



Federal Ministry  
of Transport, Building  
and Urban Development



# Roads in the 21<sup>st</sup> Century

Innovative Road Construction in Germany





# Foreword



Growing levels of traffic and the need to ensure that Germany, as a leading exporting nation, remains a competitive site for economic activity mean that our transport infrastructure has to meet enormous challenges in terms of efficiency. In addition, there are central tasks such as road safety, environmental protection, climate change mitigation and effective energy conservation. And there is also the key question as to how we can ensure that the necessary investment is made in our transport infrastructure with the funds at our disposal. There are thus a lot of issues involved in the construction of our future roads.

Given these challenges for the “roads of the future”, we need innovations. The Federal Ministry of Transport, Building and Urban Development and the Federal Highway Research Institute have thus developed a research programme entitled “Roads in the 21<sup>st</sup> Century – Innovative Road Construction in Germany”. At the same time, the programme is embedded in the Federal Government’s high-tech strategy. The objective is to pave the way for promising and innovative solutions for the road mode into everyday

application in road construction: In the future, our roads are to become more intelligent by means of modern traffic guidance systems and an innovative road works and incident management system. Vehicle-to-vehicle and vehicle-to-infrastructure communication will help to further reduce the number of accidents and smooth the flow of traffic. Another example is the development and testing of modular rapid repair systems for concrete roads, also known as concrete plugs.

Our objective in launching the “Roads in the 21<sup>st</sup> Century” programme is to achieve more quality, improve value for money and provide a crucial boost to innovation in road construction in Germany. Take a look for yourself.

A handwritten signature in black ink, appearing to read 'Peter Ramsauer', written in a cursive style.

Dr Peter Ramsauer, Member of the German Bundestag  
Federal Minister of Transport, Building and Urban  
Development

# Introduction

Transport is the foundation of our economy and society. Mobility is a prerequisite of well-functioning markets and is a crucial factor determining our quality of life. Future economic growth, and the concomitant creation and safeguarding of jobs, will not be possible without the movement of persons and goods.

The road mode is a key component of an intermodal transport system. It has to meet the travel needs of individuals and manage the sharp rise that is likely in our economy's need for freight transport. Combined with the rising need for structural maintenance, this is already resulting in conflicts between moving and stationary traffic and among the public affected by emissions. The Federal Ministry of Transport, Building and Urban Development's Road Construction Directorate-General, with the support of the Federal Highway Research Institute, has developed a research programme entitled "Roads in the 21<sup>st</sup> Century – Innovative Road Construction in Germany", which is designed to provide the necessary boost to innovation in the road mode.

21<sup>st</sup> century roads will have to confront not only familiar but also new challenges which, in the interests of a sustainable system of roads, also have to be fully taken into account. These challenges include:

## Demographic change

The roads of the future are to cater in particular to the mobility needs of an ageing society.

## Climate change

By means of adaptation measures and mitigation strategies, the roads of the future are to ensure sustainable infrastructure, thereby safeguarding mobility.

## Technological change

The roads of the future can play the role of a driver of innovation. On the other hand, postponing the introduction of new technologies, or introducing them hesitantly, will result in significant constraints. The roads of the future are thus to make Germany a more competitive site for economic activity by accelerating and directly implementing technological advances.

## Globalization

As a consequence of globalization, significantly higher volumes of traffic are already apparent today in both the passenger and freight sectors. To manage these levels of traffic, the roads of the future are to deploy intelligent transport systems to control the flow of traffic, thereby ensuring smooth mobility.

## Sustainability in a post-fossil society

The roads of the future will be designed, built, operated and maintained on the basis of modern economic instruments. Full account is to be taken of the requirements of sustainable life-cycle management, the increasing use of alternative construction materials and the application of appropriately optimized construction processes.

The objective of this framework programme is to evolve the roads in a functional manner. In the interests of sustainable mobility, they are to be made safer, more economical, more efficient, more reliable and more intelligent as regards their main use – namely their connectivity function. In addition, boosts to innovation will be generated. In this way, a holistic approach is to be adopted to address the existing and future requirements to be met by the road mode and to tackle the new global challenges.



The following thematic focus areas have been selected for the programme:

- A. Safe and reliable roads**
- B. Intelligent roads**
- C. Energy-efficient roads**
- D. Low-emission roads**
- E. Roads as part of people's living environment**
- F. Sustainable roads**
- G. Roads as innovators**

These areas include old and new challenges in various guises. The thematic focus areas are also intended to overlap when they are subsequently fleshed out.

To implement the research programme, the appropriate national bodies (government, academia, public authorities and industry) will have to take concerted and coordinated action. These bodies will thus be involved in the further implementation of the programme at an early stage. Within the Department, there are capacities that can be deployed flexibly. These include the research excellence of the Federal Highway Research Institute (which has its own research and innovation programme) and the items in the Road Construction Directorate-General's budget that cover research. However, these conventional instruments will be nowhere near sufficient to provide the desired boost to innovation. If the programme is to be successfully implemented, it is thus imperative that additional funds be provided at short notice to kick-start key issues, i.e. project families of a landmark character. Funds are available for this purpose from the Federal Government's "12 billion euro programme for education and research".

In addition, the benefit that can be achieved in the short term is to be sustained over the medium term.

To this end, all activities conducted as part of "Roads in the 21<sup>st</sup> Century" will be used that are interlinked at both the national (relevant research funded by the Federal Ministry of Economics and Technology and the Federal Ministry of Education and Research) and European level: joint research conducted by the Conference of European Directors of Roads (CEDR), relevant research programmes launched by the European Commission, the FOR (Forever Open Road) programme conducted by the Forum of European National Highway Research Laboratories (FEHRL) and bilateral collaboration, for instance with the French "Route de la 5<sup>ème</sup> génération" programme.

There follows an outline of the programme for the aforementioned thematic focus areas, covering primarily the issues relevant to the federal trunk roads. This is based on an approach with short, medium and long term elements that build on one another. The first phase of the approach provides for the preparation of blueprints plus the development of methods and the procedural analysis of individual systems. Building on this, the second phase will involve the delivery of pilot applications and the integration of subsystems. In both phases, aspects of business management and the national economy will have to be taken into account. Based on the findings from these stages, a strategy will have to be developed in each case which pursues the objective of complete system integration and the preparation of holistic practical deployment.

The programme outlined here will create a framework on the basis of which the innovations relevant to the road system as whole will be identified, evolved in a targeted manner and, taking a holistic appraisal as a basis, profitably deployed in practical applications.

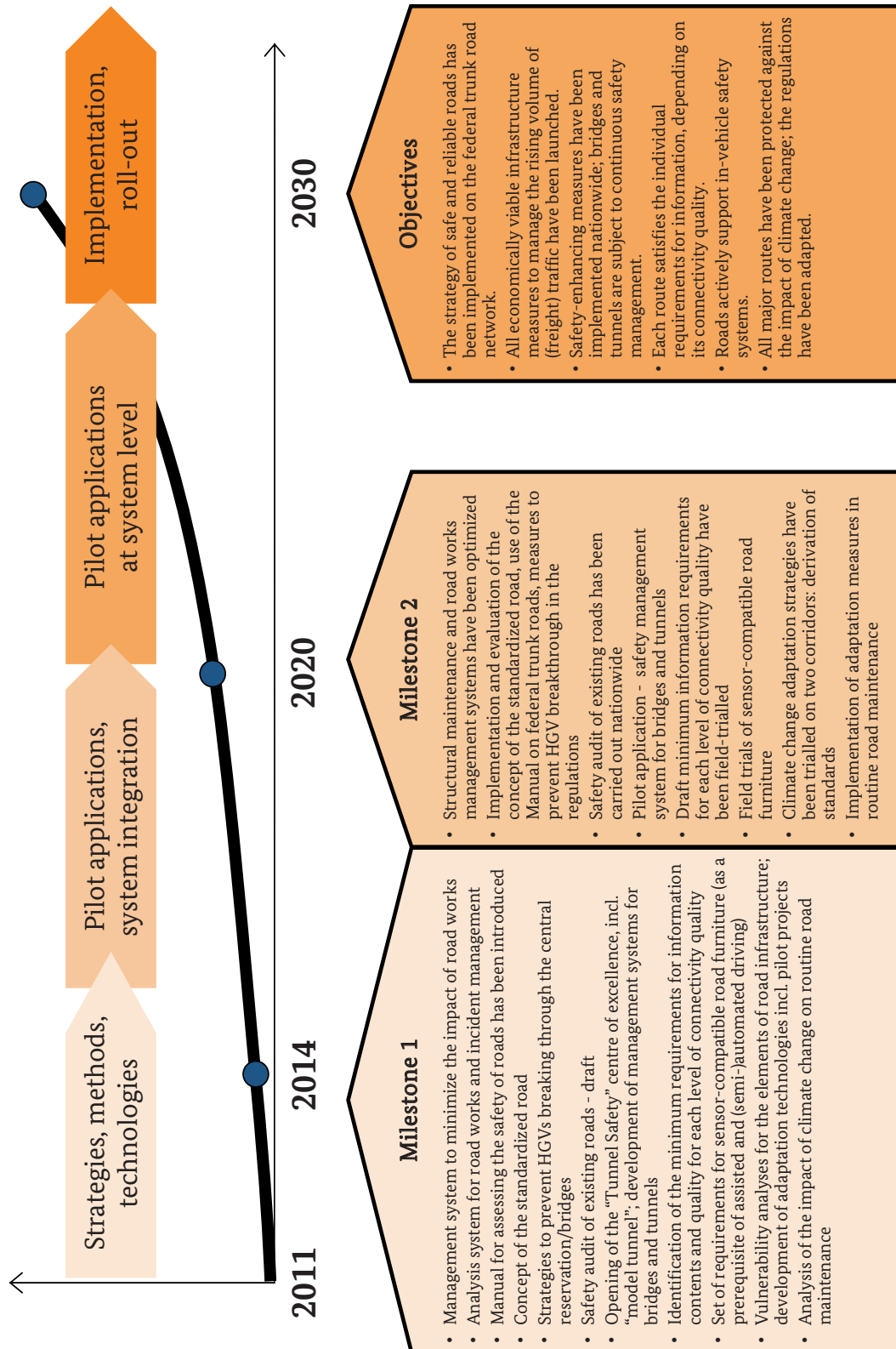
# A. Safe and reliable roads

A key objective of 21<sup>st</sup> century roads is to facilitate the safe and efficient movement of persons and goods over short and long distances and to ensure that these movements can be planned with a high degree of reliability. In addition, the capacity of the roads will be further enhanced so that they can not only carry their own passengers and freight but also absorb additional traffic resulting from disruption in other modes of transport (for instance crises such as the volcanic ash in 2010 or incidents such as the tanker accident at the Loreley in 2011).

Given the age structure of the road network, there is a great need for renewal. This need is to be met by means of an overarching structural maintenance management system. Combined with an advanced road works and incident management system, this will make it possible to significantly reduce traffic disruption. 21<sup>st</sup> century roads are to be able to handle 21<sup>st</sup> century freight traffic on the basis of technologically advanced and economically sound solutions. 21<sup>st</sup> century roads will be able to integrate information from vehicles into roadside information and management systems and to support communication between in-vehicle safety systems. This follows the guiding principle that a safe road also decisively enhances its

reliability. The basis for this will be a comprehensive safety management system for the entire road infrastructure. The network elements that are especially important for the quality of traffic (junctions, bridges and tunnels) will be subject to in-depth safety management. Accordingly, all major routes are to be provided with optimum protection against the impact of climate change, and the routine road maintenance services will be equipped to cope with extreme weather events. Another objective is to ensure that each section of road, depending on its importance, meets the information needs of every single road user, thereby facilitating an efficient flow of traffic on the basis of individual decisions.

Short-term measures to achieve these objectives will focus, inter alia, on the development of an efficient traffic analysis system that also includes instruments for minimizing the impact of road works. Furthermore, preparatory work is to be carried out for the strategy of providing road furniture that is compatible with in-vehicle sensors as a prerequisite of assisted or (semi)-automatic driving, for strategies relating to standardized roads and the improvement of tunnel safety, and for the development of analyses to determine vulnerability to impacts caused by climate change or to any other safety-related impacts.



## B. Intelligent roads

The objective of the “intelligent roads” concept is to create better conditions for operational and strategic decisions in the fields of traffic management and structural road maintenance. Road users will benefit from this in the form of less traffic disruption, better information and smoother journeys.

Supported by a multiplicity of information and communications systems, data relating to the roads will be collected and analyzed in a targeted manner. This will enable road operators to make their operations more efficient, thereby cutting costs, minimizing operational risks and enhancing road safety and thus efficiency across the entire road network.

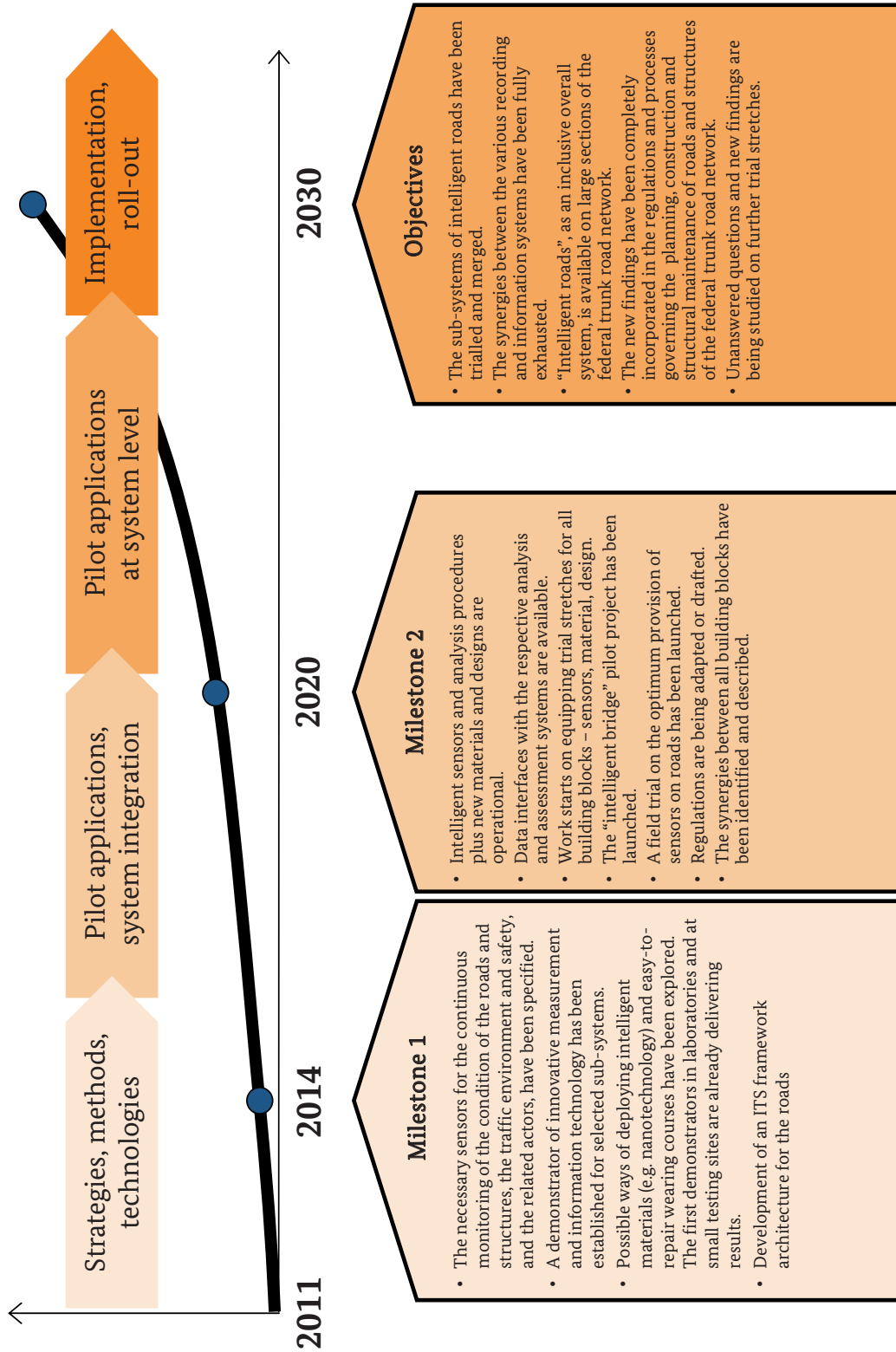
Developments in construction materials and process engineering will generate “intelligent” materials and designs that are able to measure and analyze information such as stress and impact. In a closed micro-circuit, they can react independently. Thus, one possible approach is the development of “self-healing” materials in the context of innovative road designs with integrated sensors, characterized by especially fast and simple handling.

In addition, the potential inherent in intelligent systems already in operation today has to be harnessed. The requirements of the various spheres (construction, traffic management and structural maintenance management) regarding intelligent roads have to be merged in order to exhaust existing synergies.

21<sup>st</sup> century roads will consist of intelligent materials and designs, they will use intelligent construction methods and deploy innovative information systems. The material, design and information/communications subsystems will be integrated to form an overall system.

Short-term measures to achieve these objectives will focus primarily on specifying the sensor technology required for the continuous monitoring of the condition of roads and structures, the traffic environment and road safety. In addition, possible ways of deploying intelligent materials and easy-to-repair road designs are to be explored. The findings are to be verified in demonstrators in laboratories and at test sites. Furthermore, the first decisive steps towards the development of an ITS framework architecture for the roads will be taken.





## C. Energy-efficient roads

One of the main features of all aspects of 21<sup>st</sup> century roads will be energy conservation. The roads are to be optimized in all spheres (design, construction, operation) in terms of energy consumption and, in places, facilitate energy generation from renewable sources. This energy can be used for electric systems along the roads, for instance in tunnels, or at “filling stations of the future” – electric vehicle charging points to be installed on federal trunk roads in the future.

The extent to which photovoltaic systems and wind turbines on roads can supply some of the energy required for operation of the road is to be studied. This is to be viewed in terms of balanced energy performance and not in terms of immediately and directly using the electricity generated in the road environment.

One obvious place for the production of solar power is the roadside area, which could be made available by the owner (authority responsible for road construction and maintenance). A research project is currently being conducted to identify potential space.

In addition, the combination of noise abatement structures and solar panels promises to produce synergies. An innovative pilot project is currently being prepared which will involve the deployment of photovoltaic elements that also directly perform a noise mitigation function.

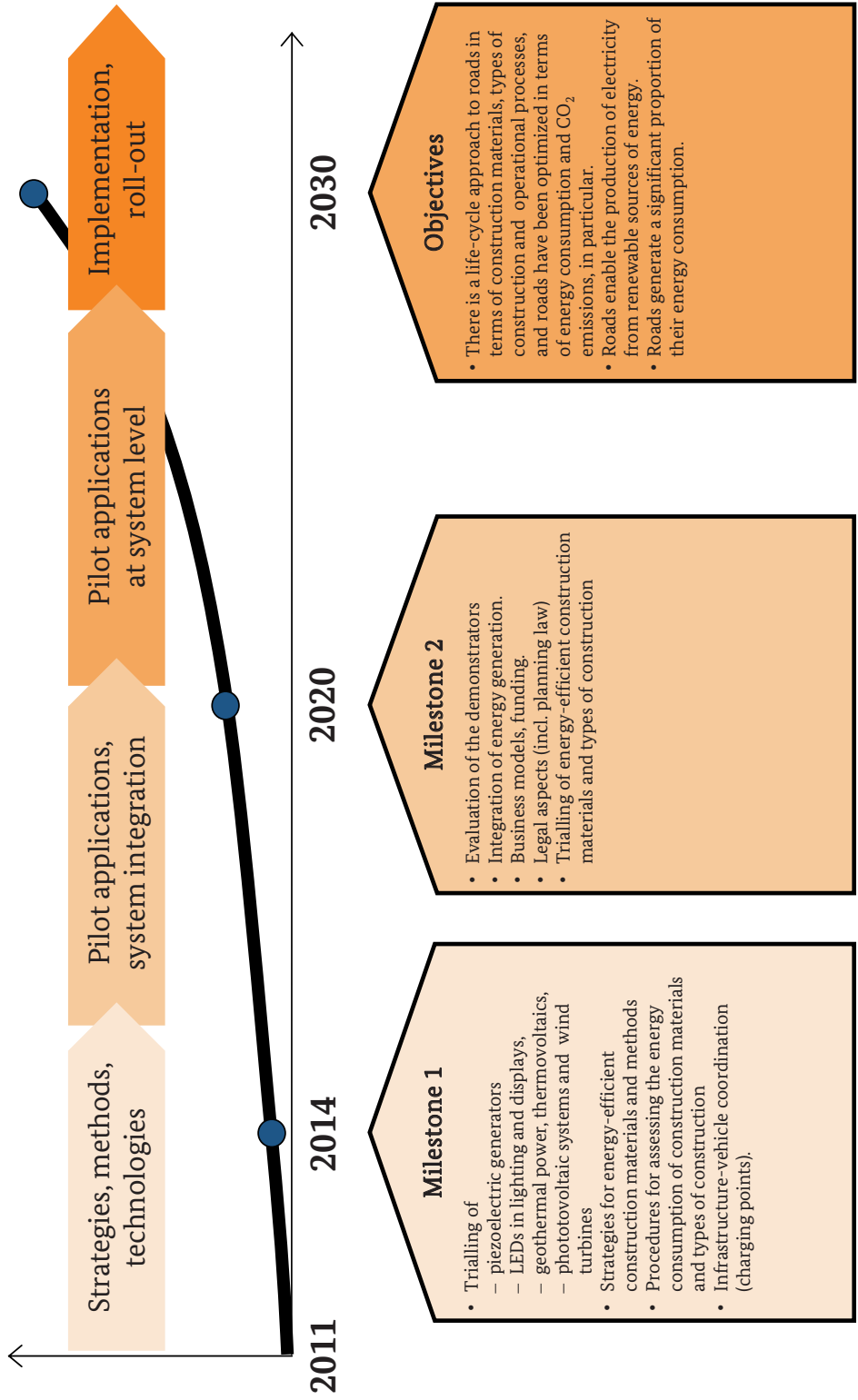
Geothermal power and wind energy can also be used in the road environment.

New construction materials and types of construction will focus on energy consumption that is as low as possible. The large-scale deployment of LED technology at rest areas or in tunnels will permanently reduce the energy requirements of lighting and adaptive traffic control systems in the places where they are needed.

As a short-term measure, the future use of piezoelectric generators to supply energy to traffic signals and lighting installations is to be studied. A further study is to be carried out to determine the extent to which the use of geothermal power, for instance on bridges, can temper carriageways, thereby enhancing road safety.

In keeping with a sustainable and life cycle approach, the design, construction and maintenance of 21<sup>st</sup> century roads will be geared to low energy consumption. Types of construction and construction materials will be optimized to reduce their carbon footprint as much as possible. In addition, CO<sub>2</sub> emissions will also be taken into account and minimized during the manufacture and disposal of construction materials.

This thematic focus area is closely linked to the area in Section F (sustainable roads).



# D. Low-emission roads

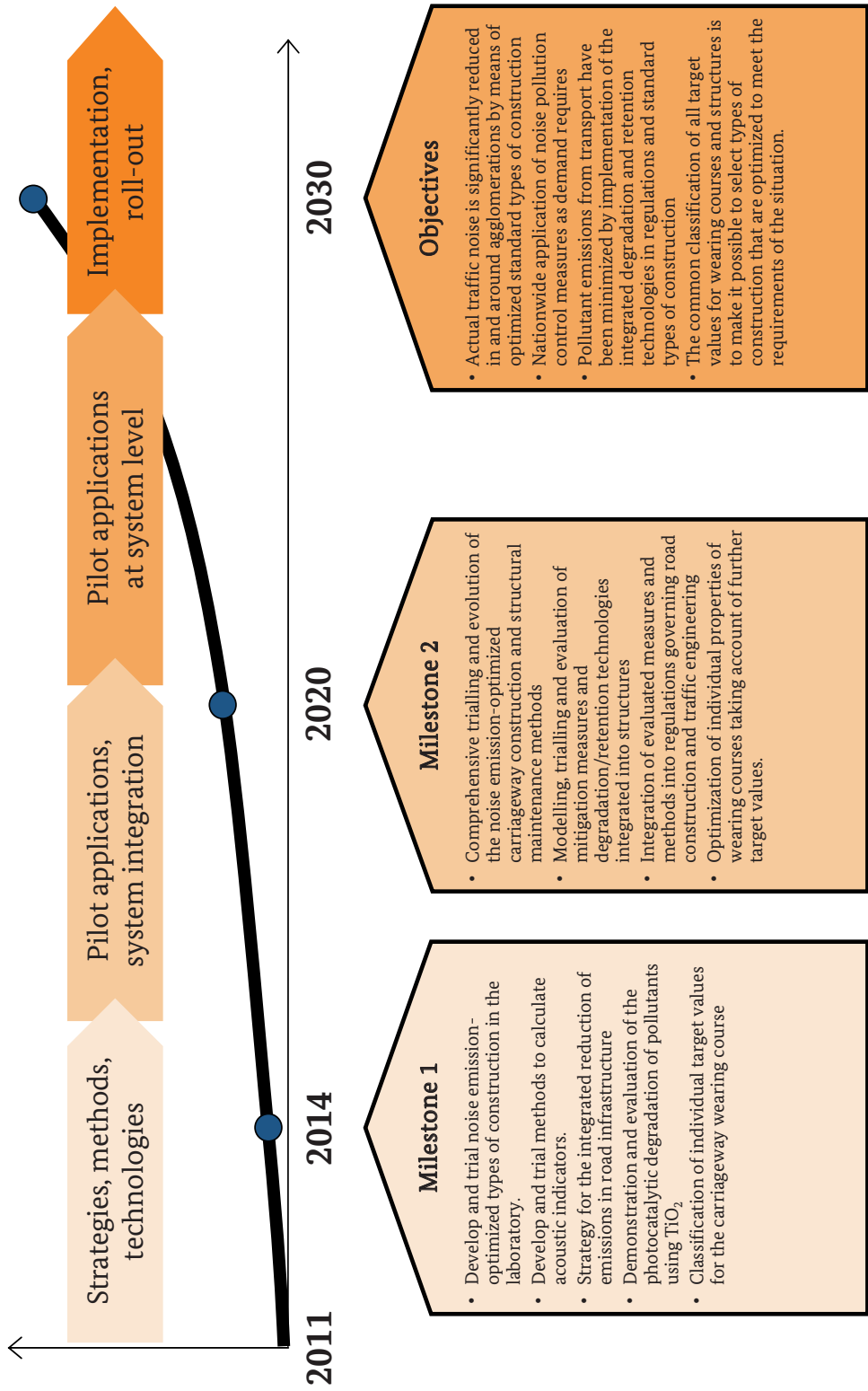
Today, the compatibility of roads and traffic with the requirements of pollution control is a major component determining people's acceptance of motorized road transport. The objective of 21<sup>st</sup> roads is to also bring this compatibility into line with the increasingly stringent requirements of pollution control. To achieve this, it is necessary to reduce emissions from transport on federal trunk roads, to lower the traffic-related pollution nuisance to people and nature, and to comply with the medically, biologically, ecologically and economically justified requirements of pollution control.

It is the objective of 21<sup>st</sup> century roads to significantly reduce actual traffic noise at source by means of new and optimized pavement designs. In addition, appropriate pollutant degradation and retention technologies are to be integrated into the standard types of construction to minimize emissions from transport. Effective measures for air pollution control on roads are to be identified and implemented nationwide and as demand requires. A system of classification

comprising all target values for wearing courses and structures is to make it possible to select designs that are optimized to meet the requirements of the situation.

Over the short term, the measures to achieve these objectives will focus on strategies for the minimization and for the integrated degradation and retention of emissions on roads. To this end, quiet carriageway surfaces will be developed and trialled on the basis of innovative methods for the calculation of acoustic indicators. In addition, procedures for photocatalytic pollutant degradation and other types of construction for integrated pollutant retention and degradation will be trialled and evaluated. This will comprise both types of construction with technologically necessary measures for the deployment of substitute construction materials and structures to retain pollutants from the road effluent.

This thematic focus area is closely linked to the area in Section F (sustainable roads).





# E. Roads as part of people's living environment

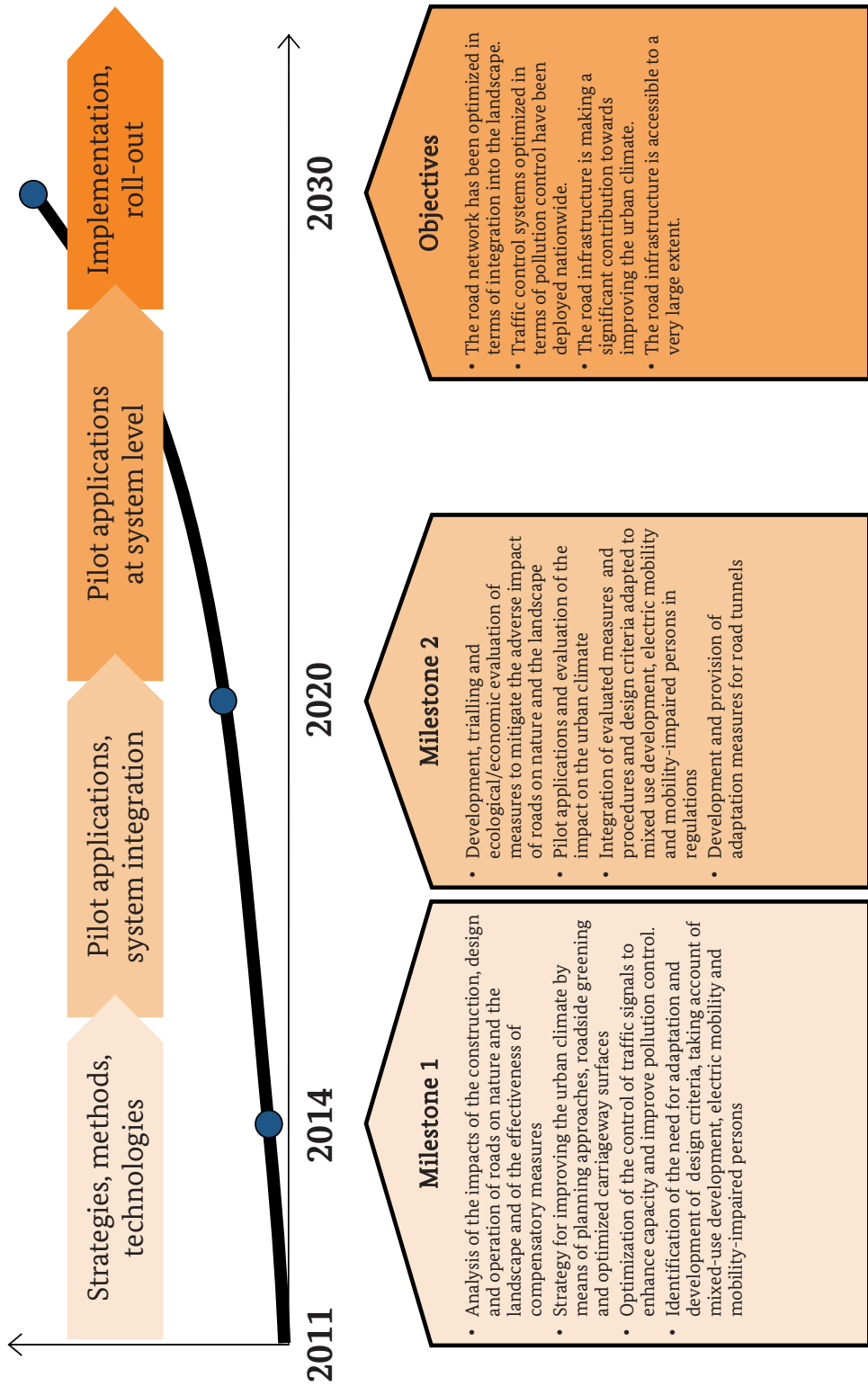
Roads are an integral part of our living environment. They are designed to connect people with one another and allow the operation of motorized transport, thereby enabling individuals to enjoy social inclusion. At the same time, the pollution associated with road traffic in people's living environments is to be kept as low as possible. Against this background, 21<sup>st</sup> century roads will undergo a process of permanent optimization, including measures to integrate them into the landscape. In addition, roads are an integral component of Baukultur. As such, they shape the ambience of city centres and the landscape of regions outside built-up areas. It is imperative that the significance of roads as part of the built environment heritage be preserved. The public will be actively involved in this wherever possible.

Roads shape spaces. They are more than just a means to an end, i.e. for getting from A to B. Roads and roadside spaces are crucial in determining the amenity value of settlement areas. Here, they are also venues for social discourse and places for experiencing urban life. For children, they are often places to play and have adventures. Distinctive features of the roads of the future will be that they are organically integrated into the landscape, that optimum use is made of their different traffic spaces and that there is a wide

spectrum of road use types. Here, it is imperative that vulnerable road users, such as pedestrians and cyclists, be protected, and it is just as essential that people with reduced mobility be able to participate actively in an accessible street environment.

Roads are the lifeblood of an interlinked, intermodal transport system in which each mode – road, rail and waterway – acts in a coordinated manner and in keeping with its specific capabilities.

Short-term measures on the path towards 21<sup>st</sup> century roads as part of people's living environment will focus on an analysis of the impacts of the construction, design and operation of roads on nature and the landscape and on the effectiveness of avoidance and compensation measures. In addition, the trialling of innovative infrastructure solutions for the protection of vulnerable road users, in particular, and for the integration of mobility-impaired road users will be of particular importance. The effectiveness of measures to improve the amenity value and to mitigate severance effects is to be analyzed in order to take account, in a targeted and systematic manner and while transport infrastructure is still at the planning stage, of the impacts of roads on the quality of human life and on nature and the environment.

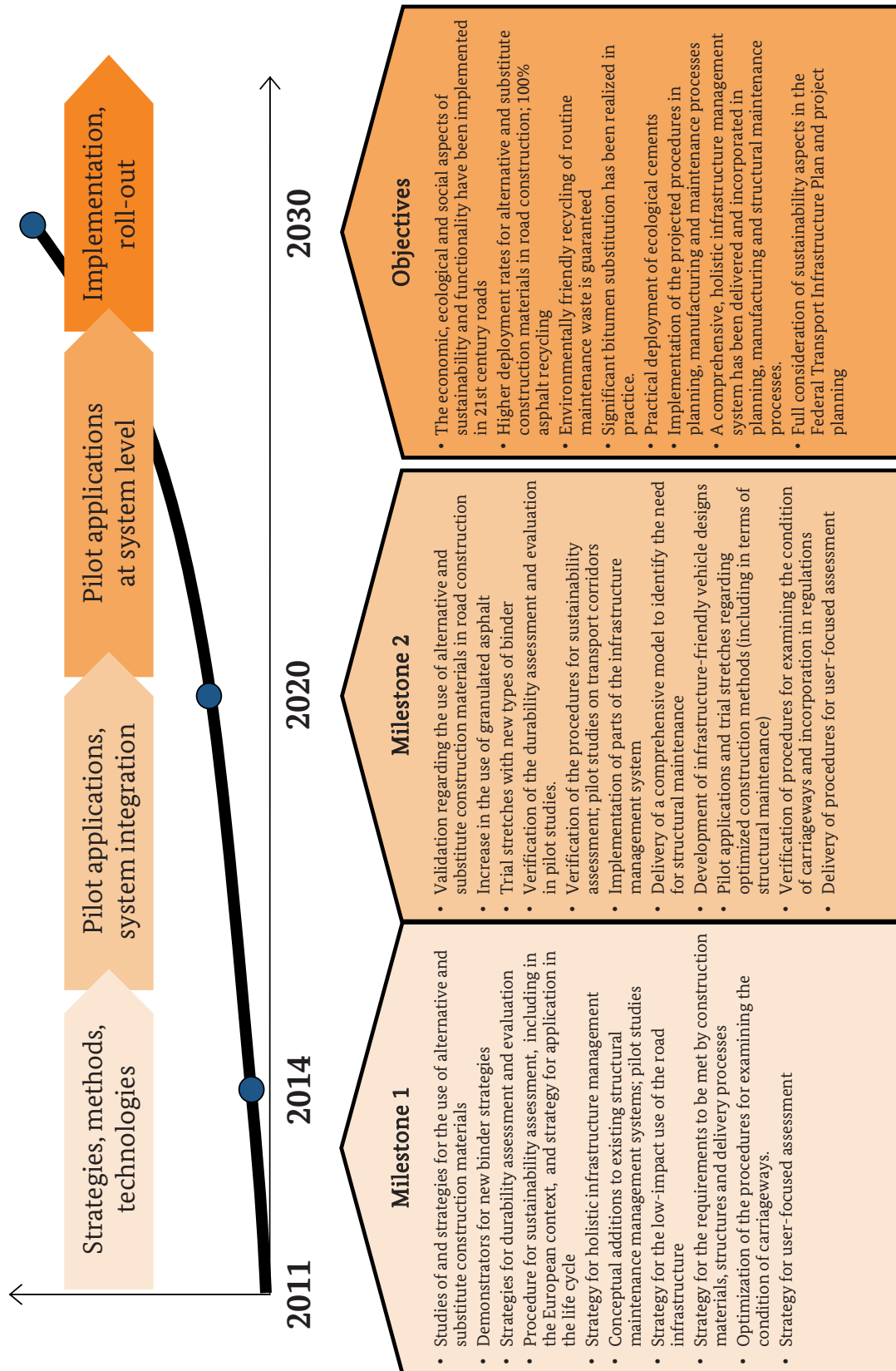


## F. Sustainable roads

It will not be possible to safeguard our society's mobility in the long term unless economic, ecological and social aspects are taken into account in the life cycle of transport infrastructure. Sustainability, value for money and energy efficiency are already major building policy and social objectives of the Federal Government. The road infrastructure is affected by the requirement for environmentally acceptable and economical construction and operation and for a guarantee of a high level of functional quality. The quality and value of the road infrastructure are increasingly being measured against whole life costs, low user and environmental costs and the health impact of construction materials.

21<sup>st</sup> century roads will seek a balance between economic, ecological and social aspects. The elements of the road infrastructure will be considered holistically over their entire life. This includes the consideration of sustainability aspects during the planning and tendering of construction projects, the careful selection of the construction materials and methods used, the sustainable administration of the infrastructure as part of a comprehensive infrastructure management system and, finally, efficient strategies for demolition.

Short-term measures for achieving these objectives will focus on, inter alia, strategies for the environmentally friendly recycling of hitherto unused materials, in keeping with the concept of life-cycle management, and the creation of alternative solutions for fossil resources. The main focus will be on studies to determine the suitability and use of recycled construction materials, such as recycled asphalt pavement (RAP) and other materials reclaimed from road construction works. Many valuable resources can be conserved and far fewer landfill sites will be required. The processing and reuse of these secondary materials will frequently be less expensive than their final disposal. This also entails the consideration of life cycle aspects in the planning, tendering, delivery and operation of road infrastructure. This will include the provision of procedures for sustainability assessment, the identification of requirements to be met by construction materials, structures and their delivery, and the development of a holistic, life cycle approach to infrastructure management. This thematic focus area is closely linked to the areas in Sections C (energy-efficient roads) and D (low-emission roads).



# G. Roads as innovators

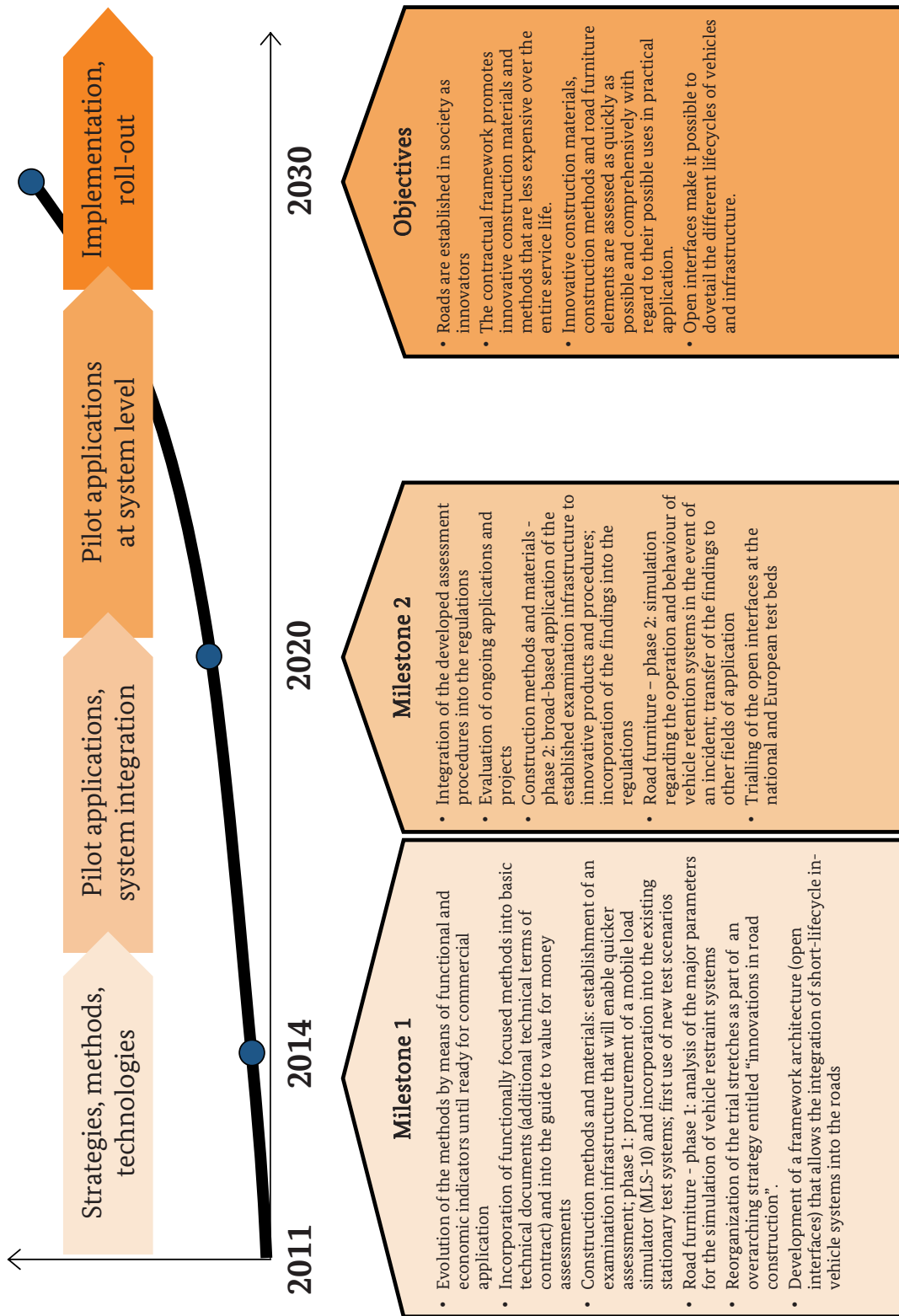
For years now, a huge innovation thrust has been emerging in the automotive industry. 21<sup>st</sup> century roads are to provide an appropriate infrastructure for such innovative vehicles. To this end, the framework must be such that technologically and economically viable innovations can be translated into practice as quickly as possible. 21<sup>st</sup> century roads are to be established not only as transport infrastructure but also as innovators and become an integral part of a positive national and European climate of innovation.

To this end, the market-based framework is to be increasingly focused on innovative construction materials and methods that are less expensive over their entire life cycle. This will involve establishing scientifically sound testing procedures and assessment methods that can be used to immediately and comprehensively appraise innovations with regard to their

use in practice. The first step is to be the establishment of a test track on which innovations from this programme will be trialled in a targeted manner. It is imperative – not least for reasons of cost – that simulation procedures be integrated into the assessment methods. In addition, open interfaces are to be developed on the basis of which the innovation cycles of vehicles and infrastructure can be dovetailed.

Short-term measures for achieving these objectives will focus on the establishment of an appropriate testing infrastructure, the evolution of familiar methodologies of functional and economic indicators for new construction materials, the development of simulation procedures in selected areas and the development of a framework architecture for open vehicle-infrastructure interfaces.





# Conclusion

There is no doubt that the roads will continue to be a foundation of the economy and society in the future. If the overall road system is to have a promising future, roads of the future will have to address new challenges in addition to the ones they currently face. It is imperative that we set the stage for this today. There will be no stopping demographic change, climate change, technological change, globalization and sustainability in a post-fossil society. The “Roads in the 21<sup>st</sup> Century – Innovative Road Construction in Germany” research programme is designed to successfully meet the challenges that lie ahead.

The present research programme was launched by the Federal Ministry of Transport, Building and Urban Development's Road Construction Directorate-General and developed in cooperation with the Federal Highway Research Institute.

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