INNOVATING IN ROAD INFRASTRUCTURES WITH R5G – THE 5th GENERATION ROAD

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Abstract

The modal part of road transport still accounts in France for approximately 80% among all available transport modes. Even if a shift to other modes of transport is wished for, this situation is not likely to change radically in the next coming years. Indeed, the road network has developed over thousands of years: emerging from the track to the paved road, then to the smooth road and on to the continuous road. However, the environmental cost of current road infrastructures is still too important. As a consequence, the development of road infrastructures is not a priority anymore and as a matter of fact excluded from ambitious greening politics. There is then a need of strong innovation in this sector to solve these issues. The 5th Generation Road program (R5G for French "Route de 5ème Génération") aims at changing the image of road infrastructures by designing, constructing and operating full scale demonstrators, which implement innovative solutions, ready for testing in research centres. To consider all aspects of this issue, the program is elaborated though a systemic approach and is organized around four emblematic conceptual elements: the adaptable road, the automated road, the resilient road and the acceptable road. The potential benefits of such a program are numerous: Maintaining the RAMS (Reliability, Availability, Maintainability and Safety) of road networks at existing levels, reinforcing industrial leaderships and targeting societal objectives (education, employment, and environment). The coming months will be devoted to the development and the implementation of the program at the National and European levels.

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1. Introduction

The modal part of road transport still accounts in France for approximately 80% among all available transport modes. Even if a shift to other modes of transport is wished for, this situation is not likely to change radically in the next coming years. Indeed, the road network has developed over thousands of years: emerging from the track to the paved road, then to the smooth road and on to the continuous road. However, the current environmental cost associated to road infrastructures cannot be neglected: impact on biodiversity, road deaths, emissions, etc. Reducing the environmental impact of road transport while maintaining current RAMS (Reliability, Availability, Maintainability and Safety) objectives, constitute a strong societal challenge. Such a challenge cannot be solved without a renewal of innovation in road infrastructures, their maintenance and operation and a way to develop them in synergy. Fortunately, this objective is clearly not beyond reach. Indeed, lots of technologies are already available in private and public research centres. What is today missing is a strong willingness to test and industrialize all the promising solutions and gather together the innovations in all fields on the same site. These innovations may benefit from two recent technological trends. Firstly, energy, materials and information are converging fields, which means that in a close future road infrastructures will be able to transport people, goods, energy and information. Secondly, the development of smart vehicles can potentially benefit to road infrastructures, in particular through the development of cooperative systems (Lepert and Hautière, 2010).

As a consequence, a holistic approach, which would cover the different aspects of road construction, operation and maintenance, road energy and environment, is necessary. This is exactly what the 5th Generation Road program is envisioning: a new road generation, built through a systemic approach, which would gather the best current ideas and would demonstrate the synergism among them.

2. Need for R5G

2.1 Present image associated to Road Transport

Road infrastructures suffer from a bad image. Even if nowadays societies cannot do without them, their environmental cost is still too high. As a consequence, the development of new road infrastructures is not a priority anymore and as a result excluded from ambitious greening politics like the "Grenelle de l'environnement" in France. Consequently, the assignments of road administrations are being reduced and the budgets allocated for road maintenance drastically decline every year. In the coming next years, these budgets may not cover the needs for maintenance anymore and the road network will begin to deteriorate.

2.2 Innovation in Road Infrastructure

Research and development in the road sector have made significant progress implemented over the past decades. However, numerous new technological components are still available in the laboratories. The implementation of these innovations on existing roads is sometimes still on a standstill because of a lack of risk taking from state road authorities, especially at the early stage of the innovation.

Indeed, nowadays, state road authorities are not deeply involved in a process of technological monitoring. They are also less able to finance innovation programs, and then to implement innovations and to require these innovations from their contractors. Finally, as a consequence, local road authorities may not implement these innovations, since they are not recommended by the national or federal authorities, although some of them show a high incentive to implement innovation, even at an early stage with the risk of failure and then definitive giving up of this innovation. Consequently, progress in road infrastructures is somehow limited to engineering aspects: continuous improvement of existing solutions without any technological breakthrough and implementation through innovation programs only occurs after several years and several site uses.

As a summary, there is a need for possibilities to implement innovation at an early stage i.e. between the first trial on the private site of the company and the validation through an official innovation program, with adapted risk taking. One of the potential solutions to this issue would be the development of a new form of Public Private Partnerships (PPP) allowing a share of risk taking.

Among the technological components available in the laboratories, the following can be quoted:

- High rate materials recycling
- Energy harvesting,
- Multi-modal information,
- Active traffic management,
- ITS cooperative systems,
- Wireless sensor networks,
- Self-cleaning and self-repairing materials,
- Long lasting overlays,
- Depolluting materials,
- Low energy lighting,
- Etc.

2.3 Technological Transfer and Industrialization

As mentioned in the previous paragraph, numerous technological components are available in the laboratories at a prototype level. In order to implement and spread out these innovations, system proving is necessary in order to foresee their potential benefits, to identify implementation problems and finally transfer them to industrial level. Such a process allows selecting the best solutions and raises new problems linked to a lack of systemic approach in implementation of innovations coming from different fields. One emblematic example deals with the recycling of pavement materials including in-pavement sensors. Technological transfer is also beneficial for laboratories which are free to tackle new research. Finally, once solutions have been proved and are ready for deployment, new environment and operation policies can be applied in order to target societal objectives.

3. Benefit of R5G

3.1 Maintaining the RAMS of Road Networks at Existing Levels

The modal part of road transport still accounts in France for approximately 80% among all available transport modes. A shift towards other transportation modes is incited through different national politics: guided transport systems (high speed rail, automated subways, FRET, and tramways), water transport (maritime motorways, wide-gauge canal). The design and construction of such new transport infrastructures takes a long time from preliminary studies to the achievement of the construction. Meanwhile, road traffic is likely to increase. The benefit of a road innovation program like R5G thus consists in maintaining the reliability, availability, maintainability and safety of road networks at existing levels along with reduced budgets. This includes the design and construction of new road sections if needed. In this case, innovative methods must be favoured.

3.2 Reinforcing Industrial Leaderships

Thanks to past ambitious road innovation programs (Sauterey, 1996) (Brosseaud, 2005), the French road industry is among the world leaders. Even if their construction sites are disseminated through the entire world, their research centres are still located in France. The restriction of budgets dedicated to road infrastructures may weaken the activities of these companies regarding road R&D activities and consequently, the existing know-how could be definitively lost. The benefit of a road innovation program like R5G is thus to reinforce industrial leaderships. Indeed, by developing innovative and sustainable techniques, road industry would be able to propose innovative solutions and in this way prevent social dumping. However, it is also necessary to support these solutions with relevant business models. As an example, it would be nonsense to design perpetual pavements, which could be implemented on entire road networks. However, it makes more sense to implement long lasting overlays on critical sections, where maintenance is very problematic.

3.3 Reaching Societal Objectives

An integrated road innovation program like R5G potentially contributes to different societal objectives. Firstly, it aims at adapting our infrastructure to the climate change and reducing greenhouse gases emissions along road infrastructures. Secondly, it aims at improving the liveability and the environment around road infrastructures. Thirdly, one of its goals is to create new jobs in the road sector and to contribute to the renewal of education programs, where civil engineering, environment and computer science would not be considered separately.

4. A Technical Approach which Encourages Risk-Taking

4.1 Design and Construction of Full Scale Demonstrators

Today, when a new technical solution is proposed to answer an open call for tenders, failure is not allowed, and this situation limits the risk taken by the company. Indeed, the failure of the tested solution would be very problematic for the image of the company. In the same way, companies are unlikely to propose complex systems, which gather the competencies of different industries, e.g. car manufacturers and road industry. Consequently, early stages innovative solutions are not likely to be implemented. Conversely, the design, the construction and the operation of full scale research demonstrators, where risk is mainly (not entirely) taken by the road authority is likely to make a great difference. Indeed, thanks to such demonstrators, the most innovative solutions but also the more risky ones, and especially those proposed by research centres, are more likely to be tested and problems related to their implementation identified and further solved. However, these demonstrators must show a clear improvement over the past and propose a technological breakthrough, so as to best meet societal objectives. Given the complexity of such a mechanism, different levels of demonstrators can be designed. At a first level, a road section in a controlled environment, e.g. a test track, used to select technical components and validate a single operation or maintenance strategy, constitutes the most simple R5G demonstrator. At a second level, a R5G demonstrator should be able to study the synergism of a subset of technologies along with a set of operation or maintenance strategies. At last, a full R5G demonstrator should be able to demonstrate the synergism of every possible innovation.

4.2 Systemic Approach

So as to examine all the aspects related to roads, the R5G program is being elaborated following a systemic approach.

4.2.1 Priorities

First, the program has been organized into a 2D matrix. The first dimension deals with the type of network. Indeed, each type of road has its own particularities, in terms of design, construction and operation. Four different types of road networks can be classically considered: urban, periurban, interurban and secondary networks. In a second dimension of the matrix, the technical domains have been organized into four interdependent elements. The first element deals with the low carbon design, construction and maintenance of roads. The second element deals with the automatization of traffic and operations. The third element relates to the resilience of road networks regarding climate change and their energetic efficiency. Finally, the fourth element concerns the acceptability (social, juridical, economical). This organization of the priorities is presented in figure 1.

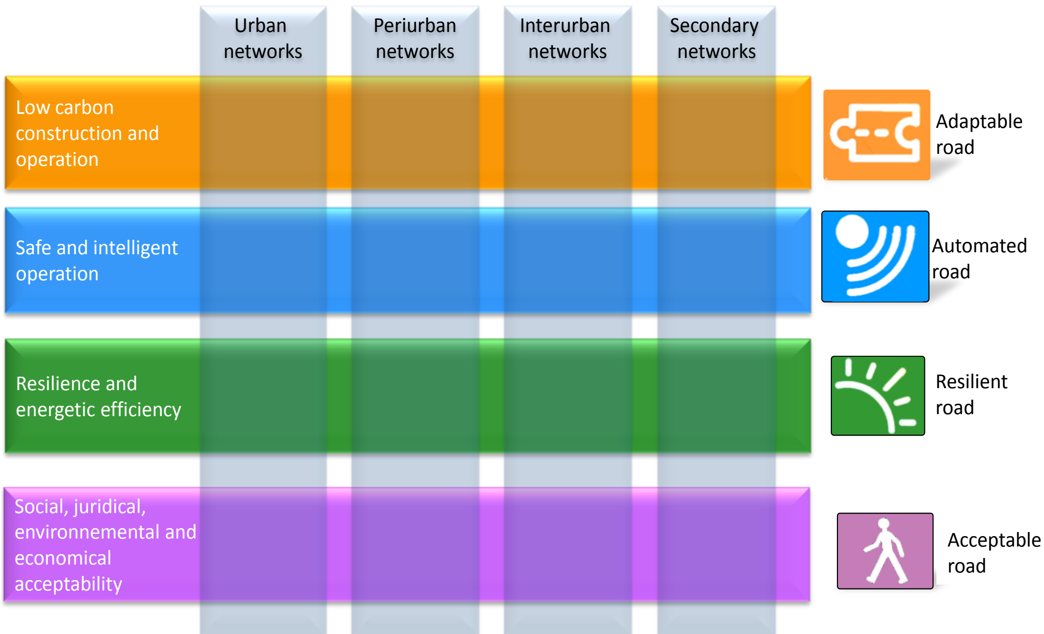

Figure 1 – Priorities of R5G program.

4.2.2 Methodology

Issues and technical areas being identified, a methodology must be developed to create a synergy between the four elements. An approach that could be described as systemic is proposed to allow consideration of the needs of different stakeholders of the road system. Thus, in order to build the R5G demonstrator, the first step is to identify the needs of society, users, operators, industry. These requirements contribute to the specification of the four elements (adaptable, automated, resilient and acceptable), but also to the emergence of new solutions on the borderline between these elements, as shown in Figure 2.

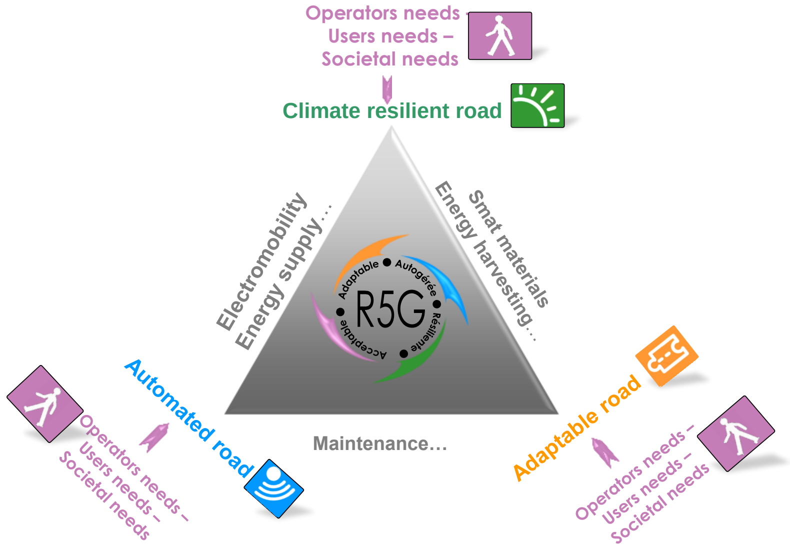

Figure 2 – Systemic approach underlying R5G demonstrators.

However, given the number of possible topics, it is not sensible to directly build a demonstrator R5G. It is then proposed to first carry out thematic or sub- R5G demonstrators. We deduced a first organization of the program in Figure 3.

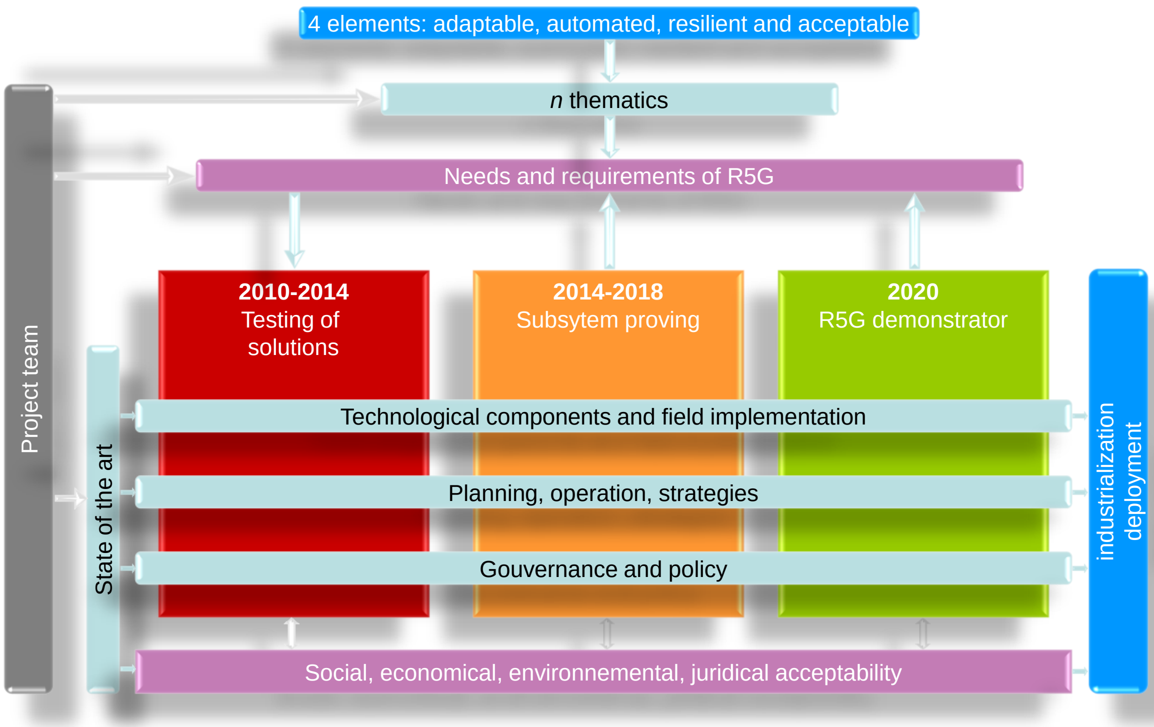

Figure 3 – Organization of R5G project.

4.2.3 State of the art

During spring 2011, a questionnaire was sent to Ifsttar's researchers. Firstly, they were asked to give their conception of the next generation road. Secondly, they were asked to list which concept, knowledge, technical component or methodology, ready for testing, should be taken into account to design the R5G. The answers to this questionnaire have been classified into innovation themes and innovation topics. Finally, the different topics have been linked to the

Innovation themes	Innovation topics	ADAPTABLE ROAD	AUTOMATIED ROAD	RESILIENT ROAD	ACCEPTABLE ROAD
Human-centred design	Driving simulation to evaluate road design	●	o		o
	Ergonomic design, automated/delegated driving		●		o
	Road design taking into account human behaviour	o			●
Cooperative systems	Localization		●	o	
	Local dynamic maps		●		
	Perception		●		
	Telecommunication		●	o	
	Data fusion		●		
	Driving automation		●		
Traffic and infrastructure management	Active traffic management		●	o	
	Control and management of GHV	o	●		
	Dynamic traffic allocation		●		
	Instrumented signage	o	●		
	Lighting and signage for dynamic lane allocation	o	●		
Urban planning and road sharing	Naked road	●	o	o	o
	Eco-neighbourhood	o	●	o	o
Intermodality	Shift from road to guided transport	●	o		o
Materials – management of natural resources	Alternative aggregates	●		o	
	Native survey	●			
	New materials for HGV retaining	●			
	Green bitumen	●			
	Functionalized materials	●	o		
Economy of transport	Long term traffic prediction using demography	o	o		●
	Business models and PPP				●
Accidentology / Safety	Automatic data collection related to accidentology		●		o
	Forgiving roadsides				
	Self-explaining roads				
Road energy	Infrastructure based vehicle recharging	●	o	o	
	Self-supplied winter maintenance	●		o	
	Energy producing road			●	o
	Electrified road	o	o	●	
	Smart grids		●	o	
Natural risks	Automatic detection of falling blocks		●	o	o
	Effect of drought on pavement	●		o	
Environment	Real-time air quality assessment		●	o	
	Real-time environmental situation assessment		o	●	
Maintenance	Road which auto diagnostics	●	o		
	Long lasting or low maintenance pavements	●			
	High speed monitoring	●			
	Cooperative monitoring		o		
New construction and design concepts	Innovative wearing courses materials	●			
	Modular pavements	●			o

Table 1. Classification of innovation themes and topics proposed by Ifsttar's researchers.

four elements of R5G. A first classification of the answers is proposed in Table 1. In this table, a solid bullet indicates a strong connection with an element. An open bullet indicates a simple connection with an element. A blank indicates no relevant connection. The same question is now being asked to the road industry. The crossing of the different opinions will enable in the short term to propose different consensual R5G demonstrators to be built, which content will be drawn among the content of Table 1.

4.3 Implementation Tools

In the previous section, a high-level view of the R5G program has been proposed along with a list of potential innovation topics. We have now to find solutions to implement this program. In this section, we present different existing tools which could be used to reach this challenging goal.

4.3.1 Internal Tools

For Ifsttar (resulting from the merger of LCPC and INRETS), the R5G program is of major importance, since it allows gathering all the competences of the former LCPC (French public works research laboratory) and the former INRETS (French national institute for transport safety) dealing with road transport. With this aim, an open forum dedicated to R5G has been created, so as to build a common view on the problematic. This forum should play an active role to regularly update the program and later to disseminate the results thanks to dedicated workshops.

4.3.2 National Tools

At the national level, the recent creation of IDRRIM (“Institut des Routes, des Rues et des Infrastructures pour la Mobilité”), which gathers the different actors of the road construction sector, in particular road authorities, local collectivities, industry and research institutes, is a tool to promote the development of R5G by allowing the identification of partnerships. Furthermore, call for tenders, dedicated to research infrastructures, are regularly launched in the framework of the ‘Investissements d’Avenir’ program launched in 2009 by the French government. In particular, some equipment of excellence is eligible for funding, which may serve to build the first level of R5G demonstrators, i.e. demonstrators dedicated to the testing of solutions. Finally, the ‘Fond démonstrateur de recherche’ lead by ADEME, the French Environment and Energy Management Agency, may be interested in financing an R5G demonstrator dedicated to the theme “road and energy”. Finally, the French National Program for Road Innovation (Brosseaud, 2005) may be one solution to implement the final full scale demonstrator.

4.3.3 European Tools

But such a project, for the part dealing with the communications between road and vehicles, as well as for the part dealing with construction and maintenance, must be European at the outset, as it must be adaptable to all European roads and all vehicles and as road technology is more and more worldwide spread through industrial globalisation. With this aim, Ifsttar is pushing the concept through different technological platforms to promote the development of large scale demonstrators at the European scale. In particular, Ifsttar together with other research institutes (TRL, RWS, AIT, BASt) is developing the Forever Open Road project, led by FEHRL (Federation of European Highway Research Laboratories) which naturally constitutes the main channel of development of R5G at the European level. FOR is the flagship program of FEHRL (see SERRP V). FOR was recently awarded with the best prize for road design and construction at the PIARC World Congress in Mexico City (Lamb et al., 2011). However, the R5G program aims at contributing to other related initiatives:

- The reFINE (Research for Future Infrastructure Networks in Europe) initiative led by ECTP (European Construction Technology Platform),
- The iMobility forum, in particular the Intelligent Infrastructure Working Group,
- The Joint Programming Initiative Urban Europe
- The German national program named “Road of the 21th Century” lead by BASt
- The roadmaps published by ERTRAC (sustainable freight transport, climate resilient transport, safety, urban and user expectations)

5. Some Potential Demonstrators

In this section, a non-exhaustive list of R5G demonstrators identified so far is proposed

5.1 Urban Road Demonstrator

Such a demonstrator would demonstrate the ability to design, to build, to maintain and to operate a mobility solution made of automated electrical shuttles, such as those demonstrated in the FP7 CityMobil project. These ones would be recharged in motion by infrastructure based recharging solutions and would evolve in open environments where conflicts with other modes of transport, such as cycling or walking, may be possible. This implies the development of an infrastructure based intelligent supervisor which allows closing the control loop of the automated shuttles.

5.2 High Speed Automation of Highways

The urban DARPA challenge has shown that autonomous driving was possible. The Nevada state (USA) just authorized the circulation of automated vehicles. However, such vehicles are very expensive to equip due to the use of high-end vehicle sensors, e.g. 64 layers LIDAR. Having a highly cooperative intelligent infrastructure (Blosseville and Parent, 2000) allows the realization of a lower cost automation of the driving task. The ABV (Low Speed Automation) project led by Ifsttar is developing solutions for the low speed automation. The FP7 SARTRE project has shown that truck platooning is realistic. The remaining challenge consists in realizing a demonstrator of high speed highway automation.

5.3 Road and Energy

Different innovations can be used to better manage energy in the road sector. Firstly, low temperature asphalts as well as emulsion treated materials for secondary network mean energy saving so as low rolling resistance pavements. Secondly, different technical solutions or concepts arise to harvest energy from road: solar road, piezoelectric road, geothermic equipment of the surroundings etc. Solutions are also under development regarding winter maintenance of roads using geothermic heat storage or self-maintaining surface materials. On the other side, eco-driving and eco-management of traffic allow reducing energy consumption by vehicles. Finally, inductive charging allows transferring the harvested energy to the passing electric vehicles. A demonstrator which would evaluate the synergism of these technical solutions is clearly desirable.

5.4 Efficient and Self-Explaining Secondary Roads

Today, the French accidentology has considerably dropped since the launch of the speed enforcement program in 2002. Even if the number of single vehicle accidents has been considerably reduced between 2002 and 2006, the gravity of this type of accidents remains in France higher than the average one in Europe and is increasing, in particular in presence of a wet road and of fog. This type of accidents usually occurs on secondary road networks where the road characteristics (e.g. geometry and skid resistance) are more demanding with respect to the vehicle dynamics. Consequently, the risk level on secondary road networks was not reduced and still encompasses at least one third of the total fatalities. Improving the safety of this type of road network calls for a better speed management, which goes beyond hotspot identification and automated speed enforcement. Inspection and audit procedures are good solutions but they are restricted (at least in Europe) to main roads. Numerous solutions are available for secondary networks, such as self-explaining roads, cooperative intelligent speed adaptation (Lepert and Hautière, 2010), etc. A demonstrator which would show the benefit of these different solutions would contribute to improve the safety of these networks.

6. Outputs

In addition to the technological transfer, the outputs of the R5G program are potentially numerous:

- Standards
- Knowledge, process, methodologies
- Recommendations
- Initial and continuous education programs
- A set of proven, implementation ready solutions

7. Next Steps

The environmental cost of current road infrastructures is still too high. As a consequence, the development of road infrastructures is not a priority anymore and as a matter of fact excluded from ambitious greening politics. However, there is a need of strong innovation in this sector to solve these issues. The 5^{th} Generation Road program aims at changing the image of road infrastructures by designing, constructing and operating full scale demonstrators, which implement innovative solutions, which are ready for testing in research centres. To examine all aspects of the problem, the program is elaborated though a systemic approach and is organized around four emblematic conceptual elements: the adaptable road, the automated road, the resilient road and the acceptable road. The potential benefits of such a program are numerous: Maintaining the RAMS of road networks at existing levels, reinforcing industrial leaderships and targeting societal objectives (education, employment, and environment). The coming months will be devoted to the development and the implementation of the program at the National and European levels.

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