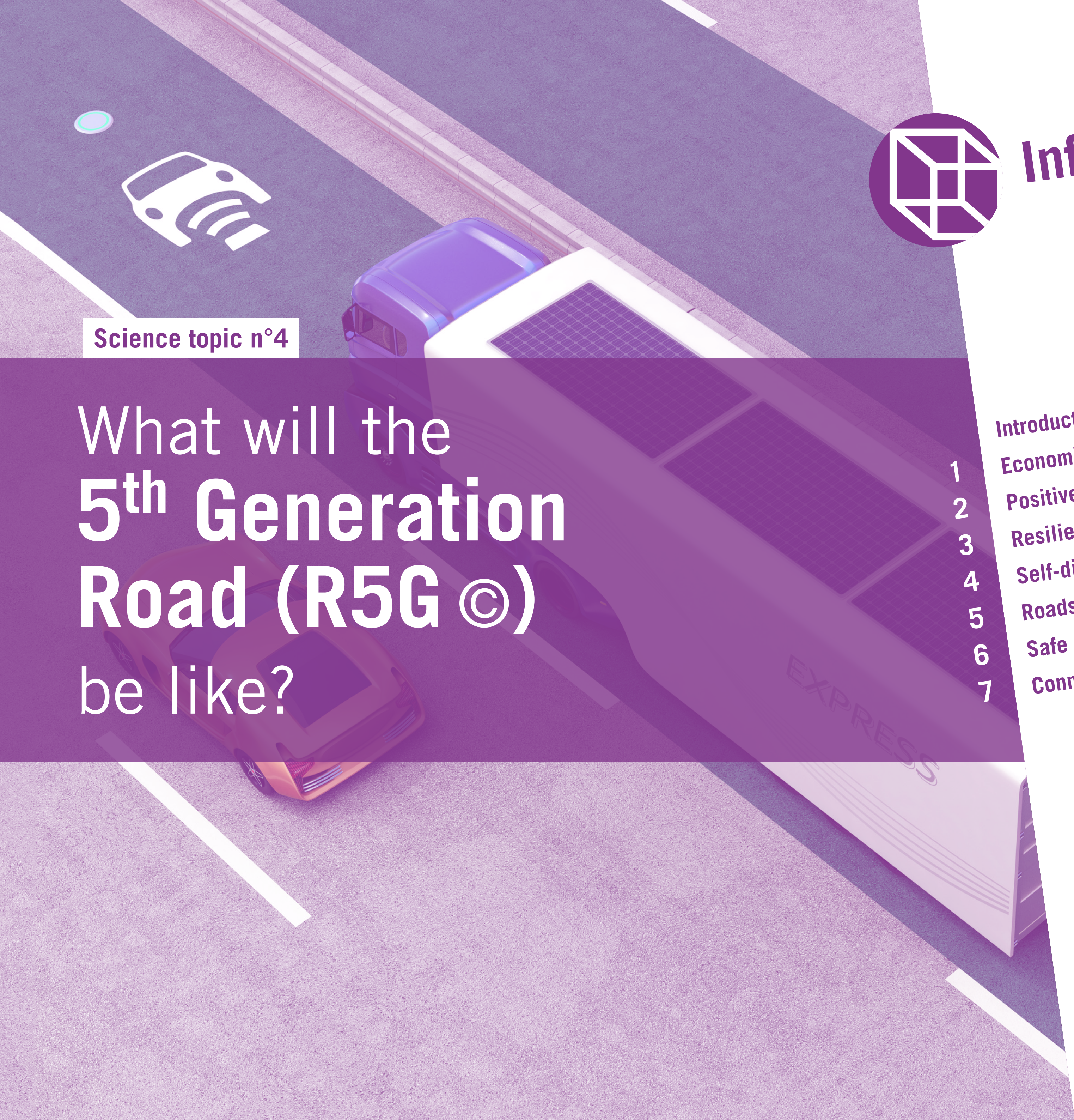

Science topic n°4

What will the 5th Generation Road (R5G ©) be like?

Infrastructure

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WHAT WILL THE 5th GENERATION ROAD (R5G ©) BE LIKE?

Nicolas Hautière,
Project director R5G © to Ifsttar

Road network managers must satisfy users' demand for unrestricted travel on a safe road network that is equipped with an increasing number of services. To achieve this, roads must be maintained without disrupting traffic and be able to withstand violent climatic events. They also need to meet societal demand for a reduction in pollution and adverse environmental impacts. The latter are directly linked to road transport and the increase in transport supply. Nevertheless, in a context of strong budgetary constraints, the road managers in question are finding it increasingly difficult to carry out essential maintenance work and obtain the teams they need for good network operation.

To take up these major challenges

IFSTTAR has launched the 5th Generation Road (R5G ©)[1], which has close ties with the European Forever Open Road programme set up and managed by the FEHRL[2].

The aim of the project is to propose solutions that have the potential for large-scale deployment: communication and energy exchange between the infrastructure, the vehicle and the network manager; recyclable materials with the potential for self-diagnosis and repair, a pavement surface that remains permanently optimal irrespective of climatic variations, etc.

The approach involves combining the components of innovative solutions in full-scale demonstrators in order to evaluate the synergies between them and propose comprehensive solutions that are appropriate for deployment on a larger scale.

A three-pronged approach

To foster the implementation of ground-breaking technologies in the area of transport infrastructure, R5G © will adopt a three-pronged approach.

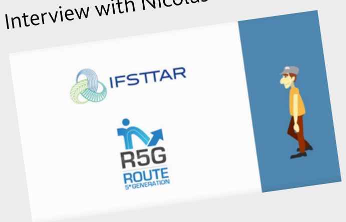
> **Component testing** consists of identifying, testing and approving the largest possible number of innovative solutions under controlled conditions.

> **Acceptability testing** consists of combining a sub-set of these innovations within what will be known as "R5G ©" demonstrators that will be installed directly on the road network. The goal is to evaluate synergy between the technical solutions and identify problems that may be encountered when implementing combinations of them. With these thematic demonstrators it will also be possible to study their acceptability and their impact of user behaviours.

> **The innovative road** consists of designing public policy instruments which allow the nationwide implementation of the innovative combination tested in R5G ©.

1. The 5th generation Route proposes to develop a new generation of infrastructure designed, constructed and maintained in a "system" approach that meets current synergistic technologies adapted to different contexts.
2. Forum of European National Highway Research Laboratories.

Video
Discover the R5G © concept
Interview with Nicolas Hautière



Consult
R5G © leaflet

1 MAKING ROADS THAT ARE MORE SUSTAINABLE, WITH LOWER EMISSIONS AND THAT USE FEWER NATURAL RESOURCES

The "5th Generation Road" project essentially aims to preserve natural resources, keep pollution to the minimum, particularly noise pollution, due to road traffic, and reduce expenditure on road network construction and maintenance. Thinking and designing a road with a low environmental impact comes with a few requirements. Its life cycle must be extended, it should remain quiet and consumes the minimum amount of non-renewable natural resources. Several research projects have been undergone in IFSTTAR to follow this path, some of which have already reached the demonstrator stage.

Long-life road surfacings

While today's pavement structures are designed to last 30 years, the life cycle of road surfacings is much shorter, about seven years when subjected to heavy traffic. Road repair works cause considerable disturbances to both users and residents and are also dangerous. The OECD "Long-Life Pavement" working group, to which IFSTTAR belongs, has been involved in a number of projects aimed at improving this situation. New mixes using epoxy asphalt have been developed and IFSTTAR has proposed a new material for ultra-strong wearing courses, a High Performance Cementitious Material (HPCM) with steel fibre reinforcement and chippings.

Contact: Ferhat Hammoum (ITF/OECD/LLPS3 project)

▲ A dismounting-remounting test on Nantes Métropole's dismountable urban pavement demonstrator

Tackle down nuisance

In urban areas, digging trenches to access underground networks (water, gas, etc.) is one of the main causes of disruption. In association with the industry and local authorities (Nantes Métropole and Saint Aubin les Elbeufs), IFSTTAR developed the concept of dismountable urban pavement that uses prefabricated hexagonal concrete blocks. These removable blocks allow rapid access to networks, improve pavement's durability and can also be recycled. As they are prefabricated, the integration of new sets of characteristics seems possible (varied textures, porous, silent, or de-contaminating surfaces, or built-in sensors, etc.).

In parallel, research aiming at reducing vehicle rolling noise in urban areas made further progress. The objective is to have a better understanding of the role of pavement texture and the effect of air pumping in the tire-road contact area. It has resulted in the development of new pavement technologies[1].

Contacts: Thierry Sedran (modular road) and Michel Bérengier (ODSurf project)

Preserve natural resources

Keeping the environmental impact of roads under control, during both construction phase and service life, is also a major concern of decision-makers. IFSTTAR is taking part in the European project LCE4ROADS, which aims to develop a European methodology for labelling roads with regard to their life cycle on the basis of their technical, environmental and socioeconomic performance.

IFSTTAR is also researching into the possibility of using renewable materials and recycling products that can be re-used for the same purpose at the end of their service life.

> **"In order to reduce oil consumption, we need to find an efficient and reliable substitute for asphalt."**

This is an major issue, especially in France where 70,000km of roads are repaired each year.

IFSTTAR has an interest in micro-algae, which have been identified as a promising biomass to manufacture a biosourced binder. They have the advantage of not being in competition with foodstuffs and their production does not require arable land. Research is being conducted in the framework of the Algoroute scientific project which is co-financed by the Pays de la Loire Region.

Techniques for recycling asphalt mixes at the end of their service lives are currently quite advanced, but questions remain about their performance when they have been recycled several times. IFSTTAR is involved in the national MURE[2] project (Multirecycling of asphalt mixes) to tackle this question, in the context of the development of new manufacturing methods for warm mixes (foam and additives).

Contacts: Agnès Jullien (LCE4ROADS project), Emmanuel Chailleux (Algoroute project) et Paul Marsac (MURE project)

1. More information on low-noise pavements can be found in the section "How can we tackle urban noise?"
2. Read the article about the MURE project on Enviscope.com (FR)

Further readings

OCDE/CEMT (2008) "Long-Life Surfaces for Busy Roads - Economic evaluation of long-life pavements. Phase II", OECD 77 2007 031 P1 / ISBN: 978-92-821-0158-2.

GITF/OECD (2014) "Long-Life Pavement Surfacing Field Trials – Phase III" Working Group on Long Life Pavements Surfacings, Final Report to be published.

Infrastructure

Algoroute Project (FR)

Micro algae pay Replace petroleum asphalt in our roads

Read the fact sheet

2 GIVING PRIORITY TO POSITIVE ENERGY ROADS

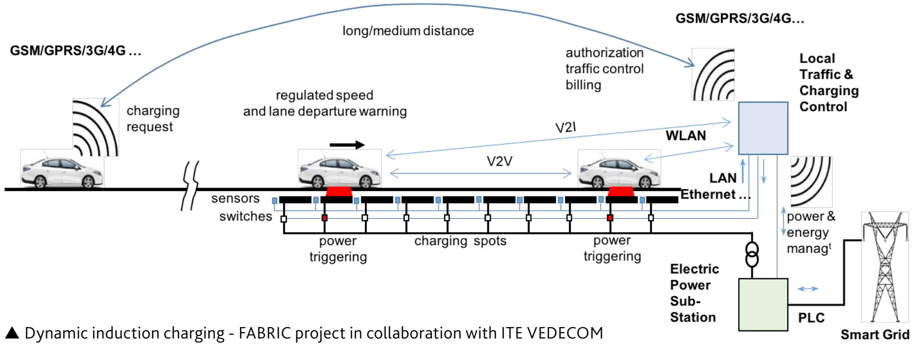
Philippe Tamagny,
Deputy Director of the MAST Department[1]

In France, energy considerations are of prime importance in the sphere of road freight and passenger transport. The road system transports 90% of the country's freight (in tonne-kilometres) and 80% of its passengers (in passenger-kilometres). The energy transition for roads themselves, which are part of a transport system that is omnipresent in the day-to-day lives of the nation's citizens, is consequently unavoidable. R5G © clearly states its aim of making a medium-term contribution to this goal. It fosters innovative engineering solutions with the aim of making considerable reductions in the amount of external energy required by the transport system. It attempts to provide energy to vehicles more efficiently and sees roads as a potential source of energy, as has long been the case for buildings with systems such as photovoltaic panels and solar water heaters, etc.

An efficient energy supply for vehicles

The first step to take in order to improve the efficiency of the energy supply to vehicles lies in the development of electric vehicles. The most conventional way of recharging the batteries is, of course, a dedicated socket: R5G © should therefore be equipped with high performance recharging stations that are fast and reliable. This is the purpose of the project MOV'EO TREVE, conducted in collaboration with ADEME[2]. The goal is to design a dedicated demonstrator for evaluating and conducting applied research into infrastructure for recharging electric vehicles. It also provides back-up for the "urban electric service station" concept.

But the most efficient solution is without doubt the large-scale development of dynamic, contact-free, recharging facilities that can be used by vehicles of any type: private, public transport and freight. The European FABRIC[3] project will make it possible to build a demonstrator for the contact-free recharging of moving vehicles (up to 80km/h), for private electric vehicles on the Versailles-Satory test site. For urban public transport systems, such as buses or trams, several experiments to insert such technologies into pavement structures have already been carried out at IFSTTAR's Nantes site.

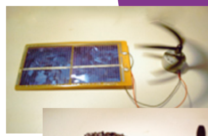


▲ Dynamic induction charging - FABRIC project in collaboration with ITE VEDECOM

Infrastructure that produces hot water?

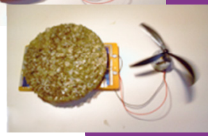
Pavement surfacings are usually black and they therefore absorb energy from the sun's rays. Their surface temperature may be several tens of degrees higher than the ambient temperature. The idea of turning them into a "solar water heater" is not a new one, and has already been trialled on a number of occasions. The thermal energy recovered in this way can be used to heat buildings directly or to produce energy. The hot water can also be stored in natural or artificial underground reservoirs. It can then be re-used in the winter for melting snow or ice on the road surface or to help heat nearby facilities. The techniques that have been deployed so far required pipes to be inserted in the pavements, but simpler solutions using specifically developed materials are currently being investigated.

▼ The solar road principle



Solar cells and engine

Solar cells covered with conventional asphalt: the engine stops



Solar cells covered with semi-transparent asphalt: the engine is running

In favour of a solar road

The reasons that makes roads potential water-heaters are the same that make them an excellent surface for the direct production of electricity with photovoltaic panels. The energy produced could either be used locally by the road itself, for illuminated messages, signs, or to power stationary roadside communications systems and road lighting in specific sections.

The main technological limitation is the development of a semi-transparent road surfacing that will cover a display of photovoltaic cells. The technical feasibility of this has been demonstrated. It is nevertheless still necessary to set up a full-scale demonstrator to test the efficiency and robustness of this technology.

1. MAST: department Materials and Structures of Ifsttar
2. ADEME: The French Environment and Energy Management Agency
3. FeAsiBility analysis and development of on-Road chargIng solutions for future electric vehiCles (in collaboration with the Institute for the Energy Transition (Institut pour la Transition Energétique VEDECOM)).

Consult

The hybrid solar road project

When roads produce electricity and heat…

Read the fact sheet

Further readings

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De Larrard F., Sedran T., Balay J.M. (2012), "Removable Urban Pavements: An innovative, sustainable technology", International Journal of Pavement Engineering, Vol. 14, Iss. 1.

3 IMPROVING THE RESILIENCE OF ROADS TO CLIMATIC EVENTS AND NATURAL HAZARDS

Yasmina Boussafir,
Project officer – GERS Department[1]

Technically, resilience refers to the ability of a road to adapt to any external event. A road is considered to be resilient when, repairs can be performed easily and rapidly after a destructive event so as to bring back the level of service as it was before the event.

Why do we need resilient roads

Damages caused by climatic events and/or natural disasters are frequent and diverse. It ranges from the complete destruction of a road section to its obstruction or the loss of its functional quality through cracking, deformation or rutting.

The natural events that occur most frequently:

- earthquakes,
- landslides,
- erosion,
- storms,
- underground cavities, etc.

▲ Collapse of a road as a result of the dissolution of gypsum in the subsoil.

Disasters caused by earthquakes are frequently quoted as an example to explain the need of resilient infrastructures. In a few seconds or minutes, an earthquake can, indeed, causes major damages and many casualties around its epicentre. The physical damages remain steady after the event, but the amount of casualties can double or even triple, if the access to the area is not rapidly restored for the emergency services.

The water-networks, telecommunications and energy (electricity, gas), which are often associated with transport infrastructure, are also sorely lacking after an earthquake and supply failures make the situation even worse. Then, a critical health situation can pile-up on the natural disaster. In the case of gas or electricity outage, risks of explosions and fires can be added.

Some recommendations for implementation

The 5th Generation Road should be designed as resilient:

- Road designers will have, in advance, a list of the catastrophic events that are likely to affect the different road sections and a ranking of these events on the basis of the importance of each in the network[2].
- The infrastructure owner must specify the minimum level of use that must be maintained in case of hazard, and the maximum acceptable period during which the road may be unusable, i.e. the repair time
- The design file will allow the assessment of the economic and social risks if hazard occurs. The infrastructure owner would then be able to select the design solution or compensatory measures which would either enable the infrastructure to withstand the abovementioned hazard or allow it to be repaired under acceptable conditions.

> **"The 5th Generation Road should be designed as resilient."**

1. GERS: Geotechnical engineering, Environment, Natural hazards and Earth sciences Department
2. To give an example, the RN2 on Reunion Island, which is priority road, has greater importance than a municipal road.

Infrastructure

More videos on web

Erosion: Caused by water

◀ Complete destruction of a section of road after a storm.

Credit: left, J-L Durville; right, Manier

4 ENCOURAGING THE SELF-DIAGNOSIS OF STRUCTURES

Frédéric Bourquin,
Director of the COSYS Department[1]

Structural Health Monitoring (SHM[2]) aims to provide continuous information about a structure capacity to bear the loads for which it was designed, for example the weight of trucks on a bridge; to identify the onset of damage, or monitor its development and evaluate its impact on the structure strength; to know the actual loads structures are subjected to.

Civil engineering structures which perform self-diagnosis offer a paradigm shift with regard to maintenance, which is still usually conducted on the basis of periodic inspections and the application of progressive monitoring in the case of a disorder. Self-diagnosis would make it possible to implement detailed inspections when necessary while helping to characterise changes in the structure or its loading, in order to reduce life-cycle costs.

These technologies also play a key role in improving winter services by better optimising the use of de-icing products or heating cycles in the case of critical infrastructure. Self-diagnosis has the potential, still barely exploited, to increase the productivity and safety of civil engineering works, such as the driving of tunnels. It also makes it possible to install systems to dampen vibrations in the case of flexible structures such as cable-stayed bridges that are subjected to wind.

New approaches in response to new challenges

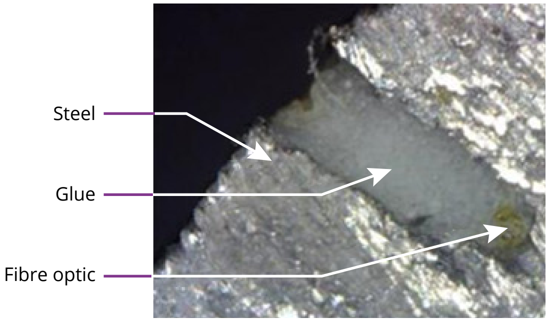
Self-diagnosis requires a close cooperation between measurement technologies, performance models and data processing techniques. It involves the observation of systems and constitutes a scientific and technological challenge in its own: the existence of self-diagnosis cannot simply be decreed and it has the potential to generate large costs. It requires a large number of sensors which must be compatible with all the physical phenomena that are at play, discriminating digital models, fast algorithms to process a very large amount of data, techniques to eliminate the impact of environmental factors such as temperature or humidity (which are often larger and more apparent than the effects of the damage in question). The science of data must be mustered for the sake of structures. For transport infrastructure, preference will be given to techniques which cost only increases moderately with the length or surface area to be monitored.

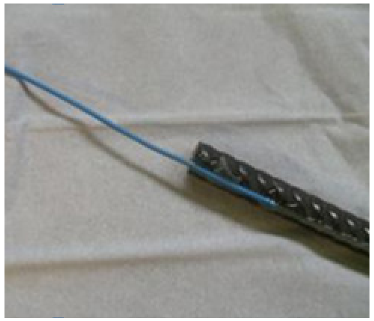
Opportunities for innovation

The cost of these innovative networks of sensors based on nanotechnology, photonics (optical fibres, infrared thermography) or electrical wave propagation, becomes reasonable once the volume of data to be processed exceeds a certain threshold, and they will be fitted to infrastructure on a massive scale, particularly in urban areas. When combined with fixed or vehicle-borne satellite technology, at network level, these sensors will provide original high-output health monitoring methodologies for roads, railways and wind farms, with major impacts on availability and maintenance. It will become easier for transport operators to perform weigh-in-motion, to estimate the real loads carried by roads and bridges and to predict their service life. These innovative sensors will form the cyber-physical infrastructure of information systems that will be integrated within the city and infrastructure of all types, in particular very high performance ultra-light prefabricated structures such as bridges made from composite materials.

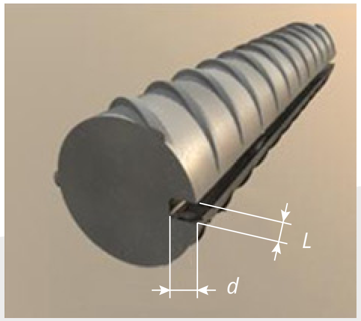
Countless variants of these systems will improve the energy efficiency of the city and transport systems, and enhance the real time assessment of urban operation with regard to mobility and energy, air, water and soil quality and electromagnetic pollution.

> **“Self-diagnosis would make it possible to implement detailed inspections […]”**





▲ A fibre-optic sensor bonded to the rebars of reinforced concrete structures



Credit: Ifsttar

1. COSYS: Components and systems Department
2. Structural Health Monitoring

5 ENCOURAGING COOPERATIVE AND INNOVATIVE TRAFFIC MANAGEMENT

Christophe Desnouailles,
Director of Studies and Leader of the Operation Group at the Direction territoriale Ouest du Cerema[1]

The new generation road is becoming automatic in order to optimise traffic flow capacity in complete synergy with communicating vehicles.

For innovative traffic management

Today's "dynamic traffic control" measures give the road a degree of flexibility in terms of traffic, safety and "modal transfer". They allow the allocation of traffic lanes to be varied at different times and from place to place, as well as according to the different categories of road user. The road thus adapts automatically to provide the best possible traffic flow at any given time. Measures that are already implemented include use of the emergency lane, reversible lanes, the creation of exclusive lanes, dynamic overtaking bans for HGVs and ramp metering.
However, traffic management is part of a more comprehensive system. To maximise the efficiency of the road in terms of energy consumption and traffic safety, innovative approaches include pedestrians and public transports in order to encourage intermodality. Sharing of the road system, coordinating priorities given to public transport vehicles, disseminating traffic information in the right place and at the right time by the infrastructure are all currently under development. Besides, parking management, in real-time and in function of the car park occupancy is proving to be a major benefit, especially for HGVs on motorways and major roads.

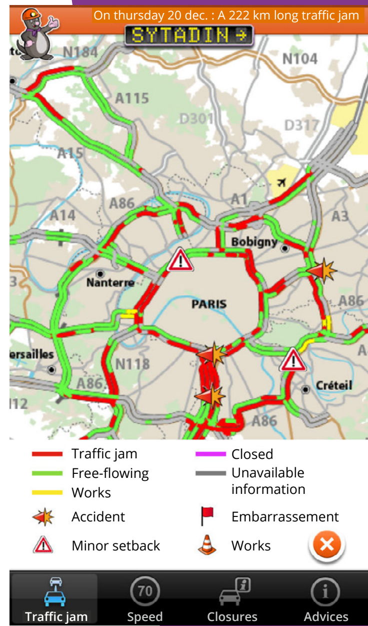
▲ The road communicates dynamically with the user through signage: the central contraflow lane on the St Nazaire – St Brévin bridge.

> **"Innovative ways of tackling congestion involve locally implemented micro-control."**

These new forms of operation will generate new needs for sensors and signing equipment. They are part of a multi-criteria approach that takes account of the level of service provided to users, acceptability and sustainable development.

Towards cooperative traffic management

Road traffic information for drivers can be disseminated not only by road signs but also by cooperative systems. Such systems are already in use and allow vehicles to connect themselves to the "cybernetic road". The data generated, obtained provided by mobility management centres, vehicles and roadside units (RUs), open up the possibility for the development of new services.
These communicating vehicles have the novel potential to host applications for communities of road users. The users expect the road to provide them information that is personalised, multimodal and contextualised. These data networks are quite useful for road managers to improve the level of service of their road.
The concept of the automated road takes on its full meaning when on-board intelligence in the vehicles and roadside intelligence in roadside units (RUs) are able to take action in the driver's stead.
For example, the automation of traffic facilitates the sharing of driving by controlling, in particular, vehicle gaps. In this case, vehicles could be guided by a traffic control centre which either gives or withholds permission to drive in automatic mode and in collaboration with the infrastructure. Calculations have shown that the automation of traffic could help to double lane capacity with no reduction in safety.



▲ The road network informs users of its state of occupancy in real time (the SYTADIN platform)

Towards environmentally friendly intelligent traffic management

Intelligent traffic management can urge drivers to reduce their fuel consumption, as well as predict emissions and the distribution and levels of the public's exposure to pollutants. In order to promote eco-driving, cooperative systems could transmit each vehicle's instantaneous consumption to infrastructure managers to enable them to evaluate their impacts on air quality.
Another possibility is to build sensors and weather stations into the network in order to inform the road manager about possible hazards or incidents such as snow-covered motorway access roads which pose problems for heavy vehicles.
Sensors fitted to vehicles that communicate with the infrastructure could enhance this meteorological data (temperature, visibility, skid resistance, wind, etc.). The communicating infrastructure would then be able to collect this data and process it so that the road provides an optimum service to users.

1. Cerema: Centre for studies and expertise on risks, environment, mobility, and urban and country planning

Credit: left, Cerema; right: DiRIF

6 DESIGNING SAFER AND MORE EFFICIENT INFRASTRUCTURE

Joël Yerpez,
Director of the LMA Laboratory[1], TS2 Department[2]

Road experts agree that real time digital data exchange systems, operating between the infrastructure and vehicles represent an essential development for the future.
Such roads are alternatively referred to as intelligent roads, the road of the future, or the 5th Generation Road. Their goal is to inform us about our trip, the weather, traffic levels, our location, the surrounding resources, etc. It will also provide improved security and safety.

Strategic data collection

Two types of information are taken into account when developing driving strategies and tactics.
The first kind is used to plan an itinerary and to adapt to meteorological and traffic conditions, etc. It eases the trip management and therefore improves safety conditions with respect to spatio-temporal constraints.
The second type of information is used to help drivers to perform the driving task, and influence their instantaneous behaviour and cognitive capacities. The issue of the social acceptability of the system and its absolute reliability, in particular the immediate accuracy of the provided information, make the question even more complex.
These two types of information play different roles and isolate or confront them would not be relevant. By its very nature, road safety depends on both approaches.

▲ Two road data recorders.

Additional research

IFSTTAR is conducting many research projects which aim at anticipating driving difficulties caused by infrastructures, weather, traffic, etc. (the DIVAS and DIVAS et PALM) projects). Other projects permit the deployment of information systems that are dedicated to adverse weather conditions and some specific features of the infrastructure (SARI) linked to the traffic (METRAMOTO).
In addition to saving energy, eco-driving, which is studied in the SERRES project, aims to achieve the multi-criteria optimisation (energy consumption, safety, comfort, journey time, etc.) of driving tasks (navigation, guidance, stabilisation, etc.). Research works also focus on speed awareness and speed optimisation, in particular using connected vehicles and smartphones (Andrieu, 2013).
One needs to be aware that various levels of equipment coexist on the road network. For example, highly equipped major roads exist alongside a dense, locally managed, secondary network on which the level of traffic is admittedly lower, but on which the fatality risk is twice as great (ONIRS, 2013).

The need for appropriate equipment

Fully equipping the secondary road network is not economically sustainable. An alternative solution is to equip vehicles with additional devices.
Research in this area involves the development and deployment of in-vehicle event data recorders which automatically identify accident and incident situations. The collected data can be remotely processed (SVRAI project - Serre *et al.*, 2013, 2014). Each pieces of information could then be directly sent to users, using their smartphone (dynamic personalised warnings in high-risk zones, for example).

1. LMA: Laboratory of Accident Mechanism Analysis
2. TS2: Transport, health, safety Department

Further readings

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Infrastructure

Credit: Ifsttar

7 CONNECTED COOPERATIVE ROADS AS A RESPONSE

Nicolas Hautière,
Project director R5G © to Ifsttar

There is every reason to believe that "5th Generation Roads" will be connected and cooperative. Current research works rely information exchange between users, vehicles, infrastructures and traffic control centres, in order to provide mobility services more efficient, more reliable and safer. The benefits for infrastructure will include greater availability and lower maintenance costs. The deployment of these "cooperative" systems is a further step towards driving automation.

Gradual deployment of roadside equipment

As far as the infrastructure is concerned, the central element in cooperative ITS systems[1] is the roadside unit (RU). Its function is to coordinate all the connected objects within its zone of coverage, whether static or mobile.

Interoperability, telecommunications protocols, data exchange security, data formats and antennas are all active areas for research and development. Standardisation also plays a decisive role in the initial deployment of these technologies.

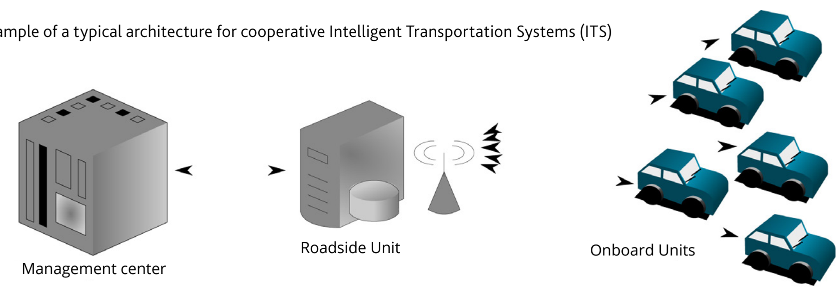
Besides, the strategy enforced to equip the infrastructure must take into account the gradual renewal of current systems.

New services for all drivers and managers

Apart from transmitting traffic information, the first services to be tested will involve driver information. Examples include warnings near worksites and in the event of a hazard (obstacles, fog, etc.), assisting speed limit compliance and providing information about advisory speeds, journey times, parking spaces and public transport.

In a second phase, these enriched data will also be available to road and fleets managers (public transport, freight and car sharing). One concrete application will concern the preventive road maintenance.

▶ Example of a typical architecture for cooperative Intelligent Transportation Systems (ITS)



Towards a new generation of road equipment

The availability of enriched data on traffic and environment opens the way for a new generation of road equipment. Road signing, street lighting and safety barriers can be design to more efficient. For instance, the power of streetlights could be directly linked to the meteorological conditions and the traffic intensity.

Sensors will not only be used to collect data. The reliability of the collected data could be improved by merging them with data from vehicles, traffic control centres and social networks. Thus, traffic monitoring cameras and sensor networks could be combined and used to collect meteorological data in order to optimise winter maintenance activities.

In the long term, generating individual instructions for vehicles could be possible thanks to the quality of the information collected. Speed, vehicle gaps and even their itinerary could be send so as to automatically regulate traffic.

1. Intelligent transportation systems

▼ Implementation test on the IFSTTAR reference track as part of the ANR Divas Project

Further readings

Hautière N., De-La-Roche C. et Op-De-Beek F. Comment adapter les infrastructures routières aux enjeux de la mobilité de 2030. In TEC: Transport Environnement Circulation, 217: 25-32, 2013.

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