM TERM (5 YEARS)	Low
Communication strategy	10.A. Develop a culture in the society for adaptation to climate change.	RECOMMENDED	MEDIUM TERM (5 YEARS)	Medium
	10.B. Promote the involvement of private sector in the adaptation of roads to climate change.	RECOMMENDED	LONG TERM (>5 YEARS)	Low

4.2. Specific measures for the construction of resilient roads

Adaptation measures must be incorporated throughout the whole roads’ life cycle; in the context of climate change, meteorological phenomena and their consequences affect the design, construction, operation, maintenance and infrastructure management.

Integrating climate risks into the decision-making process is complex due to the long lifetime of road infrastructure; during this time, climate can change. In order to consider this, and taking into account the existing uncertainties, it is necessary to build resilient roads.

As mentioned, adaptation measures can be incorporated at any stage of a highway project; however, it is preferential that the criteria to consider climate change is integrated in the early planning phases, for the following main reasons:

- In the planning phase it is easier to consider the concept of network or road system, instead of considering an isolated road. This is especially important because the consideration of road adaptation to climate change must have a global system approach.
- Large changes in road designs are more feasible in the planning phase; changes in the construction or operation phases are more expensive and their effectiveness is sometimes limited.
- In the planning phase, the best adaptation alternatives can be selected through modelling techniques.

During the design and construction phases, other adaptation measures can also be implemented; in addition, measures can be proposed for existing roads already in service.

During rehabilitation and reconstruction after disasters, it is essential to prevent new catastrophes and reduce risks through the "build back better" principle, as well as to increase social education and awareness about the disaster risks. The principle of "better rebuilding", formulated after the 2004 Indian Ocean earthquake and tsunami, is based on promoting the restoration of communities and assets so that they are less vulnerable to disasters than they were initially, by increasing its resilience; applied to road systems, any reconstruction activity constitutes itself an excellent opportunity to improve the resilience of the road network as a whole.

The starting point to improve the resilience of roads is to know to what extent climate variability and change can affect these infrastructures, as well as which measures should be considered in their design, construction and maintenance. For this, it is necessary to take into account the particularities of each territory, since the climatic conditions and forecasts are very different from one country to another, and even within the same country. The knowledge of the climatic singularity of each territory is one of the keys to identify the technical solutions that could be more effective depending on the location, the vulnerability and the existing threats.

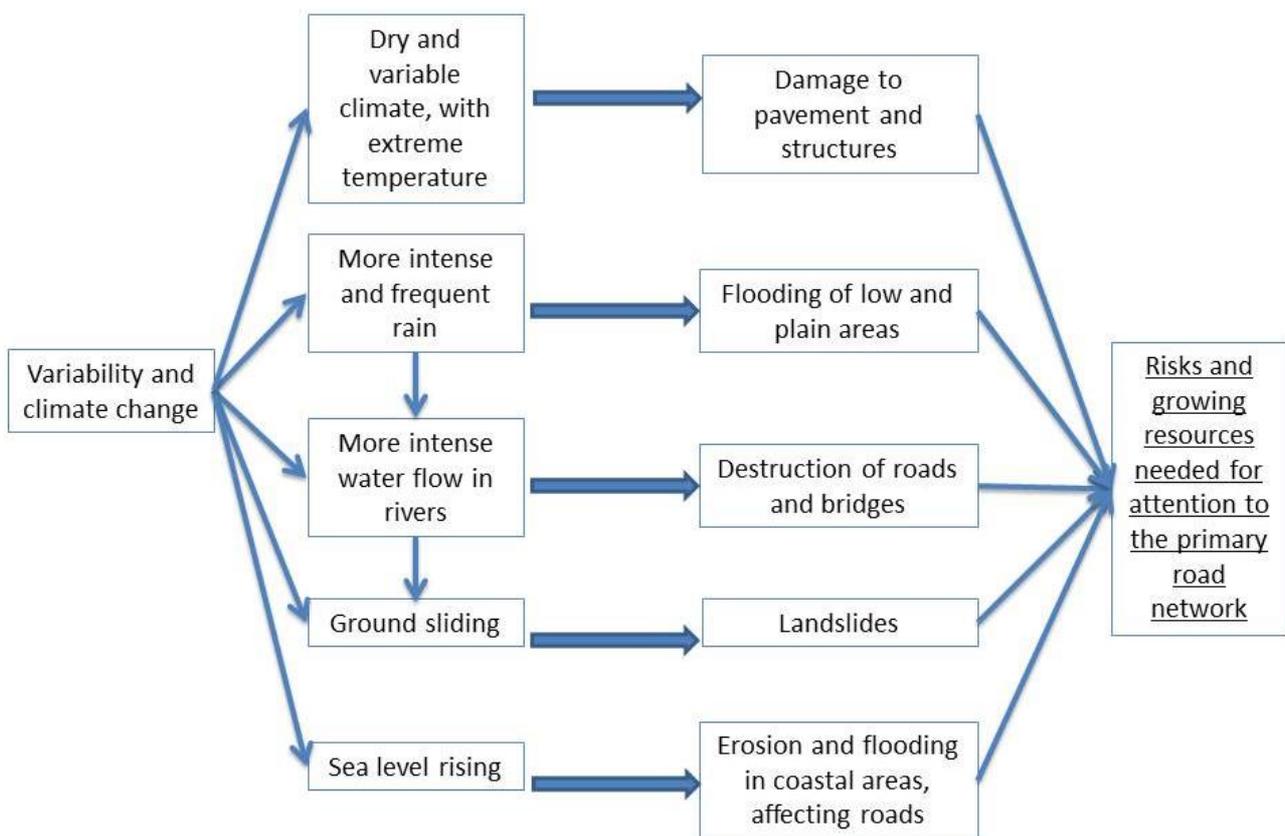
In the design of new roads, it is recommended to consider not only the effect of the historic rain volumes, but also the future estimations, as well as the possible increase in sea level,

wind action and thermal evolution, ensuring an adequate sizing of infrastructures and subsequent maintenance.

In the construction phase it is relatively common that unexpected problems could appear, which may be aggravated by the effect of climatic variability and change (for example, materials that are less resistant to those initially considered, or the presence of water that has not been taken into account); climatic variability plays a decisive role in this regard, since the forecasts derived from the planning and design phases may have been carried out in dry periods, with unpredictable effects occurring during the successive phases.

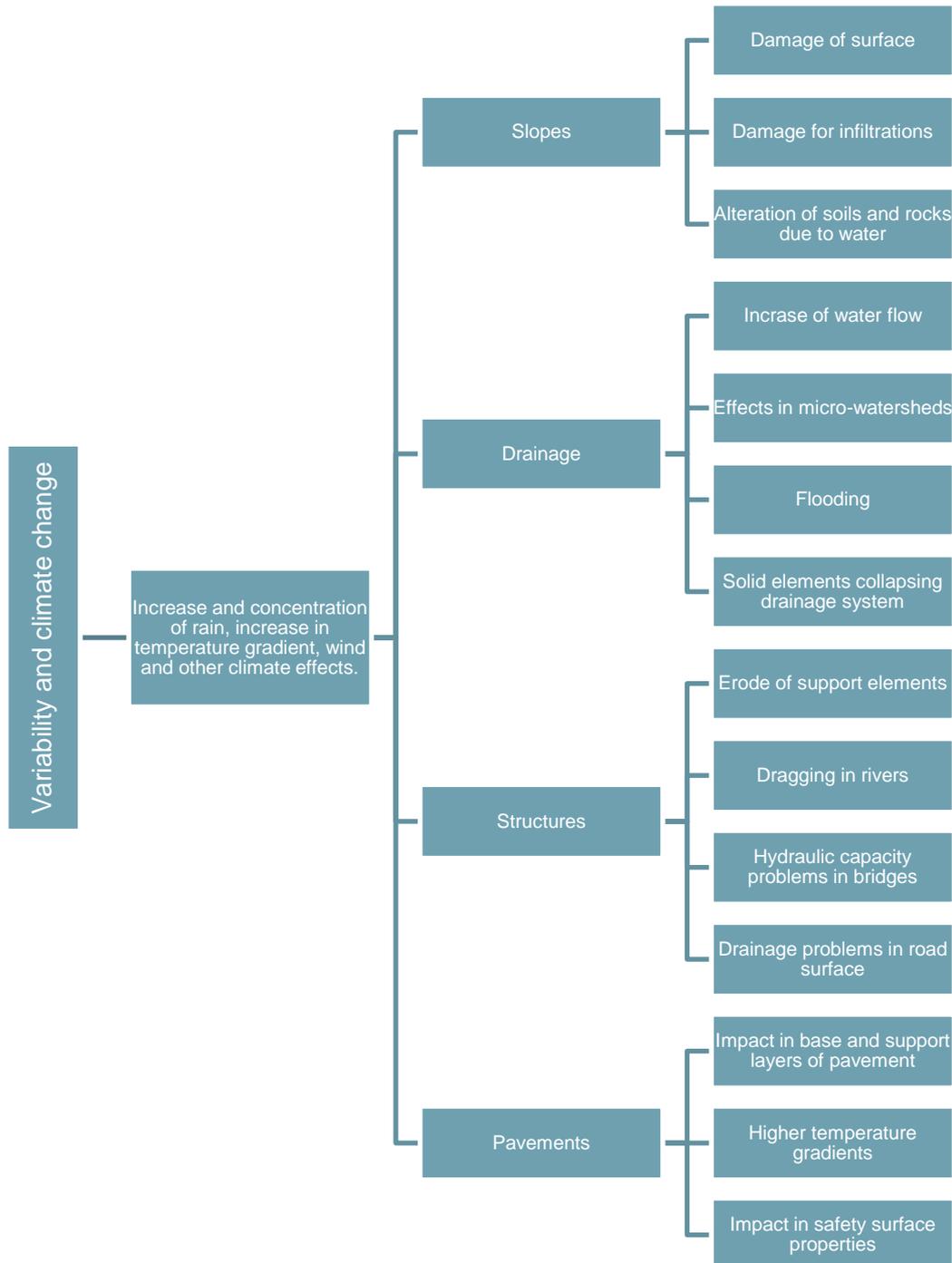
During operation and maintenance, it is necessary to implement monitoring activities to verify the adequate behaviour of the elements of the road; In case of situations of risk, measures such as those presented in these Guidelines should be considered, which will be associated with a specific design for its implementation.

Regarding the identification of risks and impacts in the road sector, the following graph shows the main threats and the elements of the road network that are most affected:



Graph 3: Diagnosis of risk management for road infrastructure (Centro Mario Molina 2017)

The previous figure shows that there are a series of risks that particularly affect four major areas of engineering work: slopes, drainage, structures and pavements. The selection of adaptation measures is focused in these areas. In addition, the following figure refers to the consequences that a changing climate can generate in each of the four major areas mentioned:



Graph 6: Impacts of climate variability and change on roads (CAF - banco de desarrollo de América Latina 2018)

Some of the measures of these Guidelines are already included in the countries’ regulations; however, it seems reasonable to consider them, since their use is not widespread. On the contrary, there are other measures that do not have a regulatory character, but are considered as good practices that have been successfully implemented. The following table includes a list of the measures included in this section of the Guidelines:

CONTEXT	CODE	MEASURE
GEOTECHNICS AND SLOPES	T-1	Improvement of slope stability: laying of slopes and plantations.
	T-2	Improvement of slope stability: riprap walls in the base of slopes.
	T-3	Improvement of slope stability: riprap walls in the base of fillings.
	T-4	Improvement of slope stability: alternative solutions to clearings and embankments (tunnels and viaducts).
	T-5	Improvement of slope stability: displacement of the road axis.
	T-6	Improvement of slope stability: false tunnel.
	T-7	Improvement of slope protection: projected hydraulic concrete.
	T-8	Improvement of slope protection: combined solution between bioengineering and surface drainage measures.
	T-9	Improvement of slope protection: protection of material susceptible of flooding.
	T-10	Plan for monitoring of slopes.
HYDROLOGY AND DRAINAGE	D-1	Detail study in watersheds and micro-watersheds.
	D-2	Drainage improvement in downpipes: sandboxes and energy dissipaters.
	D-3	Maintenance of the natural channel and protection of channels and banks: joint solution with transversal drainage works, channelling and protection systems.
	D-4	Improvement of the drainage system and flow control in watersheds downstream: ponds.
	D-5	Improvement of the drainage system and control of: control of the drag of solids (retention dams)
STRUCTURES	E-1	Improvement of the dynamic analysis of the channel / structure: studies of erosion in foundations.
	E-2	Improvement of the drainage of the structures in the boards of bridges.
	E-3	Implantation of preventive transversal drainage works in abutments of structures in embankment.
PAVEMENTS	P-1	Improvement of the behaviour of the pavement to the increase of the temperatures.
	P-2	Use of concrete pavements.
	P-3	Reduction of runoff times / run length by means of water in the pavement

Table 1: Summary of measures to adapt roads to climatic variability and change (CAF - banco de desarrollo de América Latina 2018)

5. Future lines of action

The current situation in the Latin American and Caribbean region shows a certain heterogeneity among the countries: while some have begun to develop adaptation plans, others are in their very early stages, although there is a widespread recognition of the need to act in this area in all countries. In this context, the work developed in Colombia regarding the adaptation of the primary road network to the effects of climate variability and change should be highlighted.

The “Best-Practice Guidelines for the Adaptation of Roads to Climate Change” is an interesting contribution to improving knowledge about the importance of incorporating measures of adaptation to climate variability and change in planning, design, construction, maintenance and management of roads.

Likewise, the Guidelines seek to transfer the importance of developing strategies to incorporate the mentioned adaptation measures, considering all the stakeholders involved in the region, both public and private.

During the process of development of this publication, the following evidences arise: there are numerous barriers for the adoption of measures to adapt roads to climate change; knowing them will allow us to face the challenge of adaptation in better conditions to overcome them. Some of them are listed below by typology:

- *Institutional*: lack of leadership, lack of coordination between entities involved at the national and subnational levels, lack of specialization of professionals,
- *Financial*: lack of resources, difficulties in its management,
- *Technical*: other priorities in road management, lack of normative reference technical documents, poor reliability of meteorological data,
- *Political*: lack of political commitment, difficulties in identifying priorities,
- *Social*: little social support, lack of involvement of the private sector.

This is just the beginning; there is a long way to go.

It is time to promote the creation of infrastructure funds to implement adaptation measures in road projects and existing roads, as a complement to the funds to attend emergencies.

CAF - development bank of Latin America will continue to support the countries of Latin America and the Caribbean in the development of road infrastructure that can better withstand climate variations, increasing its resilience, with the aim of improving the efficiency of investments aimed at the construction and maintenance of their networks.

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