Forever Open Road

Research & Development Plan

September 2010, v4

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Summary

The general objective of the Forever Open Road project is to achieve a step change in the construction, operation and maintenance of Road Infrastructure in Europe, which will result in a transport system that has lower whole life costs, that has reduced maintenance requirements, and that has a low, or potentially positive, environmental impact.

Innovative technologies and systems will be incorporated to develop the practical and tested solutions that will help meet strategic European goals on economy, environment and society. It will help to develop a next generation of roads that require less maintenance, are more effectively operated and are able to meet differing demands from users across Europe's motorway, rural and urban networks regardless of region or country. Most importantly, the Forever Open Road concept will apply to existing and new-build roads and would provide a means of upgrading the network on a phased basis.

The Forever Open Road project is being developed in four phases. Phase 1 of the project focussed on developing the outline concept and was completed in 2009. This document summarises the current status of the Forever Open Road project as Phase 2 is completed, where the required research, development and integration of innovation is developed, that will be undertaken during Phase 3 begins, in 2011 and 2012. Phase 4 of the project will commence in 2013 and will involve the development of prototypes and demonstration projects.

The Forever Open Road programme will bring together much of what we know already, as well as develop new research and identify new technologies to fill in the gaps in our knowledge. The programme is structured around three distinct development domains. They are:

- **The Adaptable Road** – providing a quick and cost effective method of constructing and maintaining roads. This will involve a re-think of how roads are built, including the use of prefabricated, upgradeable pavement structures with long-life characteristics that are capable of incorporating removable and changeable infrastructure services and accommodating new forms of powered vehicles and guidance systems.
- **The Automated Road** – integrating road side intelligence with ICT applications in the vehicle, the services and the operator. The sensory and communications technology involved will enable the deployment of advanced (e.g. dynamic) guidance and management systems tailored to respond to in situ requirements, in effect improving reliability and efficiency of the network management.
- **The Resilient Road** – this will ensure consistent availability under weather extremities, mitigate certain negative road effects, e.g. reduce noise and absorb pollutants as well as generating heat and power for use directly or for use by adjacent communities.

The adaptable element will be the key to making the concept work, supporting the automated and resilient elements.

A scoping study has been undertaken which has identified a number of technologies and their readiness for implementation, and selected clusters of technologies have been identified for further research. In parallel, the programme in general has continued to gain support and coverage through presentations at conferences, journal articles and a launch at TRA in June. It is imperative that the momentum is maintained and that support is secured to build upon the efforts made so far.

The research and development work required to realize the Forever Open Road concept will be significant in terms of scope, cost and the need for pan-European coordination across industries.

However, whilst challenging, with regard to respect to the substantial long-term benefits to the European economy, environment and society, it will form the most substantial and indispensable programme of road research, and development in Europe.

The key deliveries of Forever Open Road are:

- *Demonstration projects* to test the viability of the product, process or service technology that in preceding research stages has rendered feasible. The tests will be performed 'in the field', against the backdrop of real road operation practices and requirements, such to effectively reach the mark of 'implementation ready'. They concern prototype systems; new technology trials; construction and maintenance demonstrators, including the necessary standards, specifications and design guidance.
- *A knowledge database*, to ensure that the research and demonstration results from Forever Open Road are effectively shared and applies to the effect that results from accomplished research or demonstration activities are actively used and other projects may build upon these results to avoid duplication within the FOR programme
- *A set of Common European Standards and Specifications,* which will ensure that the Forever Open Road, and any component parts can be used regardless of country or location.

There will be strong and committed involvement of key stakeholders from the European Road Transport system (private and public), to ensure pan–European engagement, cooperation and collaboration as well as to ensure the technology being researched and developed is indeed state of the art.

1 The Forever Open Road

The Association of National Road Research Institutes (FEHRL) has set itself the challenge of developing a truly inspiring vision for how roads will be built, operated and maintained in the 21st century. The result is the Forever Open Road – a revolutionary concept that will bring together the best of what we have today with the best of what's to come. The Forever Open Road is adaptable, automated and resilient; based upon a concept for building and maintaining roads that can be applied whether motorway, rural or urban, and regardless of region or country.

There are three elements to the Forever Open Road:

- **The Adaptable Road**
- **The Automated road**
- **The Resilient Road**

The development of the concept will produce a new system of travel by road; where the vehicle, its driver and the road operator are integrated through a common communications and power system; where the operator automatically provides in-built vehicle guidance, as well as travel information and performance measurement. Power systems will match the needs of emerging electronic vehicles as well as harvest solar energy to service highway systems requirements.

The road will be built from sustainable material, will cope with excess water and temperature change, and will be able to clean and repair itself. It will also be built to adapt to future maintenance needs, changing capacity demand and vehicle manufacturer needs.

The overall aim would be for roads to be Forever Open, with minimum intervention for repairs and widening or for new installations or for dealing with weather hazards. The key to this new approach will be the adaptable element, formed of prefabricated, upgradable pavement structures that retain long-life despite the need for upgrades and interventions. The adaptable element will accommodate the automated and climate change resilient elements.

The concept is to be realised in four phases; in the first phase, the concept was developed by a group of FEHRL members. The second phase is being undertaken by those same members as outlined below. This R&D document will report on the activities undertaken during Phase 2 and outline the tasks, timescales and budgets required to undertake Phases 3 and 4.

1.1 Research Programme Phasing

The phasing of the programme of research will take the Forever Open Road through from concept development through to demonstration projects and monitoring, and working towards full-scale trials of elements and the complete concept. The planned phasing of the programme is:

Phase 1: Concept Development – end of 2009

Phase 2: Scoping the Research and Development – end of 2010

Phase 3: Development of the Three Elements – end of 2012; now referred to as 'Field Trial' Phase

Phase 4: Demonstration Projects and Monitoring – 2013 onwards; now referred to as 'Systems Proving Phase.

Phase 1 commenced in May 2009 and produced information about the Forever Open Road for use by FEHRL Members for seeking support from government and allocating funds and resources.

Phase 2 is expanding the research and development requirements for the three elements; Adaptable, Automated, and Resilient Roads. Phases 1 and 2 have been taken forward by FEHRL with the participation of the following members: BASt, DRI, DVS, LCPC and TRL. It will deliver the detailed research programme for developing the concept for Phase 3.

Phases 3 covers the period of 2011 to 2013, and deals with the development or testing of some promising technologies, considered as being able to contribute importantly to one or several of the three Forever Open Road elements. Phase 3 will cover Field Trials and for clarity, this term will be used in the document.

The purpose of Phase 4 from 2013 is to design and produce Integrated Demonstrators, which will make it possible in the following years to test, follow-up, refine and further develop and advertise different modes of transformation of road systems. Phase 4 will cover System Proving and this term will be used in the document.

In reality, there is unlikely to be a definite cut-off between the Field Trial and System Proving phases, and they will likely overlap to some extent.

1.2 Summary of Phase 1 and Phase 2 Activities

The research and development required to further the concept of the Forever Open Road will be significant in terms of scope, cost and pan-European coordination. Phase 2 was aimed at scoping the detailed research programme, the tasks required within it and the cost implications.

The scoping study was to direct subsequent phases of the work programme towards addressing global challenges such as climate change, carbon reduction and energy saving; as well as the increasing need for the journey time reliability that will arise from the rising demand both for private car travel and the delivery of goods by road. At the same time, the programme of work needed to identify the benefits that will be achieved and help meet European goals to provide transport infrastructure that is safe, energy efficient, sustainable and resilient.

The scoping work must ensure that the detailed research will develop the concept for a future form of road that achieves the identified objectives.

The overall aim would be to produce a concept for roads that require minimum intervention for repairs and widening or for new installations or for dealing with weather hazards. The key to this new approach will be the adaptable element, formed of prefabricated, upgradable pavement structures that retain long-life despite the need for upgrades and interventions. The adaptable element will accommodate the automated and resilient elements.

For each of the three main areas, in addition to the technological challenges faced, there will be a requirement to consider some of the associated issues that this challenge will present, namely:

- Political
- Economic
- Social
- Legal
- Environmental

In addition, the Scoping Study will bring together FEHRL Members and other European organisations that will progress later phases of the programme, identify research task managers and develop the detailed tasks, budget requirements and work programme.

1.3 Phase 2 Outputs

This report represents the main output for Phase 2 programme, which was to provide a detailed Research Proposal for the 2011 to 2013 period covering:

- Background to the concept
- Purpose, aims, and outputs for the Phases 3 and 4 of the programme
- Management structure and team
- Methods of communication and reporting
- Responsibilities of the management team and research leaders
- The tasks and sub-tasks to be undertaken for each element of research
- The research techniques to be employed and the facilities to be made available
- The budget, resources and timescales to be allocated
- The research outputs and delivery dates
- Commercial issues covering insurances, payment for work, intellectual property rights and patents.

This document also reports on the activities and methodology undertaken in Phase 2 for completeness, and as a way of framing the decisions on the Field Trial Phase. Outputs for the Field Trial Phase are presented separately in this report.

2 The Need for the Forever Open Road

Roads are indispensable to modern society. The economic importance may be illustrated by the fact that 80% of freight in the EEA 30 region of Europe is carried by road [1]. Billions of Euros are spend each year on the design, construction, operation and maintenance of roads in Europe with the sole objective of keeping Europe 'on the move' and ensuring that the European Economy remains both sustainable and able to grow; especially given that over the coming two decades, the growth in road traffic will be about 50%[2].

The provision and operation of our road networks and of the traffic that uses them comes, however, at a cost to society; including environmental impacts and financial investment. For example, about 25% of total CO_2 emissions in the EC27 region were from transport[3]. The common understanding is that under the 'business as usual' scenario road transport will be the only sector for which the CO2-emission will increase in absolute terms. Furthermore, road fatalities in the EU were 34,500 in 2009[4], not counting deaths that could in part be attributed to air pollution or the many more severe injuries[5]. Also, the cost of congestion amounts to tens of billions of Euros and has increasingly become a major concern within most European and national transport and economic policies.

During the winter season of 2009/2010 Europe experienced a breakdown of the road network availability in several occasions. For example the UK experienced extreme flooding in North West England (picture). Later as the extreme cold spell hit Europe the UK, Germany and the Netherlands were confronted by shortages in on road gritting, leading to prioritising on road network links. This resulted in severe restrictions on and even closure of many public services.

Figure 1 Flooding in Cumbria

Against this background, it is clear that efforts to simultaneously meet societal challenges for decarbonisation, journey time reliability, energy reduction and safety, will require new ways of building, operating and maintaining our road infrastructure within the overall European transport system. Indeed, this is supported within ERTRAC's Strategic Research Agenda 2010, where it is acknowledged that infrastructure plays a key role in achieving 6 of the 7 guiding objectives it pursues, but also that integration with the other components of the Road Transport System is crucial in maximizing the efficiency improvement of the system as a whole.

For example, the energy-efficiency of the vehicle in operation is significantly determined by the design of the road, such as the rolling resistance of the surface, and management of traffic flow, the provision of effective driver information e.g. on traffic situation or on services required, mobility planning, and efficient maintenance and reconstruction.

In addition, the influence of road infrastructure on the environmental quality is significant (noise, air quality, natural habitat, resources). In fact over the last decades it has been a major driving force for many large scale research programmes, such as the Dutch IPG and IPL programmes for noise and air quality, and the EUCAR programme for vehicles.

[1] http://www.eea.europa.eu/data-and-maps/figures/a-modal-shares-in-freight-2/Figure2/at_download/file
[2] ERTRAC Strategic Research Agenda 2010. Towards a 50% more efficient road transport system by 2030, May 2010
[3] http://ec.europa.eu/energy/publications/doc/statistics/ext_co2_emissions_by_sector.pdf
[4] http://ec.europa.eu/transport/road_safety/pdf/observatory/trends_figures.pdf
[5] http://www.who.int/mediacentre/factsheets/fs313/en/index.html

3 Benefits of the Forever Open Road

The long-term benefits to the European economy, environment and society from the development of a next generation road – a road that is ICT integrated, environmentally benign, and adaptable to evolving users' and societal requirements, and that comes at a lower cost and risk would be substantial.

Economic benefits of reduced congestion and associated improvement of travel time reliability are evident, and will be delivered through solutions that enhance the energy-efficiency of road transport through co-operative vehicle to highway systems, dynamic traffic management, and the integration of energy harvesting and generation within the infrastructure.

The potential to prefabricate road sections containing the required communication and power connections, drainage links and in-built sensor systems, would allow rapid road construction, whilst damaged sections could be removed and replaced easily. Moreover, off-site construction would allow road sections to be manufactured with factory quality control, in controlled conditions, improving safety for workers and increasing productivity as materials would be available on site, and different stages in the process could be undertaken concurrently on a production line, and greater automation would be possible.

Important societal benefits will also arise from the improved social inclusion that a well performing road network will bring forward. This in turn will contribute to a strong, sustainable economic growth. There will also be substantial environmental benefits from the reduced noise generation and vehicle emissions, as well as the resilience to climate change.

At the same time, the Forever Open Road will encourage Pan-European engagement and collaboration, and stimulate research across the member states bringing cost savings and benefits for all.

The Forever Open Road Programme will be geared towards identifying how all these benefits to be gained from more effective and efficient road design, maintenance and operation can be produced to include:

The Adaptable Road	Reduced maintenance/renewal requirements; Improved transport integration, adapting with light rail, guided bus, cycling and walking; Adaptable to future transport trends and technologies; Longer life – reduced maintenance costs / lower whole life costs; Low / neutral / carbon negative construction and operation; Reduced road user and road worker accidents; Reduced construction site hazards.
The Automated Road	Reduced congestion/improved journey time reliability; Improved transport integration; Continuous monitoring of the asset condition to inform asset management strategies and optimize maintenance; Improved safety for users; Improved air quality; Effective tolling of vehicles; Cost effective use of spin-off technologies.
The Resilient Road	Adaptable to climate change impacts, such as flooding, heat and cold; Reduced energy use through in situ energy generation; Emission capture and mitigation; Reduced noise.

4 The Forever Open Road Approach

The Forever Open Road concept aims to develop methods and systems that will perform across Europe's varied transport network; integrating with existing road provision and adapting to differing environments, whether urban or rural. The concept would apply to the maintenance and renewal of existing roads as well as to new road construction, and will be able to provide for, and meet targets relating to Europe's:

- highest levels of traffic intensities;
- needs for accessibility and reliability;
- aims for reducing level of fatalities and severe injuries from road accidents;
- targets for the reduction of greenhouse gas emissions and noise; and
- increasing demand for security in freight transport.

This programme will develop and demonstrate the viability, benefits and practicability of the three main elements:

The Adaptable Road – providing a quick and cost effective method of constructing and maintaining roads. This will involve a re-think of how roads are built, including the use of prefabricated, upgradeable pavement structures with long-life characteristics that are capable of incorporating removable and changeable infrastructure services and accommodating new forms of powered vehicles and guidance systems. The adaptable element will be the key to making the concept work, supporting the automated and resilient elements.

Functional Structural Modules for Innovative Road Construction
(BASt / LCPC / RWS)

This Field Trial will demonstrate the design of a new modular pavement system existing of concrete elements and interlocks dimensioning and optimisation of the elements and the interlocks construction of prototypes

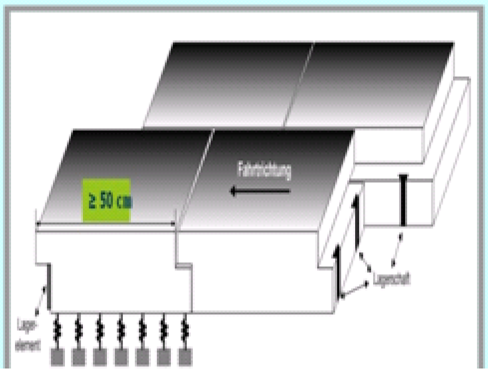

Figure 2 Structural Modules linked to Adaptable Element

Key aspects of this element will include:

- Developing new forms of road construction, such as prefabrication with integrated service provision to reduce costs;
- Providing for enable fast and effective maintenance to reduce delays;
- Using robotised methods of on-road maintenance and traffic control to improve safety;
- Integrated sensors and systems to measure and monitor road condition and performance;
- Using products that self-repair and clean roads to reduce costs and environmental impact;
- Developing flexible drainage systems to cope with storms;
- Building and maintaining using low carbon and low energy materials and processes.

The Automated Road – integrating road side intelligence with ICT applications in the vehicle, the services and the operator. The sensory and communications technology involved will enable the deployment of advanced (e.g. dynamic) guidance and management systems tailored to respond to in situ requirements, in effect improving reliability and efficiency of the network management. Key aspects of this element will include:

Removable urban pavements with excavatable materials as base materials or back filling (trenches)
(LCPC)

This Field Trial will demonstrate methods to maintain access to underground buried services

Figure 3 Removable Pavements to allow access to services

- Comprehensive, interoperable communications system linking driver, vehicle, road and operator;
- Enabling future vehicle to highway guidance, speed control and direction guidance;
- In-road vehicle guidance using to change lane usage and manage traffic;
- Powering vehicles from the highway and harvesting solar energy;
- Monitoring traffic and road conditions as well as vehicle performance to improve reliability and efficiency;
- Incident monitoring and automated response systems to reduce delays;
- Providing for effective road charging and tolling to improve effectiveness.

The Resilient Road – should be resilient to extremities of weather, such as temperature and rainfall, and also mitigate the negative aspects of road construction and operation, such air and noise pollution. Key aspects of this element will include:

- Integrating the road with its environment to make effective use of water, energy and planting;
- Means of dealing with extreme weather conditions, including storms, wind, heat and cold;
- Using harvested solar energy to moderate road temperature and reduce the need for winter maintenance, and to power roadside lighting and signs, and potentially even the vehicles themselves;
- Cost-effective, low energy integrated lighting systems;
- Low noise and low spray pavements.

Healing & Rejuvenation of porous asphalt
(RWS / Market Parties)
In a full scale field trial the benefits of inductive healing of porous asphalt will be tested (picture). This technique requires the binder to contain metal fibres.
Two other field trials are testing the application of rejuvenating oils, both preventive and curative to ravelling (no picture).

Figure 4 Healing and rejuvenation of porous asphalt

5 Development of Field Trial Phase

5.1 Purpose

The purpose of this phase is to undertake research and development activities on technologies and concepts identified for the Forever Open Road. The Field Trial Phase, in effect, will represent the main research phase of the programme, whilst the System Proving Phase should see deployment of the concept and continued further development.

A number of tasks and sub-tasks were identified During Phase 2 that were considered to be potentially important aspects of the Forever Open Road. Information was collected on technologies that currently exist (whether they are widely used or not, or whether they require improvement or not), items that might become commercially available in 2 to 5 years, mature technologies in other sectors that could be transferred to the Forever Open Road, and longer term technologies that would not be commercially available or viable within 5 years. The rationale to this approach was that by identifying existing, future and missing technologies, it will be possible to determine the implementation, research and development tasks. The pyramid below, outlines this approach.

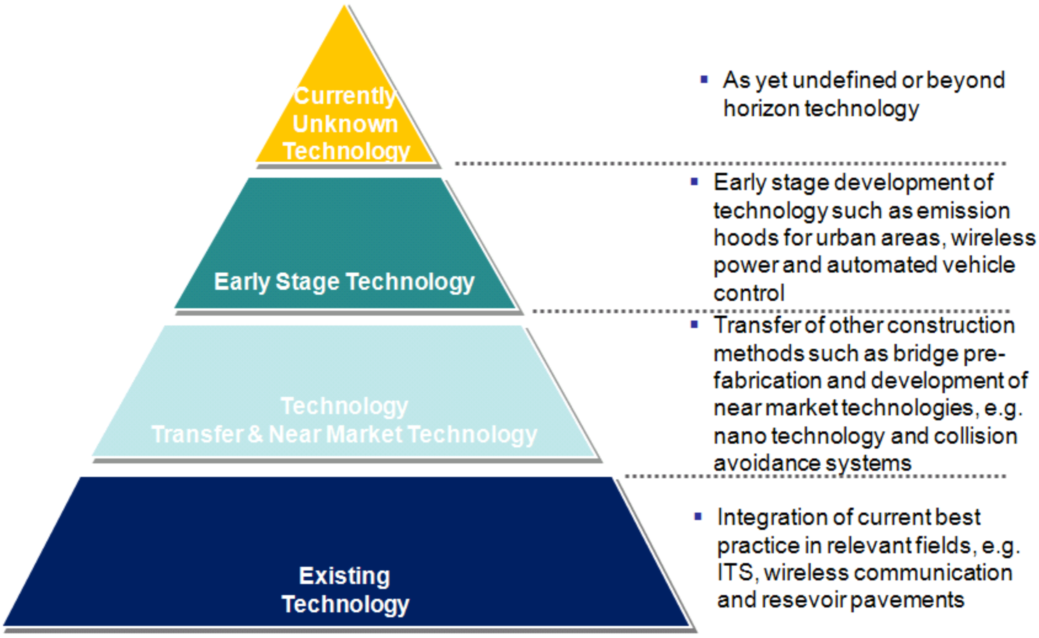

Figure 5 Technology Identification

For most of the technologies identified, the pyramid represents accurately the technology status, i.e. there is a considerable amount of technology already available, and a considerable amount to come. For only a few technologies is the technology unavailable, or subject to long term research.

5.2 Aims

The overall aim of the Field Trial Phase will be to develop technologies and processes within the three elements of the Forever Open Road concept. A number of work packages will be developed, each covering a cluster of technologies, for example, renewable energy generation, in which there exists a suite of technologies.

Within each work-package, a number of factors will be considered:

- Overview on technology status
- Technologies available for implementation
- Research requirements
- Research techniques and facilities to be made available
- Outline budget, resources and timescales to be allocated
- Research outputs and delivery dates
- Budget, resources and timescales to be allocated
- Benefits of research and how it helps achieve the aims of Forever Open Road
- Potential to retrofit to existing roads, structures or infrastructure
- Comment on applicability to bridges, structures, tunnels
- Possible barriers to implementation

Each cluster of technologies will help achieve specific goals of the Forever Open Road, which when combined should help to build up one or more of the elements.

In addition to the implementation and research work-packages, there will be results from ongoing Technology Trials that have been started within Phase 2 and the results from Champion Organisations' Research Programmes relating to the Forever Open Road that will be started in 2011.

5.3 Outputs

The outputs from the Field Trial Phase will be those from the work-packages, the ongoing Technology Trials and the Champion Organisations' 2011 Research Programmes. The outputs will be specifically aimed at the development of the Forever Open Road concept and as such will not merely be research reports. The outputs will be the development of prototype systems, results of technology trials, on-road trials, compatibility tests and the like.

6 Management of Field Trial Phase

As the Forever Open Road programme develops, and the R&D aims are crystallised and external funding is obtained, the management requirements will increase considerably, and it is important that these increased demands are planned for at an early stage. The areas for consideration, as well as the responsibilities for the Management Team and Research Leaders are outlined below.

The management structure is conceived such that there is a logical channelling of work activities from the ground upwards, as shown in Figure 6, below.

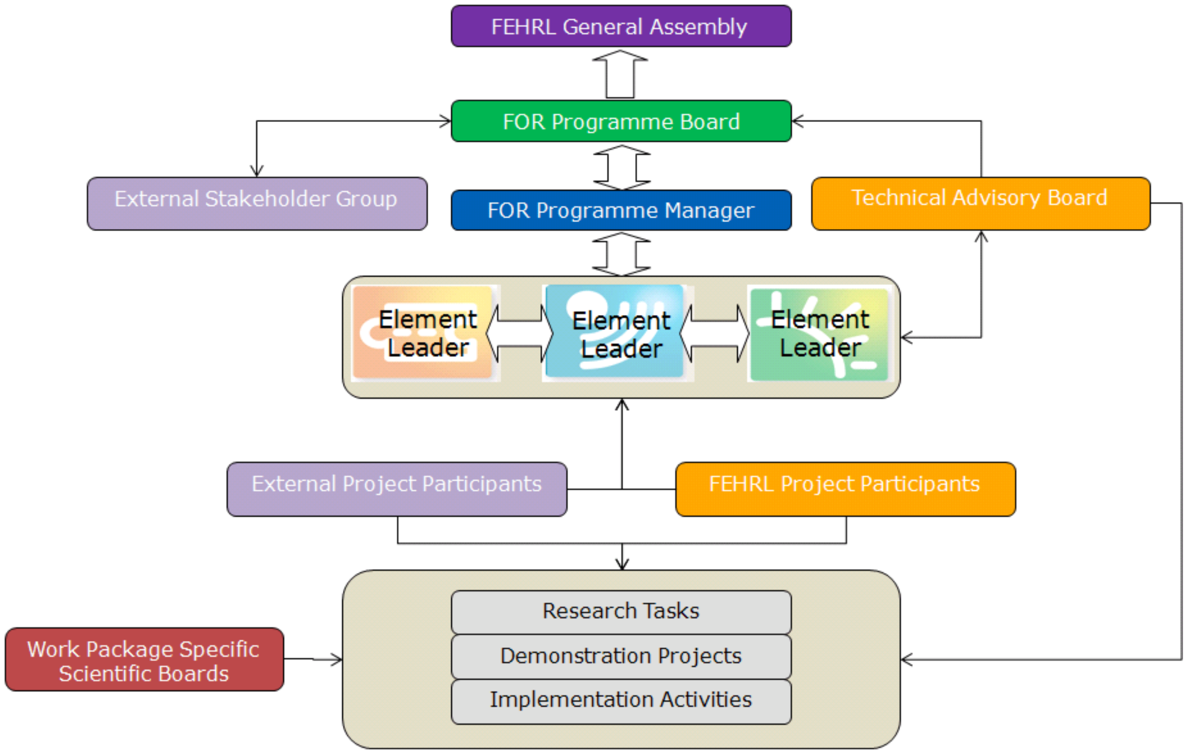

Figure 6 Potential Forever Open Road Future Management Structure

The overarching governance structure of the Forever Open Road consists of:

- **the Programme Board**, whose functions are strategically oriented i.e. establishing goals and stetting strategic direction; policies and approving procedures for the operation of the Forever Open Road programme; developing and approving the R&D plan, the annual work plans, a portfolio budget statement, and producing an annual report etc. The Programme Board will set requirements for internal reporting to the FEHRL General Assembly[6], and external reporting and publication of activities for specific external audiences and / or the general public.
- **the Programme Manager** on behalf of and reporting to the Programme Board. The focus is on monitoring and reporting progress and process. The Programme Manager will provide a link between the programme Board and the Element Leaders
- **the Element Leaders**, are responsible for project execution. The project activities are structured according to the three elements to the Forever Open Road: Automated, Resilient

[6] The governance board currently exists of the FEHRL-institutes that act as the champions to bring the Forever Open Road programme forward. In coming years this situation will evolve as participation will expand.

and Adaptable. Within each element the activities are further structured in work packages, each of which will have a Work Package Leader.

The Element Leaders will coordinate the work packages that will be undertaken from both FEHRL Institutes and 'external' partners. The element leaders will also engage in a two-way dialogue with a Technical Advisory Board.

There will be significant communication between the three elements partly as a necessity because several work packages will cover more than one element, but mainly to ensure that research is not carried out in isolation and that the research activities are driven towards achieving an integrated solution.

6.1 External Stakeholder Group

The Stakeholder Group will be formed from representatives of industry bodies such as the construction industry or automotive manufacturers that will be essential partners in the future realisation of the Forever Open Road concept. The stakeholder process will commence in September 2010 and should lead to significant participation in the 2012 research and demonstrator work plans.

Depending on the match with the programme, the involvement will vary between consultation or participating in the sharing of knowledge and co-funding particular research and demonstrations. Depending on the degree of involvement the link-in to the Forever Open Road governance will be strengthened over time.

The input of the industry bodies will be vital in helping set the direction of the Forever Open Road programme, and link in with other research programmes in their sector. Certain industry stakeholders might be invited to join the Technical Advisory Board, at the overall level, or particular Scientific Boards for specific work packages.

6.2 Technical Advisory Board

The Technical Advisory Board will provide advice on the technical direction of the Forever Open Road project to the Programme Board, and also help ensure the technical quality of the project outputs through the provision of scientific support and technical quality review. There will be a two way dialogue with the element leaders to advise on the technical direction of the research activities and also to disseminate technical information. The Technical Advisory Board can be called upon for support and advice on specific work packages, however it is considered more likely that this support would be provided by specific Scientific Boards made up from FEHRL members and external stakeholder members for individual work packages.

6.3 Participants

When FEHRL–institutes or external stakeholders participate in the Forever Open Road by aligning/coordinating respective research and innovation activities or by direct research within the Forever Open Road programme, they will be linked to the project teams and come under the direction of the element leaders.

6.4 Programme Management

The Forever Open Road concept has been taken forward as a FEHRL programme and it therefore seems reasonable that FEHRL will take the lead in its management and promotion. That said, the potential size of the programme is such that significant support will be required from the Champion Organisations and potentially others in order to fully realise the objectives. It is proposed that a Board of Directors or similar should be formed comprising FEHRL and the

Champion Organisations that would provide the strategic direction for the programme. This would likely be made up of Chief Executives or Directors of the Champion organisations and complemented by other FEHRL institutes, although the potential of having the equivalent of a non-Executive Director from the Scoping Team might also be considered.

6.5 Communication and Project Management

Given the size and complexity of the work to be undertaken in Phase 3, which will involve many research organisations and industry partners, there needs to be one overall Programme Manager who will provide leadership and direction, undertake the day to day management, coordinate research activities and provide a single point of contact internally and externally.

Within each of the three technical elements there will be a number of research, development and implementation activities that will require a degree of organisation, which will be undertaken by the three Element Leaders; they would communicate with each other, and with the Programme Manager, and would operate in a manner along the same lines as the existing Scoping Team which has been found to work successfully. The communication route is as presented in Figure 6.

One option might be to have the Programme Manager and Element Leaders and possibly a nominated Research Coordinator to meet or video conference monthly, with three monthly larger meetings, possibly to coincide with a meeting of the Programme Board, and twice yearly meetings with the Technical Advisory Board.

6.6 Technical Management

Links with the FEHRL Research Coordinators are already in place, and these will be maintained as a means of contributing to the research direction and giving feedback on related research in their countries, through participation on the Technical Advisory Board and / or specific Scientific Boards. In addition, it is anticipated that a number of Research Coordinators will continue to proactively gather information on technologies and processes that might be of value to the Forever Open Road programme, continuing the task undertaken by the Scoping Team.

It is important that the technical work undertaken is of a high standard, and a balance needs to be struck between ensuring the technical quality through robust technical quality assurance without excessive red tape. Each organisation participating in work-packages should have quality management systems for ensuring the technical quality of the work undertaken, and it considered that this will be sufficient for most activities and outputs. For major pieces of work such as published project reports or reports to the FEHRL General Assembly, it is proposed that a procedure is undertaken as follows:

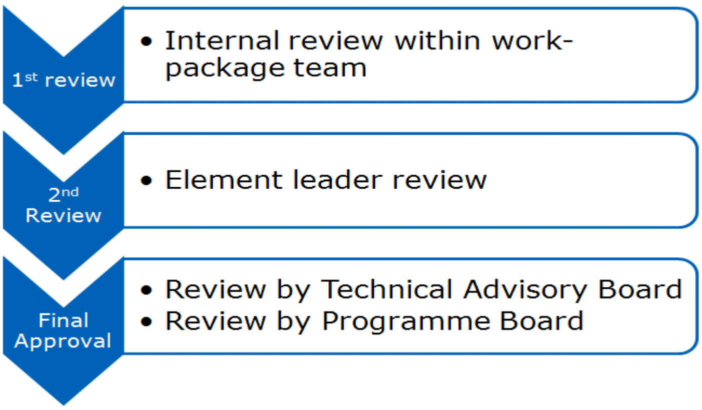

Figure 7 Proposed Technical Review Structure

6.7 Financial Management

To date, the development of the Forever Open Road concept has been undertaken by FEHRL and the Champion Organisations at their own cost through the provision of staff time and payment of travel costs. This cannot be sustained through Phases 3 and 4, as the R&D to be undertaken will be intensive and will involve constructing and testing of various elements and systems.

In anticipation of future funding coming predominantly from external sources, it is important that we gain agreement of who will control the finances for the organisations involved, plus any subcontractors and other suppliers.

A key requirement will be for a process that is efficient and where funds are distributed in a timely manner. There are a number of mechanisms that could be employed to achieve this and it must be that the process could be adapted according to the funding source requirements.

On the basis that external funding is unlikely to be awarded for the entire programme, it would seem appropriate for funding to be arranged according to individual work packages, which would have a lead partner who would undertake overall financial and operational management.

There will remain a requirement to fund the activities of the Programme Board and Technical Advisory Board, and one option for achieving this would be to pay a percentage of work-package funding for this purpose. A second option could be to establish a Holding Company that would administer all financial matters, including individual work package payments and invoicing.

6.8 Reporting Requirements

There are likely to be a number of different reporting requirements as outlined below.

FEHRL General Assembly: Progress reports on the Forever Open Road will be presented at the twice yearly FEHRL General Assemblies; it is likely that this would be presented by the Chairman of the Forever Open Road Programme Board, with support on content provided by the Scoping Team.

Deliverable Reporting: There will be specific deliverables associated with the R&D undertaken within the various technical elements of the report.

Internal Reporting: It is proposed that the leaders of each of the three elements would provide information to the Programme Manager for synthesis and overall reporting. It might be appropriate for quarterly reports to be provided to the Technical Advisory Board, Stakeholder Group and FEHRL Research Coordinators.

External Reporting: One possibility could be to have an Annual Published Research Review that would present progress on the overall programme.

6.9 Purpose, Aims and Outputs of System Proving Phase

The System Proving Phase is designated for Demonstration Projects of the technology. The Champions' Technology Trials to date have concentrated on one technology, whereas in this Phase, the research and development activities will focus more on integrating multiple technologies, as well as the ongoing development of specific technologies. The timing for the System Proving is stated as from 2013 onwards, i.e. there will be ongoing development leading towards the vision of the Forever Open Road. There is likely to be some overlap between the Field Trial Phase and the System Proving Phase.

The aim of System Proving will be to deliver a number of work packages that develop various aspects of the Forever Open Road, through live demonstrators and prototype systems integrating multiple technologies. Further, the demonstrators will show what is achievable and will form the basis of ongoing development of the three elements and the concept as a whole. The outputs will be the Technical Demonstrators, and the results of the live trials.

6.10 Management of System Proving Phase

There will be an order of magnitude increase in the funding requirements and research during the System Proving Phase. Potentially, each Demonstration Project could be a multi million Euro project in its own right, and the control of each will move further from FEHRL and the current Champion Organisations as construction companies, communications contractors and design engineers necessarily take a greater role on the roll out of the projects.

As such, each Demonstration Project will have its own Technical Review, Management and Financial arrangements. As a mechanism to ensure coordination of activities, the Project Manager for each of the Demonstration Projects should report on progress to FEHRL on a monthly basis, and meet quarterly to update on progress and share experiences. It could be that a Coordination Manager could be assigned to oversee a number of these projects for the champions, attend site visits, and undertake coordination, marketing and promotional activities, as well as reporting to the FEHRL General Assembly.

There could also be a technical role, where someone was appointed to act as a conduit for the technical information and dissemination for the Research Coordinators. Above this there would be Technical Advisory Board and Programme Board who would maintain control of the concept.

7 Technology Capture and Integration

During Phase 2, a Scoping Team was formed from Champion Organisations that reported on projects and technologies being developed both within and beyond their institutes. As the Forever Open Road project progresses, it is important that this process continues as a means of disseminating information, and also to keep a store of emerging technologies that could be developed or incorporated into the project at a future date.

At a European scale, it is important that a mechanism is put in place for sharing knowledge and implementing innovation and preventing duplication of effort. It is proposed that two strands of information will be collected; one for project information, and one for specific technology information. A mechanism currently exists for this within FEHRL through an online database known as FEHRLopedia, (http://www.fehrl.org/index.php?m=192&project=0), which contains project information from FEHRL partners and has a number of search options. This tool has been added to the Forever Open Road file zone on the FEHRL website, to contain reports on the project.

Many information databases rely on input from project participants, or from staff within an organisation, who may compile information in addition to other day to day activities. As such, the quality and usefulness of such databases can vary greatly. In contrast, to ensure the effectiveness of data collection and quality, the FEHRL Research Coordinators group will be tasked with not only reporting the results of their institutes projects that have relevance to the Forever Open Road, but also to pro-actively seek out new technologies.

In addition to the Research Coordinators, other non FEHRL organisations could provide information to the database, subject to provision of a minimum requirement of project details, a contact name and contact details. By adopting the above approach and by having specific responsibility and a formal reporting mechanism, the effective sharing of knowledge will be ensured.

8 Field Trials and Demonstration Projects

The general objective of the Forever Open Road project is to achieve a step change in the construction, operation and maintenance of Road Infrastructure in Europe, which will result in a transport system that has lower whole life costs, that has reduced maintenance requirements, and that has a low, or potentially positive, environmental impact.

One of the medium term outputs of the project (from 2013 onwards) will be a series of Demonstration Projects across Europe, which will showcase the technologies that are available, and which could be implemented to create the Forever Open Road.

8.1 Demonstrators and their Features

In this context a demonstrator is deemed to be any physical (infrastructure, vehicle or device) or virtual (software, management system) research project which aims to conceptualize, test and advertise one or several technologies envisaged for future road transportation systems.

It is worth noting that the function of Demonstrators considered for the Forever Open Road deals not only with the technological aspects. In most cases, the implementation of new functionalities in the domain of road transport also needs to evaluate political, legal, economic and social acceptability. For the Forever Open Road project, two main categories of demonstrators are considered, namely;

- Technology Trials; these are trials that have been self funded from the Champion Organisations' Innovation Programmes, and which focus on a specific technology. They are described in greater detail below, and the existing trials are listed.
- Demonstration Projects; these are to the major outputs of the Forever Open Road programme and will showcase a number of integrated technologies from the various work-packages undertaken. Funding for these is required from external sources.

8.2 Technology Trials

These trials are existing projects being delivered by FEHRL members which are being undertaken as part of Phase 2 of the project, and which will be continued into the Field Trial Phase. The Technology Trials will test several technical solutions dedicated to one or more specific function or technology. To date, the Technology Trials have been undertaken by the Champion organisations through their internal Innovation Programmes; trials from other FEHRL Institutes can be added and be awarded a Forever Open Road 'badge' subject to meeting two conditions; firstly, the trials must assist in the delivery of the Forever Open Road vision; and secondly, results of the trials should be made available. External funding will be sought for future Technology Trials to be undertaken during the Field Trial Phase.

So far, the five Champion Organisations have identified ten Technology Trials, two desk studies and a further eight projects that could be given a Forever Open Road badge. There are a further twenty five FEHRL Institutes and three Associate Institutes, and it is expected that the number of Technology Trials with the Forever Open Road 'badge' will increase dramatically, and it would be considered reasonable given the ambition for this project, that in excess of one hundred trials could be added from other FEHRL Institutes in the next twelve to eighteen months. This figure excludes Technology Trials funded externally during the Field Trial Phase.

Presented below are the Technology Trials that have been identified so far by the Champion Organisations.

Adaptable Element

8.2.1 Functional Structural Modules for Innovative Road Construction

One ambition of the Forever Open Road concept is to develop roads with minimum intervention for repairs and widening or new installations. One option to achieve this aim is by designing a new concrete modular system with interlocking pre-fabricated elements, which fulfils the requirements of road construction in the 21st century.

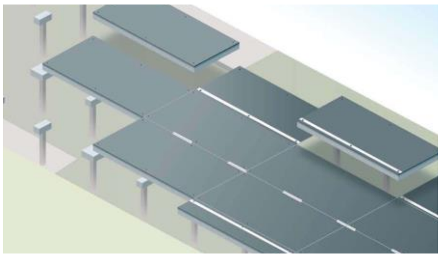

Figure 8 ModieSlab Layout (Netherlands)

The aim of the project is to develop a surface bearing structure consisting of concrete slabs. In the first step, a structural pattern with geometric variation of the concrete slabs (modules) plus external boundary conditions (loads, frequencies, surface rigidity,...) will be designed.

Based on the dimensioning results, a plan of the surface bearing structure will be designed. Following the design stage, a number of prototype slabs will be manufactured and a preliminary model of the road will be laid.

8.2.2 Removable urban pavements with excavatable materials as base materials or backfilling (trenches)

The aim of this project is to guarantee easy access to service networks embedded under road pavements or footpaths. It is based on the concept of a modular concrete pavement structure, placed on a base course, made of a controlled low strength material, enabling the structure slabs to be easily removed and the base course easily excavated to give access to the service networks. The base course and pavement structure can easily be rebuilt, reusing the initial slabs.

Two field trial demonstrators have recently been built and can be visited. One is close to Rouen city, the other one is in Nantes.

Figure 9 Laying of Removable Pavement (France)

8.2.3 Meta Carpet

The aim of this project is to develop at industrial scale a long lasting road structure allowing the reduction of the ecological footprint of materials used. The surface of the road is made of HPC concrete whereas the base and sub base are made of hydraulically bound material using Metakaolin. The results of the trial will be used to determine options for future pavement design.

8.2.4 Induction healing of porous asphalt

Ravelling is a common and inevitable phenomenon in older porous asphalt pavements. It is caused by ageing processes in the bitumen binder, which becomes brittle and less apt to bind the aggregates. As a consequence over time the aggregate comes loose from the surface. At a certain point in this progressive process, the road needs resurfacing, resulting in delays for road users. Any extension to the time period between resurfacing would be welcomed.

In order to increase the life span of porous asphalt, Rijkswaterstaat is undertaking a technical trial with a new ZOAB (porous asphalt) mixture in which steel fibres are mixed in the bitumen binder. This allows an in situ rejuvenating heat treatment of the road surface by means of induction. In recent tests with the Roll Pave concept (speeding up resurfacing by application of prefabricated porous asphalt surfaces) the induction technique was already demonstrated on the associated adhesive. Now the technology is tested on the (prepared) binder itself.

By passing a large scale induction plate over the road surface, the steel fibres are heated as well as the bitumen in which they are mixed, the latter should regain their original suppleness and the life span of the road will be prolonged. The trial is carried out in collaboration with TNO and Technical University of Delft.

Automated Element

8.2.5 Wireless devices for measurements in pavements

Up-to-date information to the road user and owner on the condition and operation of the network could be provided using devices (either embedded or built-in to the pavements) which are able to undertake measurements and to send data to a coordinating centre. Road users could also be directly informed of potential hazards with warnings sent either to their car or displayed on Variable Message Signs.

For this approach to be viable the sensing devices would have to provide easy access to the information collected/generated whilst being cost effective, simple to install/remove, maintenance free and self-diagnosing, etc. Self-organised networks with wireless sensing devices that scavenge energy from their environment (typically from light, waste heat or vibrations) could offer a potential solution. This project will investigate how such devices could be implemented.

An evaluation kit has been purchased and currently the investigation is focusing on options to power the modules. Experiments will then be carried out to assess the shortlisted energy scavenging and storage systems.

8.2.6 Calibration test track surface

TRL has recently designed and constructed a 600 metre calibration surface at a test track in England, comprising four 150 metre sections, each with different levels of skid resistance. The track has been constructed with specific surface characteristics in order that it can be used to calibrate road surface scanning machines, and pavement stiffness through FWD and TRL's traffic speed deflectometer. Transverse strain gauges have been installed between the sub-base and bituminous layers at depths of 200 mm (one at 190 mm), and vertical strain gauges have been installed beneath the sub-base at depths of between 300 and 470 mm depending on the pavement construction. In addition, RFID tags have been included in the binder course, which will be programmed with as-built information on pavement construction.

Resilient Element

8.2.7 Floor heating on bridge decks

Generally the asphalt surfacing on bridge decks - especially on steel bridges - is exposed to a higher risk of icing compared to asphalt pavements. In these cases, using geothermal energy to heat the asphalt surfacing on the bridge deck can possibly prevent the need for winter maintenance and contribute to increased road safety.

Figure 10 Laying of bridge deck heating pipes (Germany)

A new concrete bridge has been constructed in the North of Germany. This new bridge has been equipped with underfloor heating, with heating tubes placed approximately 10 cm over the bridge deck and shortly after overlaid with a layer of asphalt. Ground-water with a temperature of around 12°C will be piped through the tubes with the objective of warming the asphalt surfacing during the winter. In addition, this heating system can be also used in summer for cooling the asphalt layer in order to reduce or avoid rutting.

8.2.8 Noise reduction through integrated resonators

Generally, two-layer porous asphalt offers the highest level of rolling noise reduction among dense and porous asphalt pavements. Nevertheless, there is still a chance to improve its acoustic properties by increasing its acoustic absorption by avoiding clogging.

However, the improvement of acoustical properties can only be reached by integrating additional absorbing devices such as Helmholtz resonators. For this reason special resonators made of polymer concrete were developed last year. Ensuing laboratory tests confirmed the noise reduction of approximately 4 decibels.

Figure 11 Noise Reducing Helmholtz Resonators (Germany)

In May 2009, the resonators were integrated into the two-layer porous asphalt on a trial motorway section in Eastern Germany (A24 near Berlin). The resonators were placed on the 2 cm thick Gussasphalt layer and shortly after overlaid with a 5 cm thick bottom layer of porous asphalt (8/11) and afterwards with a 3 cm thick top layer of fine porous asphalt (4/8).

Clogging is caused by dirt entering the open structure of the porous asphalt and sticking to the binder. This can be avoided using a modified binder with water repellent properties. In this particular case a special asphalt binder was developed and applied by paving the second trial motorway section on the A24.

8.2.9 Noise Reducing Thin Layers

In 2009, the Danish government initiated a new six year noise research program that is mainly conducted by the Danish Road Institute/Road Directorate. This project has the objective to demonstrate the effect of the noise reducing thin layers currently on the market in Denmark. In August 2010 a test section with six different pavements was constructed on a rural highway. A detailed measurement program has been established including yearly noise measurements and visual inspections. It is planned to follow the test sections for at least a five year period. The test sections will also be used as a new calibration site for noise measurement equipment used in relation to the SRS System. The first report with results can be expected in 2010.

Figure 12 Construction Noise Reducing Thin Layers (Denmark)

8.2.10 Long life surface materials

The aim of this field scale project is to develop long life surface materials, in order to decrease maintenance works on high traffic roads. Such materials must be mechanically resistant and warrant high quality use properties at long run (high skid resistance, limited noise generation, protection of base course). Two technical solutions will be tested in France on pilot sites in 2010.

One is based on the use of a high performance cementitious material (8mm surface-dressing with fibres and bauxite aggregates, adhered to high modulus asphalt (EME)). A demonstrator is scheduled in 2010 close to the city of Le Mans. This project also takes place in a French national project called CLEAN. The other trial will be based on the use of epoxy-asphalt concrete, with the organisation of an experimental site presently under discussion.

8.2.11 Rejuvenating porous asphalt

The winter months in Europe can be damaging for road surfaces, as the combination of water and frost accelerates the degeneration of the surface material. The open structure of porous asphalt (ZOAB) is more prone to damage than the closed structure of regular asphalt concrete. This susceptibility increases progressively with age. With porous asphalt being the road surface material of choice on Dutch motorways, Rijkswaterstaat has a keen interest in reducing frost damage, as it would prolong the life span of road surfaces, requiring less frequent resurfacing, with associated hindrance to the traffic. Rijkswaterstaat therefore invests in a core research action carried out by the Technical University Delft to discover the key factors behind the phenomenon.

In addition, Rijkswaterstaat has started a technical trial on rejuvenating the aged bitumen binder in ZOAB with a special oil based agent. Two such products are being tested and monitored over several years. The first product should prevent ravelling (fragments coming loose from the road surface), and the second product should work on curing when ravelling has commenced. The trial aims to achieve the same result (increasing the lifespan of porous asphalt) as the trial using induction heating detailed in 8.2.4, but using a different method.

8.2.12 Pavement Power

A fundamental law of physics states that ‘energy cannot be created or destroyed, it can only change state’. Conventionally, the kinetic energy in a moving road vehicle has been obtained from the conversion of chemical energy carried on the vehicle. A common feature of these vehicles has been the final translation of the energy to kinetic energy through the application of torque to one or more of the wheels of the vehicle. Conversely, when the vehicle is made to slow down, braking forces are translated through torque in wheels to produce heat (or occasionally electricity through regenerative braking).

This project considers whether the transfer of power directly between equipment buried in the pavement and the vehicles travelling could be a realistic possibility. Such power transfer would provide a number of distinct advantages, including lower weight vehicles needing less energy, and the recovery of energy, usually wasted as heat when braking.

8.3 Demonstration Projects

The Technology Trials currently underway, and any future trials, along with applied research and development undertaken during the Field Trial Phase of the Forever Open Road project, will lead to the development of prototypes during System Proving Phase of the project. Whereas the technology trials are generally looking at one technical improvement or new technology, the trials in the Systems Proving Phase of the project will look to integrate several technologies from the three elements in a series of Demonstration Projects. The realisation of such demonstrators will largely form the output of this phase of the project.

The design, construction and location of the Demonstration Projects will result from miscellaneous criteria, including an assessment of the available technologies tested during the Field Trials, their degree of maturity and robustness. It is also likely that a Demonstrator might be constructed to address specific road contexts for which there exists a strong motivation for innovation from road users, residents and road operators.

One example suggested could be heavily trafficked roads leading to alpine tunnels which today incur high consumption of energy due to long slopes as well as high degrees of air and noise pollution, in generally highly environmentally sensitive areas. The motivation for innovation in road transport systems such as electric roads (roads able to bring electric energy to vehicles) in combination with the development of electric vehicles (cars, heavy vehicles) in this context is clear.

The development of the Demonstrators will evolve through the Field Trial Phase of the programme for deployment in the Systems Proving Phase. In general, the specific project will be drafted by the team working on the Research and Development work-package(s), addressing all the relevant features of the demonstrator, for example, location, design, scale, direct and indirect implementation costs.

9 Work Package Identification

In section 8, the Technology Trials being undertaken by the Champion Organisations were outlined. These existing trials, plus others that may be added by FEHRL Institutes have so far been funded through national budgets. The ongoing innovation programmes of FEHRL partners may also lead to the development of additional trials that will contribute to the Forever Open Road programme in the coming years.

Given the potential scale of the Field Trials and in particular the System Proving, the ongoing development of this project cannot be funded purely from the national budgets. There is a requirement for external funding to enable the necessary pan European investment that will enable the implementation of innovation and construction of prototypes at the scale envisaged.

For this reason, twelve work-packages covering fairly broad technology areas have been identified that, if proven feasible would lead to field trials or Demonstration Projects. These are outlined below, with more detailed descriptions in Appendix B. Information on the benefits of the Work Package, and the potential likely research requirements is presented, with the intention that the exact requirements would be further defined in response to a specific funding call. For this reason, budget estimates have not been provided as the exact research requirements cannot be defined at this stage. Many of the Work Packages will be interlinked, and in some cases it will be the integration of a number of elements that will create the major step forward.

9.1 Adaptable Road

9.1.1 Flexible Durable Pavements

One of the key criteria for the Forever Open Road is that there is reduced maintenance, which could be achieved though the development of more durable pavements. This would also lead to reduced costs and less hindrance of traffic.

The short to medium term research in the period 2011 to 2014 would focus on studies of new (reduced temperature) asphalt mixes, new concrete mixes, new materials and new construction elements, linking also to studies on prefabrication structures. Studies on crack repair, life span extension and self cleaning techniques. There would also be research into the sensitivity to frost of open surface materials, and possible preventative treatments.

From 2015 to 2018, it is proposed to undertake studies and tests of self healing asphalt pavements, emulsion treated gravel materials and crack repair techniques on concrete roads. Outputs will include pavement design methodology for emulsion treated gravel materials.

9.1.2 Prefabricated Pavements

Prefabricated structures have been envisaged as a method of integrating several technologies and of ensuring high quality pavement construction through a factory process in controlled conditions. The advantages of this approach will be quick construction and maintenance or repair, with associated reduction in disruption to the network. Other advantages will include easy access to underground networks and optimised co-habitation and management of service networks.

Research on the mechanical functions and durability of "puzzle" pavements and modelling and testing of individual concepts is planned from 2011 to 2015, with real life testing, i.e. prototype Demonstrators from 2015 to 2021.

9.1.3 Low Carbon Construction and Operation

For the Forever Open Road to be adopted it must have a lower whole life cycle environmental impact, through the reduction in energy and use of sustainable materials. This will result in improved air quality, lower overall carbon emissions and preservation of natural resources. This will be a significant undertaking and the work described below will undoubtedly be split into sub-projects.

In 2011 to 2014, studies of pollutant absorbing materials will be undertaken, along with tests of geogrids with cleaning properties in drainage channels, development of binders with less airborne emissions, low CO_2 hydraulic binders and self compacting concrete. This will result in the development of methods and best practice documents.

From 2014 to 2019 there will be testing of carbon absorbing concrete, development of pavement design to reduce traffic energy consumption, development of tools for global environmental assessment of road impact and studies on road equipment to support electric vehicles.

9.2 Resilient / Adaptable Road

9.2.1 Integration of Renewable Energy

Integration of renewable energy systems into the Forever Open Road is seen as highly desirable and was considered as a high priority, the advantages being the reduction or elimination of winter maintenance and the damaging effect of salt, and a reduction in thermal cracking and deformation of the pavement. The potential to produce energy for road infrastructure, such as lights and signs, communities adjacent to the highway or the vehicles themselves was also recognised as important.

Achieving this would be undertaken over a ten year timeframe from 2011 and would involved further tests with combined solar panels and noise barriers panels to power road infrastructure, tests of Peltier elements (heat to electric power) and assessment of piezoelectric generators. The development of control systems for road heating and cooling would be undertaken concurrently.

Additionally, investigations would be undertaken on the potential of emerging technologies such as solar panels that capture infrared light, and hence could provide power at night. A key element of this research would be trials on the storage of energy for later use, as well as work on the integration of different technologies and modular systems for energy harvesting, storage and use.

9.2.2 Storm Resistant Pavements

Future climate predictions suggest an increase in storm events and higher temperatures, which is something which must be factored in to the Forever Open Road design. In so doing, it will reduce the climate impact on road infrastructure, and optimise drainage systems. Allied to the design elements would be a better assessment and forecast of risks

From 2011 to 2014, further development of reservoir pavements for heavy traffic conditions would be undertaken, as well as development of pavements to master dam effects and instability of soil in sub layers. Studies on the effects of water and thaw on pavement surfaces would also be undertaken during this time.

The development of advanced methods for assessment of water flow and mapping of climatic risks along the infrastructure network would be undertaken from 2014 over a period of three years.

9.3 Resilient Road

9.3.1 Road side lighting and signs

There have been significant advancements in the field of LED lighting in recent years, and their capital costs are reducing such that they offer significant potential to reduce the energy and carbon intensity of lighting. Their use embedded in road studs or signs could offer additional benefits in terms of traffic management and traffic safety, achieved by, for example, using the lights for adaptive lane marking and provision of driver information.

The tasks that are envisaged focus mainly on integrating and improving existing systems to determine installation and power requirements, and to investigate methods for the LED lights to communicate with each other and / or a control centre, investigate power requirements and to determine the potential configurations that would offer optimum traffic management benefits. The potential for their use in streetlights, is well understood, but there may be some potential to investigate adaptive lighting, depending on traffic conditions. It is considered that the majority of the research and development could be achieved within three years from 2011, by which time the technology would be ready for full scale Demonstration Trials.

9.3.2 Porous Light Reflecting Surfaces

The use of porous asphalt is becoming increasingly common as it helps to reduce traffic noise, and can help keep roads accessibly in extreme weather. If these properties could be maintained, but with a reflective surface, there would be additional benefits of increasing the albedo effect, reducing the heat island effect, and potentially reducing the night time lighting requirements.

To achieve this, there would be a number of concurrent research activities running between 2011 and 2013, involving the testing of self cleaning technologies and high albedo reflection surface materials. At the same time, there would be the development of an Acoustic Optimisation Tool and testing and implementation of two layer porous cement concrete systems.

In the longer term of 2014 to 2020, activities would focus on the development and testing of super silent road surfaces, self cleaning technologies and the potential of CO_2 absorbing pavements.

9.4 Automated Road

9.4.1 In-built Sensor Systems

Sensors are widely used in supplying information on traffic and infrastructure condition. Extending the use of sensors further was seen as high priority by the FEHRL research coordinators to supply of data to support the management, maintenance and operation of network.

In the short term (2010 to 2012) the primary activity would involve a literature research, scanning the market for sensors in use currently and assessing the potential for improvement of data capture and integration, and also outside of the road sector where the technology could be transferred.

From 2012 to 2015 activities would centre on the development of detectors and sensors, tests and implementation in field trials.

9.4.2 Traffic speed maintenance

In recent years, pavement investigation systems have been developed that enable measurements to be taken at traffic speed, and hence keep the road open. The Forever Open Road envisages reduced maintenance requirements, but this cannot be completely eliminated. The potential to increase the speed of certain maintenance activities will help maintain traffic flow.

From 2011 to 2014 it is proposed that research would be undertaken on concept development of structural surveys at traffic speed, which would include deflection, resulting in the development of best practice guidance on road work organisation. An inventory will be made of the most common maintenance operations and investigate the potential to eliminate through alternative design, automate and / or increase the speed at which they are undertaken.

From 2014 to 2017, there would be tests of surface survey at traffic speed and development and tests of methods to survey sublayers, drainability and imaging of the near underground surface at traffic speed. There would be a link with Work Packages on sensor systems and prefabrication to improve the road operators understanding of the condition of the asset, maintenance requirements and the potential to lift and replace damaged elements.

9.4.3 Weather Protection and Warning Systems

Extreme weather events can cause significant damage to the road infrastructure, such as thermal cracking, whilst traditional methods of protection such as salt can also damage the pavement and impact on local vegetation. Protection against such damage would increase the pavement life and reduce maintenance and repair requirements, whilst warning systems would improve safety for road users.

In the short to medium term (2010 to 2013) it is proposed that research would be undertaken to improve the accuracy of the sensors used to monitor road condition. Studies and tests of ground source heat pumps and geothermal energy for winter heating and summer cooling of the pavement would also be undertaken.

In the longer term (2013 to 2018), research would be undertaken on methods of storage of geothermal energy, combining different sensor technologies, further development of heating and cooling systems and sensor systems, followed by tests and implementation of robust technologies.

9.4.4 Communication network

Improvement in the communication with vehicles, the highway and traffic control centres should enable more efficient movement of vehicles, reduced congestion and fuel savings.

In 2011 and 2012, investigations would centre on improved collection and processing of traffic condition data and studies and testing of vehicle to vehicle and vehicle to infrastructure communication systems. It is also proposed to investigate the potential of vehicles to be sensors, and to incorporate existing research into the ‘open roads’ vision.

Real life technology trials could be undertaken from 2013 with validation and testing ongoing for a further three years.

9.4.5 Self-monitoring road

A road that would accurately measure its own condition would lead to improvements in infrastructure management, which in turn could improve road safety and optimise traffic flow.

The research for this work package is envisages to take eight years from 2011, and would involve the development and tests of high precision ‘weigh in motion’ systems, improvement of systems to detect local environmental conditions, development and testing of data processing and transfer to road users.

Additional research would be undertaken on ‘Structural state’ assessment from in-built instruments, transfer of data to users in cars and into road management systems. There would be links with research on vehicle sensors and the use of the vehicle as a sensor as well as in-built sensor systems.

10 Roadmap and Deliverables

Started as a concept in 2009, the Forever Open Road programme has now been scoped and developed into a detailed programme of work with supporting Technology Trials projects that have been identified by FEHRL members as illustrative of the Forever Open Road concept. The programme of research work is intended to commence in 2011.

The R&D work plan includes some priority research technologies that are close to demonstration, and depending on the maturity of the technology, adoption and development of these will take between 2 and 5 years to complete. Figure 13 below, details the timetable of the Forever Open Road programme and an outline of the actions that will be undertaken over the coming years.

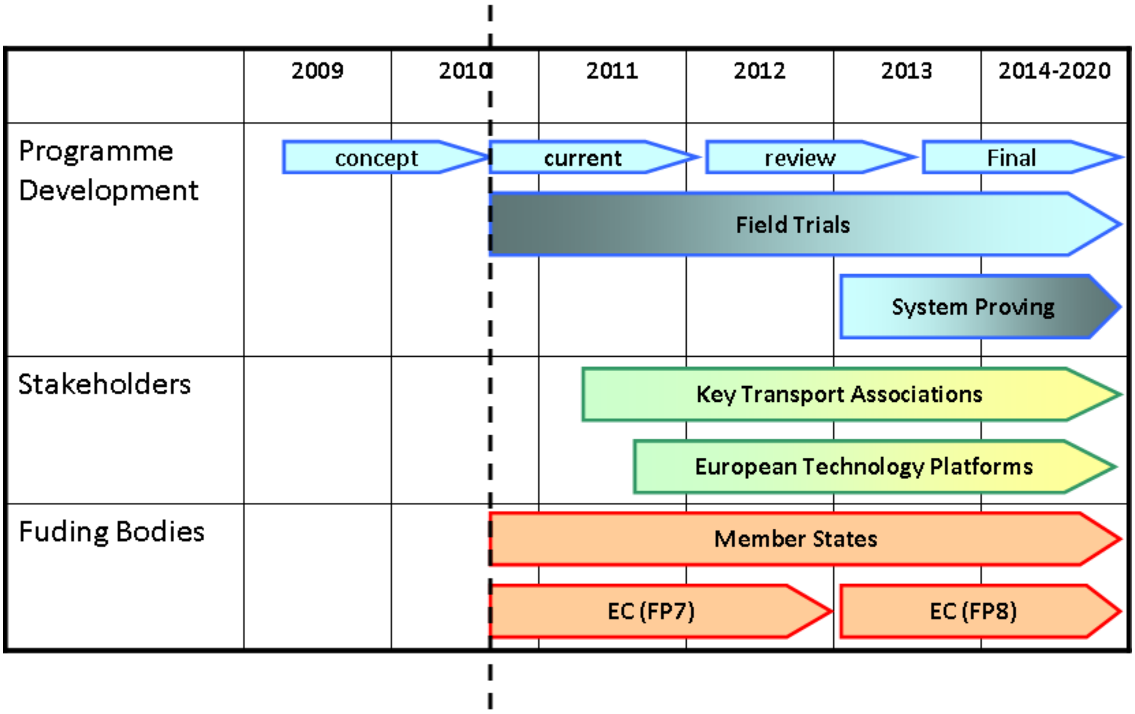

Figure 13 Forever Open Road Timetable

10.1 Deliverables

The Forever Open Road programme will deliver:

- *A series of Demonstration projects* to test the viability of the product, process or service technology that in preceding research stages has rendered feasible. The tests will be performed 'in the field', against the backdrop of real road operation practices and requirements, such to effectively reach the mark of 'implementation ready'. They concern prototype systems; new Technology Trials; construction and maintenance demonstrators, including the necessary standards, specifications and design guidance.
- *Sound knowledge transfer through a proactively updated database*, to ensure that the research and demonstration results from the Forever Open Road are effectively shared and applies to the effect that no research or demonstration activities within the Forever Open Road programme are duplicated.
- *A set of Common European Standards,* that will enable the Forever Open Road to be deployed across Europe regardless of country or region.

A further benefit will be the development of Pan–European engagement, through cooperation and collaboration to ensure the technology being researched and developed is indeed state of the art.

It is expected that the work programme will evolve throughout the life of the programme, increasing in line with new concept developments, the addition of new stakeholders and new project opportunities. In order to ensure that the programme's scope and aims are still in line with the participants interests, a first review of the programme is foreseen in 2013, after which the programme is considered finalised.

10.2 Next steps in the process

In the coming months, the following steps will ensure further consolidation of the Forever Open Road programme by:

Expanding the current project portfolio: Currently the project portfolio contains the contributions of 5 FEHRL members. Indications were that other FEHRL members would like to contribute as well, which would further consolidate the Forever Open Road programme. Also it provides a wider range of projects to which external partners may relate or even participate in. The action will be executed through the respective research coordinators. The opportunity to contribute to the portfolio is continuous.

- First leg of project portfolio expansion completed (November 2010).

Establishing the Technical Advisory Board (TAB): All projects in FOR will be subject to scientific and technical review. Therefore an advisory structure is required in which the FEHRL Research Coordinators are key. First no-regret actions are needed to initiate:

- Procedures and structures developed in association with FEHRL research coordinators (November 2010)
- FEHRL expertise identified and linked to the work packages (January 2011)
- External expertise identified and linked to the TAG structures (February 2011)
- Project portfolio screened for blind spots (February 2011)

Establishing the knowledge transfer process. Core to FOR programme concept is an effective knowledge transfer process. This requires a sound information base, for which the FEHRL database will be used. As only projects that are documented in this information base, may use the FOR label, key to this action are the participating FEHRL members (in later instance also the external partners).

- Procedures and structures developed in association with FEHRL research coordinators (November 2010)
- FEHRL database filled with information from field trials and newly funded projects from current project portfolio (December 2010)
- FEHRL database filled with the results from screening 'existing knowledge' by Research Coordinators (January 2011)
- FEHRL database filled with continuous contributions from FEHRL members, external stakeholders and FOR project proposals. (Continuous)

Preparing for the second stakeholder meeting: The first stakeholder meeting in September focused on the FOR concept and strategy, on basis of a draft version of this executive summary. The second stakeholder meeting, which is planned for March/April 2011, will focus on concrete coordination, cooperation and collaboration venues in the FOR project portfolio.

- Prospect links to external stakeholders identified on basis of their strategic research agendas (February 2011)
- Prospect links discussed in bilateral talks with respective stakeholders (March 2011)

- Recommendations presented and discussed for conclusive agreements in second stakeholder meeting (March/April 2011)

Preparing for coming calls for research projects: Currently the European Commission (under FP7) and CEDR (under ERANET-ROAD) are preparing calls for research projects. It is essential to the further consolidation of FOR that these calls are addressed. To do so, a Research Coordinators workshop will held in October/November 2010.

Developing a communication and marketing plan: The FOR concept was communicated in several occasions already, such as at the TRA 2010 conference last June. FOR was also presented at the Stakeholders meeting last September. Throughout the reception was positive. Now a structured communications approach is needed to keep FOR close to the attention. This will be released by November 2010.

Appendix A. Champion Organisations

LCPC

The French Laboratoire Central des Ponts et Chausées (Central Bridge and Highway Laboratory) has a long-established base in civil engineering and is currently expanding its presence to the areas of urban engineering, infrastructural operation and safety, the environment and risk avoidance. In the Forever Open Road, LCPC has provided substantial support through the launch of a national Forever Open Road programme called Route de 5ème generation (fifth generation road).

Hélène Jacquot-Guimal
LCPC Chief Executive

[Signature]

TRL

The UK national transport research laboratory, TRL, is leading the technical side of the development of the Forever Open Road. One current exercise from which it is contributing expertise to the Forever Open Road involves the construction of a test stretch of road that will be instrumented to monitor its own pavement condition and calibrate survey vehicles. Another, now getting under way, is exploring the feasibility of roads using stored energy to power electric vehicles.

Dr. Susan Sharland
TRL Chief Executive

[Signature]

BASt

The German Federal Highway Research Institute (BASt) is a specialist technical and scientific organisation directly responsible to the Federal Ministry of Transport, Building and Urban Affairs (BMVBS). It is also the central German agency for road traffic accident research. A current trial focuses on the use of geothermal energy to reduce the risk of winter icing and extreme summer high-surface temperatures on bridge decks.

Peter Reichelt
BASt Chief Executive

[Signature]

DRI

The Danish Road Institute (DRI)'s current research foci are on climate and the environment, noise-reducing pavements and materials technology. A key thematic project aims to deliver low-maintenance roads with a green profile.

Gert Ahé
DRI Chief Executive

[Signature]

RWS DVS

Leading the management of the Forever Open Road is the Rijkswaterstaat Dienst Verkeer en Scheepvaart (RWS DVS, Centre for Transport and Navigation), an agency within the Netherlands Ministry of Transport, Public Works and Water Management. RWS was one of the originators of the concept which draws heavily on previous innovation programmes they have coordinated including Roads to the Future, Innovation Programme Noise (IPG) and Innovation Programme Air quality (IPL).

Joris Al – Joris Al
FEHRL President & RWS
Chief Executive

[Signature]

AIT

The AIT Austrian Institute of Technology, Austria's largest non-university research institute is among the European research institutes a specialist in the key infrastructure issues of the future. Although not a champion organisation, AIT has been active in contributing to scope the FOR Programme on behalf of FEHRL.

Appendix B. Work Package Information

B1.The Adaptable Road

B1i. Traffic Speed Maintenance

Overview on technology status

The WP has its main focus on minimizing the impact of survey and maintenance operations on traffic.

- Allow surface survey at high speed
- Allow structural survey at high speed
- Reduce maintenance work duration to minimize traffic disruption.

- On each of these items, some technical solutions can already be implemented immediately. More research is needed on "structural survey at high speed" and "reduction of maintenance work duration"

Remark : The use of vehicle sensors and "Vehicle to Infrastructure" communications to monitor the road continuously is handled in the WP "self monitoring road"

Technologies Available for Implementation

It is considered that the in-use techniques referenced below can be implemented immediately or within 12 months.

Allow surface survey at high speed

- In use, traffic flow devices for the measurement of : evenness, transverse profile, roughness, skid resistance, visibility of road marking, road environment imaging, thermal and humidity data on a route, noise.

Allow structural survey at high speed

- In use, traffic flow devices for the measurement of thickness and presence of water at interlayers (Ground Penetration Radar)
- In progress, deflextion and radius of curvature

Reduce maintenance work duration to minimize traffic disruption.

- In use , very thin layers allowing quick opening to traffic
- In progress, optimized road works organisation

Research Requirements

Short to medium term

Allow structural survey at high speed

- Deflexion and bearing capacity at high speed –concept development
- Deflexion and bearing capacity in urban areas (using smaller equipments) - Feasibility concept

Remark :

- *there is globally a need to set methodologies allowing to optimize road survey using imbrications of the different survey speed/methodologies to define homogenous areas (e.g.*

combined use of GPR at high speed and local coring). Reduce maintenance work duration to minimize traffic disruption. - Optimize road works organisation *Long term* Allow surface survey at high speed - Drainability survey at high speed - Surface cracking at high speed Allow structural survey at high speed - Deflexion and bearing capacity at high speed – cost effective equipment - Deflexion and bearing capacity in urban areas (using smaller devices) – Cost effective equipment - Imaging of near underground networks in urban area. - Thickness measurement allowing differentiation between layers of the same dielectric nature - Road damage (structural fatigue) assessment - Reduce maintenance work duration to minimize traffic disruption. - Use of prefabricated elements - 3D inkjet printing; investigate the potential of this technique to be used to undertake rapid minor maintenance works, such as filling potholes or ruts.

Research techniques and facilities to be made available

General points on research techniques and note any specific requirements for research facilities 1. Stakeholder identification and engagement 2. Detailed literature review of existing and future technologies 3. Comparison of existing technologies and suitability for highway applications 4. Cost-benefit and future cost performance of technologies of interest 5. Review of practicalities of installation / maintenance and compatibility with other Forever Open Road technologies / elements 6. Review of EU legal and planning frameworks for deploying these technologies 7. Set-up of a scientific project and project team 8. Study tour to visit pre-existing installations of certain technologies 9. Lab studies and report results 10. Real life technology trials, possibly in various countries 11. Reporting and progress meetings 12. Project Management

Research outputs and delivery dates

Short to medium term Allow structural survey at high speed - Deflexion and bearing capacity at high speed – Concept development - Laboratory demonstrator 2014. - Deflexion and bearing capacity in urban areas (using smaller equipments) – Feasibility

concept – Laboratory demonstrator 2014.

Reduce maintenance work duration to minimize traffic disruption.

- Optimize road works organisation – Best practice guide 2013

Long term

Allow surface survey at high speed

- Drainability survey at high speed – feasibility 2014 – Cost effective equipment 2017
- Surface cracking at high speed – software 2017

Allow structural survey at high speed

- Deflexion and bearing capacity at high speed – Cost effective equipment 2017
- Deflexion and bearing capacity in urban areas (using smaller equipments) – Cost effective equipment - 2017
- Imaging of near underground networks in urban area. Cost effective equipment 2017
- Thickness measurement allowing differentiation between layers of the same dielectric nature - Cost effective equipment 2017
- Road damage (structural fatigue) assessment- Methodology 2017
-

Reduce maintenance work duration to minimize traffic disruption.

- Use of prefabricated elements – Best practice guide 2017
- 3D inkjet printing – develop lab scale prototype to assess potential for use.

Benefits of research and how it helps achieve the aims of the Forever Open Road

Expected benefits:

- Minimization of the impact of survey and maintenance operations on traffic.
- Improvement of damage assessment in roads.
- Cost effective spot maintenance.

Potential to retrofit to existing roads / structures / infrastructure

- All previous items listed apply for maintenance of existing roads, and for road works control
- Special need for urban infrastructures

Comment on applicability to bridges, structures, tunnels

- Advanced survey mechanisms such as LIDAR can be used for assessment of bridges, structures and tunnels
- Usable for airport infrastructure
- Possible applicability to railway infrastructure

Possible barriers to implementation

- The need for such new equipment and the possibility to operate them and to get useful information have to be validated by stakeholders.
- New physical concepts to be developed for several functions; no guarantee of successful results.

B1ii. Storm resistant pavements

Overview on technology status

The WP has its main focus on minimizing the impact of storms and extreme climatic events on roads:

- Minimize non permeability effect of pavement surfaces and its impact on drainage system (reservoir pavements and block pavements)
- Master dam effect of embankment pavements and instability of soils
- Effect of water and thaw on pavement surfaces (stripping and potholes formation) and structures (frost heave and de-bonding of layers)
- Effect of wind on vehicles especially for bridges
- Effect of wind on road sign and road environment

Remark :

- *effects of high/low temperature on road surface are taken into account in WP "Energy harvesting…"*
- *the question related to the quality of water flow is treated in WP "Low carbon… low environmental impact…"*

- On each of these items, some technical solutions can already be implemented immediately. More research is needed on "Dam effect of embankment pavements and instability of soils" and "Effect of water and thaw on pavement surfaces and structures"
- the global assessment of suck risks and the setting of "risk maps" covering a given geographical area and taking into account meteorological data.

Technologies Available for Implementation

It is considered that the in-use techniques referenced below can be implemented immediately or within 12 months.

Minimize non permeability effect of pavement surfaces and its impact on drainage system

- In use are reservoir pavements and block pavements for light traffic *(e.g. car parks)*

Master dam effect of embankment pavements and instability of soils

- In use are pipes systems in the embankments

Effect of water and thaw on pavement surfaces and structures

- In use are anti stripping agents in mixes

Effect of wind on vehicles especially for bridges

- in use, wind deflectors on the most affected bridges.

Effect of wind on road sign and road environment

- In use, design rules

Research Requirements

Short to medium term

- Improve the strength of reservoir pavements to allow heavy traffic
- Design of pavement infrastructure to master dam effect of embankment pavements and

instability of soils in the most affected areas.

- Effect of water and thaw on pavement surfaces (stripping and potholes formation) and structures (frost heave and de-bonding of layers): better understanding of phenomena and prevention solutions.

Long term

- Global assessment of water flows on a given geographical area taking into account all the existing or future infrastructures and buildings, coupled with meteorological data. Detection of the high risk areas.
- Mapping of climatic risk along infrastructure network.

Research techniques and facilities to be made available

General points on research techniques and note any specific requirements for research facilities

1. Stakeholder identification and engagement
2. Detailed literature review of existing and future technologies
3. Comparison of existing technologies and suitability for highway applications
4. Cost-benefit and future cost performance of technologies of interest
5. Review of practicalities of installation / maintenance and compatibility with other Forever Open Road technologies / elements
6. Review of EU legal and planning frameworks for deploying these technologies
7. Set-up of a scientific project and project team
8. Study tour to visit pre-existing installations of certain technologies
9. Lab studies and report results
10. Real life technology trials, possibly in various countries
11. Reporting and progress meetings
12. Project Management

Research outputs and delivery dates

Short to medium term

- Improve the strength of reservoir pavements to allow heavy traffic – feasibility (laboratory demonstrator) 2011 – cost effective deployment 2014
- Design of pavement infrastructure to master dam effect of embankment pavements and instability of soils in the most affected areas. Better understanding of phenomena – calculation methodology 2014
- Effect of water and thaw on pavement surfaces (stripping and potholes formation) and structures (frost heave and de-bonding of layers) :better understanding of phenomena. PhD Thesis report 2014

Long term

- Design of pavement infrastructure to master dam effect of embankment pavements and instability of soils in the most affected areas: Research and testing of preventing solutions. Feasibility 2014 - Demonstrator 2017
- Effect of water and thaw on pavement surfaces (stripping and potholes formation) and structures (frost heave and de-bonding of layers): research and testing of preventing solutions. Feasibility 2014 - Demonstrator 2017
- Global assessment of water flows on a given geographical area taking into account all the

existing or future infrastructures and buildings, coupled with meteorological data. Detection of the high risk areas. Feasibility 2014 – Cost effective software 2017

- Mapping of climatic risk along infrastructure network. Feasibility 2014 – Cost effective software 2017

Benefits of research and how it helps achieve the aims of the Forever Open Road

Expected benefits:

- lower climatic impact on road infrastructures at the different stages : construction, maintenance, in use
- cost optimization of rain water and road drainage systems
- better assessment and forecast of risks

Potential to retrofit to existing roads / structures / infrastructure

- Most of the previous items listed can apply for maintenance of existing roads

Comment on applicability to bridges, structures, tunnels

- Usable for bridges (wind effect)
- Usable for airport infrastructure
- Usable for rail infrastructure (dam effect)

Possible barriers to implementation

- The objectives of this work package meet global requirements for sustainable development; so no barrier is expected in this field.
- The lack of long term validation for all the considered new systems is a barrier for massive implementation. This stage is then compulsory using for example demonstrators
- The number of implied stakeholders (road owners, local authorities, meteorologists, geographers, hydro geologists) may lead to difficulties to implement such projects
- Risk assessment implies management of legal responsibility.

B1iii. Flexible Durable Pavements

Overview on technology status

Flexible durable pavement surfaces are commonly used. However, there is a strong motivation for increasing the life span and reducing the cost, time and hindrance involved in construction and repair and maintenance.

The sub-tasks to reach these ambitions are in different phases of development:

There are several technologies for the construction of thin and open asphalt concrete, which are already being widely used. Surfaces made of alternative materials or with alternative binders and aggregates focused on better durability (and noise reduction) are generally in the trial stage. Although some technologies for self-cleaning are in the trial stage, most of the self-cleaning and self-healing technologies still have to be developed.

Technologies Available for Implementation

Several technologies for (re)paving of thin and open asphalt concrete are in use. The object of applying these layers is usually noise reduction, but the technology also has advantages regarding splash and spray, road works duration, use of resources and skid resistance.
Manufacturing and processing is made possible at lower temperatures (which reduces the amount

of energy and CO_2 emission).
Other technologies facilitate in situ recycling of asphalt top layers.
Adaptations in the application process make construction (repair) in low temperatures (winter) possible, if necessary.
On low traffic roads emulsion gravel mixes can be applied using energy saving materials.

Research Requirements

Short to medium term:

- Improving life span by using new asphalt mixes (PMA), new concrete mixes (with porous exposed aggregates), new materials (polyurethane, glace granular) and introducing new construction elements like fibres (glass, steel, textile).
- Methods for crack repair by use of steel wool combined with heating by induction.
- Lengthening the life span of existing road constructions by overlaying (plastic with chipping, thin reinforced concrete, ultra high performance concrete).
- Reduction of maintenance by self-cleaning techniques like rinsing and brushing.

Medium term:

- Reduction of asphalt maintenance by ways of self-cleaning via additives.
- Reduction of the sensitivity to frost of open surface materials.
- Pavement design methodology for emulsion treated gravel

Long term:

- Reduction of asphalt maintenance and improving life span by new asphalt mixes (self healing micro-cracks), using additives (like nano-particles) or capsules (with juvenator).
- Improving life span of concrete roads through use of glue and crack repair techniques.
- Reduction in salt use in winter conditions by use of CMC (carboxymethylcellulose).

Research techniques and facilities to be made available

The following points might be considered:

1. Stakeholder identification and engagement
2. Detailed literature review (desk-study)
3. Comparison of existing technologies
4. Cost-benefit analysis
5. Review of practicalities
6. Review of EU legal frameworks
7. Set up of a project team
8. Study tour
9. Lab-studies and report results
10. Find interested parties and financing
11. Real life technology trials (sometimes in various countries)
12. Report results
13. Communication
14. Project management

Research outputs and delivery dates

Short to medium term:

Research (including technology trials) can be completed as follows:
For the new asphalt mixes (mastic asphalt), new concrete mixes (concrete with porous aggregates on top), new materials (binders of PUR or glace granular) and the introduction of additives (fibres) 2015 is feasible.
This also applies to using steel wool to prevent raveling for easy repair (the melting of microcracks by induction).
(Improving noise reduction is part of the new mixes and new materials.)
Research on the lengthening the life span of existing road constructions by overlaying (ultra high performance concrete, thin reinforced concrete, thin plastic coatings) can be finished by 2013 / 2014.
Developments in the reduction of maintenance by self cleaning technologies like brushing can be finished in 2013.
The reduction of the maintenance of asphalt by way of self cleaning via additives (hydrophob, TiO_2) can be delivered in 2013.

Long term

The estimate for the time scale for the long term developments is 2015 – 2018, comprising the following:
Reduction of asphalt maintenance and improving life span by self-healing new asphalt mixes, using nano-particles, capsules with juvenator.
Improving life span of concrete roads by usage of glue and crack repair techniques.
In winter conditions reduction in salt use by using CMC.

Benefits of research and how it helps achieve the aims of the Forever Open Road

Results of these developments are of great importance for the essence of the “forever **open** road”. Increasing the life span and reduction of the maintenance (its costs and the hindrance) of roads are the objectives of the research in this task. It is therefore essential to the concept.

Potential to retrofit to existing roads / structures / infrastructure

All technologies can be applied to existing roads at a moment of maintenance and of course also used on new roads.

Comment on applicability to bridges, structures, tunnels

Most technologies can be used on bridges; some technologies are only applicable in situations with porous asphalt and therefore unsuitable for tunnels.

Possible barriers to implementation

Implementation of the technologies to make more durable roads with low lifetime costs (higher construction costs and lower maintenance costs) is only possible if there is one integrated budget.
Contract forms should have incentives for long life spans and low maintenance costs

B1iv. Prefabricated Pavements

Overview on technology status

The WP has its main focus on high tech road section construction as regards :

- use of dedicated “elements” to specific functions (infrastructure for power supply) (technical gallery for underground networks, in built sensors, continuous power supply for electric vehicles, noise reduction using Helmholtz resonators)
- allowing easy access to underground networks (in urban areas)
- allowing easy insertion/replacement of prefabricated elements (e.g. crossroad elements between road and tramway)
- road construction over “soft soils”
- strength and durability of sub bases
- bonding with the other layers and adjacent elements

Generic technical solutions for the above listed functions are modular structures, mainly incorporating concrete “rigid” elements

On each of these items, some technical solutions can already be implemented immediately. More research is needed on “the global functioning of such “puzzle” pavements, avoiding the usual drawbacks of rigid pavements”.

Technologies Available for Implementation

Some modular techniques are already available for each of the items listed above :
Among them :

- ModieSlab, which is a patterned technique (NL) of modular road supported on piles, allowing construction on soft soils. The different elements are interlocked and integrate chambers for networks.
- Concrete utility tunnels below/beside the pavement
- Modular chambers for communication and power.
- CUD (Chaussée urbaine démontable), which is a patented technique (F) of removable modular pavements made of hexagonal concrete slabs, supported on easily re excavatable lean concrete allowing easy access to underground networks. Especially designed for urban areas.
- Grids made of steel or glass fibres or plastic to improve resistance of layers

In progress :

- Locking grids and cells for stabilisation of the shoulder.

Research Requirements

What needs to be researched?

Generic technical solutions for the above listed functions are modular structures, mainly incorporating concrete “rigid” elements
Research is needed on the global functioning of such “puzzle” pavements, avoiding the usual drawbacks of rigid pavements.
Focus has to be made on the mechanical functioning and durability of the global system well as durability of the individual functions and interlocking between elements.

It seems to be interested to consider different stages :
Short to medium term

individual concepts, numerical model demonstrators *Long term* physical demonstrators, ALT tests and open to traffic trial tests

Research techniques and facilities to be made available

General points on research techniques and note any specific requirements for research facilities

1. Stakeholder identification and engagement
2. Detailed literature review of existing and future technologies
3. Comparison of existing technologies and suitability for highway applications
4. Cost-benefit and future cost performance of technologies of interest
5. Review of practicalities of installation / maintenance and compatibility with other FOR technologies / elements
6. Review of EU legal and planning frameworks for deploying these technologies
7. Set-up of a scientific project and project team
8. Study tour to visit pre-existing installations of certain technologies
9. Lab studies and report results
10. Real life technology trials, possibly in various countries
11. Reporting and progress meetings
12. Project Management

Research outputs and delivery dates

Short to medium term
individual concepts, numerical model demonstrators – 2014

Long term
physical demonstrators, ALT tests and open to traffic trial tests – 2017

Benefits of research and how it helps achieve the aims of FOR

Expected benefits:
- Optimized technical networks with easy access, maintenance
- Less inconvenience for users and road side residents
- Road construction over “soft soils”

Potential to retrofit to existing roads / structures / infrastructure
- This WP is mainly suitable for new construction or re-construction.

Comment on applicability to bridges, structures, tunnels
- Pavements with high tech functionalities can especially be useful for bridges, tunnels and any short and costly specific road sections.

Possible barriers to implementation
- Co-ordination between several network operators; Legal responsibility for shared owner galleries.
- Construction costs
- Stakeholder validation of these concepts

B1v. In-built Sensor Systems

Overview on technology status

Sensors for traffic detection are in use widely and a proven technology. Also environmental sensors to detect wetness, icy roads or visibility are commonly used on motorways. Special detectors are in use for traffic load observation (weight in motion).
At trial stage is permanent integrated roadside noise monitoring. A new field of application and also at trial stage is detecting parking vehicles (especially trucks) on rest areas.

A special field of interest concerning (built in) sensor systems is the integrated communication network for traffic data, road and weather conditions.

Technologies Available for Implementation

MIDAS (Motorway Incident Detection and Automatic Signalling system) has been operational on a number of motorways as part of the traffic management system. They are widely used across EU.
Weight in Motion, Sensor network for bridge monitoring and Trajectoris observation are existing technologies but not widely used.
Permanent integrated roadside noise monitoring is a trial stage technology, which will be available in the short to medium term.

Research Requirements

Most detectors gather only local data or for a limited area. Mathematical models help to estimate data between detectors. Although a lot of effort has been made, these models are not sufficient to assess all situations correctly.
Innovative Roads allow a continuous detection of data in high quality. Their installation does not need any pavement cutting procedure (since detectors are already integrated or above surface of road). The future detection methods are flexible to shifted lanes, are sufficiently accurate and need only little maintenance although life-cycle is as long as the road's life cycle. Furthermore detection methods are cost and energy-efficient.
Today's existing detection methods do not fulfil above mentioned criteria which lead to research needs to address future intelligent roads. Existing technologies can be a basis for research plans. It should be shown which kind of technology seems most appropriate and need minimum of improvements.

Short to medium term

Literature research, common understanding of sensor requirements in future, study on sufficiency of existing detection systems for various fields of usage

Long term

Development of sustainable, long-life, high quality detection systems that allow road net wide data collection; test and implementation for various fields of usage

Research techniques and facilities to be made available

the following points might be considered:

1. Stakeholder identification and engagement
2. Definition of requirements, application and conditions of future sensors
3. Detailed literature review of existing and future sensor technologies
4. Comparison of existing technologies and suitability for future highway applications
5. Cost-benefit and future cost performance of technologies of interest
6. Review of practicalities of installation / maintenance and compatibility with other FOR technologies / elements

7. Review of EU legal and planning frameworks for deploying these technologies
8. Study tour to visit pre-existing installations of certain technologies
9. Developing a prototype sensor fulfilling (most, at least high ranked) requirements
10. Real life technology trials, possibly in various countries and for different applications.
11. Reporting and progress meetings
12. Project Management

Research outputs and delivery dates

Feasibility study until 2012,
Development, Implementation and Test in 2013 – 2015

Benefits of research and how it helps achieve the aims of FOR

Results are basic conditions to allow a road to be an intelligent road with data on traffic, environment and status of road parameters. Future applications can be developed on that basis. Within FOR this WP is of interest for Self-monitoring Road, Weather warning systems and Weather protection.

Research in this area will be closely linked with research in the field of communication and power network.

Potential to retrofit to existing roads / structures / infrastructure

To retrofit sensors to existing roads should be a requirement if it seems necessary for the case of application. Today's sensor could be retrofitted with negative effects on road surface in some cases. Best benefits are expected in case of installation during road maintenance.

Comment on applicability to bridges, structures, tunnels

Road sensors continue in tunnels and on bridges. There could be significant potential to develop sensors for continuous real time monitoring of structures.

Possible barriers to implementation

The need of sensor systems and data is widely accepted. Improvements in technology should address cost, political, economic, social and legal aspects, which depend on field of application.

Development of road site sensors should be done in cooperation with vehicle sensor development (C2X-initiative). Synergies should be used; strength of both technologies should be used in combination to allow best results, although the results should be able to work independently.

B1vi. Integration of Renewable Energy

Overview on technology status

- Geothermal energy and groundwater (energy) is currently in use at a field stage level to heat road surfaces in winter in place of road salt and cooling in summer to prevent permanent deformations.
- Furthermore solar panels (PV) (e.g. mounted on noise barriers) can be used to capture the necessary energy for the road infrastructure (e.g. signage) or just as an energy source.
- Use of micro wind mills to power signage in remote regions.

Technologies Available for Implementation

Improved usage of renewable energies (geothermal, groundwater, wind, sun) for temperature control of the surfaces as well as (electric) energy for road infrastructure.

Research Requirements

Short to medium term:

- Use of Peltier elements to convert the heat of the surface layer and/or construction in electric energy
- Use of solar panels (PV) with noise barrier function
- Improved accuracy and speed of the control of surface heating and/or cooling due to the environmental data
- Solar panels (PV) to power local communities and LED road markings and up lighting
- Integrate micro wind mills or wind turbines into noise barriers
- Use of piezoelectric generators under the road surface to capture energy due to the "elastic deformation" of the surface as well as validation of these generators

Long term:

- Storage of renewable energy (e.g. solar-, wind-, geothermal energy)
- Use of PV panels configured to collect infra-red light spectrum after nightfall
- Combination and integration of different technologies
- Implement different technologies in modular systems (from adaptable road)

Research techniques and facilities to be made available

1. Detailed literature review of existing and future (renewable) technologies, with regard to energy harvesting (sun, wind, heat), storage of energy, converting different forms of energy (e.g. heat into electricity) and their possible application in roads and/or road infrastructure as well as combining of different technologies
2. Comparison of existing technologies and suitability for highway applications
3. Cost-benefit and future cost performance of technologies of interest
4. Advantages and drawbacks of known technologies and new technologies
5. Stakeholder identification and engagement
6. Study tour to visit pre-existing installations of certain technologies (e.g. in roads or in other fields)
7. Review of practicalities of installation / maintenance and compatibility / combination with other FOR technologies / elements
8. Real life technology trials, possibly in various countries (e.g. not considering incentives, the performance of solar PV is likely to vary considerably between Spain, the UK and Finland, also the usage of geothermal or ground water energy, in southern Europe it will be likely used for cooling in the summer while in northern Europe it will be used primarily for heating in the winter).
9. Review of EU legal and planning frameworks for deploying these technologies
10. Reporting and progress meetings
11. Project Management

Research outputs and delivery dates

- *Heating/cooling of road surfaces:* feasibility – 2010, cost-effective deployment (building of long sections, not only one bridge) – 2013
- *Improved accuracy and speed of the control of surface heating and/or cooling due to the environmental data:* feasibility – 2010, cost-effective deployment – 2013
- *Usage of Peltier elements to convert the heat of the surface layer and/or construction in electric energy:* feasibility – already proven during various projects, cost-effective deployment – 2014
- *Usage of solar panels (PV) with noise barrier function:* feasibility – 2011, cost-effective deployment – 2013
- *Solar panels (PV) to power local communities and LED road markings and up lightings:* feasibility – 2011, cost-effective deployment – 2015

- *Integrate micro wind mills or wind turbines into noise barriers:* feasibility – 2011, cost-effective deployment – 2014
- Storage of renewable energy (e.g. solar-, wind-, geothermal energy): feasibility – 2013, cost-effective deployment – 2018
- *Usage of piezoelectric generators under the road surface to capture energy due to the "deformation" of the surface:* feasibility – 2010, validation – 2013, cost-effective deployment– 2017
- Usage of PV panels configured to collect infra-red light spectrum after nightfall: feasibility – 2014, cost-effective deployment – 2022
- *Combine different technologies:* feasibility – 2010, cost-effective deployment – 2016
- *Implement different technologies in modular systems (from adaptable road):* feasibility – 2012, cost-effective deployment – 2018

Benefits of research and how it helps achieve the aims of FOR

- Temperature controlled surfaces would prevent winter maintenance including salting as well as cracks and permanent deformations because of the temperature – will prevent maintenance measures as well as congestion
- Usage of renewable energy through PV, windmills or convert heat into electric energy make it possible to use the energy for road infrastructure (e.g. signage, lighting) also in remote locations (to prevent long electric lines) – will provide the energy for road infrastructure (e.g. signage, lighting) to prevent accidents and congestion
- Generation of renewable energy could reduce whole life costs of road infrastructure and help to justify the additional capital expenditure of the FOR. It will also work towards the goal of the road being a net exporter of energy and hence climate neutral of carbon negative.

Potential to retrofit to existing roads / structures / infrastructure

- Solar panel (PV) and/or wind mills beside the road and /or on noise barriers – easiest way to retrofit roads
- Technologies which need to implemented in one of the layers or in the infrastructure – can be retrofitted during reconstruction

Comment on applicability to bridges, structures, tunnels

- Applications to civil engineering structures are possible – currently used in some countries on bridges and stations for (underground) rail as well as tunnels
- special considerations are needed for the expansion joints of bridges when using a bridge deck heating/cooling system

Possible barriers to implementation

- Legal: usage of geothermal energy, concerning the drilling depth and/or ground water use
- Costs: construction costs will be higher than current technologies mainly at the beginning of implantation of the new technologies - construction companies as well as road agencies need to be encouraged to use the new technologies; maintenance costs will not be higher than for current technologies
- Political: enforce the usage of renewable energy – therefore this is no barrier
- Economic: at beginning the new technologies will be inefficient, but due to energy harvesting and the usage for road infrastructure can help to prevent cost for energy and maybe less maintenance will be needed

B1vii. Low Carbon Construction and Operation

Overview on technology status

The WP has its main focus on minimizing the environmental impact of roads concerning :

- air and water pollution
- use of natural resources (oil , aggregates)
- emission of CO2
- energy use

On each of these items, a lot can already be implemented immediately. More research is needed on “air and water pollution” and the global assessment of environmental impact of road infrastructures, both for construction and use.

Technologies Available for Implementation

t is considered that the in-use techniques referenced below can be implemented immediately or within 12 months.

Minimizing air and water pollution

- In use are materials absorbing pollutants (e.g TiO2), less airborne emitting materials (warm and cold mixes, especially to replace asphalt mastic for footpath), systems controlling water or pollutant flow release to the environment
- In progress, use of treated geogrids with cleaning properties in drainage channels, new hot binders with less airborne emission

Saving natural resources

- In use are recycling techniques for hot bituminous materials (currently up to 30% and with specific equipment up to 70%), in-place recycling techniques up to 100% with emulsion and/or cement
- In use are secondary of alternative aggregates from miscellaneous sources of by-products
- In use very thin wearing course for maintenance
- In progress, long term performance assessment and design rules for such “low-materials”

Minimizing CO2 emission

- In use, mobile asphalt/concrete production machines to minimise travel time, new hydraulic binders producing less CO2 when manufactured, prefabricated pavement units, all low energy process (see hereafter)
- Bituminous mixtures with reduced temperatures and also cold mixtures
- In progress carbon absorbing concrete, specific pavement design to reduce traffic energy consumption (rolling resistance, longitudinal profile, evenness)

Minimizing energy needs

- In use reduced temperature bituminous mixtures (all types of warm processes), cold mixes, specific equipment for in-place recycling, optimized worksite organisation to minimize user hindrance
- In progress, potential for road to be net energy exporter (see WP In-built energy harvesting) , equipment to favour electric vehicles

General

- In progress, use of Life Cycle Analysis software to globally minimize environmental impact of road transport

Research Requirements

What needs to be researched?
Short to medium term - Check the effectivity and the range of usage of material absorbing pollutants (TiO_2) and also life cycle analysis and long term performance - Treated geogrids with cleaning properties in drainage channels - New hot binders with less airborne emission - New hydraulic binders producing less CO2 - Assessment of long term performance of all new "low-materials" - New design rules for pavement structures including "low-materials" technologies - Optimise use of Life Cycle Analysis software - Local implementation of best practices for minimizing road transport environmental impact during construction, maintenance, use stages - Self compacting concrete - Local implementation: use of asphalt mixtures with reduced temperatures combining with high percentage of used material (recycled material) *Long term* - Carbon absorbing concrete - Specific pavement design to reduce traffic energy consumption - Prefabricated pavement - Potential for road to be net energy exporter (see WP In-built energy harvesting) - Equipment to favour electric vehicles

Research techniques and facilities to be made available

General points on research techniques and note any specific requirements for research facilities
1. Stakeholder identification and engagement 2. Detailed literature review of existing and future technologies 3. Comparison of existing technologies and suitability for highway applications 4. Cost-benefit and future cost performance of technologies of interest 5. Review of practicalities of installation / maintenance and compatibility with other FOR technologies / elements 6. Review of EU legal and planning frameworks for deploying these technologies 7. Set-up of a scientific project and project team 8. Study tour to visit pre-existing installations of certain technologies 9. Lab studies and report results 10. Real life technology trials, possibly in various countries 11. Reporting and progress meetings 12. Project Management

Research outputs and delivery dates

Short to medium term - Treated geogrids with cleaning properties in drainage channels – feasibility (laboratory demonstrator) 2011 –cost effective deployment 2014 - New hot binders with less airborne emission – feasibility (laboratory demonstrator) 2011 – cost effective deployment 2014 - New hydraulic binders producing less CO2 - feasibility (laboratory demonstrator) 2011 – cost effective deployment 2014

- Assessment of long term performance of all new “low-materials” - 2014 onwards
- Optimise use of Life Cycle Analysis software – 100 000 €, 2 years min – 2013 onwards

Long term
- Carbon absorbing concrete – validation 2015
- New design rules for pavement structures including “low-materials” technologies – validation 2016
- Specific pavement design to reduce traffic energy consumption – validation 2015
- Prefabricated pavement – field of application 2011 - validation on scale model 2013 - demonstrator 2015
- Potential for road to be net energy exporter (see WP In-built energy harvesting)
- Equipment to favour electric vehicles – field of application 2011 - validation on scale model 2015 - demonstrator 2017

Benefits of research and how it helps achieve the aims of FOR

Expected benefits:
- lower environmental impact of road infrastructures at the different stages : construction, maintenance, in use
- air quality (better or improved)
- health preservation on road works
- diminution of the needs for energy
- diminution of the needs for oil products (as energy supplier or as a source for carbon products)
- preservation of natural resources

Potential to retrofit to existing roads / structures / infrastructure
- Most of the previous items listed can apply for maintenance of existing roads

Comment on applicability to bridges, structures, tunnels
- Low emission products and materials absorbing pollutants can be specially useful for tunnels.
- Low carbon concrete can be used for bridges, tunnels and structures construction

Possible barriers to implementation

The objectives of this work package are global requirements for sustainable development so no barrier is expected in this field.
The massive development of electric vehicle is still questionable especially in non urban areas
The lack of long term validation for all the considered new products and structures is a barrier for large scale implementation. This stage is then compulsory using for example accelerated loading testing facilities.
Nowadays existing competition between “white” and “black” technologies promoters may be a barrier for objective assessment of proposed research projects.
Cost of implementation of the technology will be a barrier, as initially it will be more expensive than current technology, and because long term behaviour cannot be accurately predicted.

B2. Automated Element Work Packages

B2i. Communication Network

Overview on technology status

There is a significant amount of communication and sensor equipment already deployed on the majority of the primary road network in Europe. These report on weather conditions, traffic volume and speed. Additionally, the telecommunications sector keeps developing at a significant pace and there is considerable scope for future development and integration of mobile, wireless and satellite technology into vehicles, which are themselves becoming increasingly sophisticated in their communication and data processing. There have been significant developments in in-car technology enabling autonomous solutions and also in communication technologies that could combine with autonomous solutions to form cooperative systems. In addition, sophisticated traffic models currently exist, although there is potential to further improve their functionality.

Technologies Available for Implementation

There are numerous technologies that are currently deployed on the highway network that monitor traffic flow, traffic speed and weather conditions. This is increasingly being linked to variable speed limits and/or active traffic management and in the short term it is likely that deployment of these technologies will increase. Certain vehicles now have adaptive cruise control and/or active braking that will automatically reduce speed in response to a trigger, such as a vehicle slowing down or a pedestrian walking out in front of a vehicle. Increasing deployment of these technologies over time should enable an increased degree of automation. There is the potential for communication between road side technologies and in-vehicle technologies to optimise infrastructure and traffic management.

Research Requirements

Short to medium term

- *Integration of technologies; this has been addressed by a number of existing projects and requires a review task to prevent duplication*
- *Improved collection & processing of traffic condition data, including data fusion issues to cope with multiple, possibly conflicting, data sources, and also address data aging.*
- *Investigate European potential to build upon USA Freeway merge assistance project, given different management protocols.*
- *Increased V2V communication to inform of speeds and braking. This should acknowledge recent developments in communication (reserving of spectrum for exclusive transport use, definition of 802.11p WAVE protocol) and should consider if an application layer is needed, and if so, does the CVIS/CALM work have relevance?*
- *Investigate what data is really necessary and with which frequency, etc. to limit the data quantity, minimize time loss while transferring and processing the data or to get the relevant information faster*
- *Investigate the potential of a vehicle itself to be a sensor or sensors, and link to infrastructure, other vehicles, control centre and data management.*
- *Understand how existing research into cooperative vehicles research such as CVIS could be incorporated into the 'open roads' vision. Also consider competing technologies such as ETSI ITS Communication Architecture.*

- *Development of Wireless Sensor Networks*
- *Extension of existing Adaptive Cruise Control technologies to include route guidance, covering the requirement for V2V and V2I communications for dynamic guidance, involving review of current and completed projects.*
- *Reduction of speed limits based on incipient congestion detection*
- *Research into vehicle platooning and associated communications requirements*

Long term

- *Ongoing monitoring of the increasing automation of vehicles controlled by lead vehicles or directed by infrastructure, and potential integration into the FOR.*
- *Automation and vehicle platooning are very complex topics with many technical and legal implications and would not be covered within the FOR programme.*

Research techniques and facilities to be made available

The following research items should be considered:

1. Detailed literature review of existing and future technologies and existing projects, both in EU, and worldwide (particularly Japan and US), to cover communications technologies, cooperative systems (e.g. DriveC2X (cooperative systems) TeleFOT (nomadic devices) and vehicle platooning / automation.
2. Comparison of existing technologies and suitability for highway applications
3. Cost-benefit and future cost performance of technologies of interest
4. Review of practicalities of installation / maintenance and compatibility with other Forever Open Road technologies / elements
5. Study tour of automated vehicle research facilities and liaison with auto manufacturers to determine potential and further define research scope.
6. Review of EU legal and planning frameworks for deploying these technologies
7. Real life technology trials, possibly in various countries
8. Reporting and progress meetings
9. Project Management
10. Stakeholder identification and engagement

Research outputs and delivery dates

A report on available technologies and common system requirements could be provided by late 2011 assuming the project was started in January 2011. Track trials could be commenced in early 2012 and completed by the end of 2012. Real life technology trials could commence during spring 2013 with validation and testing ongoing for a further 2 – 3 years.

Benefits of research and how it helps achieve the aims of the Forever Open Road

Automated traffic and vehicle to vehicle and vehicle to infrastructure communication are key elements of the Forever Open Road; this would help achieve these goals. Additionally, automation of traffic could in the future result in far more efficient movement of vehicles, reducing congestion and saving fuel and carbon, which are two further objectives of the Forever Open Road concept. Note that significant research exists in V2V and V2I communications, both in public (CVIS etc) and private (C2CCC).

Potential to retrofit to existing roads / structures / infrastructure

There should be only limited technical barriers to retrofitting the technologies, many of which will be wireless and vehicle based. There would be a requirement for investment plans and the demonstration of a sustainable business case to proceed, accepting that initial implementation costs will be high.

Legal frameworks would need to be established for vehicle platoons / automation, technologies that might capture personal data amongst others.

Comment on applicability to bridges, structures, tunnels

The systems should be applicable to bridges and structures. Depending on the technology chosen, there could be requirements to ensure communications coverage in tunnels.

Possible barriers to implementation

In general there should be no barriers to improved communications systems for road transport systems assuming that information was being collected from roadside sensors. The only major factor would be the cost-benefit of investing in new technology. Vehicle to vehicle and vehicle to infrastructure communication would have a hurdle of the potential requirement to retrofit communication technology to existing vehicles for complete coverage, or gradually introducing the technology as the vehicle park is replaced. There could be some legal challenges to the potential collection of data, i.e. government agencies knowing the location of individuals' vehicles. Whilst the technical barriers should be surmountable, retro-fitting of technologies cannot be assumed possible. The possibility of refusing access to certain infrastructure to unequipped vehicles should be considered. This then raises the issue of how to enforce access to infrastructure. An example would be denying unequipped vehicle access to certain motorway lanes reserved for vehicle equipped for platoon driving. A vehicle attempting to drive on this type of lane could be given an in-vehicle warning; for safety reasons other vehicles using the lanes may need to be warned and actively kept well clear of the unequipped vehicle. Physical access control (e.g. using barriers) is unlikely to be acceptable. There should also be a fallback system in place that would allow necessary (e.g. safety related) access to unequipped vehicles. There are also potential social issues, as in transmission years, only newer vehicles are likely to be equipped for automated driving, raising issues of social exclusion. This would also apply to those disadvantaged in other ways, for example the elderly and those uncomfortable with technology (although technology could also be seen as a benefit helping overcome mobility problems of those with disabilities, for example). A socially-acceptable balance will need to be achieved. Automation of vehicles would face some of the technology maturity and legal issues detailed in the previous paragraph. Additionally there would be legal concerns regarding liability in the event of accidents involving automated vehicles, although this could potentially be mitigated if insurance companies could be convinced that automations of vehicles would be safer. There would potentially be social acceptance / psychological issues for many in handing over control of some or all control to a machine. There is a German project group (technical experts from the automotive industry, legal experts) chaired by BASt focussing on legal aspects of increasing vehicle automation (PG: legal consequences due to increasing vehicle automation). They discuss the issues mentioned here and trigger further studies and projects were necessary (e.g. regarding social / psychological aspects), and contact should be made and maintained.

B2ii. Self Monitoring Road

Overview on technology status

The WP has its main focus on all techniques allowing to collect real time data regarding :

- road surface conditions (temperature, humidity, …)
- structural state (damage, stresses, …)
- traffic data (counting, speed, weight, incidents detection including slowdown)
- Environmental conditions (rain, fog, local fumes, wind, storm…)

On each of these items, some technical solutions can already be implemented immediately. More research is needed on :
- "road surface conditions" to include other characteristics such as evenness, roughness, skid resistance… and allow detection of much localized variations.
- "structural state", for which no existing real time continuous solution exists.
- "traffic data" as regards high precision weight in motion.
- "environmental conditions" as regards much localized events.

More generally, research is needed to integrate these data in Road Management Systems and make them available for users.
A new field of research is the use of car sensors or even more the car as a sensor to collect these data and make them usable in Road Management Systems.

Remark : the present WP is linked to the WP on "in Built sensors", as the self monitoring of roads may use in-built sensors.

Technologies Available for Implementation

It is considered that the in-use techniques referenced below can be implemented immediately or within 12 months.

Monitoring of road surface conditions
- Temperature and humidity sensors and post processing systems allowing to forecast icing levels and salting need.

Structural state (damage, stresses, …)
- Instrumented section on short and specific trial sections dedicated to some given pavement technologies.

Traffic data
- Inducting loops for Weight in Motion, speed, traffic density and composition
- Cameras with post processing software for incident detection including slowdown, speed.
- Instrumented barriers for hit detection

Environmental conditions
- rain sensors
- cameras for rain or fog properties measurement
- meteorological station
- humidity sensors
- sensors for detecting salt content

Research Requirements

What needs to be researched?

Short to medium term

- "traffic data" as regards high precision weight in motion.
- "environmental conditions" as regards much localized events.
- data processing and transfer to users via Variable Message Sign

Long term

- "structural state" assessment via witness sections with in-built instrumentation
- Data processing and transfer to users in cars
- Integration of data in Road Management Systems.
- Use of car sensors or even more the car as a sensor to collect these data and make them usable in Road Management Systems.
- Real time characterization of skid resistance and unevenness as well as detection of localized variations using car sensors, and combination of road surface / environmental conditions and other sensor data.

Research techniques and facilities to be made available

General points on research techniques and note any specific requirements for research facilities

1. Stakeholder identification and engagement
2. Detailed literature review of existing and future technologies
3. Comparison of existing technologies and suitability for highway applications
4. Cost-benefit and future cost performance of technologies of interest
5. Review of practicalities of installation / maintenance and compatibility with other FOR technologies / elements
6. Review of EU legal and planning frameworks for deploying these technologies
7. Set-up of a scientific project and project team
8. Study tour to visit pre-existing installations of certain technologies
9. Lab studies and report results
10. Real life technology trials, possibly in various countries
11. Reporting and progress meetings
12. Project Management

Research outputs and delivery dates

Short to medium term

- High precision weight in motion. Cost- effective system - 2014
- "environmental conditions" as regards much localized events. Risk map and warning via Variable message Sign - 2014
- Data processing and transfer to users via Variable Message Sign. Cost effective system - 2014

Long term

- "structural state" assessment via witness sections with in-built instrumentation – Concept 2014, Demonstrator, 2017.
- Data processing and transfer to users in cars – concept 2014, demonstrator 2017
- Integration of data in Road Management Systems. concept 2014, software demonstrator 2017
- Real time characterization of skid resistance and detection of localized variations using car sensors. concept 2014, demonstrator with communication to cars 2016
- More generally: use of car sensors or even more the car as a sensor to collect these data and

make them usable in Road Management Systems. Cost 1 000 000 €, 8 years, concept 2014, demonstrator with communication to cars 2019

Benefits of research and how it helps achieve the aims of FOR

Expected benefits: - Increased road safety - Optimized traffic flow management - Optimized infrastructure management

Potential to retrofit to existing roads / structures / infrastructure

- All previous items listed can apply on existing roads, especially if there is a massive use of the car sensors to monitor the road - If additional sensors are needed, they can be integrated during maintenance operations (even for structural assessment if witness sections are used).

Comment on applicability to bridges, structures, tunnels

- Applicable to tunnels and bridges, with other and additional technologies to be used especially for structural assessment. - Limited application of "car sensors"

Possible barriers to implementation

- Good Interaction needed between road owners, road managers and car manufacturers, communication operators. - Legal aspect of risk warning in cars (homogeneity of car equipments) - Over cost of sensor equipped vehicles/ search for specialized fleets - Legal aspect of localization of vehicles - Existence of business plan based on win/win strategies.

B2iii. Weather Protection and Warning Systems

Overview on technology status

Weather warning systems: • In use are different sensors systems to determine e.g. fog, slippery roads, moisture and temperature • Various alert systems Weather protection: • Currently in use but only on some test fields are Ground source heat pumps and geothermal energy to heat pavement surface in winter (winter maintenance) and cool in summer (reduce permanent deformation) • In some countries electric energy to heat surface in winter (winter maintenance) and cool in summer (reduce permanent deformation) are in use on field trials • De-icing spraying units are in use on several test tracks for a better winter maintenance • Flood barriers are known in other fields to protect specific industrial or residential sites from flooding • Reservoir pavements are used to prevent flash flooding from rainwater run-off in urban areas

Technologies Available for Implementation

Different sensor systems and alert systems are available for weather warning. In addition, ground source heat pumps and geothermal energy for heating/cooling pavement surface and de-icing spraying units are in status of implementation for weather protection

Research Requirements

Short to medium term:

- Improved accuracy of sensor (e.g. fog, moisture, temperature)
- Improved use of ground source heat pumps and geothermal energy for heating/cooling pavement surface

Long term:

- Storage of geothermal energy
- Combine different sensor technologies
- Implement different technologies in modular system (from adaptable road)
- Development of sustainable, long-life, high quality sensor systems that allows road net with data collection; Test and implementation for various field of usage

Research techniques and facilities to be made available

1. Detailed literature review of existing and future technologies with regard to weather protection, weather warning systems and the detailed influence of climate change on the pavement (e.g. extreme temperature, amount of precipitations)
2. Comparison of existing technologies and suitability for highway applications
3. Cost-benefit and future cost performance of technologies of interest
4. Review of practicalities of installation / maintenance and compatibility with other FOR technologies / elements
5. Review of EU legal and planning frameworks for deploying these technologies
6. Study tour to visit pre-existing installations of certain technologies
7. Real life technology trials, possibly in various countries.
8. Reporting and progress meetings
9. Project Management
10. Stakeholder identification and engagement

Research outputs and delivery dates

- *Heating/cooling of road surfaces:* feasibility – 2010, cost-effective deployment (building of long sections, not only one bridge) – 2013
- *Sensor systems:* feasibility – 2012; development, implementation and Test - 2015
- *Combine different technologies:* feasibility – 2010, cost-effective deployment – 2016
- *Implement different technologies in modular systems (from adaptable road):* feasibility – 2012, cost-effective deployment – 2018

Benefits of research and how it helps achieve the aims of FOR

Weather protection:
Temperature controlled surfaces would help prevent cracks and permanent deformations because of the predicted temperature increase of climate change as well as winter maintenance including salting – will prevent maintenance measures as well as congestion.
Flood barriers could enormously decrease the amount of maintenance e.g. at extreme amount of precipitation.

Weather warning system:
Results are basic conditions to allow a road to be an intelligent road with data on environment and status of road parameters. Future applications can be developed on that basis. The warning

system is necessary for all systems of weather protection.

Within FOR this work package is of interest for in-built sensor systems, in-build energy harvesting, heat transfer for intermediate use and storage

Potential to retrofit to existing roads / structures / infrastructure

Weather protection system:
Technologies (e.g. Temperature controlled surfaces) which need to implemented in one of the layers or in the infrastructure – can be retrofitted while reconstruction. Maybe the developed flood barriers could retrofit to existing roads.

Weather warning system:
Today's sensor could be retrofitted with negative effects on road surface in some cases. Best benefits are expected in case of installation during road maintenance/reconstruction.

Comment on applicability to bridges, structures, tunnels

Special considerations are needed for the expansion joints of bridges when using a bridge deck heating/cooling system

Possible barriers to implementation

Weather protection:

- Legal: usage of geothermal energy, concerning the drilling depth and/or ground water use
- Costs: construction costs will be high but the maintenance cost decrease by reason of extreme amount of precipitation and high temperature depends on climate change
- Economic: (Temperature controlled surfaces) at beginning the new technologies will be inefficient, but due to energy harvesting and the usage for road infrastructure less maintenance will be needed
- Political: enforce the usage of renewable energy – therefore this is no barrier

Weather warning system:
The need of sensor systems and data is widely accepted. Improvements in technology should address cost, political, economic, social and legal aspects, which depend on field of application.

B3. Climate Change Resilient / Environmental Work Packages

B3i. Porous Light Reflecting Surfaces

The Work Package "Porous light reflecting pavement surface" has its main focus at noise reduction. The other issues are light reflection, spray water and cleaning. Storm resistance and pavement construction are covered in more detail in separate work packages.

On the field of noise reduction many technologies have already been developed and are implemented, sometimes in the top layer, sometimes in the form of noise barriers. As traffic noise is still an issue, (because of the costs and the impact of noise barriers) there is much interest in improving the noise reduction of the top layers, both for the short and the longer term.

Technologies Available for Implementation

Traffic noise reduction can be achieved by using two layers porous asphalt, low noise surfacings, ModieSlab (with restrictions) and also noise barriers (modular or with topping).
Low spray asphalt (PA and two layers) and drainage systems are available technologies.
Special coatings (titanium dioxide TiO_2 can cause pollutants to be broken down on noise barriers.
High albedo reflection top-layers are in at the edge of implementation (short term trial stage)

Research Requirements

<u>Short to medium term:</u>
Several self cleaning technologies (porous asphalt or road objects) are in development.
An Acoustic Optimization Tool is in further development.
Two-layer porous cement concrete (e.g. ModieSlab) is getting available for trials and implementation (see before).

<u>Long term:</u>
Many (sometimes complex) technologies aimed at a further reduction of noise are under in development: e.g. honeycomb constructions, Helmholtz, membrane under porous top-layer, a carpet system and rubber.
More recently there have been developments in the field of PERS (poro elastic road surface).
Self cleaning technologies using glass and bitumen coating;
A cement technology that absorbs CO_2.

Research techniques and facilities to be made available

the following points might be considered:

1. Stakeholder identification and engagement
2. Detailed literature review (desk-study)
3. Comparison of existing technologies
4. Cost-benefit analysis
5. Review of practicalities
6. Review of EU legal frameworks
7. Set up of a project team
8. Study tour
9. Lab-studies and report results
10. Find interested parties and financing
11. Real life technology trials (sometimes in various countries)
12. Report results
13. Communication
14. Project management

Research outputs and delivery dates

<u>Short to medium term:</u>
In the short term, two layer porous cement concrete and ModieSlab and also high albedo reflecting surfaces could become ready for implementation.
Self cleaning technologies could become available in 2013/2014.

<u>Long term</u>
Advanced noise reduction technologies (e.g. PERS) can become ready for deployment between 2015 and 2020
This also applies for further self cleaning technologies and carbon absorbing pavements.

Benefits of research and how it helps achieve the aims of the Forever Open Road

The results of the research in this work package leads to a further reduction of traffic noise by measures in the road surface (reducing the necessity for noise barriers). Furthermore porous light reflecting surfaces help to reduce lighting energy (and maintain or even improve traffic safety).
As climate change may cause heavier rain downpours, low spray and drainage measures can help to keep roads accessible. (This package should be combined with the task “weather protection and

weather warning systems”).

Potential to retrofit to existing roads / structures / infrastructure

Most technologies can be applied to existing roads (at a moment of maintenance).

Comment on applicability to bridges, structures, tunnels

Most technologies can be used on bridges; some technologies are only applicable in situations with porous asphalt and therefore unsuitable for tunnels.

Possible barriers to implementation

Measures to reduce traffic noise in itself are widely accepted. Depending on the technology the construction and maintenance costs and political, social and legal aspects should be addressed. Some technologies have higher construction costs and lower maintenance costs therefore integrated budgets are necessary.

B3ii. Roadside Lighting and Signs

Overview on technology status

The specific technology considered is that of LED lighting rather than conventional lighting, and specifically where the lights could be integrated into the pavement for lane marking and driver information. This was one area where numerous existing technologies existed and none where short to medium term R&D was identified, with just one area recognised for long term research.

Technologies Available for Implementation

What tasks can be implemented immediately or within 12 months? There are a number of technologies that could be implemented immediately including LED cats eyes, LED streetlights, LED signs and low voltage and / or solar powered. Advances in LED lighting technology generally, and lower operating costs will see increased use of LED technology in road lighting and signage generally.

Research Requirements

Short to medium term There were no short term goals identified. *Long term* There were two long term areas of research identified; one was the development of adaptive lighting depending on road conditions, the second was the Solar Roadways project in the USA. It is suggested that the research should focus on understanding the potential of integrating LED lights into standard pavement surfaces, and assessing the potential for a network of lights for lane marking and driver information. It is not proposed to investigate streetlights, but the potential of uplighting will be considered.

Research techniques and facilities to be made available

General points on research techniques and note any specific requirements for research facilities The task envisaged for this area of research are as follows. 1. Detailed literature review of existing and future lighting systems and cats-eyes lighting systems 2. Site visit(s) to pre-existing installations of LED cats eyes 3. Comparison of existing technologies and suitability for highway applications 4. Review of practicalities of installation / maintenance and compatibility with other Forever Open Road technologies / elements

5. Review of EU legal and planning frameworks for deploying these technologies
6. Stakeholder identification and engagement, likely to include LED manufacturers, cats-eyes manufacturers, ICT specialists and road operators.
7. Identification of power requirements and networking potential, particularly the potential for renewable power (e.g. solar or piezo) and wireless networking
8. Identify potential for up-lighting and any disadvantages
9. Simulator studies to determine driver acceptability to active road surface lighting and active traffic management.
10. Track trials of various configurations to determine optimum solution
11. Real life technology trials, possibly in various countries to determine performance and acceptability.
12. Reporting and progress meetings
13. Project Management

Research outputs and delivery dates

Assuming research was started in January 2011, it would be possible to have a working trial on a track by October 2011, and a full scale trial possible in the summer of 2012. The outputs would be the demonstration of the technology in terms of provision of active traffic management capabilities, and a review of in-service performance, limitations and options for improvement.

Benefits of research and how it helps achieve the aims of the Forever Open Road

Successful development and deployment of the technology would assist in potentially lowering the cost of lighting and reducing carbon, assist in traffic management to ease congestion and improve safety and through increased acceptance of traffic intervention, help pave the way for further interventions such as automated driving. It will also improve sensor and communications technology for infrastructure to vehicle and vehicle to vehicle communication.

Potential to retrofit to existing roads / structures / infrastructure

There should be no impediment to retrofitting to any existing structures, although techniques for doing so quickly, efficiently and safely will require development. The timing of retrofitting, especially if cabling is necessary, would require consideration.

Comment on applicability to bridges, structures, tunnels

Some consideration should be given to the depth of installation for bridges. For tunnels, solar power would not be an option. There would however be the potential to integrate lighting into the sides and roofs of a tunnel.

Possible barriers to implementation

The benefits of this technique in terms of whole life cost would require consideration. There may be some issues of uplighting in terms of light pollution in non-urban areas, whilst careful consideration would be required to ensure the lights were not distracting, and that they conveyed sufficient, but not excessive information for drivers.