FOX AND USE-IT: HARMONIZED AND INTEROPERABLE TRANSPORT INFRASTRUCTURE ACROSS ALL TRANSPORT MODES

Thierry Goger and Miglė Paliukaitė
FEHRL - Forum of European National Highway Research Laboratories,
Blvd. de la Woluwe 42 bte 3, B-1200 Brussels, Belgium
thierry.goger@fehrl.org; migle.paliukaite@fehrl.org

Caroline Evans
ARRB - Australian Road Research Board,
500 Burwood Hwy, Vermont South, VIC 3133, Australia
caroline.evans@arrb.com.au

ABSTRACT

Increasing mobility needs, technologic advance, as well as the EU policy and strategic vision for future transport sector lead to the more integrated transport system where transport modes are fully interoperable and cooperative in terms of infrastructure and customers. Paper presents holistic and cross-modal approach for further development of efficient European transport system. Two international projects (FOX and USE-iT) are oriented to investigate common needs and challenges between the transport modes and develop a highly efficient and effective cross-modal R&D environment, where involvement of the four transport modes helps to determine the state-of- the-art in research and practice and identify the most promising practices and solutions. Best practices and technological solutions from different transport modes in the areas of transport infrastructure construction, maintenance, inspection, recycle and reuse, user information, safety and security, energy and carbon were gathered, analysed and evaluated according their potential to be implemented cross-modally (at least two transport modes).

KEYWORDS: cross-modal, technologies, transport infrastructure, transport modes**.**

1. INTRODUCTION

Efficient transport infrastructure is a fundamental requirement for the connectivity of people and goods in Europe, and forms the basis for economic growth, competitiveness and territorial cohesion. In general, the transport network in Europe is of a high standard, however is still fragmented regarding both its geographical distribution and co-operation between the transport modes.

In recent years, first networking activities and exchange of strategic programmes among the stakeholders of the four transport modes – road, rail, water and air – are noticed but still a mono-modal, monodisciplinary culture exists. In the light of the future challenges, e.g. increasing transport demand, ageing infrastructure, changing climatic conditions, it is inevitable to strengthen the collaboration of the single transport modes in order to create an improved future integrated and functioning transport system for Europe.

In 2013, the four-transport research advisory councils covering road, rail, air and waterborne modes, along with the European Construction Technology Platform (ECTP) published a cross modal research roadmap, establishing a desire to work together and share experience.

In parallel, from 2010, FEHRL had been developing the Forever Open Road (FOR) concept and it became apparent that many of the challenges faced by the road industry such as increased traffic loads, ageing infrastructure and constrained budgets were also common to other modes.

As a result of FOR and with reference to the cross modal research roadmap, the FORx4 (Forever Open Road, Rail, Runway and River, 2013) initiative was developed and the cross-modal research roadmap was used as the basis for FEHRL's FORx4 document produced in November 2013. FORx4 proposes that the four transport modes will have four shared domains, comprising "Infrastructure", "Governance", "Technology" and "Customers".

As a result, two international projects USE-iT and FOX were influenced strongly by FORx4 programme, with FOX largely covering the infrastructure domain across all four modes and USE-iT covering customers, technology and governance in various areas. Both projects will feed into the ongoing FORx4 programme with FEHRL using the results to help further develop the vision, through the development of a full roadmap.

The vision for the FOX and USE-iT projects is to better understand the common challenges experienced across transport modes, bring representatives of transport modes together to share experience and skills and to develop a set of common research objectives. In the longer term, the ambition is that there will be a vibrant community of stakeholders from a range of transport modes, sharing experiences and technologies, undertaking joint research projects and creating a European transport network that is safer and more secure, produces lower carbon emissions, and which is focused on user needs. The vision will be implemented by creating research roadmaps, gaining endorsement for these and finally from developing a business plan that will enable the longer term vision outlined above to be realised (Figure 1).

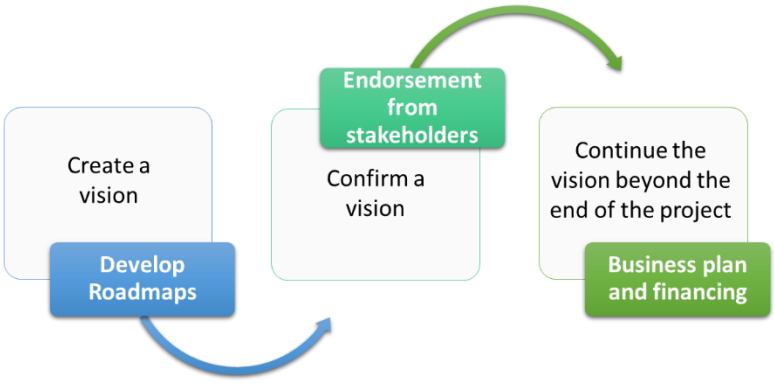


FIGURE 1 Implementing project vision

2. FOX AND USE-IT PROJECTS

Transport sector across Europe faces challenges (e.g. carbon reduction targets, energy, safety, security, and depletion of natural resources without sacrificing its efficiency and compromising mobility) that are common to all transport modes. There is a considerable geographical, technical and mode-wise fragmentation in existing transport network. Existing road and rail infrastructure is ageing rapidly and require renewal. Advances in sensors and mobile communications, smart ticketing and 'big data' influence the development of transport system offering the potential for customers to become an active part of the transport operations system and have the information to make decisions and for freight operators to have more resilience and better reliability in their systems. Social challenges (e.g. mobility and connectivity needs, air and noise pollution) are

more and more related from the transport and need to be tackled. It is necessary to identify the potential and develop the functionality of all transport modes to form a holistic transport system for the future (Figure 2).

These are the main challenges that FOX and USE-iT projects are dealing with. Projects will help to create an improved future integrated and functioning transport system for Europe and facilitate cooperation between infrastructure owners, transport operators and other stakeholders in the road, rail, water and air sectors ensuring the continuity and reinforcement of networking among stakeholders by defining a cross modal approach. FOX and USE-iT ensures the continuity and reinforcement of networking among stakeholders in the road, rail, water and air sectors by defining a cross-modal approach in the areas of construction, inspection, maintenance and the recycling and re-use of transport infrastructure. This will be achieved by the identification of common needs and innovative techniques, as well as the establishment of mechanisms for the necessary cooperation between the modes in the future.

Both projects are coordination and support action type projects and form a project cluster which is focused to develop multidisciplinary and multimodal research culture, foster modernization and harmonization of existing transport infrastructure and integrate all transport modes into one sustainable and highly efficient mobility system. Projects will bring together key stakeholders to create new forms of cooperation that will facilitate the exchange of knowledge, experience, information etc. across the four transport modes.

FIGURE 2 FOX and USE-iT transport modes and domains

Project coordination and cooperation

The membership of FEHRL comprises over 30 national research and technical institutes from across Europe. Associates from non-European countries provide FEHRL with strong links to the considerable research capacity available globally. FEHRL's mission is to promote and facilitate collaboration on road research and provide high quality information and advice on technologies and policies related to roads.

The main objectives of FEHRL are to:

- provide scientific input to European and national government policy on highway engineering and road transport matters
- create and maintain an efficient and safe road network in Europe

- encourage innovation in the European road construction and road user industries
- improve the energy efficiency of highway engineering and operations
- protect the environment and improve quality of life.

The FOX program involves joint collaboration between FEHRL's European transport research institutes. The concepts underpinning the FOX project have been separated into key areas of analysis. The respective work package leaders are as follows:

- WP1 – Project Management (FEHRL, Belgium) – covers administrative and technical coordination
- WP2 – Construction (IFSTTAR/France) – aims to identify construction methods which could be applied to at least two transport modes
- WP3 – Maintenance (BASt/Germany) – aims to identify new technologies and modular precast components, which have the required in-use properties, in a cost-effective way and to optimize maintenance methods
- WP4 – Inspection (ZAG/Slovenia) – aims to increase the use of new inspection methods for existing and new infrastructure
- WP5 – Recycling and re-use (TNO/The Netherlands) – aims to decrease energy consumption and the use of natural resources in construction and maintenance
- WP6 – Dissemination and exploitation/implementation (FEHRL, Belgium) – ensures that FOX's outcomes are widely disseminated to the appropriate target stakeholder audiences, at the appropriate time, via appropriate tools, and that those who can contribute to their exploitation can be encouraged to participate.

Similarly, for the USE-iT project, it involved respective work package leaders from:

- WP1 – Project Management (FEHRL, Belgium) – covers administrative and technical coordination
- WP2 – User Information (IBDiM, Poland) – aims to investigate how the customer can become an active part of the transport planning process through sharing and receiving data with transport operators and across modes.
- WP3 – Safety and Security (AIT, Austria) – aims to understand how operators and owners can enhance and reinforce safety and security operations and procedures.
- WP4 – Energy and Carbon (TRL, United Kingdom) – aims to understand how owners and operators can lower the carbon intensity of their operations, assess the potential to harvest energy from their infrastructure and alternative fuels infrastructure.
- WP5 – Dissemination and exploitation/implementation (FEHRL, Belgium) – ensures that FOX's outcomes are widely disseminated to the appropriate target

FOX – Forever Open infrastructure across (X) all transport modes

FOX (Forever Open Infrastructure across (X) all transport modes) is a 30-month Horizon 2020 Coordination and Support Action (CSA) project under H2020 topic of MG-8.1b-2014 - Smarter design, construction and maintenance.

The aim of the FOX project is to develop a highly efficient and effective cross-modal research and development (R&D) environment and culture to meet the increasing requirements of transport and connectivity of people and goods. Main objectives of the FOX project are:

- Contribute to the common cross-modal development of the transport sector.
- Strengthen the culture of partnership among operators in the various transport modes.
- Establish the broad scope of partnerships and cooperation in the transport sector.
- Identify common needs and opportunities for further co-modal development and implementation.

The FOX project involves a network of stakeholders from the different modes. It sets the agenda for the further improvement of cross-modal research development innovation, as well as the demonstration and implementation of the results. In order to reach this goal, a phased approach has been developed, which includes three steps in the project:

- State-of-the-art research methods across the four transport modes
- Identification of most promising methods in cross-modal development
- Roadmapping for the future research development and implementation initiatives methods across the modes.

FOX will therefore ensure the continuity and reinforcement of networking among stakeholders in the road, rail, water and air sectors by defining a cross modal approach in the area of construction, inspection, maintenance and recycle & reuse of transport infrastructure. This will be reached by the identification of common needs and innovative techniques, as well as the establishment of mechanisms for the necessary cooperation between the modes in the future.

USE-iT – Users, Safety, Security and Energy in Transport Infrastructure

USE-iT (Users, Safety, Security and Energy in Transport Infrastructure) is a 24-month Horizon 2020 Coordination and Support Action (CSA) project under H2020 topic of MG-8.2b-2014 - *Next generation transport infrastructure: resource efficiency, smarter and safer* call.

USE-iT builds on the FORx4 methodology in which the four transport modes (road, rail, water and air) were merged with the four shared domains (infrastructure, technology, governance and customer) to form a holistic transport system for the future.

The aim of USE-iT is to better understand the common challenges facing transport modes and in conjunction with stakeholders to produce a multi-modal research roadmap to develop technologies and approaches to addressing these challenges.

The project will draw upon the experience gained from the Joint European Transport platform with the focus on infrastructure operations, and will also focus on research objectives presented in the FOR - Forever Open Road programme and the work of the FORx4 - Forever Open Road, Railway, Runway and River – A Cross-modal transport initiative for research initiated by FEHRL (Forum of European Highways Research Laboratories).

USE-iT examines common challenges across the FORx4 domains and modes, identifying potential areas for transferring good practice and potential future areas for collaborative research. The specific objectives are to:

- Understand the state of the art in three technical areas: user information; safety and security; energy and carbon; across all four modes.
- Determine opportunities for the transfer of knowledge and working practices across modes
- Develop common future research objectives covering at least two modes
- Bring together infrastructure owners, operators and other stakeholders from across the transport modes to facilitate knowledge transfer and develop a network for future co-operation
- Develop a Roadmap describing the research challenges and implementation steps to achieve greater cooperation and co-modal operations in the areas covered by the project.

1. Methodology

A large number of partners covering all transport modes from various EU countries participated in the FOX and USE-iT projects. First task was to scan the existing literature to perform preliminary investigation of the state-of-the-art of Research, Development and Innovation (R&D&I) across all four modes of transport, following with the preliminary investigation across the domains:

- **Infrastructure**. The transport network formed from Europe's routes and interchanges; the changes required in construction in maintenance, and the specifications used, set in the context of how the network will be used across the modes, how it can be adapted for future use, and the understanding of the human factors and the technology that will be involved.
- **Technology**. The information, communications, sensor and power systems that will support the future transport network, and also the integration of different technologies and shared systems that will underpin the transformation of the transport network to allow common timetables, journey time reliability and planning, common ticketing across modes, regions and countries.
- **Governance**. The management, operations, investment and appraisal of the network. There will need to be a transformation from the status quo, as infrastructure management will need to be integrated geographically and across modes with the development of shared systems and processes with focus on overall network capacity and operation.
- **Customer**. The most important, and yet often forgotten element of our transport system. Customers, whether they are individuals, transport companies or freight movers have to pay regardless of modes though tickets, fuel, taxes and duties. Linked to the Governance domain will be an understanding of their motivation for travelling and mode choice in order to implement policy interventions to support political objectives, such as for example promotion of active travel or modal shift.

Figure 3, identifies three steps, which includes: a state-of-the-art review of each work package method across each of the four transport modes; the identification of the most appropriate methods which could be applied on a cross-modal basis or for at least two transport modes; roadmap for the future research development and implementation of initiatives across each mode. During the first phase (state-of-the-art) analysis, best practices and technologies or methods with high potential for cross-modal application in construction, maintenance,

inspection, recycle & reuse, user information, safety, security, energy & carbon areas were identified. State-of-the art analysis helped to identify most promising methods and technologies that can be applied for at least two transport modes and to roadmap the transfer of methods with high potential for cross-modal application, including necessary additional R&D&I development and implementation strategy. This state-of-the-art analysis was the first step, and involved an expert elicitation process whereby experts and scientists across different modes were contacted in order to combine the best practices and methods associated with each mode. To achieve this, it was necessary to establish a communication with the FOX project partners in Germany, the Netherlands, Slovenia, France, FEHRL and other third parties such as Lithuania, Austria and Australia. On the basis of input provided by the partners, and an extensive literature review, a list of reports, guidelines and regulations was created relating to each of the four transport modes. A preliminary assessment of the submitted publications was made which potentially provided a possible use for applications in other transport modes.

Following this initial assessment, the information was then further analysed in the second stage. This involved a short description of each proposal with a view to classifying the documents into four categories (design method, technology, model, and guideline) and identifying possible future transport modes. This required the identification of the most relevant candidates for inclusion in the state-of-art review after the assessment criteria were defined in accordance with the main objectives of the project. In this stage, a common template was created and distributed to the consoritum partners. This template focused specifically on identifying methods with high potential for cross-modal application. This assisted in the process of selecting the most promising concepts for application on a cross-modal basis, and the identification of the state-of-the-art best practices methods across each work package area. Input was also provided from the Australian Road Research Board (ARRB) in the development of this deliverable and subsequent phases of the projects (Figure 3).

In supporting the outcomes of these projects, it is recognised that stakeholder's engagement is of critical importance. In order to enhance each phase of these projects, the consultation entailed:

- A survey process to seek preliminary input to support the identified concepts and areas
- 1st FOX and USE-iT workshop to seek stakeholders' input regarding the preliminary investigation across modes and domains-technologies
- Interviews to conduct with the key stakeholders in national languages to seek more in-depth input
- 2nd FOX and USE-iT workshop to seek input regarding the common research challenges

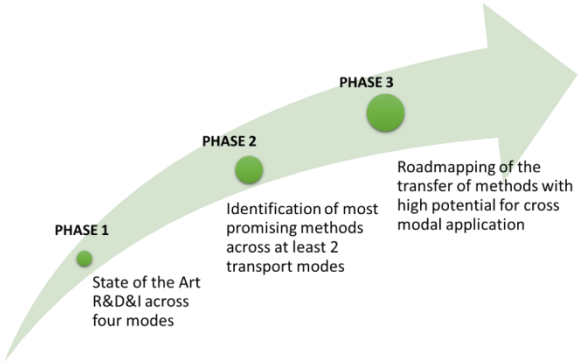


FIGURE 3 Three phases of USE-iT FOX

2. Challenges

There are significant synergies within FOX and USE-iT projects, e.g. security has user acceptance implications or construction and maintenance might use similar products or processes. In addition, there are overlaps across the projects too, such as reuse and recycling in FOX and energy and carbon in USE-iT having numerous common aims.Over the course of the USE-iT and FOX projects, a significant number of technologies have been identified, which were validated and improved with stakeholders' interviews and stakeholders' workshops. These technologies were then prioritised by the partners, along with further interviews and a 2nd FOX and USE-iT stakeholders' workshop. A prerequisite was that each challenge covers at least two transport mode, resulting in a total of 42 challenges identified across the three technical work packages in USE-iT and the four technical work packages in FOX. The challenges have been mapped against nine 'Drivers' that are relevant to Europe's transportation system. For each research challenge, a headline 'from-to' statement detailing the current state and the desired future state, should the research topics identified within each research challenge be successfully undertaken, with an indicative timescale of 2017 to 2030.

Each individual research topic was mapped against the FORx4 modes (road, rail, air, water and multimodal) and domains (governance, infrastructure, technology and customer) and also the 'level of application' identified in the REFINET project determining the area in which a particular research challenge is most applicable, namely; urban mobility, long distance corridors, multi-modal hubs and a system level (widely applicable in transport infrastructure). Icons were developed for simplicity of reading

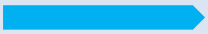
In addition to the modes and domains identified in the FORx4 programme, the challenges have also been mapped against 'level of application' identified in another CSA project REFINET (REthinking Future Infrastructure NETworks) project covering urban areas, long distance corridors, hubs and system level approach. For simplicity of reading, icons have been developed for modes, domains and level of application as shown in the Table 1 below.

TABLE 1 Modes, Domains and Level of application icons applied in the project

Mode		Domain		Level of application	
	Road		Technology		Urban mobility
	Rail		Infrastructure		Long-distance corridor
	Water		Governance		Multi-modal Hubs
	Air		Customer		System level
	Multi-modal				

In addition to the domain symbols, there is an indicative timeline for the research challenges covering the period 2017 to 2030+ with arrows to demonstrate the stage of development related to Technology Readiness Levels (TRL) as shown in the Table 2 below.

TABLE 2 Key for timescale and level of development

Technology Readiness Level	Development Stage	Symbol
≤ 5	Research and Development	
6 – 8	Demonstration	
9	Market introduction and implementation	
Already implemented	Transferring mature technology from one mode to another	

3. Drivers influencing co-modal transport research

Societal developments and the challenges they bring should drive research priorities, so researchers need to predict and meet the future needs of society. This initiative aims to identify the challenges facing the transport sector and suggest how research can help to address these challenges and create an improved future integrated and functioning transport system for Europe.

Therefore, nine 'Drivers' influencing co-modal transport research were identified:

1. Change in transport demand
2. Globalisation
3. High costs of operation and use
4. Ageing infrastructure
5. Scarcity of natural resources
6. Decarbonisation of transport and environmental and social impact
7. Safety
8. Security
9. Rapid development of technology and social behaviour

This paper describes only two 'Drivers' ('Change in transport demand' and 'Ageing infrastructure') and the expected challenges.

Change in transport demand

Transport demand in Europe has been increasing annually across all modes, with the largest increases in road and air travel. Passenger transport and freight demand have grown as well. This is being driven by changes in: demographics, economics, social factors, travel costs and new technologies (Truly integrated transport system for suistainable and efficient logistics, 2017).

The increase in transport demand presents a major challenge. The cost of building additional infrastructure is high; construction is not always possible due to lack of land and it can exert high social and environmental impacts. Research areas include methods of reducing the costs and impacts associated with construction and exploring methods of expanding the capacity of existing infrastructure, and managing demand.

Many of the work packages in USE-iT and FOX impact on changes to travel demand, such as new types of construction, maintenance and inspection in FOX, and user information giving people the information they need to make multi-modal journeys, and new concepts in safety and

security as well as the reduction in carbon which is a key consideration for governments and society, particularly moving to lower carbon and active travel modes.

The first key challenges are identified in **Error! Reference source not found.** and relate to predictable performance for people and goods and will seek to provide reliable information. There is also a link to the influencing travel choices challenge identified in the decarbonisation driver. There are challenges around decision support tools, user origin-destination data and real time measurements as detailed in the figure. What is particularly noticeable is that most of these technologies already exist in each individual mode, and the task here is to harmonise this for multi-modal transport to make best use of the 'network of networks'. As such, there is a relatively short Research and Development (R&D) phase followed by demonstration with deployment indicated to be possible by the late 2020s.

Similar to the research challenges identified for predictable performance for people and goods, another way in which the transport system could be readily improved is through greater cooperation and coordination between transport mode operators. Currently, much of the public transport is fragmented with public or private operators on the same or different modes offering competing services without integration.

Once there is improved integration of systems and data harmonisation between transport operators, there is the potential for large gains to be made by enabling connected and seamless traffic. At this stage, there is a requirement to provide multi-modal information platforms for passengers and freight, to provide uniform tariffs and single tickets and enable mobility as a service.

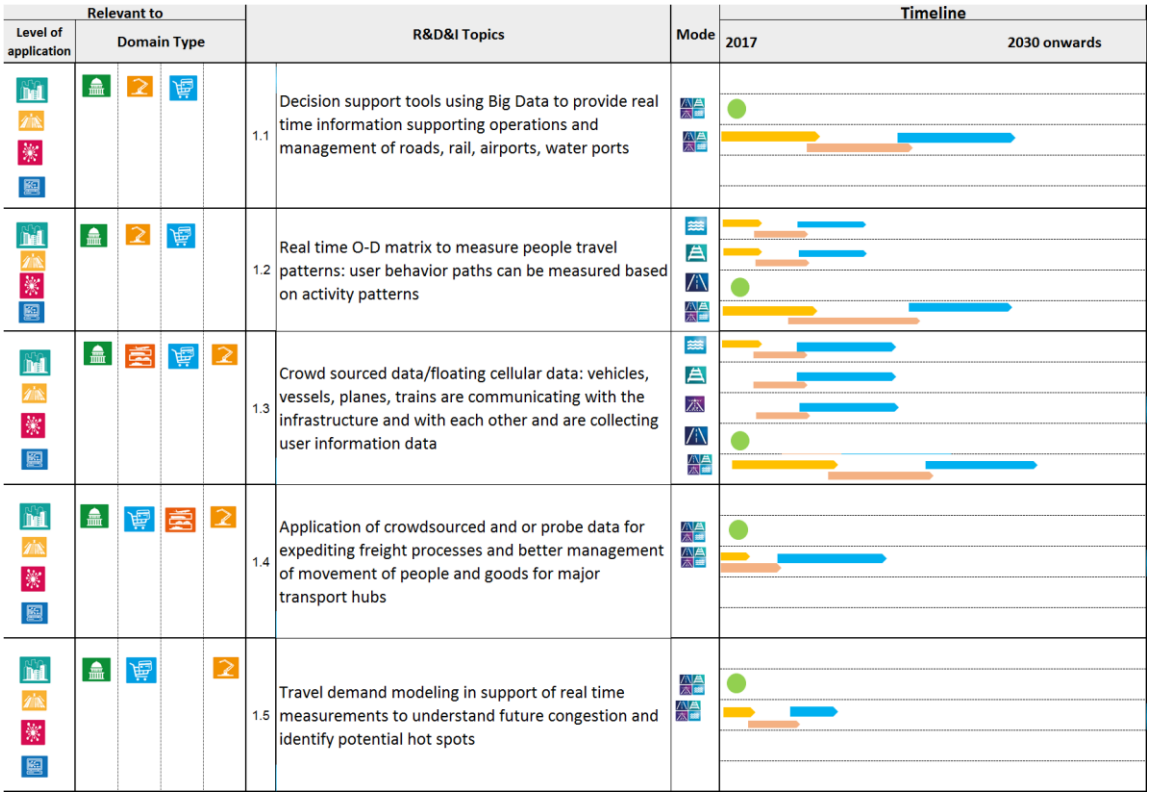


FIGURE 4 Predictable performance for moving people and goods

Ageing infrastructure

The condition of the transport infrastructure throughout Europe varies greatly. Some regions have largely complete and well maintained networks; while some regions have ageing networks that need cost-effective and large-scale maintenance treatment. Conversely, some regions are still developing their infrastructure networks, and cost-effective solutions to design and construct new infrastructure are therefore desirable in these areas. More of some types of infrastructure such as high speed rail is being constructed.

Extreme weather events and the long-term effects of climate change, together with increasing traffic loads will put further strain on Europe's infrastructure, and will require adaptation solutions. Solutions will need to cover the development of cost-effective solutions for design, construction and maintenance of new and existing infrastructure.

There are a number of research challenges identified in topic that could also help with ageing infrastructure, particularly those regarding remote sensing and smart sensors and smart materials that can provide high quality information regarding the performance of infrastructure, potentially confirming that it is safe to keep operating beyond its design life, to give evidence as to any potential upgrade that might be required, or to determine that it is unsafe for certain categories of vehicles.

Materials and structures that are longer-lasting not only address issues regarding the high cost of operation, but also help extend the life of today's aging transport infrastructure and help it adapt to future changes in transport demand, extreme weather events and climate change. It will also help new construction or reconstruction last longer, reduce whole life costs and improve safety and service levels. Maintenance operations can be optimised regarding costs and frequency of maintenance measures by developing long-lasting, energy-efficient and self-healing materials taking into consideration the latest technical developments (Figure. 5).

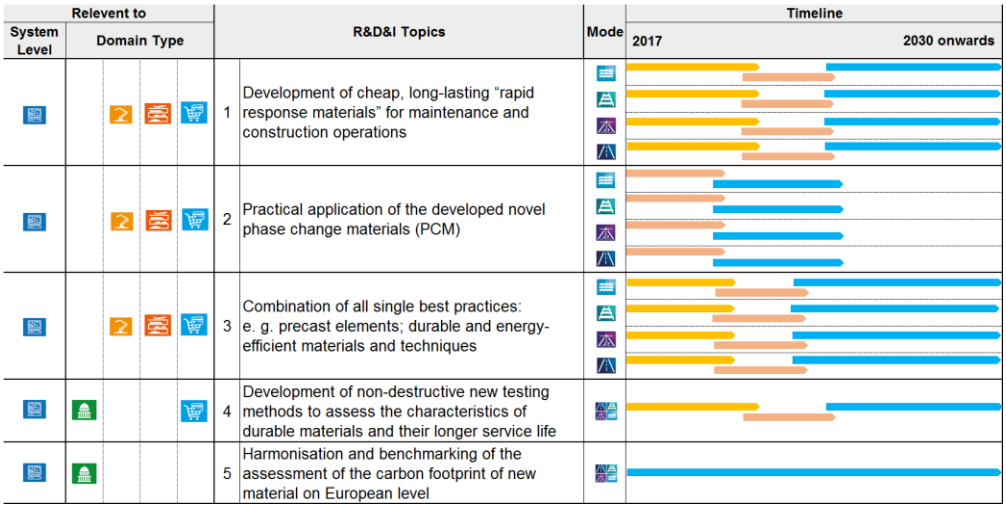


FIGURE 5 Durable and energy efficient materials

4. CONCLUSIONS

The USE-iT project has now been completed, and FOX will be finished at the end of October 2017. These projects are intended to assist in setting the agenda for the further impovement of cross-modal research development and innovation technques across all modes of the the transport sector. The main findings are as follows:

1. State-of-the art analysis helped to identify most promising methods and technologies that can be applied for at least two transport modes and to roadmap the transfer of methods with high potential for cross-modal application, including necessary additional research, development and implementation strategy.
2. The USE-iT and FOX projects have identified 42 research challenges, covering construction, maintenance, inspection, user information, safety and security, energy and carbon and reuse and recycling. All challenges cover at least two modes and have been mapped against the four domains of FORx4 (infrastructure, technology, governance and customers) and against the four levels of applications identified in the REFINET project (urban mobility, long distance corridors, multi-modal hubs and system level).
3. The challenges have been mapped against nine 'Drivers' that are relevant to Europe's transportation system: change in transport demand; globalisation; high costs of operation and use; ageing infrastructure; scarcity of natural resources; decarbonisation of transport and environmental and social impact; safety; security; rapid development of technology and social behaviour.
4. The outline research programme for the challenges has been proposed between 2017 and 2030 and beyond and identified according to Technology Readiness Level (TRL) levels of ≤ 5, 6-8 and 9.
5. FOX and USE-iT projects have developed a clear vision for the future of cross-modal research and development, and a network of stakeholders from across the modes remaining active beyond the end of the project.

REFERENCES

1. Forum of European Highway Research Laboratories (FEHRL). The Resilient Road. A Roadmap for Research 2017 update. An element of the Forever Open Road Programme, April 2017.
2. Forum of European Highway Research Laboratories (FEHRL). Strategic European Road and cross-modal Research and implementation Plan. 2017-2020.
3. Forum of European Highway Research Laboratories (FEHRL). FORx4 – Forever Open Road, Rail, Runway and River. A co-modal transport initiative for research. ISBN 9789491749056. Brussels, 2013. 28 p.
4. Forum of European Highway Research Laboratories (FEHRL). The Adaptable Road. A Roadmap for Research. An Element of the Forever Open Road. Brussels, 2013. 24 p.
5. Forum of European Highway Research Laboratories (FEHRL). The Automated Road. A Roadmap for Research. An Element of the Forever Open Road. Brussels, 2013. 32 p
6. European Technology Platforms (ETP) – ACARE, ALICE, ERTRAC, ERRAC, Waterborne, ACARE. A roadmap for a truly integrated transport system for suistainable and efficient logistics, 2017.
7. European Road Federation (ERF). Road Asset Management. An erf position paper for maintaining and improving a sustainable and efficient road network. Brussels, 2014. 24 p.
8. European Commission. WHITE PAPER. Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system. Brussels, 28.3.2011, COM (2011) 144 final. 31 p.
9. H2020 Transport Advisory Group. Consultation of the Horizon 2020 Advisory Groups, Response of the Transport Advisory Group. 2014. 23 p.