MANAGING ROAD ASSETS
IN THE CONTEXT
OF SUSTAINABLE DEVELOPMENT
AND CLIMATE CHANGE ADAPTATION

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STRATEGIC THEME D
QUALITY OF ROAD INFRASTRUCTURE

INTRODUCTORY REPORT

CONTENTS

ABSTRACT

The topic selected for Strategic Direction Session D is “Managing road assets in the context of sustainable development and climate change adaptation”. It has been broken down into four principal topics:

- pavement quality and sustainable development;
- asset management and sustainable development;
- the impact of climate change on the quality of roads;
- road research and professional training.

It seems obvious that sustainable development is a major goal at a global level, and roads cannot be excluded from this as they are a fundamental component of the world’s transport system. The need to achieve sustainability is considered from the design phase of road infrastructure, then in construction, operation and maintenance. A whole series of players is involved in pursuing the goals: politicians, managers from road administrations, contractors, research and professional training institutes, and together they can, for example, promote valid development strategies, satisfactory solutions for carrying out works and modern asset management systems, and also provide human resources through effective professional training.

It is easy to see that as roads in developed countries have reached a very high level of quality, in the context of the climate changes which are affecting our planet concerns about the sustainable development of roads have become a priority issue. In line with PIARC’s principal goal, which is to disseminate knowledge to emerging and developing countries, it is necessary to exploit the good practice experience that is described in the national reports.

FOREWORD

As Coordinator of Strategic Theme D “Quality of road infrastructure”, I would like to thank all the countries who have sent in national reports, thereby complying with PIARC’s desire to gather together the points of view of its different member countries. We have analyzed the reports from 12 countries: Germany, Austria, Canada-Quebec, Cuba, Spain, the USA, Hungary, Mexico, Portugal, the Slovakian Republic, Romania and the United Kingdom.

This report does not give a detailed account of each national report but presents the main features of the experience of the different countries with regard to the quality of roads and the management of road assets with a view to contributing to sustainable development, and also covers the foreseeable impacts of climate change on road infrastructure. This report also sets out very succinctly various ideas about the need to extend road research and professional training.

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1. INTRODUCTION

The statistics on transport as a whole that have been given in several national reports show that the road transport system is the most important for both passenger and freight transport. The modal structure of the world's transport system is not expected to undergo a spectacular upheaval in the future. Consequently, it is necessary to continue to pay particular attention from all points of view to road infrastructure as an element in the road transport system.

High quality infrastructure means a safe road network which provides enhanced comfort for lower cost transport, without harming the environment. Modern road infrastructure should be able to adapt to new requirements with regard to transport needs and environmental impacts.

Against the background of the current energy crisis, energy consumption is a very important factor when building, maintaining and operating road infrastructure. Our efforts to reduce road vehicle fuel consumption should be accompanied by the promotion of low energy consumption technologies and the improvement of the technical state of roads, their layout and also by providing a higher level of service which can ease traffic flow.

While developed countries have a sophisticated road infrastructure managed by virtue of advanced techniques and which is integrated within the transport system as a whole, the same thing cannot be said about emerging and developing countries: the budgets allocated to development, management and maintenance are several times lower than what is required. Nevertheless, we must highlight that some of these countries wish to take advantage of the transfer of knowledge from developed countries, with the intention of making the maximum use of the material and financial resources at their disposal.

The 12 national reports reveal interesting experience on the effective management of the road network, the guarantee that works are performed to a high standard, the sustainable development of roads, and the impact of climate change on the quality of roads and their performance during operation.

Unfortunately, the problem of unpaved roads is barely covered by the national reports we have received, although sustainable development in the context of anticipated climate change also involves this category of roads.

Of course, research is important and contributes to the findings in the reports, but we feel that better management of research could be beneficial, particularly in countries with limited possibilities. Likewise, it is noticeable that professional training, which is the principal factor in the qualification of staff and which makes sure human resources are available, has not been covered in the reports we have received.

In addition to the points selected from the national reports, some information which is the outcome of the activities of Technical Committees will provide challenging topics for the debates and discussions which will take place and which will allow us to identify the most appropriate directions for our future actions, not only at association level but also in countries at varying levels of development that wish to share our experience.

2. THE QUALITY OF ROADS AND SUSTAINABLE DEVELOPMENT

We can note some interesting concerns as far as the quality of roads and the sustainable development of road networks is concerned. These concerns generally relate to identifying the most appropriate solutions in the framework of master plans for the construction of new road links, and improving the operation of the existing roads by efficient maintenance. Road budgets, which are frequently insufficient or poorly used, may be allocated in an imbalanced way between the investment which is required because of the continuous increase in the need for road transport, and the funding of road maintenance activities with a view to making sure that the quality of roads meets the requirements of users.

A great deal of effort is focused on developing technical regulations for roads which lay down clear procedures for improving the sustainability of road infrastructure. These regulations result in highway projects which minimize the risks of polluting the natural or built environment. The regulations thus consider the possibility of using recycled materials and promoting solutions which permit subsequent recycling. The authorities and their partners are involved in innovative activities directed at many aspects of the construction, maintenance and operation of road infrastructure. There has been a reduction in the time taken for results to be applied in practice. Examples of good practice include models for the in-situ recycling of cement concrete foundation layers (*Crack and Seal)* and a document that deals with the environmental monitoring of projects (*Sustainable Resource Management Framework)* [12].

A number of countries, particularly developed ones, have clear and precise legal regulations for sustainable development. Great attention is paid to transport plans, with regard to impacts on sustainable development through environmental impacts, accident risk, social impacts, the consumption of material and financial resources, the influence on climate change, etc. The United States has initiated research to evaluate the sustainability of motorway projects [6]. Criteria will be applied to determine the extent to which all the aspects of sustainable development (the economy, equity and the environment) are considered during the planning, design, construction and operation of motorways. The resulting sustainability criteria for motorways will be applied experimentally to existing motorways. The adopted criteria will be incorporated into a web-based application which transportation organizations will be able to use easily to assess motorway sustainability. The design of motorway routes is of fundamental importance for their sustainability in view of the environmental, economic and social impacts which must be considered during this phase of design.

The restrictions are physical (ecosystems, etc.), financial (the total cost over the service life of the road) and linked to human needs (which include safety and accessibility).

To encourage innovative road construction techniques and the introduction of innovative technologies it is necessary to conduct studies and research to ascertain the characteristics of materials and how they perform when subjected to in-service traffic stresses under a variety of hydrological and temperature conditions. Simulation using accelerated test tracks [11] is a viable technique that gives useful conclusions much more

quickly than studies using experimental zones on road sites. However, the latter approach must not be ruled out, as it is absolutely necessary for calibrating experimental models on the basis of real operating conditions. Research using an accelerated test track sets out to investigate certain construction techniques for concrete cement surfacings. These are compacted by vibration or with conventional compaction equipment and also use steel fibre reinforcement that has been recovered from used tyres. The studies in question have been conducted in the framework of the "EcoLanes" programme for research into sustainable surface transport that is part of the 6th European Community Framework Programme. Full-scale trials will be conducted in order to validate the results obtained from the test tracks on roads with different climates (4 types) in the United Kingdom, Cyprus, Turkey and Romania. The potential of accelerated testing has also been highlighted for the verification and fine tuning of design models for sustainable flexible structures.

Sustainability construction techniques for road structures produce structures that are able to benefit from subsequent strengthening as they experience fatigue and an increase in stresses that have a positive impact on the environment because they can be recycled, and that produce less pollution (vibrations, noise) or use recovered materials.

The promotion of recycling technologies in road construction and maintenance is of great importance for their sustainability. But the solutions in question must be thoroughly studied to ensure that the quality of the works and their performance during operation are not impaired. An important example of this is given by the experience of Austria [2] which conducted a pilot study to determine practical rules for the re-use of asphalt and promote their application. The particular attention that is given to the re-use of asphalt is also shown by the fact that 100% of asphalt is recycled in some regions. It should also be highlighted that the use of cement concrete surfacings on roads with high volumes of heavy traffic has clear road safety benefits because of their higher luminosity, as an alternative to the asphalt surfacings that are recommended for urban areas,. Such concrete surfacings are also appropriate for recycling, generally after crushing as foundation materials, either unbound or stabilized with binders.

One highly topical issue is energy savings and the promotion of technical solutions based on recoverable energy. The re-use of the materials from a road structure which has reached the end of its service life obviously provides a way of harnessing a very considerable energy potential. Not only is the regenerative energy used to construct new pavement layers or in other highway engineering applications, but environmental pollution through the creation of material stockpiles is avoided.

It is possible to ensure that works which re-use materials will satisfy requirements may be obtained by complying with the recommendations and standards developed in the framework of a large number of studies and research projects carried out by experts working at the laboratories of research institutes or universities. A survey conducted in the United States in 2007 showed that the relatively small-scale use of recycled asphalt is due to the lack of technical specifications, the high variability in the characteristics of the asphalt which is a candidate for recycling, not very convincing technical experience and a lack of sustained interest in the issue. Three preliminary directions for action have been identified with a view to promoting the large-scale recycling of asphalt: setting up a group of technical experts from the public sector and industry, conducting certain coordinated research projects that aim to adapt technical regulations and procedures used in the design of existing mixes, and performing demonstration projects. In addition to the interest in re-using bituminous surfacings, the recycling of other materials that contain bituminous binders from the construction industry (when roof units on buildings have to be replaced)

and cement concrete from road surfacings are the subject of activities to promote the use of renewable energies in the road industry. Approximately 90 million tonnes of materials are recycled each year [6].

In emerging and developing countries, unpaved roads account for a large percentage of the road network. Traffic on these roads generates a particularly large amount of environmental pollution due to the dust it produces during dry weather and the mud it produces during rain. These roads can frequently become impassable, turning into genuine “obstacles” to travel. In these situations, it is not possible to talk about sustainable pavements either from the environmental point of view or with regard to social, financial or economic impacts. The road administrations in these countries must make particular efforts to create programmes to construct some pavements with asphalt or cement surfacings on these roads. The technical solutions should be sustainable, and the quality of the pavements constructed in this framework must meet the requirements of users. Laying surfacings on unpaved roads significantly improves traffic conditions and considerably reduces the amount of energy consumed by vehicles. But the need to build durable surfacings must be borne in mind: for this purpose, it is recommended to construct a capping layer above the earthworks [11].

The irrational distribution of road budgets between investment and the maintenance of existing assets has led to a deterioration in the technical quality of existing roads in many countries. In situations where the need for funding is generally greater than the funds that are actually available, the planning of maintenance works must be optimized with regard to their type, periodicity and volume in order to ensure that works are of high quality.

The allocation of insufficient resources to keeping roads in a serviceable state that meets the requirements of users leads, by the accumulation of negative impacts, to severe pavement deterioration and has a considerable effect on safety, comfort and efficiency and generates negative environmental impacts. It is obvious that this situation is not conducive to roads that are sustainable. The responsible parties (governments, local authorities) must understand the situation and reconsider the financing of maintenance activities in order to improve the technical condition of existing roads.

The example of the government of Quebec which in 2007 launched the “foundation of success” programme is important in this connection [3]. The idea behind the plan was to make up for 15 years of inadequate maintenance and ensure the durability of all Quebec’s public infrastructure. This plan is based on the following principles:

- to pass down high quality infrastructure to future generations (intergenerational equity);
- to possess modern, efficient high quality infrastructure, which is a fundamental condition for dynamic and harmonious economic development;
- to guarantee safety and improve the quality of life of the citizens who use public infrastructure on a daily basis.

The plan was accompanied by adequate financial support, which made it possible to carry out the planned works. The government also created a legislative framework for applying the plan by passing the “Act to promote the maintenance and renewal of public infrastructures”. Another Quebec government plan is the “Road network recovery plan” whose aim is to bring the roads in the main network into a serviceable condition that makes them safe for users and efficient and that optimizes the investment costs for maintenance and recovery. The goals for quality were to increase the percentage of roads with a good level of quality from 63% in 2007 to 83% in 2023, and increase the percentage of bridges that are in good technical condition from 53% in 2007 to 80% in 2023.

Promoting the performance of works of high quality requires an appropriate regulatory framework. The road administrations use their institutions to organize the creation of technical standards and guides for design, construction and maintenance. There is a certain amount of interest in taking account of and adapting the technical standards which exist in other countries with strong road traditions, as mentioned by Cuba in its report [4]. Although Cuba's economic difficulties are those of a developing country, it has made a significant effort to promote new technologies with regard to regulations (introduction of technical standards), construction technology for new works and the rehabilitation of existing roads, thereby ensuring the sustainable development of roads.

We can state with certainty that high quality roads are in themselves a reflection of sustainable development because they are safe, comfortable, efficient and do not impair the quality of life and the environment. The technical regulatory framework ensures that their design, construction and operation complies with the precepts of sustainable development by reducing energy consumption and the level of NOx emissions through the recycling of used road pavement materials or waste (renewable energy), and by reducing energy consumption during operation.

Generally speaking, road maintenance activities are focused on the network of major roads, which in all countries carries the great majority of transport, by applying a systematized approach to maintenance that takes account of traffic stresses, the technical conditions of roads and the efficient use of available budgetary resources with a view to satisfying the present and future needs of road users.

Systematized maintenance can provide the following [1]:

- the guarantee of uniform serviceability of roads, according to their functional category;
- roads that remain at an appropriate level of quality in the long term;
- support to road administrations in scheduling works and providing the budgets required for necessary maintenance activities, and providing genuine support for the implementation of these activities.

Evaluating the state of roads makes it possible to create a technical road database which, by using highly effective software-based techniques, can optimize maintenance activities on the road network.

We now have an impressive range of laboratory and field equipment with associated computer programmes for investigating the quality of pavements, structures (bridges) or other ancillary structures in a more cost-effective manner. It is important for this activity to be scheduled so that the data obtained can be used to model the behaviour of the road during operation and forecast how this will change in the future. Under these conditions, optimizing the planning of maintenance works for which an appropriate budget will be provided is possible and will reduce total expenditure on transport infrastructure, certainly making up for the expenditure involved in road surveys and all the other related activities.

3. ASSET MANAGEMENT AND SUSTAINABLE DEVELOPMENT

The concept of sustainable development has many applications with regard to surface transport infrastructure. The most important of these is road transport facilities as most transport activities are performed by the road network which consequently accounts for a large proportion of the built surface of an area. It is therefore obvious that particular attention should be given to the way that road infrastructure is constructed, enhanced and managed.

The need to manage road assets should assist the goals of sustainable development by conserving and improving existing roads, by enhancing networks by building new roads, by maintaining and operating them using efficient methods with minimal costs which provide the maximum quality impacts.

Each country has a specific approach to the sustainable development of road networks. Mexico's experience [8] shows two main directions for action:

- the identification and application of public-private partnership models to supplement available public finance which is always inadequate for maintaining and improving road assets;

- imposing a number of requirements on road managers and private concessionaries with regard to the use of reliable data and effective road management tools to carry out their appointed tasks, namely: evaluating the economic and financial feasibility of road projects, developing preliminary maintenance programmes for all roads (whether operated by the public or private sector), evaluating the performance of concessionaries, estimating the road maintenance works that are necessary in the framework of Private-Public Partnerships and preparing terms of reference for new concessions.

In 2001, after its experience of applying a Road Maintenance Strategy Simulation Model (RMSSM), Mexico began to use the HDM-4 system that has been developed and promoted by PIARC. Even if the very large amount of data required to apply the system creates some data collection difficulties, application of this model in many countries in the world shows it has a number of qualities: the programmes of works generated by HDM-4 meet maintenance needs better, the optimization of the use of resources is more reliable, the configuration of the analyses and the choice of the options are more flexible, and the calculations are faster. In order to take best advantage of the model's possibilities an additional computer programme has been designed known as the "Pavement Information System" (PIS). This is used to manage all the data required by the model, generate input files and collect results in order to produce personalized reports that are designed to assist decision-making processes within road administrations.

Road management is thoroughly covered in almost all the national reports we have analyzed. This is an area where remarkable progress has been made with regard to developing effective models for planning works in a way that makes optimum use of the available resources. This is possible because of the availability of a technical database which describes the state of the roads on the basis of specific indicators that relate to the bearing capacity of the structure, the evenness of the wearing course, the roughness of the surface and the deterioration of the pavement surfacing. An aggregated index of the technical state of the road is used by some administrations, but the way this is constructed varies a great deal. Germany can be mentioned in this connection as it applies a road use indicator which gives a user value in which the emphasis is placed on comfort and safety and a structural indicator that represents the technical state of the pavement structure which is mainly of interest to the public managing body [1].

There have been developments in road infrastructure managing systems both for roads as such (PMS) and for bridges (BMS). The report from Germany mentions an interesting application which is currently being developed, namely a management system for ancillaries.

A problem with regard to the application of these high performance road management systems which is generally limited to emerging and developing countries is the difficulty of creating and maintaining a technical database which is fundamental for the optimum planning of maintenance works. Limited financial resources, which in so many cases are completely inadequate, make it difficult to obtain the high output equipment which is necessary for data acquisition (whether by purchasing on the part of public institutions engaged in studies and research, or in the context of concessions or service contracts for surveys).

However, it is important to make every effort to create the conditions in which high performance road management systems can be applied. The sustainable development of the road network, which includes not only the construction of new roads but also the improvement of existing ones by effective asset enhancement, is only possible with the application of these techniques which are the outcome of several road research programmes in which PIARC has taken part.

As a result of the complexity of the interdependencies which must be considered, the functional capacity of roads can only be maintained in an efficient and effective manner by applying a comprehensive maintenance management approach which makes use of computerized management systems. Systematized road maintenance can increase the overall transparency of the decision-making processes and provides a credible tool for quantifying the financial resources that are required and for convincing political decision-makers of the need to act in time and allocate sufficient finance [1].

In order to provide the necessary funding for the development of roads, a variety of financing models can be promoted which mobilize resources from the public or private sector in order to ensure the budgets of the countries in question are not severely affected in the long term by adverse impacts which create intergenerational inequities. The Portuguese model is important [9]. This promotes *Public Private Partnership* (PPP), concession contracts which are seen as a genuine means of rapidly developing road infrastructure and improving the services that it provides to users. Intensive application of PPPs was the key factor in the success of *National Road Plan*, which was launched in 1998 and which set out to modernize the Portuguese road network completely. The PPP is also the instrument used for the construction of new motorways.

4. THE IMPACT OF CLIMATE CHANGE ON THE QUALITY OF ROADS

Climate change is a global phenomenon which, among other things, can modify the conditions of road operation, by changing certain aspects of road performance. The changes in question affect the functional and structural qualities of roads and have a direct impact on the quality of service provided to users.

From our standpoint, as highway engineers, it is necessary to take account of the forecasts of climate change experts in order to make appropriate modifications to roads, and also analyze the extent to which the construction and operation of roads, which carry the majority of transport, in their turn, influence climate change. It is therefore possible to identify an interdependence between roads and climate change. With regard to this issue, our strategic theme is concerned with the first aspect, namely the extent to which climate change affects the quality of roads, the necessary characteristics of materials, the adaptation of road construction techniques and technologies, the need to reconsider certain regulations with regard to road operation, etc. Overall, all these effects of climate

change must be considered as parameters which influence the strategies which administrators must develop for roads.

The main factors that we consider with regard to the possible impact of climate change on roads are increased temperatures due to global warming (average and extreme temperatures), increased precipitation, the melting of icecaps, rising sea levels, and changes in groundwater regimes which are responsible for landslides, avalanches and fires.

Canada-Quebec is a leader in this area and has adopted a number of policies to reduce the impact of transport on climate change, essentially by targeting a 20% reduction in greenhouse gas emissions by the 2020s, a goal which is comparable to that of the European Union [3]. With regard to adapting roads to climate change, the Quebec Ministry of Transportation is engaged in research activities with universities and other partners in five priority areas: the vulnerability of airports to the thawing of permafrost, the vulnerability of maritime infrastructure as a result of the melting of icecaps and the increase in storms and coastal erosion, the fall in river levels and the rise in the number of freeze-thaw cycles. The latter may cause specific types of damage to pavements with a direct impact on traffic conditions.

We can identify two ways of responding to the problems generated by climate change: first, protection responses that are intended to attenuate the impact of road transport which above all aim to reduce emissions of the harmful products that are considered to cause climate change, and second, adaptation responses, which consist of specific measures to reduce the damage caused by climate change, or even completely avoid it. Thus, we can mention the following approaches for adapting the road network to the adverse effects of climate change:

- adapting works scheduling strategies to take account of the risks associated with climate change;
- creating an inventory of the affected roads, in order to evaluate the current situation and provide a basis for deciding on the measures to be taken;
- adding climate change data to the other public information systems;
- conducting scientific research programmes to modify road vehicles and the infrastructure.

In the current context, which is also affected by the economic crisis, it is necessary to apply modern and efficient technologies for the construction, maintenance and operation of road networks.

When seeking appropriate solutions, the influence of climate change should be considered as a risk factor from the road design phase. The vulnerability of transport infrastructure to specific risk factors and climate change varies according to the region and the environmental context. For example, in coastal zones a great deal of attention should be given to rising sea levels, coastal erosion, tropical storms, cyclones and the way these propagate [6]. A study conducted by the University of South Alabama reached the conclusion that approximately 60,000 miles of roads in the United States are exposed in the coastal zone.

One of the criteria for verifying the validity of certain road design solutions or selected materials is their ability to withstand climate change [10]. Considering just the temperature regime and the amount of rainfall, we can mention the following effects:

- during project development: the design of the longitudinal and transverse gradient of the roadway, the transverse profile of the pavement and the minimum and maximum gradient of ditches, etc.;
- the choice of materials, resistance to permanent deformation, protection of the structure from frost action;
- the choice of technologies: the performance of earthworks and the stabilization of earth (capping layers);
- the design of the drainage system.

Based on an analysis of the present-day climate and scenarios for climate change up to the year 2100, climatologists have formulated the following partial conclusions which are relevant to the road sector:

- climate change will lead to change in average annual air temperatures which will continue to rise (up to 2100);
- minimum air temperatures will increase, the number of days when the temperature will exceed freezing point will increase, and, in the summer, the number of nights with a minimum temperature of over 18°C or even 20°C will increase;
- the anticipated increases in air temperature and in precipitation levels will tend to increase the intensity of rainfall, thunderstorms and strong winds, as well as increase the amount and intensity of frost in winter (as well as increasing the risks of thick fog).

We must accept the urgent need to modify technical standards and formulate regulations concerning the measures to be taken. It is also necessary to develop research activities to find responses where we do not as yet have technical solutions.

5. ROAD RESEARCH AND PROFESSIONAL TRAINING

Analysis of the national reports shows that sustainable development represents a major challenge in the road sector at all stages of the implementation of projects and throughout the operation of roads (preliminary studies, design, construction, maintenance, operation).

It is noticeable that there is a strong focus on fundamental and applied research that aims to increase the in-service performance of pavements as a result of the materials that make up pavement layers, the techniques and technologies that are applied, methods for monitoring long-term pavement behaviour and changes in technical condition, etc. Interest in resolving these problems is high both among the public institutions that manage roads for whom improving road quality for users is helpful and within their responsibilities, and among the other actors, particularly contractors who must carry out works of good quality, with good technical performance which ensure good long-term performance, a minimum risk of deterioration and high economic efficiency.

The reports have not provided us with any information about the organization of research activities, but there are frequent references to a number of programmes to promote new materials, technologies and action strategies, high efficiency road and bridge survey techniques, models for optimizing the decision-making process, etc. This clearly shows that in many cases such activities are coordinated by the ministries and involve a number of partners.

The large investment required for sustained research activities often poses problems, particularly in the case of countries with limited financial resources (for example emerging

or developing countries). One way round this problem is to encourage transnational research programmes that involve public institutions, universities and economic agents.

Likewise, we found almost no comments on professional training activities in the national reports. The reports do, however, mention the need for staff working the road sector to undergo training to ensure they understand the challenge of sustainable development so they can act accordingly and, above all, apply their knowledge to produce high quality works with good sustainability.

An important aspect of professional training is to ensure that initial training is carried on throughout the individuals' careers, with several types of in-service training. In this context, universities should provide a wide range of alternatives that suit the needs of society.

The availability of a full range of professional training courses is also facilitated by regionally-based teaching systems. An example of this sort of thing is the European transferable credit system where the possibility of student exchanges increases the range of available educational opportunities.

Professional training activities and research are closely linked, and without exception both exist in good universities. Cooperation between universities and economic operators is helpful for improving performance as it makes it possible to exploit the qualities of each partner.

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PROVISIONAL CONCLUSIONS

Improving the quality of road infrastructure by efficient asset management and in compliance with the requirements of users and governments while adapting to climate change is one of the principal goals of the road profession and therefore, implicitly, our Association.

Even though changes in technology, society and the environment are broadening the scope of action of highways authorities, road infrastructure management remains their fundamental concern. The need to use budgets more efficiently means that financial resources must be distributed in a balanced manner between road construction and maintenance.

Evaluating the budgets that are required to ensure optimum maintenance of roads and a balanced distribution of the allocated resources to different categories of road, bearing in mind financial restrictions and the impact on the environment, should constitute a major objective of administrations.

Road structures must be of high quality to achieve the longest possible service and adapt to the effects of climate change. The materials and techniques that are used for road works should produce the lowest possible carbon emissions (carbon footprint).

Works involving bridges, whether existing structures or new constructions, must take account of climate change with regard to construction, maintenance and operation. These aspects are managed effectively by efficient management of the existing bridge stock, with regard to its functional characteristics (bearing capacity) and exposure to risk during operation.

Earthworks and unpaved roads are a particularly important problem. Emphasis must be placed on the optimum use of local materials and the application of effective maintenance techniques, particularly in developing countries. The extension of road networks and the improvement of unpaved roads must be approached from the standpoint of practical appropriateness, bearing in mind the need for sustainable development, particularly with regard to accessibility and increasing mobility.

Appropriate solutions should be promoted that save energy while improving pavement quality. The solutions in question should involve design, construction, maintenance and operation. Transport energy consumption is significantly reduced by roads with better functional qualities, and renewable energy can also be used on a large scale in the sphere of roads.