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REthinking Future Infrastructure NETworks

REFINET

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Abbreviations

Acronym	Full name
CSA	Coordination and Support Action
SIP	Strategic Implementation Plan
CEF	Connecting Europe Facility
EU	European Union
ERTRAC	European Road Transport Research Advisory Council
ERRAC	European Rail Research Advisory Council
ACARE	Advisory Council for Aviation Research
ECTP	European Construction Technology Platform
ALICE	Alliance for logistics Innovation through collaboration in Europe
HLSI	High Level Service Infrastructure
RMMTI	Refinet Multimodal Model for Transport Infrastructure
STA	Smart Transportation Alliance
S2R	Shift to Rail
LDT	Long distance transport
GHG	Greenhouse gas
CEDR	Conference of European Directors of Roads
FEHRL	Forum of European National Highway Research Laboratories
ERTMS	European Rail Traffic Management System
ITS	Intelligent Transport System
TIIM	Transport Infrastructure Information Modelling ()
SHM	Structural Health Monitoring
BIM	Building Information Modeling
BOT	Build-Operate-Transfer
PPP	Public Private Partnership
LOS	Level of service
KPI	Key Performance Indicator

MOT	Ministry of Transport
PM	Particulate Matter
NZTA	New Zealand Transport Agency

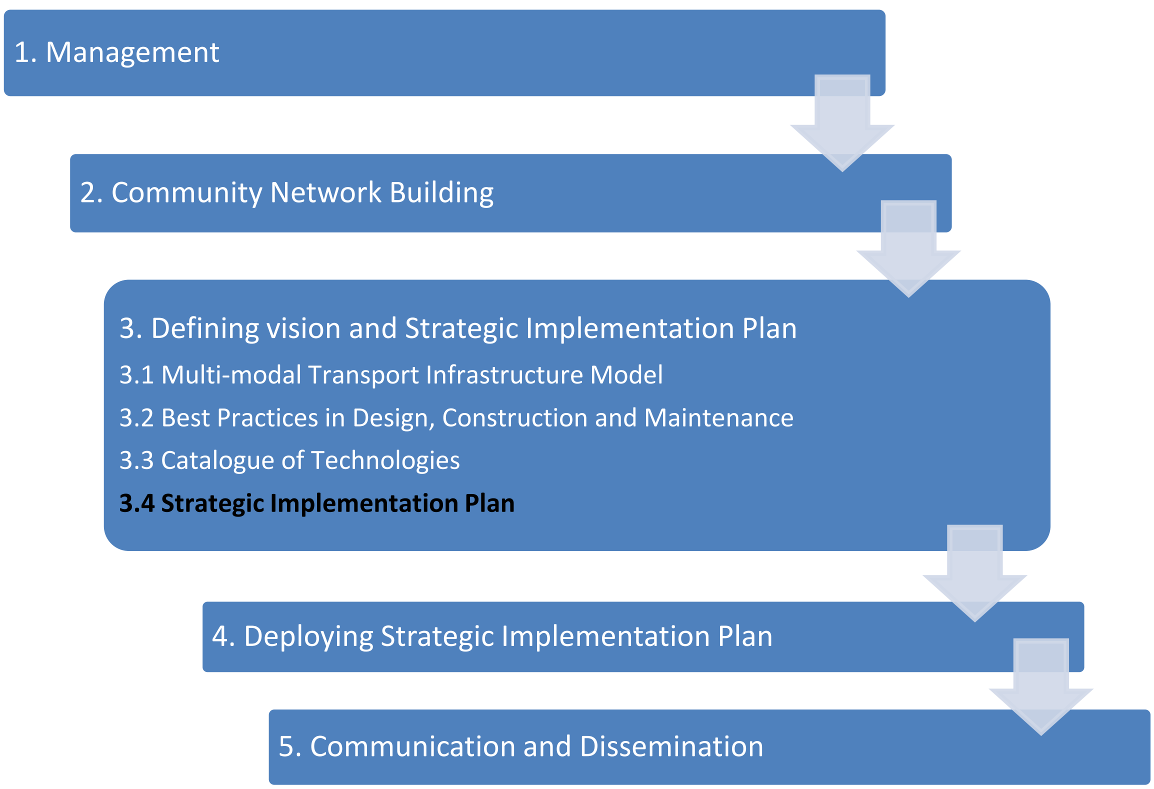
Definitions

Term	Full name
Multimodal transport	Multimodal transport: The carriage of freight or passengers or both, using two or more modes of transports.

1. Introduction

The REFINET is a project under the H2020 topic of MG-8.1b-2014 which intends to create a sustainable network of European and international stakeholders' representatives of all transport modes and transport infrastructure sectors. It will also deliver a shared European vision of how to specify, design, build or renovate, and maintain the multimodal European transport infrastructure network of the future along with innovative processes to enhance the effectiveness of the sector.

This document will look at challenges, key policies, stakeholders, technology, research and innovation associated with transport infrastructure. The aim is to establish a comprehensive set of prioritised actions to be carried out within the current context and within the REFINET multimodal Transport Infrastructure framework. It is deliverable 3.4 and sits within work package 3, as illustrated in the flow chart below.



The context of the REFINET project is given in this section. Transport infrastructure is fundamental for the mobility of people and goods, which in turn facilitates economic growth, competitiveness and territorial cohesion of Europe. It is faced with challenges including growing mobility needs, reducing impact on the environment, increasing energy-efficiency and resilience against climate change and extreme weather events and ensuring the safety and security levels. These are all constrained by the limitations on economic budgets.

The European transport infrastructure network is one of the densest and most developed in the world. According to the Statistical Pocketbook 2014 of the European Commission[1], the magnitude of European transport infrastructure accounts for:

- Roads: More than 70,000 km of motorways in a total road network of approximately 5 million km in the 28 European Union Member States.
- Railways: with a total length of lines around 215,734 km across EU28, of which 115,508 km are electrified and 7,343 km are high speed lines.
- Waterways: 41,000 km of navigable inland waterways across EU28.
- Airports: Almost 400 airports, 92 of those carrying from 15,000 to 100,000 passengers per year in EU28.

However, as stated by ECTP[2] most of this infrastructure was constructed in the period 1960-1970 and was designed for a working life of 50 years. They now seem to be often strained far beyond their intended capacities in terms of traffic flows and loads and are reaching the end of their lifetime.

Thus, much of the existing infrastructure no longer fulfills current functional requirements or today's safety and quality standards, and require being strengthened and transformed towards improved efficiency and quality.

Though the challenges have been well-recognised, the resources for maintaining and improving the transport infrastructure are scarce. The coordination among Member States regarding interoperability and joint investments further complicates the issue.

1 http://ec.europa.eu/transport/facts-fundings/statistics/doc/2014/pocketbook2014.pdf

2 ECTP Refine Initiative (2012) Building up Infrastructure Networks of a Sustainable Europe – Strategic Targets and Expected Impacts
http://www.ectp.org/cws/params/ectp/download_files/39D2434v1_reFINE_Targets&Impacts.pdf

2. Transport infrastructure policy and regulatory framework

European transport policy is set by the 2011 White Paper "Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system" (COM (2011) 144 final). This document envisages a European Transport System characterised by:

- Tackling growing transport and mobility needs
- Reducing 60% of greenhouse gases (GHG) emissions.
- Developing core networks and better employing multimodal intercity travel and transport.
- Keeping the European maritime and aviation sectors playing a prominent role at global level.
- Promoting clean urban transport and commuting.

According to this vision, the main objective is to achieve a *"Single European Transport Area that ease[s] the movements of citizens and freight, reduce[s] costs and enhance[s] the sustainability of European transport".* In addition it aims to do this while simultaneously addressing the security and safety of transport and the *"quality, accessibility and reliability of transport services".*

Within this framework research, technology and innovation play a major role in transforming the transport sector into an integrated, inclusive, seamless, safe and sustainable mobility system. This strategy focuses technological innovation on three main areas:

- Vehicle efficiency through new engines, materials and design.
- Cleaner energy use through new fuels and propulsion systems.
- Better use of networks and safer and more secure operations through information and communication systems.

Regarding infrastructure, the scope of action involves the adoption of the "corridor approach" and the introduction of the "smart" infrastructure concept through the deployment of information technology tools.

This perspective has been further developed through the main European policy for transport infrastructure: the TEN-T[3]. According to this, the objectives of the trans-European transport network have been summarised in the following table:

Cohesion	Efficiency	Sustainability	Increased benefits
• Accessibility of all regions of the Union, including remote ones. • Reduction of infrastructure quality gaps. • Interconnection of long distance and regional and local traffic.	• Removal of bottlenecks and bridging of missing links. • Interconnection and interoperability of national networks. • Integration of different transport modes. • Efficient use of new and existing infrastructure.	• Sustainable and economically efficient development of transport modes. • Low greenhouse emissions. • Low carbon and clean transport.	• Safe, secure and high quality standards for passenger and freight transport. • Supporting mobility even in the event of natural or man-made disasters. • Accessibility for all users: elderly, reduced mobility or disabled passengers.

Table 1 TEN-T principles - Source: Source: Regulation (EU) № 1315/2013

[3] Regulation (EU) No 1315/2013 of the European Parliament and of the Council of 11 December 2013 on Union guidelines for the development of the trans-European transport network

The development of the TEN-T regulation considers resilience and sustainability alongside safety, security, accessibility for all users and the quality of services. However, connectivity and interoperability of the European Transport Network are at the heart of this policy.

The new TEN-T guidelines define general objectives and specific technical requirements for the trans-European transport network. This includes a dual-layer structure: a core network (completed by 2030) and a comprehensive network (completed by 2050).

The comprehensive network should be a Europe-wide transport network that ensures the accessibility and connectivity of all regions in the Union, including the remote, insular and outermost regions, and that consists of all existing and planned transport infrastructures.
On the other hand, the core network consists of those parts of the comprehensive network which are of highest strategic importance. Thus, it contains nine corridors connecting the main European hubs and aims particularly at:

- Removing the transport bottlenecks.
- Building missing cross-border connections.
- Promoting modal integration.
- Reducing greenhouse emissions.

The core network comprises the most important urban nodes, ports and airports as well as border crossing points in terms of traffic needs and it should include all transport modes and their connections as well as relevant traffic and information management systems. The figure below maps the nine corridors of the TEN-T network.

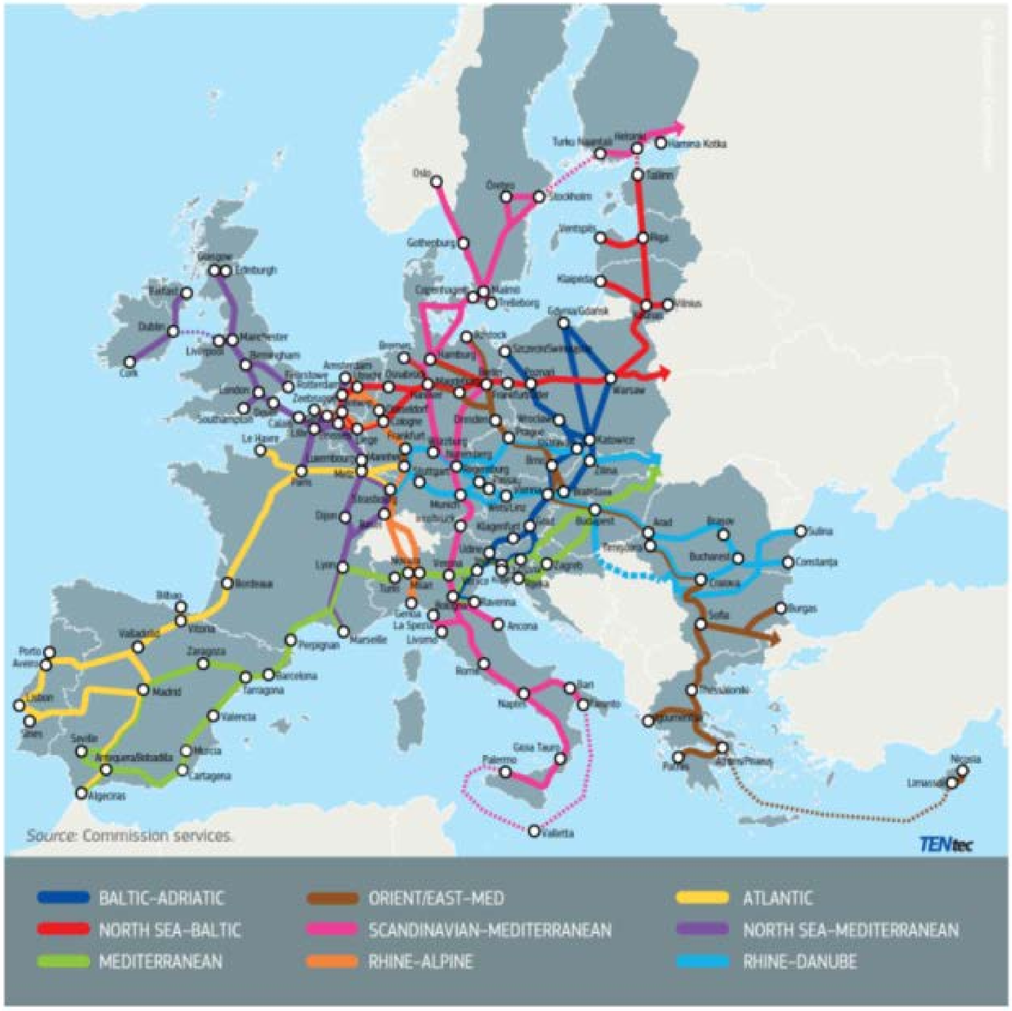


Figure 1 Core Network Corridors of TEN-T - Source: EC, TENtec Informative System[4].

A study has been carried out on the current state of infrastructure along the core network corridors, and it sets out the challenges for future infrastructure development. It also includes a list of projects to be undertaken in order to strengthen the corridor vision. For each core corridor, the level of investment needed and the number of projects proposed in the study are as follows:

[4] http://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/site/index_en.htm

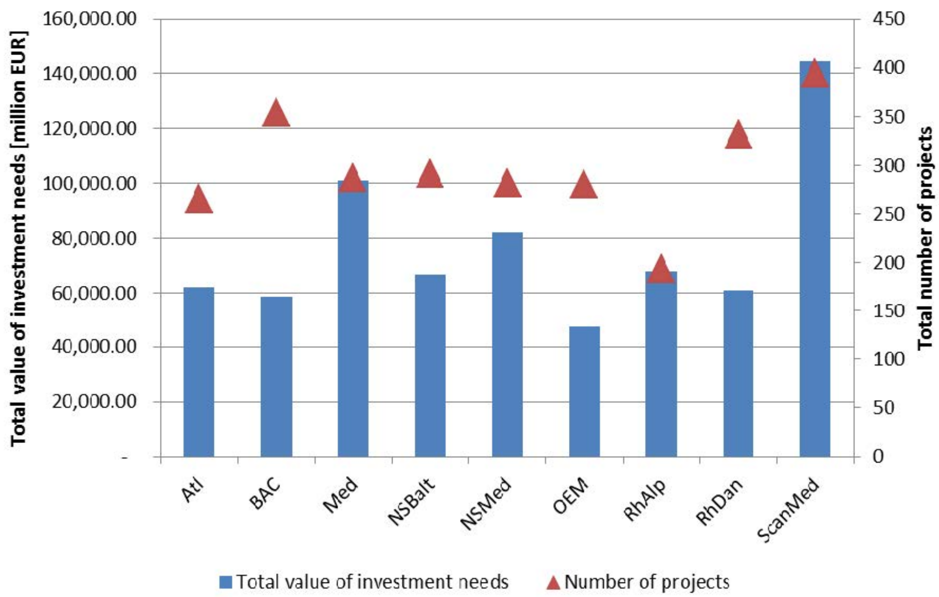


Figure 2 Level of investment need (million Eur) and number of projects for each corridor - Source: European Commission

From the Regulation (EU) Nº 1315/2013, the general priorities for infrastructure development in order to comply with the TEN-T policy for each transport mode:,

Transport mode	Infrastructure development priorities
Rail transport	• Deployment of ERTMS. • Migration to 1435 mm nominal track gauge. • Mitigation of the impact of noise and vibration. • Interoperability. • Improvement of the safety of level crossings. • Connection of railway transport infrastructure with inland waterway port infrastructure. • Full electrification of the line tracks. • Freight lines featuring at least 22,5 t. axle load, 100km/h line speed and possibility of running trains of 740 m. • Adoption of infrastructure oriented to reducing noise and vibration impacts
Inland waterways	• Standards of the inland waterways class IV. • Existing waterways modernization and creation of new waterways. • Telematic applications implementation, including RIS. • Connection of inland port infrastructure to rail freight and road transport infrastructure. • Modernisation and expansion of the capacity of the infrastructure necessary for transport operations within the port area. • Availability of alternative clean fuels. • Develop network of inland terminals-logistical hubs.
Road transport	• Improvement and promotion of road safety. • Use of ITS, in particular multimodal information and traffic management systems, and integrated communication and payment systems. • Introduction of new technologies and innovation for the promotion of low carbon transport. • Provision of appropriate parking space for commercial users offering an appropriate

	level of safety and security. • Mitigation of congestion on existing roads. • Rest areas on motorways every 100 km. • Availability of alternative clean fuels.
Maritime transport	• Promotion of "Motorways of the sea" including short-sea shipping, facilitating the development of hinterland connections and developing measures to improve the environmental performance of maritime transport. • Interconnection of maritime ports with inland waterways. • Implementation of VTMIS and e -Maritime services. • Introduction of new technologies and innovation for the promotion of alternative fuels and energy-efficient maritime transport, including LNG. • Modernisation and expansion of the capacity of the infrastructure necessary for transport operations within the port area.
Air transport	• Increasing airport capacity. • Implementation of the Single European Sky and of air traffic management systems, in particular those deploying the SESAR system. • Improving multimodal interconnections between airports and infrastructure of other transport modes. • Improving sustainability and mitigating the environmental impact from aviation • Availability of clean fuels.
Multimodal transport	• Through access infrastructure and through freight terminals and logistic platforms. • Removal of the main technical and administrative barriers to multimodal transport. • Development of a smooth flow of information between the transport modes. • Provision of multimodal and single mode services. • Last mile access to seaports and airports • Development of multimodal facilities

Table 1 TEN-T priorities by transport mode - Source: Regulation (EU) № 1315/2013 and corridor studies

In order to overcome the above mentioned priorities and to reach foreseen objectives related to the development of the "core" network, actions should be undertaken mainly in the following fields:

- **Construction of new facilities**
- **Provision of maintenance services of transport infrastructure**
- **Adoption of new construction materials and procedures**
- **Incorporation and integration of information systems and applications** (ERTMS, Road Tolling Systems, ITS, SESAR, etc.)

Introduction of innovation and new technologies Special focus of the policy is also to pave the way towards increased opportunities for private investments and internationalization aspects of TEN-T network being better connected with neighboring countries.

The TEN-T policy is backed-up by the Connecting Europe Facility (CEF) programme. TEN-T guidelines above mentioned establish obligations incumbent upon member states to ensure that the "comprehensive" and "core" networks are duly achieved and identifies projects of common interest to the European Union. This keeps the investment needs in the European transport a challenge, especially taking into account that the level of investment in the transport sector remains subdued seven years after the global financial crisis started.

To face the challenge of funding, it is necessary to mobilise both public and private investment, at EU, national, regional and local level. The Connecting Europe Facility is one of the funding instruments devoted to boost a more efficient, well maintained and greener transport system.

In the current funding period, 2014 to 2020, a total of 24.05 billion euros is available to co-fund TEN-T projects in Member States and in addition 11.3 billion euros is available exclusively for countries eligible for Cohesion Fund. Studies on all modes of transport receive 50% funding while implementation projects receive 20% funding covering new infrastructure, increasing capacity, traffic management systems, new technologies and innovations.

The CEF funds will be provided mainly in the form of grants, but one of the CEF´s key elements is more systematic use of innovative financial instruments to provide a funding alternative to traditional grants and fill financing gaps for strategic investments, aiming at attracting funds from the capital market.

These instruments are the Loan Guarantee for TEN-T (LGTT) which provides guarantees for the banking sector to share demand risks or the Project Bonds Initiative (PBI), which provides credit enhancing to projects to attract private investment or Marguerite, infrastructure equity fund. Becoming operational in 2015, the CEF Debt Instrument (CEF-DI) has potentially substantial financial backing, with up to 1.5 billion Euro of funding that could be available for transport in the period 2020 with a potential to leverage up to 15 fold this amount of investment. Support actions will also be provided under the CEF-DI to help procuring authorities with financial structuring of priority projects such as traffic management systems.[5]

The CEF is presumed to act as a catalyst for further private and public funding by giving infrastructure projects credibility and lowering their risk profiles, thereby attracting investors.

[5] Opportunities for the transport sector under the Investment Plan: Non-paper to Ministers for 8 October 2015 Transport Council

3. Stakeholder expectations including user requirements

The key actors and stakeholders of transport infrastructure include:

- Public administration related to transport, energy and climate change in various governance levels (European, national, regional, local).
- Infrastructure owners and operators.
- European Technology Platforms related to different modes of transport.
- Other relevant associations such as European Infrastructure Managers (EIM), Community of European Railway and Infrastructure companies (CER), European Union Road Federation (ERF), International Road Federation (IRF), World Road Organization (PIARC), Airports Council International Europe (ACI EUROPE), European Sea Ports Organisation (ESPO), European Association for Battery, Hybrid and Fuel Cell Electric Vehicles (AVERE), European Federation of Inland Ports (EFIP), European Federation for Transport and Environment (T&E), UNIFE as the European rail manufacturing industry representing body, European Construction Industry Federation (FIEC), European Network of Construction Companies for Research and Development (ENCORD), European Passengers Federation, among others.

Considering the large number of the stakeholders involved in the transport infrastructure, some drivers could be considered as main sources of the impacts on the transport infrastructure development, giving response to stakeholder´s expectations.

The main drivers which generate impacts on transport infrastructure development could be classified as:

- Policies around global challenges, such as ”reduce oil dependence” and other specific ones, such as “increase of capacity of existing infrastructures”.
- Supply chain through the whole life-cycle stages of transport infrastructure (planning, designing, construction, and operation and maintenance).
- End-users, which corresponds to socio-economic trends.

And the main impacts on transport infrastructure development are linked to one of the five categories considered for “performances”, which have been defined in the Refinet Multi-Modal Transport Infrastructure framework RMMTI (See D3.1 or Annex 2): GREEN, COST-EFFICIENT, SOCIAL/INCLUSIVE, RESILIENT and SAFE/SECURE.

4. MAIN CHALLENGES TO INCREASE THE PERFORMANCES AND SUSTAINABILITY OF THE MULTIMODAL TRANSPORT INFRASTRUCTURE

According to the Transport Research and Innovation agenda in Horizon 2020, in the field of transport infrastructure, the targets are related to:

- More resilient infrastructure.
- Infrastructure duly responding to the growing mobility needs and aspirations of people and businesses.
- Infrastructure not impacting on the environment.
- Well maintained and upgraded infrastructures.
- Innovative infrastructures.

These targets address the necessity to face the global challenges which our European society must live together nowadays and the following decades. The unique way to improve ourselves is to be aware of them as well as to act at the same time as soon as possible, in order to overcome future problems without delay.

In this sense, the global main challenges could be summed up and clustered in:

• A paradigm shift towards **increased environmental awareness**: Infrastructure networks must be designed, built, operated and maintained in a sustainable way, reducing resource and material consumption, with a reduced environmental impact and with increased level of safety;
• New concern about **the availability and cost of energy**: new types of equipment will be developed, new uses of infrastructure will require new concepts, new products and new regulations to existing and new infrastructure;
• **An ageing society**: a new concern on the variety of users' needs will necessitate a new approach to the design of infrastructure;
• New conditions caused by **climate change**: infrastructure networks must be adapted to cope with new and increased risks from natural hazards, including extreme events such as floods, droughts and rising sea levels;
• Increasing **economic constraints**: global competition obliges to optimise construction and maintenance costs and favours larger application of ICT solutions.

Following these general challenges, the European Platforms on Road (ERTRAC), Rail (ERRAC),Water (Waterborne), AIR (ACARE) and Construction (ECTP) contribute to policy design in terms of innovation and technology development in a mode-oriented perspective through the establishment of their own strategic research agendas and through the development of different technology roadmaps.

Being infrastructure an important facilitating asset to improve the sector performance, some key indications on innovation and research related to infrastructures are also given, in order to tackle previously mentioned set of key challenges.

Beyond the platforms corresponding to the different transport modes, the construction platform has also much to say on innovation and technology development on transport infrastructure. In this sense, the ECTP platform has developed a vision within reFINE initiative. This vision lies on the concept of High Service Level Infrastructures (HSLI) that comprises the following concepts: Multimodal Hub, Urban mobility and Long Distance Corridors. ECTP presents key research areas in the three pillars of the HSLI[10].

In addition to this, in 2013, the 5 already mentioned platforms (ERTRAC, ERRAC, WATERBORNE, ACARE and ECTP), exceeding their respective mode-specific oriented roadmaps, agreed to create a joint task force in order to develop a new roadmap from a cross modal perspective.

The recent Roadmap for cross-modal transport infrastructure innovation[12] considers the elements that affect to more than one transport mode and involves:

- Construction and maintenance of fixed facilities, such as roadway segments, railway tracks, public transportation terminals, harbours, and airports.
- The infrastructure facing control and information systems that support its proper operation and permit people and goods to traverse geographical space in a timely, efficient manner for an intended purpose.
- The governance and management systems, structures and processes that link the functioning of the infrastructure with the framework of policies, regulations and legislations.

Thus, conducting a joint analysis of the European Platforms roadmaps and H2020 work programmes on smart, green and integrated transport, the direction of research and innovation regarding transport infrastructure in Europe focuses on the following fields of knowledge:

- Innovative design and construction methods and materials
- New techniques for maintenance and upgrading: predictive techniques, early damage detection, advanced systems for survey, satellite system for infrastructure health monitoring, autonomous inspection and testing, etc.,
- Advanced information management systems and travel process management systems
- Innovative concepts and methods for new fuels and energy infrastructure: distribution, harvesting,

New governance and funding process,
According to the previously mentioned different platforms and initiatives, main research and innovation fields depend to some extent on the mode of transport, because of the particularities of each mode when dealing with specific challenges and developing and implementing each technology into the corresponding transport mode.

However, it is crucial not to disdain the systemic approach, where the multimodal performance of the transport network makes sense and where the main objective of the transport system could be achieved.

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[10] Building Up Infrastructure Networks of a Sustainable Europe The reFINE Roadmap (2013) http://refinet.eu/fileadmin/user_upload/documents/ECTP_reFINE_Roadmap__May_2013_.pdf
[12] Roadmap for cross-modal transport infrastructure innovation towards a performing infrastructure ERTRAC-ERRAC-Waterborne-ACARE-ECTP Task Force

That is the reason why this Strategic implementation Plan (SIP), and the overall objective of REFINET project, is to kick-start a long-term ambition and initiative, paving the way to enhanced technology transfer and mass-market development for innovative materials, components, systems and process supporting the pan-European generalization of advanced multimodal infrastructures, guiding the evolution of the European transport infrastructure.

Within this framework, REFINET intends to create a sustainable network that integrates the relevant stakeholder representatives of all the transport modes and transport infrastructure sectors in order to create a shared European vision of how the multi-modal European transport infrastructure network of the future should be specified, designed, built or renovated, and maintained.

Starting from existing roadmaps and strategic research agendas of different technology platforms of each mode, the SIP of REFINET aims at integrating them, defining priorities areas and specific actions; and pushing special emphasis into Systemic approach perspective, where all aspects related to multimodality are included. Taking into account the crosss-cutting feature of the multimodality, it is mandatory to know the different interests of the technology platforms and to allocate them into a common framework, defined in task 3.1 in the REFINET project, in order to structure all characteristics of the future European Transport Infrastruture.

5. BARRIERS

The barriers which impede the adoption of the technologies and innovation related with the above mentioned topics, hampering the real achievement of an integrated and optimised European transport system, are identified. These general barriers attend to the specificities of the transport infrastructure regarding its cost-intensive and long-life time features as well as its market conditions or the construction value/supply chain characteristics.

The main barriers could be considered the following[15]:

- Funding Gap
- Risk averse policies.
- Mainly national, public and price based market
- Lack of long term vision and perception of high cost
- High risk perception: Long lifespan and high fixed costs of transport infrastructure innovations
- Strict regulatory framework for infrastructure construction sector and lack of support to demonstration
- Non-integrated value/supply chain of transport infrastructure
- Low motivation to innovation by the supply chain
- Lack of Key Performance Indicators
- Policies at national level lack transnational and network vision
- Large number of agents involved with different priorities and visions
- Specialisation of transport modes
- Economic competition among transport modes
- Difficult cross border collaboration
- Information Gap and uncertainties on climate behavior and its impact on the infrastructure
- Lack of standards & harmonized standards

[15] "The barriers have been identified by the SINTRAS project "Towards a Single and Innovative European Transport System" Focus Area 2: Transformation of infrastructure to address connectivity, resilience, new fuels and energy efficiency. SINTRAS project utilized a wide spectrum of methods including desk research, stakeholder interviews, stakeholder survey and a series of stakeholder workshops in order to identify and describe the most important barriers embedding the transport infrastructure to become more innovative (http://sintras.eu/site/)" TECNALIA participates as a stakeholder in one of the mentioned workshop.

6. SWOT (Strengths; Weaknesses; Opportunities AND Threats) analysis of the multimodal transport infrastructure

Keeping on mind the Transport Infrastructure policy and Regulatory framework, as well as the identified main key challenges and barriers which the multimodal transport infrastructure should confront in order to achieve the goals for a competitive and resource-efficient transport system, this section will present the current SWOT analysis of the multimodal transport infrastructure within the general Transport sector perspective where is included.

	STRENGTH	WEAKNESS
the internal environment factors tend to be in the **present**	* Europe has a Transport sector policy defining the objectives and targets by 2050. "Trend-setting policies" stimulating R&D and innovation. * EU worldwide leadership in transport infrastructure, logistics, traffic management system and manufacturing of transport equipment. * Long experience in transport infrastructure lead to an advantage and strong business models of market leaders arise. * Highly-skilled work force and long-term experience supports innovation. * Trans-European transport Infrastructure policy in place and being developed, (TEN-T and CEF) * Transport industry sector employs around 10 million people directly and accounts for about 5% of GDP. * Further Market opening has taken place in aviation, road and partly in rail transport: single EU sky, increased safety and security across all transport modes. * International cooperation has been strengthened. * EU stimulates sustainable mobility approaches and therefore supports a sustainable framework for research and innovation (H2020 and member states) with a continuous funding for R&D. * The transport sector innovation is promoted and organised through well-established technology platforms and associations.	* Unequally developed transport infrastructure network at EU level (Eastern vs Western countries) * Much work to do to achieve a comprehensive multimodal transport system at EU level for freight and passenger. * Transport system as today is not sustainable (oil dependence, congestion, environmental impact) “business as usual”. * Aging transport infrastructure. * There is no a comprehensive European multimodal assessment methodology to monitor the improvements of the targeted performances provided by R&I actions. * Lack of interaction and integrated vision between transport infrastructure and mobility services. * Mainly national, public and price based market: the integration of innovation in transport infrastructure projects depends on the cooperation and collaboration among member states. * Existing system & infrastructure as a barrier for transformation towards new forms of mobility in Europe due to slow change capacity and associated high costs * Cooperation between transport modes in research and innovation is limited. * The investment in transport infrastructure sector is low. * Strict regulatory framework for infrastructure construction sector and lack of support to demonstration. * Safety and environmental policies/regulations may include additional costs for the transport infrastructure. * Technology change & transformation of "transportation towards mobility" maybe underestimated. * Aging work force due to a lack of staff renewal in the transport sector in general.

	OPPORTUNITIES	THREATS
the external environment - factors tend to be in the **future**	* The society demands GREEN, COST EFFICIENT, SOCIAL/ INCLUSIVE, RESILIENT and SAFE/ SECURE multimodal transport infrastructure at EU level. * Europe ambitioned to develop an integrated multimodal transport system at EU level for freight and passengers while promoting sustainable mobility. * Investments in transport infrastructures have positive impacts on economic growth, create wealth and jobs, and enhance trade, geographical accessibility and the mobility of the people. * Infrastructures have the potential to shape the mobility and to promote new technologies for vehicles and traffic management. * Better use of infrastructure will maximize positive impact on economic growth and minimizes negative impact on the environment. * Logistic sector is promoting integrated transport corridors optimised in terms of energy use, emissions, attractive for reliability, limited congestion and low operating and administrative costs. * New funding schemes are being developed for transport infrastructures. * EU could lead an integrated and long-term research and innovation program for multimodal transport infrastructure that could increase industrial investment due to clear and sustainable planning.	* Delayed action and timid on transport system adaptation will condemn the whole transport network. * Possible decrease of investment at EU level for transport infrastructure development. * Oil dependence. * Congestion costs will increase 50% by 2050 and social costs of accidents and noise would continue to increase.[16] * Transport modes compete among each other instead of creating EU wide common multimodal strategy. * Ageing Infrastructure not able to support and be adapted to new sustainable mobility concepts and multimodality. * Lack of interaction between research and innovation framework and infrastructure development projects. Difficulty of innovation transfer. * Multimodal infrastructure technology and innovation challenges are not enough recognised in research priorities. * Standardisation activities do not encompass with research activities. * Multimodal Transport development plans need to be aligned to the urban, local, and regional development plans.

Table 2 SWOT

As conlusion of the SWOT analysis, Europe has the opportunity to lead an integrated and long-term research and innovation program for multimodal transport infrastructure based on the current strengths in terms of long experience in transport infrastructure by EU worldwide leadership in transport industry and the well-established policies to stimulate R&D and innovation looking for sustainable mobility solutions across all modes.

In order to face global challenges and to achieve the goals established by the Transport 2050 Roadmap, the weaknesses and threats should be overcome and avoided, respectively, in order to get the real multimodal transport system at EU level for freight and passengers through technology improvement and deployment.

[16] A Description of how transport could evolve up to 2050 if new policies did not intervene to modify the trends. SEC (2011) 358.

7. Objectives and targets

By 2050, a new **European multimodal transport infrastructure network** will ensure efficient transport of goods and passengers through the **High Level Service Infrastructure** concept spread out by **urban mobility, multimodal hubs and long-distance corridors** with the performances of **GREEN, COST-EFFICIENT, SOCIAL/INCLUSIVE, RESILIENT and SAFE/SECURE**, based on advanced and development of technologies and by means of **systemic approach perspective**, considering **GOVERNANCE, COMMUNICATION, FINANCIAL/ECONOMIC, LEGAL/STANDARDS and RISKS/INTERDEPENDENCY aspects**.

This REFINET vision is expressed through the development of High Level Service Infrastructure concept and the achievement of the following objectives related to its performances.

As a reminder of the **High level service infrastructure HLSI concept definition**, it has the following features:

- Providing infrastructure for **high quality mobility services** for people and goods while using resources more efficiently.
- Ensuring overall better service and performance, **including multimodal integration and intermodal continuity for the end-user**, less congestion, optimised transport time, etc.
- Higher degree of convergence and enforcement of **social, health safety, security and environmental rules for infrastructure**, with the adequate service standards at all times,
- Interconnected solutions for the next **generation of multimodal transport management**, including information services and systems for all infrastructure

And related to the achievement of its performances, following objectives and targets have been defined, connecting different main challenges to the expected response through the investment in research field in order to improve technological level and to deploy it in the real transport infrastructure network:

- ✓ **GREEN**: This performance corresponds to the increased environmental awareness and the current contribution of transport sector to get it worse. That is why, transport infrastructure should contribute to take into account its entire life cycle and including in all its stages environmentally-friendly construction materials and processes.

- ✓ **COST-EFFICIENT**: This performance answers to the economic constraints obliges to optimise construction and maintenance costs, specially taken into account the whole life cycle of transport infrastructure and the availability and cost of energy associated.

- ✓ **SOCIAL/INCLUSIVE**: This performance is connected to the challenge of the ageing society, which requires making the transport infrastructure be more accessible for all citizens. Not only in physical way, but also to be accessible in economic and social integration way.

- ✓ **RESILIENT**: This performance addresses to the long life of the transport infrastructure and the new challenges and requirements which has to be fulfilled through a high quality and continuous service. So, the new transport infrastructure should improve in the adaptability to face with disruptive events, independently from their origin and to be able to respond and to mitigate the effects and to recover to the normal situation with minor consequences.

- ✓ **SAFE/SECURE**: This performance tries to consider the high quality level and safe/secure service. The transport infrastructure should contribute with respect to reduction of accidents and severe injuries so as to the cargo lost, theft and damage, by means of improved highly efficient management and operation of the networks.

Finally, as potential and future main outcome will be a REFINET index applied to different infrastructure types, where each infrastrucutre owner / manager should establish their individual targets but it could be a EU wide tool to evaluate and improve the European Transport Network with a common perspective and it would be a coherent way to identify the areas of investment and evaluate the impacts.

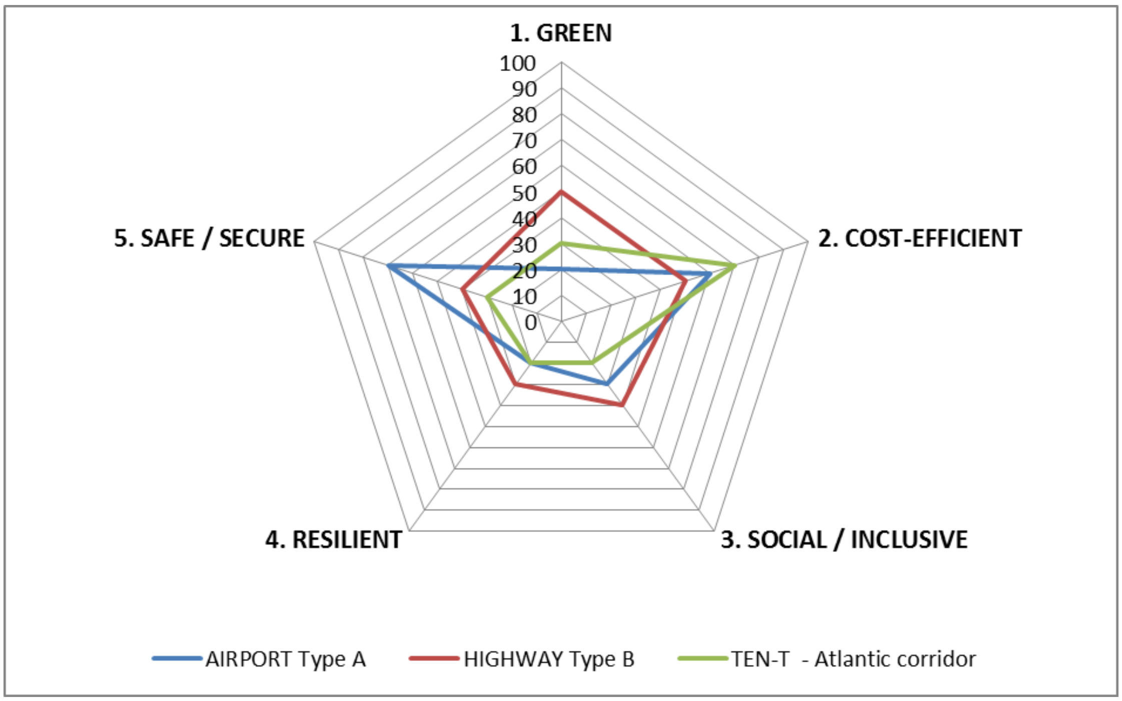

Figure 3 Example of potential future outcome

8. Priority areas and specific actions for research and innovation

Moreover, the demographic growth and other factors like urbanisation and macro-economic development impose an increasing demand on infrastructure networks, leading to critical saturation of infrastructure lines and nodes. It is necessary to increase their capacity and to extend their service life, while coping with new demands for safety, quality of service and sustainability.

Within the constraints of current funding, the construction of a large number of new infrastructures is not feasible, so efforts will have to be concentrated on rehabilitation, strengthening and monitoring of existing assets.

Solutions must aim at assuring the same level of service for both new and existing infrastructure, throughout Europe, by:

- the development of new projects integrating with and complementing the existing networks;
- the maintenance and upgrading of a huge existing asset of networks.

The Transport 2050 roadmap to a Single European Transport Area (The white paper on Transport) sets out to remove major barriers and bottlenecks in many key areas across the fields of: transport infrastructure and investment, innovation and the internal market. The aim is to create a Single European Transport Area with more competition and a fully integrated transport network which links the different modes and allows for a profound shift in transport patterns for passengers and freight.

The Transport 2050 roadmap sets different goals for different types of journey - within cities, between cities, and long distance. For this reason, three priority areas have been defined following the previously done work in reFine Initiative, and the fourth priority area corncerning the "systemic approach" perspective for multimodal transport infrastructure. Following, the fourth priority areas have been defined linked to the different goals expresed in the White Paper document:

PRIORITY AREA A: URBAN MOBILITY:

Infrastructure networks support a high quality of life in sustainable European cities by ensuring a continous and safe circulation of life, water and food and by providing the physical means for mobility to live and work.

According to urban transport, a big shift to cleaner cars and cleaner fuels. 50% shift away from conventionally fuelled cars by 2030, phasing them out in cities by 2050.

- Halve the use of 'conventionally fuelled' cars in urban transport by 2030; phase them out in cities by 2050; achieve essentially CO2-free movement of goods in major urban centres by 2030.
- By 2050, move close to zero fatalities in road transport. In line with this goal, the EU aims at halving road casualties by 2020. Make sure that the EU is a world leader in safety and security of transport in aviation, rail and maritime

Examples: Grand Paris Express Network / Dublin M50 Motorway / Stuttgart 21

PRIORITY AREA B: MULTIMODAL HUBS

Infrastructure networks support European social and territorial cohesion. Infrastructure networks are integrated, efficient and well-connected, thanks to multimodal hubs that constitute essential nodes of the integrated transport systems. They guarantee Europe´s integration with the international and intercontinental market, while complying with the principle of sustainable development.

With regard to Transport 2050 roadmap. for intercity travel: 50% of all medium-distance passenger and freight transport should shift off the roads and onto rail and waterborne transport. This modal shift needs multimodal hubs to interchange the transport modes in the

- By 2050, the majority of medium-distance passenger transport, about 300km and beyond, should go by rail.
- By 2030, 30% of road freight over 300 km should shift to other modes such as rail or waterborne transport, and more than 50% by 2050.
- Deliver a fully functional and EU-wide core network of transport corridors, ensuring facilities for efficient transfer between transport modes (TEN-T core network) by 2030, with a high-quality high-capacity network by 2050 and a corresponding set of information services.
- By 2050, connect all core network airports to the rail network, preferably high-speed; ensure that all core seaports are sufficiently connected to the rail freight and, where possible, inland waterway system.

Examples: Schipol Amsterdam Hub / King´s Cross Station Hub / Genoa Hub

PRIORITY AREA C: LONG DISTANCE CORRIDORS

Infrastructure networks support a competitive European economy by providing fast means to develop European trade in a sustainable way between city centres and along major routes connecting Europe with rest of the world.

For long-distance travel and intercontinental freight, air travel and ships will continue to dominate. New engines, fuels and traffic management systems will increase efficiency and reduce emissions.

- Low-carbon fuels in aviation to reach 40% by 2050; also, by 2050, reduce EU CO_2 emissions from maritime bunker fuels by 40%.
- A complete modernisation of Europe's air traffic control system by 2020, delivering the Single European Sky: shorter and safer air journeys and more capacity. Completion of the European Common Aviation Area of 58 countries and 1 billion inhabitants by 2020.
- Deployment of intelligent land and waterborne transport management systems (e.g. ERTMS, ITS, RIS, SafeSeaNet and LRIT1).

Examples: South Europe Atlantic high-speed line / Greek Attiki Odos Motorway / Seine-Nord Europe canal.

PRIORITY AREA D: SYSTEMIC APPROACH

Infrastructure networks provide a core and comprehensive multimodal transport system at Europe level through the development of TEN-T corridors. Systemic approach perspective for efficient management of multimodal transport system should be considered accordingly to the different transport modes and infrastructures. Following objectives had already been included in the Transport 2050 roadmap:

- By 2020, establish the framework for a European multimodal transport information, management and payment system, both for passengers and freight.
- Move towards full application of "user pays" and "polluter pays" principles and private sector engagement to eliminate distortions, generate revenues and ensure financing for future transport investments.
- Work with international partners and in international organisations such as ICAO and IMO to promote European competitiveness and climate goals at a global level.

After defining the fourth priority areas of this REFINET Strategic Implementation Plan document, the different specific Research and Innovation needs have been gathered following the REFINET MultiModal Transport Infrastructure (RMMTI) framework (see Annex2). The specific actions formulated by Research and Innovation needs have been structured into the following two tables; providing information about the different fields: specific challenges, scope, impacts, required level of investment, priority level and geographic scale.

All of these research and innovation demands have been based on:

- the analysis of the contributions of the experts in the workshops held on Madrid and London,
- the contributions proposed by the CSAs USE-IT & FOX (Brussels, 15th September 2016),
- the outcomes of the reFINET deliverables: Best practices (D3.2) and available technologies (D3.3),
- contributions of the members of the REFINET consortium
- the analysis of Transport related ETP strategic research agendas and roadmaps.
- And the contributions of external stakeholders through the open consultation process launched to the national technology platforms.

PRIORITY AREA A, B and C:		ID	Scope	Impact	Specific Challenges	Investment Level	Priority Level	Geographic Scale
RESEARCH TRL<5	GREEN	R1.1						
	COST-EFFICIENT	R2.1						
	SOCIAL / INCLUSIVE	R3.1						
	RESILIENT	R4.1						
	SAFE / SECURE	R5.1						
INNOVATION 6<TRL<8	GREEN	I1.1						
	COST-EFFICIENT	I2.1						
	SOCIAL / INCLUSIVE	I3.1						
	RESILIENT	I4.1						

	SAFE / SECURE	I5.1						
DEPLOYMENT TRL>8	ALL	D1						

PRIORITY AREA D: SYSTEMIC APPROACH		ID	Scope	Impact	Specific Challenges	Investment Level	Priority Level	Geographic Scale
RESEARCH TRL<5	GOVERNANCE	R1.1						
	COMMUNICATION	R2.1						
	FINANCIAL / ECONOMIC	R3.1						
	LEGAL / STANDARDS	R4.1						
	RISKS/INTERDEPENDENCIES	R5.1						
INNOVATION 6<TRL<8	GOVERNANCE	I1.1						
	COMMUNICATION	I2.1						
	FINANCIAL / ECONOMIC	I3.1						
	LEGAL / STANDARDS	I4.1						
	RISKS/INTERDEPENDENCIES	I5.1						
DEPLOYMENT TRL>8	ALL	D1						

In Annex 4 of this document, the different 87 specific research and innovation needs have been gathered.

9. FEEDBACK OF THE R&I ACTIONS FROM THE WORKSHOP IN BUCHAREST AND FROM CONSULTATION TO ECTP & NTPS

In this chapter feedback and contributions to the firstly presented R&I actions (gathered in the Annex 4 of this document) are presented in order to incorporate them in this final version of Deliverable D3.4.

The two feedback sources used to gather the information, once the whole Strategic Implementation Plan was completed, were: the workshop held on Bucharest and the open consultation process distributed by email to the stakeholders through the European Construction Technology Platform and the network of National Technology Platforms

A) FEEDBACK FROM THE WORKSHOP IN BUCHAREST

After the first submission of the deliverable D3.4, a presentation about the content of Strategic Implementation Plan, the Priority Areas and its Research & Innovation Actions was made in the workshop, held on Bucharest (March 2017) within the scope of WP4"Deployment of the Strategic Implementation Plan".

After the presentation of the Strategic Implementation Plan (SIP), a specific two hour workshop session was held in the afternoon.

The main objective was to contrast (test, validate?) the SIP (already provided before the meeting) with different experts and stakeholders in order to gather their feedback and contribution concerning mainly the prioritisation of the Research and Innovation Actions.

The specific objectives of the workshop session were:

1. to check and analyse the existing R&I topics with stakeholders and to identify few (3-4) of them that are relevant and try to reach consensus among them.
2. to add new R&I topics from the stakeholder´s view (3-4) in case of missing priorities.
3. to rank and prioritise the selected available topics and the new topics for the short, medium and long-term.

The work was carried out by dividing the experts into groups.A set of activities were planned for each of the priority areas, URBAN MOBILITY, MULTIMODAL HUBS, LONG-DISTANCE CORRIDORS and SYSTEMIC APPROACH), with the following block of activities :

- Comment existing topics from the current lists. (individual task)
- Identify which ones among them are the most relevant
- Share all views among stakeholders in the team. The rapporteurs will take notes.
- Identify missing topics. (Individual task)
- Share all views among stakeholders in the team. The rapporteurs will take notes.
- Rank both existing and new topics. (Individual task)
- Share all views among stakeholders in the team. The rapporteurs will take notes.

B) FEEDBACK FROM THE CONSULTATION TO ECTP & NTPs

After the first submission of the deliverable D3.4, and with the intention to disseminate it and to get feedback from other stakeholders/experts, an open consultation process by email was undertaken addressing stakeholders from the the ECTP and the NTPs.

This consultation process was an email based exercise using the same methodology as was adopted at the workshop in Bucharest.

MAIN RESULTS OUT OF THE FEEDBACK AND CONTRIBUTIONS FROM THE WORKSHOP IN BUCHAREST AND THE OPEN CONSULTATION TO ECTP & NTPS

In the following Tables, the description of the scope of the Research and Innovation actions are provided with the modifications and contributions proposed and especially with the ranking of the most prioritised actions among the four priority areas.

Some new topics have also been included in the last row of each Table.

The Research and Innovation actions with the highest support in terms of urgency to be tackled have been highlighted in yellow. This factor is presented through a score or selection indicated in the column on the right.

All the Research & Innovation Actions have been classified using the REFINET Multi-Modal Transport Infrastructure framework and its performance categories (GREEN, COST-EFFICIENT, SOCIAL/INCLUSIVE, RESILIENT and SAFE/SECURE) and the four priority areas (URBAN MOBILITY, MULTIMODAL HUBS, LONG-DISTANCE CORRIDORS and SYSTEMIC APPROACH). Note that the TRL criteria described in Annex 4 has not been used , in order to avoid the repetition of the description of the topic

A) FEEDBACK RESULTS FROM THE WORKSHOP IN BUCHAREST

		REFINET priority on transport infrastructures	PRIORITY LEVEL
		PRIORITY AREA A: Urban mobility	**SHORT-TERM**
A	**1**	Advanced technologies and materials to improve air quality, noise and vibration in cities through smart infrastructure - Integration of nature-based solutions (both GREEN & SOCIAL / INCLUSIVE) - Superabsorbing surface materials (CO2, Nox)	**5**
A	**2**	Adaptation technologies for sustainable energy harvesting and recovery for future sustainable urban transport infrastructure - Heat removal - solar road -inductive technology - electrification	**0**
A	**3**	Flexible and adaptable transport infrastructure to favour sustainable transport mobility - increasing soft transport modes, such as biking, electric vehicles - automated mobility- underground mobility and parking - integration of charging infrastructures for Electrical vehicles in urban regeneration- electric buses - movement energy harvesting - inductive technology electrification - rapid-charging of vehicles	**4**
A	**4**	Optimization of construction materials for prefabrication and development of advance production techniques, including additive manufacturing, improving recycling and reuse.	**1**
A	**5**	New construction processes and techniques for low intrusive, fast and cost-efficient infrastructure adaptation to the new demands and needs of the operation and maintenance stage in the large city environment.	**4**
A	**6**	Advanced materials and technologies for urban infrastructure looking for increased durability, resilience and increased performance levels in order to reduce the whole life-cycle costs of infrastructures. Self-healing materials. - Addictive manufacturing (3D printing) - Design for upgradebility, retrofiting.	**2**
A	**7**	Accessibility for All citizens to all transport modes, taking into account ageing society challenge and the increasing urban demography trend for the daily operation and emergency situations.	**5**
A	**8**	Adaptation of a Smart Urban infrastructure to ensure inclusiveness of all citizens to all transport modes based on ICT and Construction aspects. - safe and friendly routes for vulnerable population (children, ageing...) - Informing customer - providing choice-traveller needs - Vwide spread technology APP - Transport links info on delays across modes.	**1**
A	**9**	Increasing the resilience and adapting urban infrastructure to the impacts of environmental and man-made hazards, including: - Self-sufficient technologies to ensure day-to-day activities under exceptional circumstances - Understanding the impacts of severe weather events on infrastructure networks - Adaptation to both incremental and abrupt increases of weather and longer-term climate change -Terrorist attacks (explosions, cyberphysics) - Understanding the impacts of floods, earthquakes, landslides, volcanoes (could incorporate real time response, recovery technologies etc.) - Use of real-time info to forecast environmental hazards and Expected Impact based on simulations/modelling	**4**
A	**10**	Safe and Secure Urban Infrastructure: safety in relation to the incorporation of new vehicles and autonomous driving concepts and security with regard to man-made hazards, specially terrorist attacks and ciber-security.	**2**

		REFINET priority on transport infrastructures	PRIORITY LEVEL
		PRIORITY AREA B: Multimodal hubs	**SHORT-TERM**
B	**1**	Application of new technologies, new materials to the design of multimodal hubs enabling low-carbon and resource efficient green hubs.	**1**
B	**2**	Development of tools to analyse whole-life whole-system energy and carbon impacts, considering multimodal hubs as energy producer centers .	**0**
B	**3**	New designs and construction techniques for multimodal hubs in order to optimise the structure repair, maintenance and life extension processes - prefabrication and automatisation processes -use of the underground - vertical designs specially in urban environment	**3**
B	**4**	Friendly environments for inclusive mobility and accessibility for persons whatever their social category, age and life charcteristicss and their possible impairment. (people with reduced mobility).	**2**
B	**5**	Adaptive design. Increase flexibility to interchange route or transport mode adaptable for increasing demand of future population adaptable for climate change events link with other hubs (network of hubs)	**5**
B	**6**	Modelling of consequences via different scenarios assessment and management to preparedness to disruptive events, study of interdependencies, cascade effects and other consequences. -Real-time data acqusition tool to prepare for disruption (SHM, …)	**2**
B	**7**	Security against man-made extreme events in transit environments (preparedness, prevention, robustness and recovery)	**0**
B	**8**	Security by design: including proven and effective measures to prevent, mitigate or detect man-made extreme events.	**0**
B	**9**	Minimise Security Barriers to mobility without decreasing the overall system security level (security controls, ...) -fast & non intrusive safety controls in accordance with ethics, health and privacy requirements : biometric identification, non radioactive scanning and detection and identification of dangerous material	**2**

		REFINET priority on transport infrastructures	PRIORITY LEVEL
		PRIORITY AREA C: Long distance corrodors	**SHORT-TERM**
C	**1**	**Adaptation of road infrastructure to new sustainable energy sources**: Rapid electric charging infrastructure linked to renewable energy sources. Low energy bound materials (LEBM) for pavements. New efficient technologies and systems are required to increase the energy efficiency, harvest energy from vehicles, and reduce the carbon intensity of the infrastructure as a whole, while maintaining levels of safety, security and resilience. Energy generating road surfaces. The use of Piezoelectric devices within the road infrastructure will lead to the harvesting of vibrational energy from vehicle movement.	**1**
C	**2**	**Innovative solutions and concepts for ressource harvesting**, such as integrated energy harvesting, heat recovery or rain collection systems should be explored in order to take advantages of surface transport infrastructures. Diverse technologies are currently used and developed for city buildings, but rarely applied to insfrastructure facilities and networks. Surface infrastructures are covering large areas and connecting cities and industries, therefore infrastructure with the ability of ressource harvesting could profit to the infrastructure system and nearby residential or industrial areas.	**0**
C	**3**	**New transport infrastructure with low environmental impact.** New improved design of corridors, such as vertical or/and underground corridors or multi-utility routes, should be considered to include the increasing future demands on autonomous and electric vehicles with the minimum environmental impact. New and recycled materials and improved construction techniques should be included in these new designs to minimise acoustic, water, soil and air contamination. Not only in design and construction stages, the environment should be taken into account, but also modelling tools to analyse whole-life system energy and carbon impacts are crucial in order to ensure the environment is always taken in to account. Traceability of materials & products - to ensure the performance and durability of materials and hence, the user´s safety in new design approach. Durable and energy-efficient materials - increasing the lifetime of assets. Recycling and reuse by design - to ensure R&R aspects in designing new products.	**1**
C	**4**	**Performance based approach for maintenance of transport infrastructure**: New methods and tools for monitoring and assessing (the status of) existing structures, relatively to structural loading and deterioration potential. New (non-destructive) testing methods (radar, ultrasound, optical fibre, wireless smart sensors, Inspection robots/self-repairing robots in maintenance….) for diagnostic, early damage detection and maintenance of the infrastructures. Smart inspection and robotics for maintenance. Integration of terrestrial and satellite systems for the structural health monitoring of key infrastructures located in a natural risk prone area (earthquakes, landslides, floods). Such parameters may therefore be called indicators and associated threshold values can be established on a risk basis, as well as admissible average frequencies for outcrossing.	**3**
C	**5**	**Extending the life time of existing infrastructure.** New methods and tools for monitoring and assessing (the status of) existing structures, relatively to structural loading and deterioration potential. * New (non-destructive) testing methods (radar, ultrasound, optical fibre, wireless smart sensors…) for diagnostic, early damage detection and maintenance of the infrastructures; * Smart inspection and robotics for maintenance * Integration of terrestrial and satellite systems for the structural health monitoring of key infrastructures located in a natural risk prone area (earthquakes, landslides, floods). Developing alternative structural models for deteriorating structures * The resistance of an ageing structure is dependent on the condition of the materials of which it is composed, for example the level of degradation of reinforcement bars. Precast elements for quick and efficient maintenance measures. This also will include new track forms, switches and crossings, and their potential for commercial development.	**4**
C	**6**	**Smart Infrastructures enabling condition based Maintenance.** It is important that the sensing and inspection technology as well as the models for degradation and structural integrity are developed in projects combining the two elements. The output of sensing and inspection is input for modelling. Hence, the input data that models require and the information that sensing and inspection can produce must fit. This program will have wide application for maintenance of large structures. - fewer maintenance operations mean fewer interruptions of the infrastructure network	**5**
C	**7**	Seamless cross borders transport operations, Freight Competitiveness via co-operation and co-ordination across Europe with technology and innovation, including: cross-European means of coordinating, managing and exploiting freight operations; Focus on corridors and create network dedicated to rail freight and strengthen the international corridors (TEN-T freight network), cross border ticketing-> faster, better quality, - Using sensor-based technology to monitor transport fleets.	**1**
C	**8**	Ensuring new LD corridors has minimal impact on Accessibility (e.g. cycling and walking routes), minimising disruption to travel whilst ensuring that vulnerable users can safely cross the network.	**0**
C	**9**	Innovative solutions for preparedness, prevention, robustness and recovery from the occurrence of emergency situation based on disruptive events (natural and man-made hazards)	**1**
C	**10**	Infrastructure adaptation to climate change increasing the resilience against natural hazards considering service performance and related costs balance.	**1**
C	**11**	**Resilient transport and logistics networks by design** Real Time Traffic Management enable control, command and communication systems runs across the whole European Rail network; Infrastructure resilience via technology innovation and governance, management and finance of the infrastructure; Transport chain design and operation for synchro modality	**1**
C	**12**	**Future infrastructure for all users' safety: Road infrastructure**, both in urban and in rural areas, needs to be adapted to the requirements of new vehicle technologies, in particular automated driving functions, and its performance needs to be guaranteed by intelligent maintenance and monitoring. Also for pedestrians and cyclists a focus should be on their dedicated infrastructure to avoid amongst others single vehicle / road user accidents. Infrastructure design should take into account the need for interactions with all kinds of road users (human factors).	**0**
C	**13**	Improved management of critical interfaces with others modes and smart methods for monitoring road-rail intersections with the use of advanced solutions (GNSS systems, advanced CCTV tools, etc.) and analysis (collaborative tools) integrated by new human centred safety measures . eg Level crossing for rail/road with the aim to minimize risks at and around level crossings by developing a fully integrated cross-modal set of innovative solutions and tools for the proactive management and new design of level-crossing infrastructure.Properly adapted technical solutions deployed within an appropriate human, legal and organisational framework are necessary. Expected Impact	**0**

			REFINET priority on transport infrastructures	PRIORITY LEVEL
			PRIORITY AREA D: Systemic approach	SHORT-TERM
D	1	R1.1	Integrated information system for asset management to ensure the proper decision-making process on prioritisation of asset maintenance and investment, based on sensing, measuring, imaging, simulation and computing tools through the whole life cycle of the transport infrastructure.	5
D	2	R1.2	Transport infrastructure Network assessment through asset management including BIM for monitoring and assessing the existing structures in order to prioritize the maintenance actions.	3
D	3	R2.1	Coordinated Travel Process - Multimodal Information Platforms, developing accurate information systems and integrating predictive urban and long distance traffic models with real-time information and mobility services.	5
D	4	R2.2	Active Integrated Transport Infrastructure: Data /Information systems to inform different stakeholders, as a Service supply model to be included in Transport industry, e.g. procuring for traffic information instead of traffic sensors.: to end-users on traffic conditions, to infrastructure managers on maintenance needs, to community to look for public acceptance of major infrastructure works, …	3
D	5	R3.1	Supply and demand - to make an overview of the streams of reuse and recycling materials and products, adding GREEN and COST-EFFICIENT aspects and to support company investments and the development of the regulation on the use of waste materials in the infrastructure construction/upgrading.	1
D	6	R4.1	Codes: lack of multimodal standards and tools related to multihazard resilience, considering the government and private organisation collaboration, in order to achieve a seamless transport.	2
D	7	R4.2	Standards for multimodal transport data aggregation in a common format for the development of multitude potential services from multimodal approach.	3
D	8	R5.1	Advanced traveler information - cross modal emergency evacuation/events/weather user information - integration, aggregation and dissemiantion of data acrros sectors (Transport operators, weather information providers, emergency sercives, public and authorities)	3
D	9	R5.2	Systemic multi-scale approach for assessment of the performance of transport infrastructure against multi-hazard risk within transport sector and from or to other sectors (intradependencies and interdependencies, such as cascade effects - in this sense cybersecurity as security of the data is so relevant)	2
D	10	I1.1	Inclusion of carbon in procurement decisions. That is why, lack of data on carbon emitted by different methods and materials should be known and the regulation should be developed.	1
D	11	I1.2	**Identification of Operational, Tactical and Strategy Key Performance Indicators for securing the uptake of transport infrastructures innnovation in TEN-T projects/networks**: *Ensure efficient transport of goods and passengers using the High Level Service Infrastructure concept throughout needs relating to urban mobility, multimodal hubs and long-distance corridors. *Emphasising characteristics such as GREEN, COST-EFFICIENT, SOCIAL/INCLUSIVE, RESILIENT and SAFE/SECURE, OPEN, ACTIVE and QUALITY as a reference framework for any new multimodal transport infrastructure. *Identification of Key Performance Indicators for securing the uptake of transport infrastructures innovation in TEN-T projects/networks	2
D	12	I2.1	**Increasing awareness of transport (multi-modal) operators on high-potential technologies and future trends in design, construction, operation and maintenance of the future (after 2020) European infrastructure network**: Widespread, shared and agreed roadmap on high-potential technologies and future trends for an European infrastructure network, taking into account of key partnership roles from sectors such as energy and ICT.	2
D	13	I2.2	Transport user Expectations and Acceptance factors (age, sex, backgroung, cultural aspects) across modes and according to new technologies in order to encourage the use of more sustainable behaviours of transport.	4
D	14	I3.1	**Better funding and financing methods**: ***Innovative funding methods:** innovative approaches are required to draw upon tax revenues, there is a need to consider innovative user engagement methods. Improved social and environmental impact assessment methdologies are required in order to improve existing financial assessments. ***Innovative financing methods:** to involve institutional investors more directly and actively. Application and testing of the suitability of different emerging common performance metrics and key performance indicators is required, through collaboration with the financial sector. New approaches are also required to the assessment and management of risk and resilience, through collaboration with the insurance industry.	4
D	15	I4.1	Standards and service quality assurance - interoperability: legislation and standards.	3
D	16	I4.2	Rules and Regulations - to facilitate and stimulate recycling and re-use in the field of infrastructure	5
D	17	I5.1	Undesired travellers behaviour to reponse emergency situations	3
D	18	D1	**Spreading innovation and research in smart high-level service infrastructure**: Leveraging on the continuous development of a multi-modal infrastructures European stakeholders network for dialog and consultation between all actors, and to update and enhance a pan-European vision and approach towards the needs for collaborative R&D covering products, systems & services for HLSI development, operation & management.	4

B) FEEDBACK RESULTS FROM CONSULTATION TO ECTP NTPs

			REFINET priority on transport infrastructures	HIGH PRIORITY												
		Connection to the RMMTI model	PRIORITY AREA A: Urban mobility	UK-UNIVERSITY	UK-UNIVERSITY	DENMARK-UNIVERSITY	FRANCE-RAIL ASSOCIATION	FRANCE-RAIL ASSOCIATION	GERMANY-UNIVERSITY	HUNGARY-COMPANY	ITALY-ROAD OPERATOR	NORWAY-UNIVERSITY	PORTUGAL-TECHNOLOGY PLATFORM	SPAIN-COMPANY	SPAIN-COMPANY	SWEDEN-RESEARCH ORGANIZATION
A	1	G	Advanced technologies and materials to improve air quality, noise and vibration in cities through smart infrastructure - Integration of nature-based solutions (both GREEN & SOCIAL / INCLUSIVE) - Superabsorbing surface materials (CO2, NOx) "The adaptable road- Advanced technologies and materials to : Porous, low noise surfacing, light reflecting for night time driving. Adaptable to fright transport communications, location and monitoring requirements. Flexible, durable, self-repairing/self-cleaning and instant crack repair .In-built sensors for traffic monitoring/control and condition monitoring. In-built lane control/vehicle guidance. In-built power system for electric vehicles. Energy harvesting grid and storage/use of solar energy to power lighting, signs and sensors. In-build system for replacing and adding lanes/infrastructure, eg barriers, signs and sensors). Low carbon sub-bases and pavements. Pre-fabricated inter-locking, sub-base with integrated drainage, services and communications channels. Adaptable /removable communication/power channels for lane control, traffic monitoring, driver information and condition monitoring. Removable/self-cleaning drainage reservoirs feeding carbon capture planting." (in, Forever Open Roads, Roads to the 21th century,FEHRL.) *	3(=)	H	X			X	YES						
A	2	G	Adaptation technologies for sustainable energy harvesting and recovery for future sustainable urban transport infrastructure - Heat removal - solar road -inductive technology - electrification "The resilient road- Integrated road and de-icing system. Demand and condition responsive traffic control for extreme weather conditions, Real time local weather forecast information system. Geothermal and solar harvesting for resilience to extreme weather and information system. Drainage system and reservoirs for storm control and water management" (in, Forever Open Roads, Roads to the 21th century,FEHRL.) *	3(=)												
A	3	G	Flexible and adaptable transport infrastructure to favour sustainable transport mobility - increasing soft transport modes, such as biking, electric vehicles - automated mobility- underground mobility and parking - integration of charging infrastructures for Electrical vehicles in urban regeneration- electric buses - movement energy harvesting - inductive technology electrification - rapid-charging of vehicles "The automated road – Satellite and radio communications for road infrastructure, drivers and network control. Integrated asset management communication and tolling systems, between vehicle sensors and communication systems (public/private transport). In-pavement demand responsive LED speed and guidance systems for vehicle to highway cooperation and network management. Adaptable inter-operable communication and power system for lane control, vehicle guidance, traffic monitoring ,driver information and condition monitoring. Facilitation of platooning of vehicles. Inter-operable in-vehicle communication and guidance system to provide drivers with direction, weather, hazard and messaging information. In-vehicle sensors to provide vehicle location, performance information and incident management. In-pavement sensors for traffic control, vehicle to highway communications, conditions /weather and pollution monitoring. (in, Forever Open Roads, Roads to the 21th century,FEHRL.)" *					X		YES						Third high priority
A	4	G	Optimization of construction materials for prefabrication and development of advance production techniques, including additive manufacturing, improving recycling and reuse. Design for reuse. (implementing a "circular economy approach" by taking advantage of the actual by-products and waste produced by the regional industries)	2(=)		X			X	YES						Second high priority
A	5	C	New construction processes and techniques for low intrusive, fast and cost-efficient infrastructure adaptation to the new demands and needs of the operation and maintenance stage in the large city environment. (induction-heating of asphalt, PCM phase change materials)	2(=)							3			1		
A	6	C	Advanced materials and technologies for urban infrastructure looking for increased durability, resilience and increased performance levels in order to reduce the whole life-cycle costs of infrastructures. Self-healing materials. - Addictive manufacturing (3D printing) - Design for upgradebility, retrofiting.	Suggest combine with number 4-all linked to design of materials for whole-life cycle (circular economy)	H	X		X	X	YES	2			2		
A	7	S/I	Accessibility for All citizens to all transport modes, taking into account ageing society challenge and the increasing urban demography trend for the daily operation and emergency situations.					X								
A	8	S/I	Adaptation of a Smart Urban infrastructure to ensure inclusiveness of all citizens to all transport modes based on ICT and Construction aspects. - safe and friendly routes for vulnerable population (children, ageing...) - Informing customer - providing choice-traveler needs - Wide spread technology APP - Transport links info on delays across modes.													
A	9	R	Increasing the resilience and adapting urban infrastructure to the impacts of environmental and man-made hazards, including: - Self-sufficient technologies to ensure day-to-day activities under exceptional circumstances - Understanding the impacts of severe weather events on infrastructure networks - Adaptation to both incremental and abrupt increases of weather and longer-term climate change -Terrorist attacks (explosions, cyberphysics) - Understanding the impacts of floods, earthquakes, landslides, volcanoes (could incorporate real time response, recovery technologies etc.) - Use of real-time info to forecast environmental hazards and Expected Impact based on simulations/modelling		H			XXX			1			3		Highest priority
A	10	S/S	Safe and Secure Urban Infrastructure: safety in relation to the incorporation of new vehicles and autonomous driving concepts and security with regard to man-made hazards, especially terrorist attacks and ciber-security.	1			X	XXX								Highest priority
NEW TOPICS			Adaptation technologies for FRP fiber reinforced polymer composite materials for maintenance including repair, strengthening and refurbishment actions													
			Advanced technologies for automated compilation of BIM models (bridges and highways) to development of a comprehensive solution for rapid and intelligent survey and assessment. (3D solid bridge model objects from pint clouds and BIM models)													
			Reconfiguration framework of road urban networks to take advantage of improved dynamic traffic control methods to incorporate driver in and autonomous vehicles, in order to respomd to more efficient and sustainable performance of motorised mobility.													
		G: GREEN; C: COST-EFFICIENT; S/I: SOCIAL & INCLUSIVE; R: RESILIENT; S/S: SAFE & SECURE														

			REFINET priority on transport infrastructures	HIGH PRIORITY												
		Connection to the RMMTI model	PRIORITY AREA B: Multimodal hubs	UK-UNIVERSITY	UK-UNIVERSITY	DENMARK-UNIVERSITY	FRANCE-RAIL ASSOCIATION	FRANCE-RAIL ASSOCIATION	GERMANY-UNIVERSITY	HUNGARY-COMPANY	ITALY-ROAD OPERATOR	NORWAY-UNIVERSITY	PORTUGAL-TECHNOLOGY PLATFORM	SPAIN-COMPANY	SPAIN-COMPANY	SWEDEN-RESEARCH ORGANIZATION
B	1	G	Application of new technologies, new materials to the design of multimodal hubs enabling low-carbon and resource efficient green hubs.			X										Third priority
B	2	G	Development of tools to analyse whole-life whole-system energy and carbon impacts, considering multimodal hubs as energy producer centers.	3												
B	3	C	New designs and construction techniques for multimodal hubs in order to optimise the structure repair, maintenance and life extension processes -prefabrication and automatisation processes - use of the underground - vertical designs specially in urban environment		H	X					2	X		1		
B	4	S/I	Friendly environments for inclusive mobility and accessibility for persons whatever their social category, age and life characteristics and their possible impairment. (People with reduced mobility).					X								
B	5	R	Adaptive design. Increase flexibility to interchange route or transport mode adaptable for increasing demand of future population adaptable for climate change events link with other hubs (network of hubs)		H						1					
B	6	R	Modelling of consequences via different scenarios assessment and management to preparedness to disruptive events, study of interdependencies, cascade effects and other consequences. -Real-time data acquisition tool to prepare for disruption (SHM, ...)	2			X				3a			3		Highest priority
B	7	S/S	Security against man-made extreme events in transit environments (preparedness, prevention, robustness and recovery)	1 suggest combine with number 8 and number 9			X	XX						2		Second priority
B	8	S/S	Security by design: including proven and effective measures to prevent mitigate or detect man-made extreme events but also daily crime and incivilities.				X	XX			3b	X				
B	9	S/S	Minimise Security Barriers to mobility without decreasing the overall system security level (security controls, ...) -fast & non intrusive safety controls in accordance with ethics, health and privacy requirements : biometric identification, non radioactive scanning and detection and identification of dangerous material				X	XXX								
NEW TOPICS			Increasing the responsability of all security participants (e.g. Police, government, society, prosecutor, etc.)					XX								
			Multimodal hubs in a context of developing countries and very low capacity by the users to take advantage of IT to manage trips and fares.													
			Human-centered studies to identify low-cost measures aiming to improve the perception of security at multimodal hubs and main railway stations and to facilitate intervention and evacuation													

G: GREEN; C: COST-EFFICIENT; S/I: SOCIAL & INCLUSIVE; R: RESILIENT; S/S: SAFE & SECURE

		Connection to the RMMTI model	REFINET priority on transport infrastructures PRIORITY AREA C: Long distance corridors	HIGH PRIORITY UK-UNIVERSITY	UK-UNIVERSITY	DENMARK-UNIVERSITY	FRANCE-RAIL ASSOCIATION	FRANCE-RAIL ASSOCIATION	GERMANY-UNIVERSITY	HUNGARY-COMPANY	ITALY-ROAD OPERATOR	NORWAY-UNIVERSITY	PORTUGAL-TECHNOLOGY PLATFORM	SPAIN-COMPANY	SPAIN-COMPANY	SWEDEN-RESEARCH ORGANIZATION
C	1	G	**Adaptation of road infrastructure to new sustainable energy sources**: Rapid electric charging infrastructure linked to renewable energy sources. Low energy bound materials (LEBM) for pavements. New efficient technologies and systems are required to increase the energy efficiency, harvest energy from vehicles, and reduce the carbon intensity of the infrastructure as a whole, while maintaining levels of safety, security and resilience. Energy generating road surfaces. The use of Piezoelectric devices within the road infrastructure will lead to the harvesting of vibrational energy from vehicle movement.								1					Second Priority
C	2	G	**Innovative solutions and concepts for resource harvesting**, such as integrated energy harvesting, heat recovery or rain collection systems should be explored in order to take advantages of surface transport infrastructures. Diverse technologies are currently used and developed for city buildings, but rarely applied to insfrastructure facilities and networks. Surface infrastructures are covering large areas and connecting cities and industries, therefore infrastructure with the ability of ressource harvesting could profit to the infrastructure system and nearby residential or industrial areas.	3	H											
C	3	G	**New transport infrastructure with low environmental impact.** New improved design of corridors, such as vertical or/and underground corridors or multi-utility routes, should be considered to include the increasing future demands on autonomous and electric vehicles with the minimum environmental impact. New and recycled materials and improved construction techniques should be included in these new designs to minimise acoustic, water, soil and air contamination. Not only in design and construction stages, the environment should be taken into account, but also modelling tools to analyse whole-life system energy and carbon impacts are crucial in order to ensure the environment is always taken in to account. Traceability of materials & products - to ensure the performance and durability of materials and hence, the user´s safety in new design approach. Durable and energy-efficient materials - increasing the lifetime of assets. Recycling and reuse by design - to ensure R&R aspects in designing new products.						X		2					Highest priority
C	4	C	**Performance based approach for maintenance of transport infrastructure**: New methods and tools for monitoring and assessing (the status of) existing structures, relatively to structural loading and deterioration potential. New (non-destructive) testing methods (radar, ultrasound, optical fibre, wireless smart sensors, Inspection robots/self-repairing robots in maintenance....) for diagnostic, early damage detection and maintenance of the infrastructures. Smart inspection and robotics for maintenance. Integration of terrestrial and satellite systems for the structural health monitoring of key infrastructures located in a natural risk prone area (earthquakes, landslides, floods). Such parameters may therefore be called indicators and associated threshold values can be established on a risk basis, as well as admissible average frequencies for outcrossing.	1 Suggest combine with number 5 and number 6	H	X			X		3a	X		3	X	Third Priority C4, C5 & C6 can be combined
C	5	C	**Extending the life time of existing infrastructure.** New methods and tools for monitoring and assessing (the status of) existing structures, relatively to structural loading and deterioration potential. * New (non-destructive) testing methods (radar, ultrasound, optical fibre, wireless smart sensors...) for diagnostic, early damage detection and maintenance of the infrastructures; * Smart inspection and robotics for maintenance * Integration of terrestrial and satellite systems for the structural health monitoring of key infrastructures located in a natural risk prone area (earthquakes, landslides, floods). Developing alternative structural models for deteriorating structures * The resistance of an ageing structure is dependent on the condition of the materials of which it is composed, for example the level of degradation of reinforcement bars. Precast elements for quick and efficient maintenance measures. This also will include new track forms, switches and crossings, and their potential for commercial development.			X			X		3b	X		1	X	
C	6	C	**Smart Infrastructures enabling condition based Maintenance.** It is important that the sensing and inspection technology as well as the models for degradation and structural integrity are developed in projects combining the two elements. The output of sensing and inspection is input for modelling. Hence, the input data that models require and the information that sensing and inspection can produce must fit. This program will have wide application for maintenance of large structures. - fewer maintenance operations mean fewer interruptions of the infrastructure network						X		3c			2		
C	7	C	Seamless cross borders transport operations, Freight Competitiveness via co-operation and co-ordination across Europe with technology and innovation, including: cross-European means of coordinating, managing and exploiting freight operations; Focus on corridors and create network dedicated to rail freight and strengthen the international corridors (TEN-T freight network), cross border ticketing-> faster, better quality, - Using sensor-based technology to monitor transport fleets.	2 Suggets combine with elements from numbers 8, 11, 12 and 13												
C	8	S/I	Ensuring new LD corridors has minimal impact on Accessibility (e.g. cycling and walking routes), minimising disruption to travel whilst ensuring that vulnerable users can safely cross the network.					X								
C	9	R	Innovative solutions for preparedness, prevention, robustness and recovery from the occurrence of emergency situation based on disruptive events (natural and man-made hazards)			X	X	X								
C	10	R	Infrastructure adaptation to climate change increasing the resilience against natural hazards considering service performance and related costs balance.					X								
C	11	R	**Resilient transport and logistics networks by design** Real Time Traffic Management enable control, command and communication systems runs across the whole European Rail network; Infrastructure resilience via technology innovation and governance, management and finance of the infrastructure; Transport chain design and operation for synchro modality					X								
C	12	S/S	**Future infrastructure for all users' safety: Road infrastructure**, both in urban and in rural areas, needs to be adapted to the requirements of new vehicle technologies, in particular automated driving functions, and its performance needs to be guaranteed by intelligent maintenance and monitoring. Also for pedestrians and cyclists a focus should be on their dedicated infrastructure to avoid amongst others single vehicle / road user accidents. Infrastructure design should take into account the need for interactions with all kinds of road users (human factors).				X									
C	13	S/S	Improved management of critical interfaces with others modes and smart methods for monitoring road-rail intersections with the use of advanced solutions (GNSS systems, advanced CCTV tools, etc.) and analysis (collaborative tools) integrated by new human centred safety measures . eg Level crossing for rail/road with the aim to minimize risks at and around level crossings by developing a fully integrated cross-modal set of innovative solutions and tools for the proactive management and new design of level-crossing infrastructure.Properly adapted technical solutions deployed within an appropriate human, legal and organisational framework are necessary.				X	XX				X				
	NEW TOPICS		Development of new materials and new ways to use existent and new solutions in order to facilitate (technological quality goal and cost efficiency) design and construction of pavements in regions with lack of local materials and low accesibility													
		G: GREEN; C: COST-EFFICIENT; S/I: SOCIAL & INCLUSIVE; R: RESILIENT; S/S: SAFE & SECURE														

		Connection to the RMMTI model	REFINET priority on transport infrastructures PRIORITY AREA D: Systemic approach	HIGH PRIORITY UK-UNIVERSITY	UK-UNIVERSITY	DENMARK-UNIVERSITY	FRANCE-RAIL ASSOCIATION	FRANCE-RAIL ASSOCIATION	GERMANY-UNIVERSITY	HUNGARY-COMPANY	ITALY-ROAD OPERATOR	NORWAY-UNIVERSITY	PORTUGAL-TECHNOLOGY PLATFORM	SPAIN-COMPANY	SPAIN-COMPANY	SWEDEN-RESEARCH ORGANIZATION
D	1	G	Integrated information system for asset management to ensure the proper decision-making process on prioritisation of asset maintenance and investment, based on sensing, measuring, imaging, simulation and computing tools through the whole life cycle of the transport infrastructure.						X						X	Second priority
D	2	G	Transport infrastructure Network assessment through asset management including BIM for monitoring and assessing the existing structures in order to prioritize the maintenance actions.						X		2					Third priority
D	3	C	Coordinated Travel Process - Multimodal Information Platforms, developing accurate information systems and integrating predictive urban and long distance traffic models with real-time information and mobility services.													
D	4	C	Active Integrated Transport Infrastructure: Data /Information systems to inform different stakeholders, as a Service supply model to be included in Transport industry, e.g. procuring for traffic information instead of traffic Sensors: to end-users on traffic conditions, to infrastructure managers on maintenance needs, to community to look for public acceptance of major infrastructure works, …													
D	5	F/E	Supply and demand - to make an overview of the streams of reuse and recycling materials and products, adding GREEN and COST-EFFICIENT aspects and to support company investments and the development of the regulation on the use of waste materials in the infrastructure construction/upgrading.	**3(=) Circular economy. Use of blockchain technology to monitor suply chain sustainability?**												
D	6	L/S	Codes: lack of multimodal standards and tools related to multihazard resilience, considering the government and private organisation collaboration, in order to achieve a seamless transport.											2		Highest priority
D	7	L/S	Standards for multimodal transport data aggregation in a common format for the development of multitude potential services from multimodal approach.											3	X	
D	8	R/I	Advanced traveler information - cross modal emergency evacuation/events/weather user information - integration, aggregation and dissemination of data across sectors (Transport operators, weather information providers, emergency sercives, public and authorities)													
D	9	R/I	Systemic multi-scale approach for assessment of the performance of transport infrastructure against multi-hazard risk within transport sector and from or to other sectors (intradependencies and interdependencies, such as cascade effects - in this sense cybersecurity as security of the data is so relevant)	3(=)												second priority
D	10	G	Inclusion of carbon in procurement decisions. That is why, lack of data on carbon emitted by different methods and materials should be known and the regulation should be developed.													
D	11	G	**Identification of Operational, Tactical and Strategy Key Performance Indicators for securing the uptake of transport infrastructures innovation in TEN-T projects/networks**: *Ensure efficient transport of goods and passengers using the High Level Service Infrastructure concept throughout needs relating to urban mobility, multimodal hubs and long-distance corridors. *Emphasizing characteristics such as GREEN, COST-EFFICIENT, SOCIAL/INCLUSIVE, RESILIENT and SAFE/SECURE, OPEN, ACTIVE and QUALITY as a reference framework for any new multimodal transport infrastructure. *Identification of Key Performance Indicators for securing the uptake of transport infrastructures innovation in TEN-T projects/networks	**1 (link to update of EU transport Scorecard?)**				X	X		1			1		Third priority
D	12	C	**Increasing awareness of transport (multi-modal) operators on high-potential technologies and future trends in design, construction, operation and maintenance of the future (after 2020) European infrastructure network**: Widespread, shared and agreed roadmap on high-potential technologies and future trends for an European infrastructure network, taking into account of key partnership roles from sectors such as energy and ICT.					X			2					
D	13	C	Transport user Expectations and Acceptance factors (age, sex, background, cultural aspects) across modes and according to new technologies in order to encourage the use of more sustainable behaviors of transport.					X								
D	14	F/E	**Better funding and financing methods**: ***Innovative funding methods:** innovative approaches are required to draw upon tax revenues; there is a need to consider innovative user engagement methods. Improved social and environmental impact assessment methodologies are required in order to improve existing financial assessments. ***Innovative financing methods:** to involve institutional investors more directly and actively. Application and testing of the suitability of different emerging common performance metrics and key performance indicators is required, through collaboration with the financial sector. New approaches are also required to the assessment and management of risk and resilience, through collaboration with the insurance industry.	2					X							
D	15	L/S	Standards and service quality assurance - interoperability: legislation and standards.			X										
D	16	L/S	Rules and Regulations - to facilitate and stimulate recycling and re-use in the field of infrastructure			X										
D	17	R/I	Undesired travelers behavior to response emergency situations				X	X								
D	18	-	**Spreading innovation and research in smart high-level service infrastructure**: Leveraging on the continuous development of a multi-modal infrastructures European stakeholders network for dialog and consultation between all actors, and to update and enhance a pan-European vision and approach towards the needs for collaborative R&D covering products, systems & services for HLSI development, operation & management.													
NEW TOPICS			**Standards and open data formats for road inventory and asset management data:** by defining a common and open data format for all information concerning the road infrastructure (dimensions, materials, surroundings, performance data, etc.) the exchange of data between different stakeholders becomes more efficient and offers the possibility developing unlimited user-oriented applications (Similar to D7, but related to infrastructure)												X	

G: GOVERNANCE; C: COMMUNICATION; F/E: FINANCING & ECONOMICS; L/S: LEGAL & STANDARDS; R/I: RISKS & INTERDEPENDENCIES

10. Conclusion

As main conclusion, Europe has the opportunity to lead an integrated and long-term research and innovation program for multimodal transport infrastructure, leveraging the current European transport and construction industry position to increase its strengths and in order to achieve high level service Infrastructure.

The REFINET vision is:

By 2050, a new **European multimodal transport infrastructure network** will ensure efficient transport of goods and passengers through the **High Level Service Infrastructure** concept spread out by **urban mobility, multimodal hubs and long-distance corridors** with the performances of **GREEN, COST-EFFICIENT, SOCIAL/INCLUSIVE, RESILIENT and SAFE/SECURE**, based on advanced and development of technologies and by means of **systemic approach perspective**, considering **GOVERNANCE, COMMUNICATION, FINANCIAL/ECONOMIC, LEGAL/STANDARDS and RISKS/INTERDEPENDENCY aspects**.

This vision statement is the result of set of activities with regard to:
Analysing the previous studies from different European Technology Platforms related to specific research needs for each trasnport modes and others, understanding the main transport policies with its main goals, identifying key global challenges, detecting barriers for innovation, conducting a SWOT analysis of the European multimodal transport infrastructure, and establishing priority areas and specific Research and Development needs based on Transport 2050 Roadmap and contributions from REFINET Stakeholders community (through the workshop held on Madrid, London, Rome and Bucharest) and the other two CSAs (FOX and USE-IT).

After defining the four priority areas of this REFINET Strategic Implementation Plan document, the different specific Research and Innovation needs has been gathered folowing the REFINET MultiModal Transport Infrastructure (RMMTI) framework (see Annex2). The specific actions formulated by Research and Innovation needs has been structured providing information about different fields: specific challenges, scope, impacts, required level of investment, priority level and geographic scale.

In this final version of the deliverable, feedback and contributions from different stakeholders of the transport infrastructure value-chain has also been included in order to provide some additional information in terms of the urgency to tackle the different specific research and innovation actions. Some few new actions have also been identified from the workshop hel on Bucharest and by an open consultation process to the stakeholders through the ECTP and the NTPs.

It is Obvious that the true nature of this Strategic Implementation Plan stays in considering it as a living reference document which rises the need to be updated and upgraded constantly. The evolving environment and the changes suffered with regard to new future scenarios in terms of constraints, boundary conditions and evolution of technologies leads to a continuous identification and definition of the research and innovation demands. It should be considered as a continuous task to respond to the main challenges of the transport infrastructure through the improvement of the High Level Service Infrastructure concept, considering the REFINET Multi-Modal Transport Infrastrure Framework to monitor and assess all these performances from both individual transport infrastructure and system network approach.

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ANNEX 1: EUROPEAN TRANSPORT INFRASTRUCTURE PROVISION BY MODE AND BY COUNTRY

After have analised European key policies and stakeholders expectations of transport infrastructure, the current state of European transport infrastructure provision by mode and by country, could be found in the following main references:

- European Commission Statistical Pocketbook 2015 https://ec.europa.eu/transport/facts-fundings/statistics/statistical-pocketbook-2015_en
- Eurostat: modal split of freight and passenger transport
- EU Transport Scoreboard http://ec.europa.eu/transport/facts-fundings/scoreboard/compare/investments-infrastructure/quality-roads/2013_2014/index_en.htm

ANNEX 2: REFINET MULTI-MODAL TRANSPORT INFRASTRUCTURE MODEL (FRAMEWORK)

Europe needs an interconnected multimodal transportation system that ensures a safe, efficient, accessible, affordable, convenient and comfortable move of people and goods with minimal adverse impacts to the environment. The design of a seamless integrated transportation system is required to achieve a competitive and connected EU. Drawing on the analysis of several documents produced by European Technological platforms, industry and other influential organizations, **this annex outlines the most relevant characteristics of the REFINET Multi-Modal Transport Infrastructure (RMMTI) Model** (for more detail, see Deliverable 3.1)**.**

There are several European initiatives that share this vision. A major one is the ECTP **reFINE[21] initiative** that advocates the need for developing **High-Level Service Infrastructure (HLSI),** to be considered the core elements of a future fully functional and EU-wide multimodal integrated transport by 2030 – the HLSI exposing the major following features:

- providing infrastructure for high quality **mobility services for people and goods while using resources more efficiently**;
- ensuring overall **better service and performance**, including multimodal integration and intermodal continuity for the end-user, less congestion, optimised transport time, etc.;
- higher degree of convergence and **enforcement of social, safety, security and environmental rules for infrastructure**, with minimum service standards (including minimum service obligations) at all time;
- **interconnected solutions for the next generation of multimodal transport management**, including information services and systems for all infrastructure.

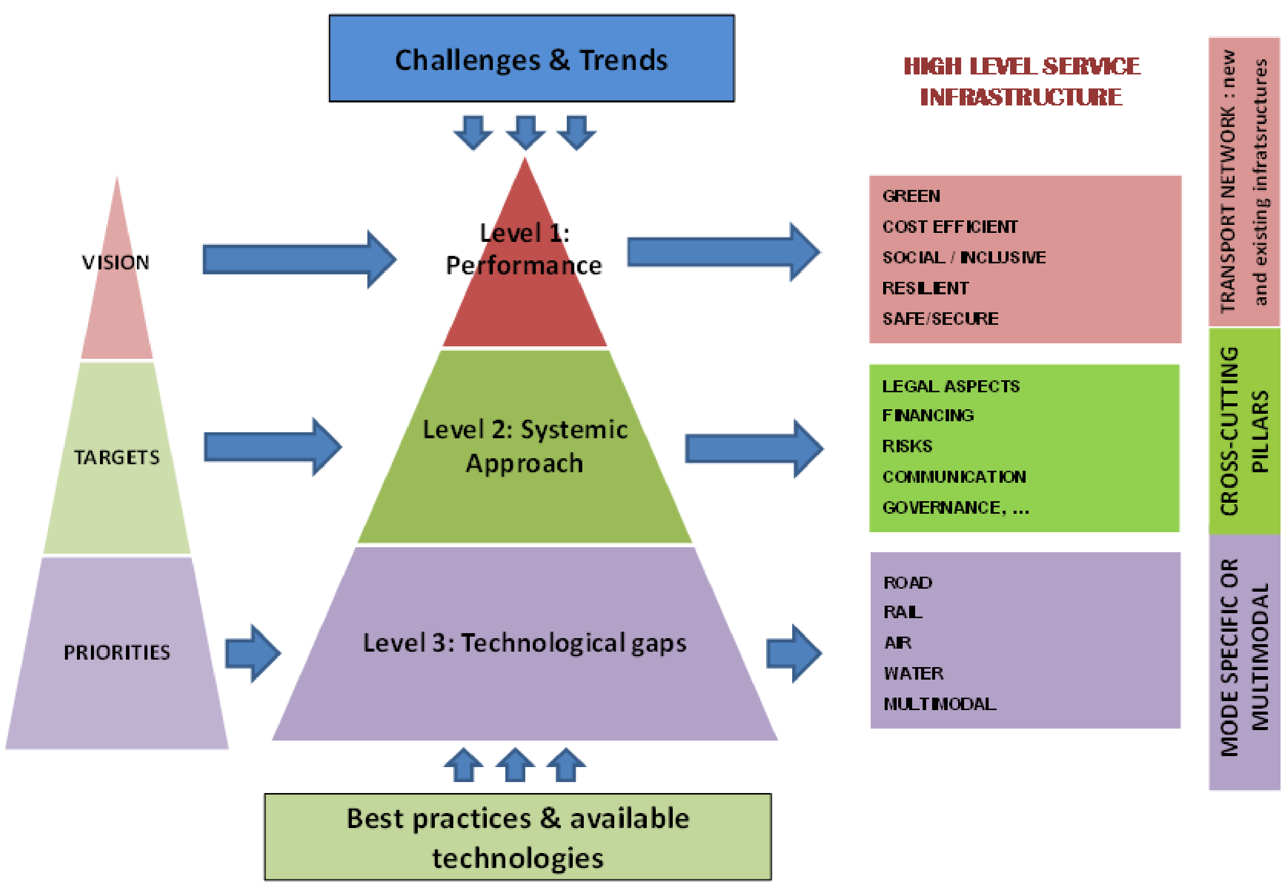
21 The reFINE initiative is now managed in the context of the newly formed “Infrastructures & Mobility” Committee within the ECTP – http://www.ectp.org.

The **ERTRAC-ERRAC-Waterborne-ACARE-ECTP Task Force** also raised high the need for research and innovation actions in order to enable an improvement of 50% in infrastructure performance, risk and cost versus a 2010 baseline as well as enable seamless door-to-door services for passengers and freight by 2030.

It is already acknowledged across Europe that there is need for a common European-wide approach to the development and delivery of innovative design, construction, maintenance and upgrading concepts and solutions to improve and extend in a customer-centric way the capacity of the existing network. In order to answer to this necesity REFINET CSA has defined the following model/framework to house the required specifications, previously mentioned in the reFINE initiative and in the Task Force.

As it could see in the figure below, the REFINET multimodal transport infrastructure framework is composed by three levels, which correspond to the following ones:

- Level 1: where to allocate target service level specifications.
- Level 2: to enable the integration of a systemic perspective for cross cutting specifications.
- Level 3: to place the technological improvements required.



Level 1, PERFORMANCE, corresponds to identifying which key features should be considered in order to define the European Multi-modal Transport Infrastructure of the future from the all stakeholder´s perspective (end-users, operators/ owners, construction companies, engineering firms and administration), and which they should match with the transport system strategy from a local, regional or global point of view. The considered performances which will be addressed are the following ones:

- **GREEN**
- **COST-EFFICIENT**
- **SOCIAL / INCLUSIVE**
- **RESILIENT**
- **SAFE / SECURE**

Level 2, SYSTEMIC APPROACH, corresponds to identifying which key aspects should be considered in order to have a systemic approach from multi-modal and whole mobility chain perspective This level aims at gathering all aspects related to "holistic integrated transport infrastructure" concept, identifying the main targets which enable the provision of high level service.

In this second level, under the umbrella of integrated design, construction and operation, building on the conclusions extracted from several Strategic Research Agendas, Roadmaps, and documents addressing the way forward for transport, the following aspects of the infrastructure network, selected on the basis of cross-cutting issues, are the most impacted if considered from a systemic approach :

- **Governance.**
- **Communication**
- **Financial/Economic aspects**
- **Legal/Standards**
- **Risks/Interdependencies**

Level 3, TECHNOLOGICAL GAPS, corresponds to identifying which key technology/knowledge has to be developed or adapted in the following years/decades to cope with identified challenges and to fulfil requirements of upper levels (1&2). The technological gaps have been structured into transport modes and into the three pillars as components of the transport network. However, it is true that some technology or knowledge could be cross- cutting through modes or the transport network. In this direction, the two submitted deliverables: "D3.2 Best practices in design, construction and maintenance of transport infrastructures" and the "D3.3 Analysis of available technologies in design, construction and maintenance of transport infrastructures" were written with aim of knowing the current state of the art and future trends in the field of this 3rd level of the model.

On the other hand, **the model will be used for structuring the priority areas and actions of the Strategic Implementation Plan**, around the identified 5 performance features which define the High Level Service Infrastructure in Level 1 of the model (Green, Cost-Efficient, Social/Inclusive, Resilient and Safe/Secure), as well as the other 5 performance features related to Systemic approach (level2 of model).

The reasoning is that all research and innovation strategies for the infrastructure sector should be aligned with the model. Therefore, the research priorities can be aligned with the elements of the model and the project results monitored and quantified in terms of their contribution for achieving the desired infrastructure performance.

It is important to highlight that this model needs to be dynamic, requiring continuous updating. This model has been outlined with the aim of serving as a reference, against which the gradual shift to multimodal networks could be benchmarked through the KPIs to be defined in each specific case, with the ambition that the deployment of the labelling will contribute to greener, more cost efficient, resilient and safer multimodal transport infrastructure, and, in order to pave the way for its implementation, a Strategic Innovation Plan has to be set up and agreed at a large scale in order to launch a pan-European Programme in that field.

The REFINET MMTI model and this document, the Strategic Implementation Plan, should guide the research and innovation investments of the infrastructure sector for the next period with the support of EU, national and regional bodies.

ANNEX 3: CONCLUSIONS OF WORKSHOP HELD IN LONDON (16TH MARCH 2016)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 653789.

Coordinated and Support Project (CSA)
Call: H2020-MG-2014_SingleStage_B
Topic: MG-8.1b-2014

REFINET INFRASTRUCTURE MOBILITY

REthinking Future Infrastructure NETworks

REFINET

Project Duration: **2015.05.01 – 2017.04.30**
Grant Agreement number: **653789**
Coordinated and Support Project

WP3

Activity Report from T3.4 | TECNALIA

Conclusions of workshop held on London (16th March 2016)

Dissemination Level

PU	PP	RE	CO

Project Coordinator: Alain ZARLI (CSTB)
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Project website address: http://infra.ectp.org/refinet (TBC)

Revision History

Date	Version	Author/Contributor[22]	Revision By[23]	Comments
05.07.2016	V01	TECNALIA		
29.06.2017	V02	TECNALIA	Jon Aurtenetxe	Final version submited to EC/INEA with changes linked to publication on CORDIS (EU emblem, disclaimer).

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LIST OF FIGURES

ABBREVIATIONS

Acronym	Full name
RMMTI	REFINET Multi-Modal Transport Infrastructure
HLSI	High Level Service Infrastructure

1. INTRODUCTION

This workshop activity, held at Headquarters of ARUP in 16th March 2016 and organised by TECNALIA with strong support of ARUP, is included in Task 3.4 "Strategic Implementation Plan (SIP) definition", which objective is to elaborate the REFINET Strategic Implementation Plan (SIP) within the Work Package 3 "Defining Vision and SIP".

The contribution to define the Strategic Implementation Plan of REFINET has been carried out by the REFINET´s partners with the attendance of the members of the REFINET network, who have been invited and involved in the discussion through the mentioned workshop, in order to involve different and all stakeholders´ perspectives related to transport infrastructure (user, Administration, operator/owners, construction companies, engineering firms and Universities and Research centres)

Finally fifteen experts, from different companies, research organisations and universities could attend to the workshop, which are distributed as 7 companies (from UK and Spain), 1 research organizations (from UK) and 2 universities (from UK and Czech Republic)

The REFINET partners, who attend the workshop were:

- Alain Zarli: CSTB, France
- Ben Kidd: ARUP, United Kingdom
- Jesús Rodriguez: PTEC, Spain
- Jon Aurtenetxe: TECNALIA, Spain
- María Zalbide: TECNALIA, Spain
- Migle Paliukaite: FEHRL, Belgium
- Miguel Segarra: DRAGADOS, Spain
- Thierry Goger: FEHRL, Belgium

The European initiciative reFine, whose aim was to foster Innovation for Transport Infrastructure of the Future, and the REFINET Multi-Modal transport Infrastructure (RMMTI model), developed in Task 3.1 of the project were stablished as a background and the framework. Concepts, such as "High Level Service Infrastructure " or " the three pillars of transport network" were regained in order to present the experts a draft version of the framework to work with during the all day workshop session.

2. OBJECTIVES

The workshop has been divided into two specific themes in order to gather valuable and useful information to define the REFINET Strategic Implementation Plan (SIP), according to the following agenda of the day:

REFINET INFRASTRUCTURE MOBILITY

REFINET WORKSHOP

Strategic Implementation Plan
Technological demands of transport infrastructures

16th March 2016
ARUP, 8 Fitzroy Street, London W1T 4BQ
Emmerson/Shears meeting room

Agenda

Thursday 16th	
8:30-9:00	*Registration*
9:00-9:10	Welcome by Terry Hill (ARUP)
9:10-9:25	Overview of REFINET project (Alain Zarli, CSTB). *Vision, Challenges Definition of the Refinet Multimodal Model for Transport Infrastructure RMMTI, collecting Best practices, Overview of projects and initiatives, Analysis of available technologies, REFINET selection & evaluation criteria for European & International research on REFINET topics*
9:25-9:50	Rail infrastructure innovation towards a European integrated transport system John Pelton (Innovation Manager. Cross Rail) TBC
9:50-10:15	Analysis of available technologies towards the RMMTI. Ben Kidd (ARUP)
10:15-12:35	Participants view on I+d+I Challenges and Technological Priority Areas for the European Multimodal Transport Introduction by Terry Hill (Transport Systems Catapult) Moderators: Maria Zalbide (TECNALIA), Miguel Segarra (DRAGADOS) Rapporteurs: Jon Aurtenetxe (TECNALIA) and Ben Kidd (ARUP)
12:35-12:50	**DEBRIEFING from the workshop by the rapporteurs**
12:50-13:30	*Lunch*
13:30-13:45	oneTRANSPORT project (Tim Gammons, ARUP) Overview of CIRIA best practice guidance for UK transport infrastructure (Owen Jenkins, ARUP)
13:45-16:15	Participants view on scope, barriers and timeline for implementation of research priorities for the European Multimodal Infrastructure Moderators: Maria Zalbide (TECNALIA), Miguel Segarra (DRAGADOS) Rapporteurs: Jon Aurtenetxe (TECNALIA) and Ben Kidd (ARUP)
16:15-16:40	**DEBRIEFING from the workshop by the rapporteurs**
16:40-17:00	*Wrap up and Conclusions. Follow-up Plan*
17:00	*End of workshop*

REFINET Workshop Agenda Page 1/1

Figure 4. Workshop Agenda

The two workshop sessions have focused on different targets with the following specific objectives:

The objective of the **morning workshop session** was:

- to identify the R&I **Challenges and Technological Priority Areas** for the European Multimodal Transport Infrastructure.
-

The objective of the **afternoon workshop session** was:

- to collect participants **view on scope, barriers and timeline for implementation of research priorities** for the European Multimodal transport Infrastructure.

3. METHODOLOGY

As mentioned before, some concepts from the European reFine initiative were recovered to define the context about the objectives and framework of the REFINET project as a starting point, in order to dynamise the participation of all attendees.

Moreover, ARUP, CSTB and TECNALIA presented some explanatory slides with specific focus on the overview of REFINET project, available technologies and the methodology to follow during the workshop.

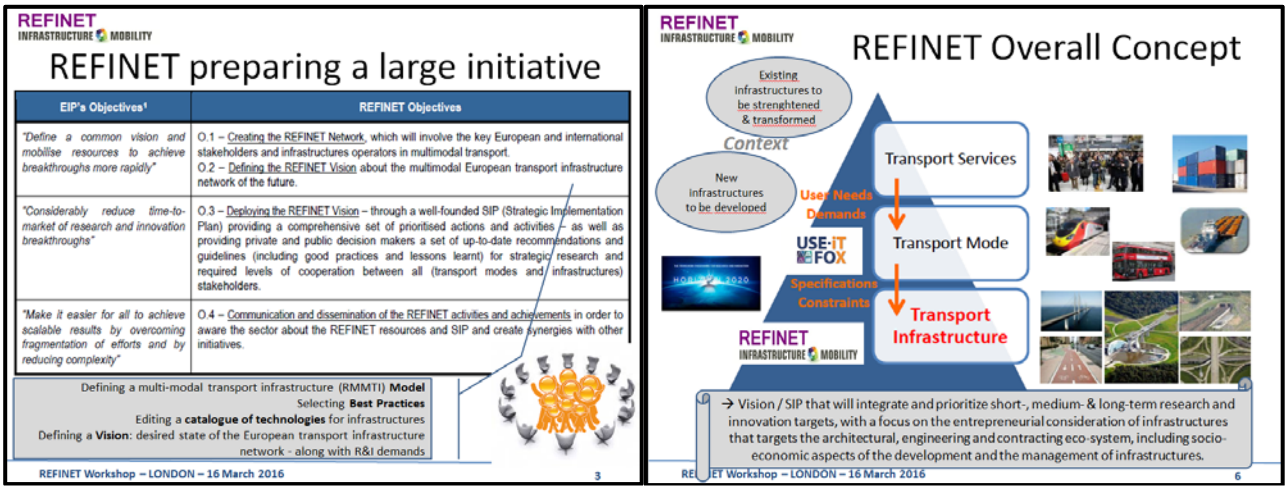


Figure 5: REFINET objectives and Concept

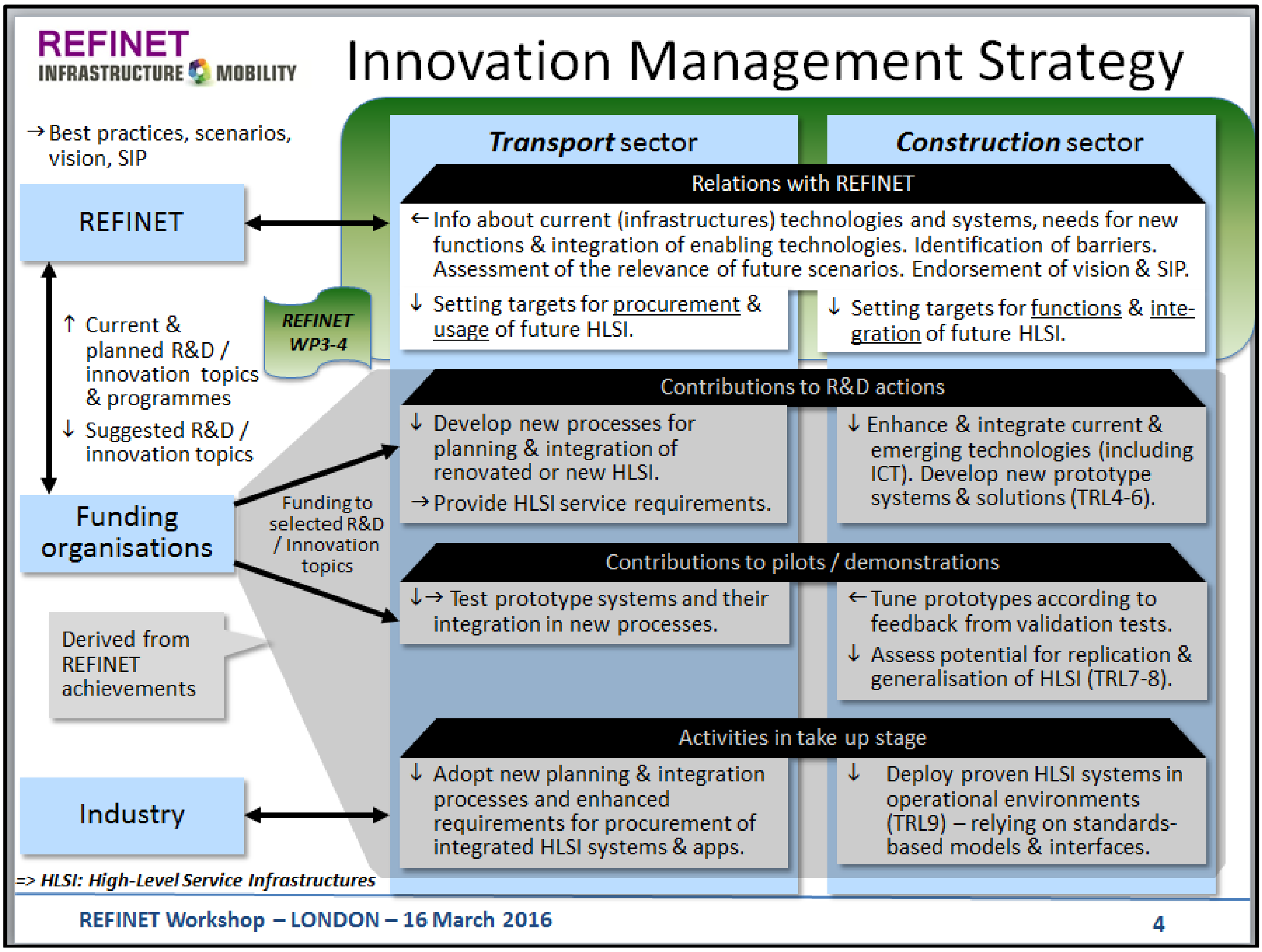


Figure 6:REFINET & Innovation Management System

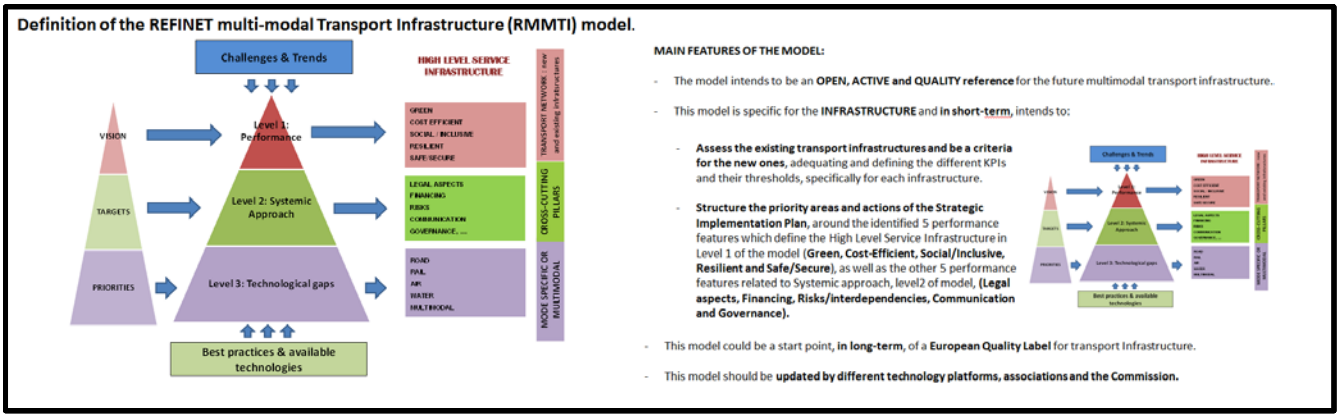


Figure 7: REFINET MultiModal Transport Infrastructure model (RMMTI Framework)

Before each workshop session, Rail infrastructure innovation, analysis of available technologies, oneTRANSPORT project presentation and Overview of CIRIA best practice guidance were presented by some of the experts.

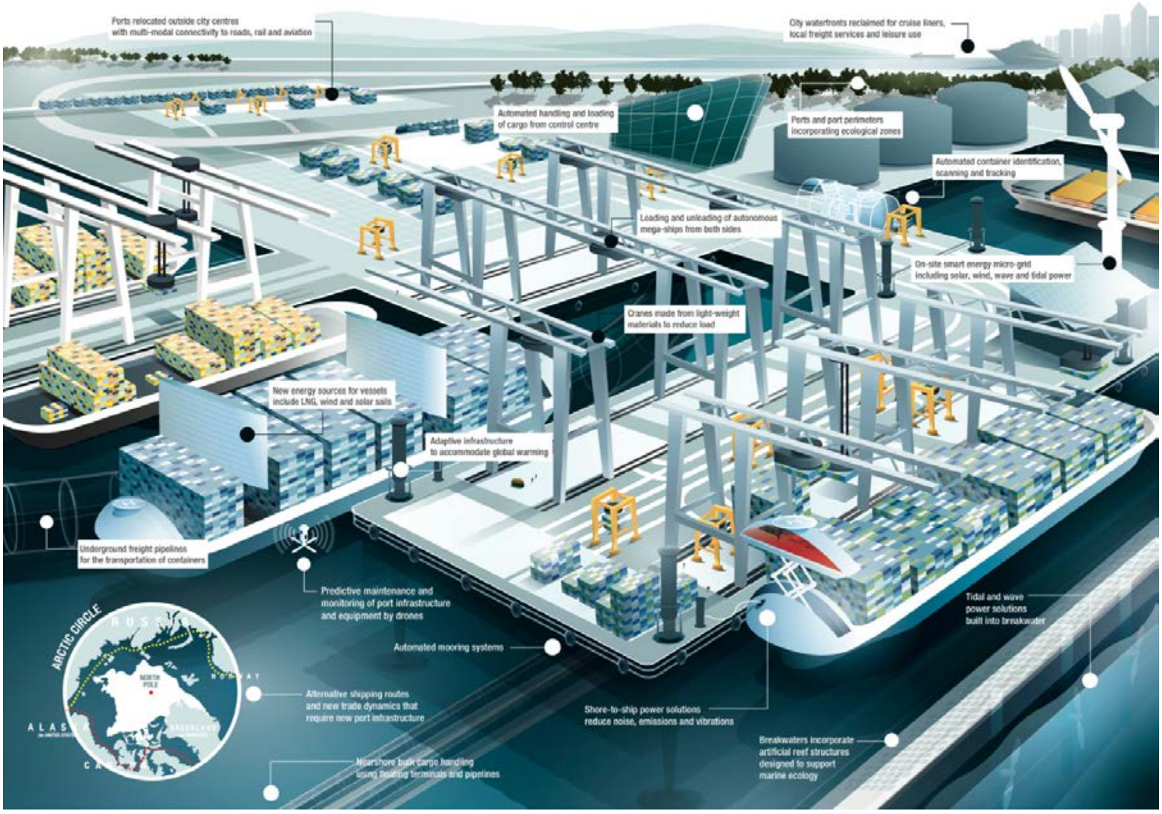


Figure 8: Example of available technologies andPort of the Future - ARUP

As in the first workshop in Madrid, some concepts from reFine initiative were also reminded and explained to every attendee:

- **High level service infrastructure HLSI** has the following features:
  - Providing infrastructure for **high quality mobility services for people and goods** while using resources more efficiently.
  - Ensuring overall better service and performance, **including multimodal integration and intermodal continuity for the end-user**, less congestion, optimised transport time, etc.

- Higher degree of **convergence and enforcement of social, health safety, security and environmental rules** for infrastructure, with the adequate service standards at all times,
- **Interconnected solutions** for the next generation of multimodal transport management, including information services and systems for all infrastructure

- The **three identified pillars of the high-Level service infrastructure "HLSI"** concept were: Urban mobility, multimodal hubs and long distance corridors, which compose the transport network, where in the baseline the transport infrastructure is allocated.

Figure 9: Three pillars of the High Level Service Infrastructure

3.1 Methodology for morning workshop session: Challenges and Technological Priority Areas for the European Multimodal Transport – Identification

The group of twenty three people was divided into two groups, and they were seated in two groups.

The participants in each team were required to identify the research needs individually with hand-outs during thirty minutes for each priority area (URBAN MOBILITY; MULTIMODAL HUBS; LONG DISTANCE CORRIDOS and SYSTEMIC APPROACH).

After this time, they discussed in group for another thirty minutes to put it in common with everyone in the group.

The rapporteurs (Ben Kidd and Jon Aurtenetxe) in each group reported to the larger group and then the discussion followed using the flipchart a starting point for debate. (30min)

3.2 Methodology for afternoon workshop session: Collecting participants' view on scope, barriers and timeline for implementation of research priorities.

The group of twenty three people was divided into two groups, and they were seated in two groups.

The participants in each team were required to complete the scope, barriers and timeline for implementation of previously identified research needs with hand-outs during thirty minutes for each priority area (URBAN MOBILITY; MULTIMODAL HUBS; LONG DISTANCE CORRIDOS and SYSTEMIC APPROACH).

After this time, they discussed in group for another thirty minutes to put it in common with everyone in the group.

The rapporteurs (Ben Kidd and Jon Aurtenetxe) in each group reported to the larger group and then the discussion followed using the flipchart a starting point for debate. (30min)

4. RESULTS

The contributions of the two teams have been gathered as follows and classified them by the four priority areas:

PRIORITY AREA A: URBAN MOBILITY		ID	Scope	Impact	Barriers	Budget €	Timeline	Scale	Comments
RESEARCH TRL<5	GREEN	R1.1	Air quality issues - technologies e.g. coatings	Health					
		R1.2	Reducing air pollution in cities						
		R1.3	Relationship between smart grids + energy storage electric vehicles						
		R1.4	Research in Reuse and after life disposal	environment					
		R1.5	Heat removal of tube lines						
		R1.6	Undergrounding large avenues with connections to local car-parks in the cities	Cities are mainly pedestrians or small and smart vehicles oriented					
		R1.7	Technologies for automated transport means inside the cities	More flexibility in transport avoid traffic jams thanks to automation. Mobility as service.					
		R1.8	Solar road						
		R1.9	Inductive technology - electrification						
	COST-EFFICIENT	R2.1	Risk sharing and transactions in construction	Financial / value for money					
		R2.2	3D-printing large scale						
		R2.3	Vehicles as a service	optimise assets both vehicle+road					
		R2.4	Financial innovation to fund new /maintenance of old infrastructure						
		R2.5	New construction techniques to decrease time scales						
		R2.6	Composite materials for sale, smart, cheap structures						
		R2.7	Prefabrication - modular construction/upgrade						
	SOCIAL / INCLUSIVE	R3.1	Approaches to improving access	Social mobility / Independence					
		R3.2	Congestion & evacuation / Crowd control	Public safety					
		R3.3	Smartening versus vulnerable group of people (disabled, old people,…)						
		R3.4	Journeys pertinent to user and not generic						
		R3.5	Assessing HCD aspects of urban mobility + modeling - simulation - accuracy						
		R3.6	Sensors for real-time geolocalised information to cars	Need for collaboration between cars manufacturers & infra contractors					
		R3.7	Co-planning and management of all infrastructure (transport, water, other networks)						
	RESILIENT	R4.1	Self-healing materials	Life extension					
		R4.2	Asset degradation / residual life for older structures						
		R4.3	Impacts of severe weather events-adaptation measures						
		R4.4	Adaptation to abrupt increase of temperature and moisture content						
		R4.5	Governance of transport system						
	SAFE / SECURE	R5.1	cyber security / privacy issues related to "smart"						
		R5.2	Cyber security R&D to keep ahead hackers						
		R5.3	Autonomus vehicles / trains, etc.						
		R5.4	PRT systems	lower casualties/accidents					
		R5.5	Safety standards processes for SIS - ISO 26262						
		R5.6	Forgiving road						
		R5.7	Automated and connected vehicle - Adaptation of transport infrastructure						
		R5.8	Flood partial management by infrastructures (road?) based on new materials / new construction methods.						
		R5.9	Robotics for silent, undisruptive "keynote surgery" construction/rehabilitation						
INNOVATION 6<TRL<8	GREEN	I1.1	Low carbon whole -life costing						
		I1.2	Multiple-benefit design	e.g. air quality, biodiversity					
		I1.3	Advanced materials e.g. materials that repai	less disruption					
		I1.4	Electric buses						
		I1.5	Movement energy harvesting						
		I1.6	Superabsorbing surface materials (CO2, Nox)	Absorb + reduce emissions					
		I1.7	Integration of nature-based solutions (both GREEN & SOCIAL / INCLUSIVE)	Infrastructures participate to "greening" the cities + CO2 -free cities					
		I1.8	Inductive technology - electrification						
		I1.9	rapid-charging of electric vehicles-deployment and usage in cities						
		I1.10	Noise & pollution reduction						
	COST-EFFICIENT	I2.1	Greater use of standardiesed approaches	design at once build in n times					
		I2.2	Standard way of commicating innovation in infrastructure	industry-wide impact					
		I2.3	whole life time -> intelligent signs in vehicles for instance.						
		I2.4	Low cost sensors in mobility infrastructures	smartening entire system					
		I2.5	Modular, prefabricated roads + sidewalks	Short construction phase					
		I2.6	Warm-mix asphalt (prefabrication)						
		I2.7	self-healing (long lasting)						
		I2.8	DPI - > airspace and departure planning						
		I2.9	Generalisation of data-communication networks along transport avenues (sensors, cameras, etc.) to improve transport management	Improve traffic in cities, bus raises issues to cost & maintenance of the data networks					
		I2.10	Infrastructure for autonomous travel						
	SOCIAL / INCLUSIVE	I3.1	Transport links info on delays across modes						
		I3.2	Informing custome - providing choice-traveller needs						
		I3.3	Autonomous vehicles/hybrid systems	improve mobility for elderly/ disabled					
		I3.4	Vwide spread technology APP						
	RESILIENT	I4.1	Use of real time info to forecast environmental hazards						
		I4.2	Prioritisation of asset maintenance + investment						
		I4.3	Real time travel options to users						
		I4.4	Addictive manufacturing (3D printing)						
		I4.5	Networked trials and evaluation to engage with SME groups to accelerate TRL progress						
		I4.6	Design for upgradebility, retrofiting	cost reductions for maintenance/retrofit					
	SAFE / SECURE	I5.1	Public communication & awareness						
		I5.2	System of systems thinking requeriment						
		I5.3	Responsive infrastructure - ligths that came on when you walk past						
		I5.4	Autonomous vehicles -> trials + testing in representative environments/hybrid systems						
		I5.5	Management of people/public during upgrade of infrastructure						
		I5.6	Roadway ligthing systems						
DEPLOYMENT 8<TRL		D1	Connectivity for vehicles						
		D2	Open information of data						
		D3	Public acceptance of major infrastructure works.						
		D4	Green procurement for vehicles + infrastructures						
		D5	24/7/365 operation						
		D6	Reduction on impact on adjacent networks whilst infrastructure works being undertaken.						

PRIORITY AREA B: MULTIMODAL HUBS		ID	Scope	Impact	Barriers	Budget €	Timeline	Scale	Comments
RESEARCH TRL<5	GREEN	R1.1	Air quality &congestion in location						
		R1.2	Design for accomodation of new technologies - how to prevent physical lock-in .e.g. Birmingham New Street						
		R1.3	Energy usage in hubs						
		R1.4	Range and usage of vehicles against hub frequency -> electric vehicles on-demand						
		R1.5	Multi-modal hubs as specific energy centers	Hubs as large infrastructures being the case of local energy networks					
		R1.6	Automation (freight)						
		R1.7	low carbon material						
	COST-EFFICIENT	R2.1	Financing models & public-private investment						
		R2.2	Oversite development						
		R2.3	Automatization						
		R2.4	Concentration of infrastructure (vs. Widespread)						
		R2.5	Funding opportunities for cross-sectorial approaches						
		R2.6	Design and construction opportunities						
		R2.7	DPI departure planning-> multimodal, role-out						
		R2.8	Vertical, space-effcient						
	SOCIAL / INCLUSIVE	R3.1	Avoiding congestion at hub						
		R3.2	Multi-lingual communication						
		R3.3	Accesible - Accesibility for elderly and disabled people						
		R3.4							
		R3.5	Vertical hubs: business model centered around "retail business-model" is against good mobility. It needs to have business-model centre around mobility						
	RESILIENT	R4.1	Avoiding rush-hour peaks	overall large increase in capacity					
		R4.2	Pressure in increasing demand of future population						
		R4.3	Vulnerability created by phisical interdependencies - assessment of impacts -cascade effects						
		R4.4	Modelling and prediction occurrency of events	Think twice, build once					
		R4.5	Link with other multimodel hubs (network of hubs)						
		R4.6	Multi-function hubs - Interchange, shopping, working, living, play, energy distribution, healthcare.						
		R4.7	High flexibility to interchange route or transport mode						
	SAFE / SECURE	R5.1	Facial recognition						
		R5.2	Step-free adaptations in congested spaces	ensuring vulnerable/elderly do not get lost/ confused					
		R5.3	Resilience to terrorism attacks (preparedness, prevention, robustness and recovery)	increased security,...					
		R5.4	Barriers to mobility (security controls, ...)	faster mobility, improved customer service and satisafction					
		R5.5	Data sharing, security, privacy,...						
INNOVATION 6<TRL<8	GREEN	I1.1	Renewables/ligthing/low enegy vehicles/low carbon						
		I1.2	Energy self-sufficient						
		I1.3	Provide ecosystem services to city	reduce PM, Nox, CO2					
	COST-EFFICIENT	I2.1	Google maps & Transport options						
		I2.2	Transfer of knowledge + skills from previous projects						
		I2.3	Better linkage across modes for travel times reduction						
	SOCIAL / INCLUSIVE	I3.1	Seamless multi-mode ticketing						
		I3.2	Improved communication at interchanges /apps						
		I3.3	Peak load distribution to increase capacity						
		I3.4	Design for all of multi-modal hubs	Easy access/mobility for all					
		I3.5	Full integration in design of regulations (security, disabled,...) download of plans for easily transfer in hubs/personalised interactive maps	Ease for passenger to move in the hub thanks to digital info on his/her smartphone, tablet, augmented reality.					
		I3.6	Modular						
		I3.7	Accesability, barrier free						
		I3.8	Accessibility for physically impaired users						
		I3.9	Travel information sharing + communication between operators						
		I3.10	Information permanent to user needs. Sent to devices, therefore reomval of sign.						
	RESILIENT	I4.1	Real-time data to predict disruption						
		I4.2	Utility corridors + deliveries						
		I4.3	Distributed model hubs						
		I4.4	Data access and information creation: traffic,...						
		I4.5	Structural Health Monitoring	Less down-time					
	SAFE / SECURE	I5.1	Security surrounding transport hubs	e.g. Birminghan					
		I5.2	Digital design						
		I5.3	Working distance minimisation						
DEPLOYMENT 8<TRL		D1	Integrated transport system						
		D2	Different technology deployment						
		D3	Virtual powerstations - demand side energy management						
		D4	Automation						
		D5	Concentration of infrastructure						
		D6	Time to transversce hub-unknown						
		D7	Funding + financing opportuinities created by merger with retail + real estate						
		D8	Disruption during upgrades						

PRIORITY AREA C: LONG DISTANCE CORRIDORS		ID	Scope	Impact	Barriers	Budget €	Timeline	Scale	Comments
RESEARCH TRL<5	GREEN	R1.1	Use as multi-utility routes						
		R1.2	In-built energy sources for electric vehicles (highways)						
		R1.3	MULTI-MODAL vehicle (able to g on road, rail, …)						
		R1.4	Vertical corridors						
		R1.6	Platooning - energy efficiency						
		R1.7	Understanding demand patterns and "nudging" demand						
		R1.8	Recycled materials for surface transportation						
		R1.9	Noise Cancellation (acoustic performance)						
	COST-EFFICIENT	R2.1	Construction tecniques						
		R2.2	How to re-purpose assets when the centres they connect are no longer relevant.						
		R2.3	Automatic status / maintenance needs detection for bridges and tunnels	Information to corridor operator/manager to enhance maintenance and reduce risks					
		R2.4	Multi-user corridors						
		R2.5	Synchro-modality						
		R2.6	Standard components						
	SOCIAL / INCLUSIVE	R3.1	How to adapt for new vehicle technology						
		R3.2	positive impact infrastructure (increase price of building)						
		R3.3	Google cars - people						
		R3.4	Acceptance & approval process of new routes						
		R3.5	Assessment value added for communities"along the way"						
	RESILIENT	R4.1	Avoiding vehicle impact						
		R4.2	Deterioration of long-term assets - how to model to better target maintenance						
		R4.3	Upgradability and decomissioning						
		R4.4	Long tem shift in vehicle types (especially rail)	Future adaptability					
		R4.5	No maintenance infrastructure						
	SAFE / SECURE	R5.1	Evacuation on to tracks						
		R5.2	Platooning of vehicles						
		R5.3	cyber, systems approach - EU standards	pooling efforts					
		R5.4	Automated freight /hyperloop for goods						
		R5.5	Techniques / methods for maintaining 24/7 365 operation						
		R5.6	Route to autonomy-technologies embedded into onfrastructure to aid autonomous vehicles						
INNOVATION 6<TRL<8	GREEN	I1.1	Greening linear infrastructure						
		I1.2	Hydrogen Infrastructure						
		I1.3	how to design + construct for multiple uses e.g. road/rail embarkment as flood protection						
		I1.4	Electric car - power sources - distributed grids	CO2 decrease					
		I1.5	low carbon materials						
		I1.6	Inductive fast charging while driving						
	COST-EFFICIENT	I2.1	Standard condition assessment e.g. highways/rail/flood protection						
		I2.2	Intelligent signs, removal of sign for in-vehicle information systems						
		I2.3	Intelligent infrastructure						
		I2.4	LOGISTICS / HYBRID MACHINES						
		I2.5	Remote condition assessment techniques						
		I2.6	Integration of multiple scales of data to monitor performance (e.g. radar with sub-surface pant sensors)						
	SOCIAL / INCLUSIVE	I3.1	Communication with travelling public-informed traveller						
		I3.2	inductive chaging integration						
	RESILIENT	I4.1	Critical nodes & interchanges & diversions						
		I4.2	Remote monitoring of condition in use						
		I4.3	Data Communication networks coupled with corridors	Get info through sensors on all sections of corridors					
		I4.4	Cloud Nvigation - intelligent re-routing						
	SAFE / SECURE	I5.1	Autonomy - platooning	User error elimination - adapting autonomous and user interaction					
		I5.2	Drone-based maintenance	Ease of maintenance, incease safety of infra					
DEPLOYMENT 8<TRL		D1	Better communication especially delays						
		D2	BRT systems for connecting center+suburbs						
		D3	Bike highways						
		D4	Wind (microturbines)						
		D5	Solar panels on side of infrastructure						
		D6	Connectivity of vehicle						
		D7	Pollution - Nox						
		D8	Asset monitoring / smart infrastructure						
		D9	Hard shoulder runninng troughout whole EU network						

PRIORITY AREA D: SYSTEMIC APPROACH		ID	Scope	Impact	Barriers	Budget €	Timeline	Scale	Comments
RESEARCH TRL<5	GOVERNANCE	R1.1	Skills focused so far on "offer" side, but it is needed some "demand" - client - side						
		R1.2	BIM - Condition awareness						
	COMMUNICATION	R2.1	interdependences & vulnerabilities						
		R2.2	Artificial intelligence (autonomous decision-management)						
	FINANCIAL	R3.1	ownership &						
		R3.2	real performance based maintenance - remote sensing						
	LEGAL / STANDARD	R4.1	Codes: lack of multimodal standards and tools related to multihazard resilience	Improved, efficient interfaces between different modes at transhipment points for achieving seamless transport.					
		R4.2	RAG standards/codes, specifications to encourage innovation: Red (mandatoy, few) , Amber (advisory, some), Green (suggested, most)						
		R4.3	Regulation						
	RISKS / INTERDEPENDENCIES	R5.1							
		R5.2							
INNOVATION 6<TRL<8	GOVERNANCE	I1.1	How we travel - TSC study-Times?						
		I1.2	Advanced capability of experienced construction project managers. European school for client-side infrastructure commissioners						
	COMMUNICATION	I2.1							
		I2.2							
	FINANCIAL	I3.1	contract forms / risk ownership						
		I3.2	New business models	mobility as service					
		I3.3	Whole life time costs						
	LEGAL / STANDARD	I4.1	Distinguish between standards & regulations						
		I4.2							
	RISKS / INTERDEPOENDENCIES	I5.1							
		I5.2							
DEPLOYMENT 8<TRL		D1							
		D2							
		D3							
		D4							
		D5							

Urban mobility				
Technologies / research needs	Notes	KPIs	metrics	Challenges
Electrification - inductive technologies and energy harvesting	Energy harvesting from regenerative braking, driving asset management remote condition monitoring (MEMS sensors). Automation of freight, autonomous vehicles and the impacts on infrastructure requirements, linked to changes in rail sector through ETCS.	tbc	All scales, short time, low cost	Deployment issues and organisational bounaries. How does transport infrastructure sit into the new emerging decentralised energy system (energy vectors into cities)?
Modular and multi-functionality	Highways as energy and communication corridors too. Robotics and self-maintaining assets. Environmental Product Declarations (EPDs) and material passports for components and structures	tbc	Local, long term	Risk averseness of transport infrastructure sectors. Converting / retrofitting existing infrastructure. Short 'possession' times to undertake retrofit / refurbishment. Driver of circular economy in its infancy
Interdependencies across infrastructure	Weather data and information on system impacts. Passenger information and end-to-end journey planning, last mile logistics. Data security and cyber threats	tbc	Long term	Policy and regulation, harmonisation of platforms.

Multi-modal hubs				
Technologies / research needs	Notes	KPIs	metrics	Challenges
Vertical hubs - business model	High value of land above and below ground, squeezing footprint. Multi-functional spaces.	tbc	High cost, long term	Technical challenges, expectations of developers (eg existing retail alongside)
Designing resilient hubs	Structures, materials, predictive analytics using BIM models, visualisations. Adaptive structures. Accessibility, behaviour, lifestyle changes. Ticketless barriers, blast resilient materials. Integrated cycling infrastructure. Multi-functional electrical charging, and energy harvesting	tbc	Short term projects	Existing infrastructure constraints - eg drainage issues. Understanding behaviour of structures. Concentrating energy, communication infrastructure, and people in small spaces. Digitisation of design and construction introduces cyber risk (BIM models)
Network of apps				Competition - lack of data sharing

Long distance corridors				
Technologies / research needs	Notes	KPIs	metrics	Challenges
Multi-use corridors	Stacked roads on railways. Invisible design seamless with landscape. Concealed, attractive, silent. Use of energy generated in braking. Climate resilient corridors (drainage, flooding, snow)	tbc	Medium scale, high cost, regional, longer term	Majority of issue is existing infrastructure. Cost and ownership barrier. Desire to coordinate with electricity and other utilities but complexity of organisations involved.
Whole life asset management	Retrofit / renewal vs ongoing maintenance. Zero maintenance vegetation. Benefit model (energy, communications, mobility, social benefits).	tbc	Moderate cost, mid-term, national and European scale	Need for communication of innovation between transport operators. Data barriers, business models and ownership of data.
Condition aware infrastructure	Optimising renewal / maintenance cycles. Predicting durability and asset deterioration. Aggregating datasets to make better predictions. Access to best data	tbc	Local (multiple operators sharing data), moderate cost, short term	Reliability of data and cost involved upgrading all existing infrastructure into 'smart infrastructure'
Self healing and other innovative materials and components	Additive manufacturing for self-healing and modular materials and components. Linked to specific call within SHIFT2Rail. Lightweight	tbc	High cost, medium term, regional	Standards and design codes - holding back emergence of additive manufacturing applications in transport infrastructure
Climate resilient infrastructure	Climate change adaptation, material resilience (eg de-icing), business continuity, transport planning and emergency planning.	tbc		Understanding the cascading impacts and where to set boundaries for systems research.

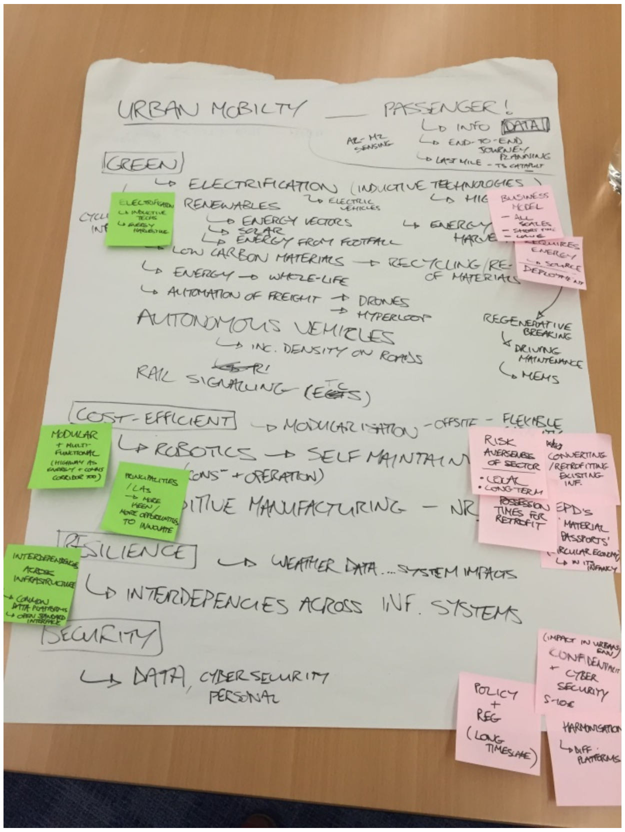
Systemic				
Technologies / research needs	Notes	KPIs	metrics	Challenges
Common performance metrics	Whole life performance, not just lowest cost procurement. London Underground Bank station refurbishment example - demand capacity (rather than supply side)	Procurement focussed on outcomes and TOTEX, not simply CAPEX	Medium term, medium cost, national scale	Procurement as a barrier (least cost normally selected). Mobility as a service is not considered in procurement. Resilience not considered sufficiently in procurement
Condition aware infrastructure for life extension	vehicle to vehicle (V2V) sensing, vehicle to infrastructure (V2I) sensing, remote condition monitoring	tbc	Short term, low cost, national scale	Accuracy of data
Cross-modal asset management (whole-life)	Predictive engineering from BIM / AIM	tbc	Short term, low cost, national scale	More than 1 authority for long distance corridors (eg rather than just TfL for urban mobility)
Research into future skill requirements	Client understanding. Pipeline of projects - network of major project clients across Europe (building on UK group of Crossrail, HS2, Thames Tideway via Major Projects Association	tbc	tbc	Lack of published pipeline of major projects across Europe. Lack of coordinated future skill plans across transport modes and across Europe
Resilience throughout lifecycle	Resilience to natural hazards and future climate change risks, interdependencies between transport modes and with energy/water sectors. Uncertainty in predictions.	tbc	Short to medium term, high cost, all scales	Understanding hazards, vulnerabilities and risks.
Performance based standards	Interoperability - building on TSIs developed in rail sector. Overhaul of codes / specifications / standards	tbc	Longer term deployment, shorter term research	Different levels of maturity in different European Union member states

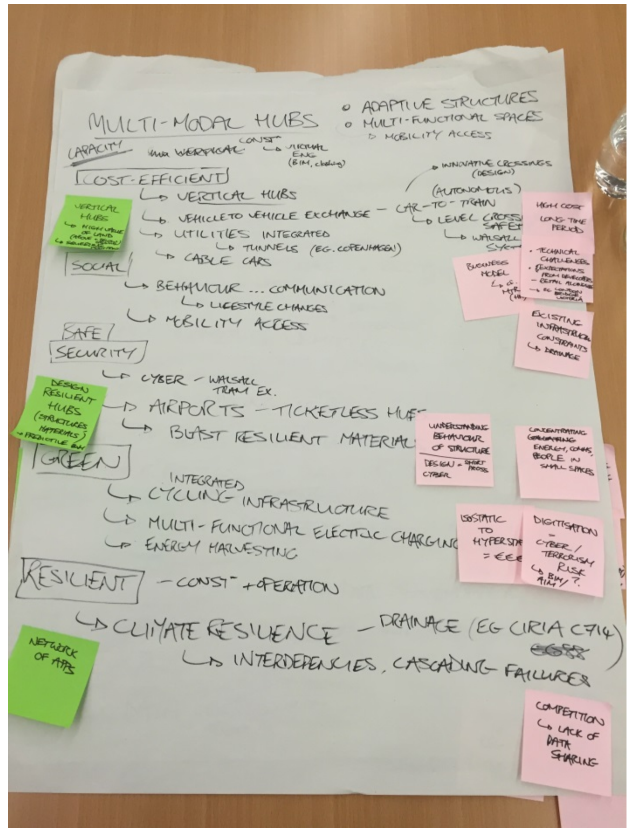
5. CONCLUSIONS

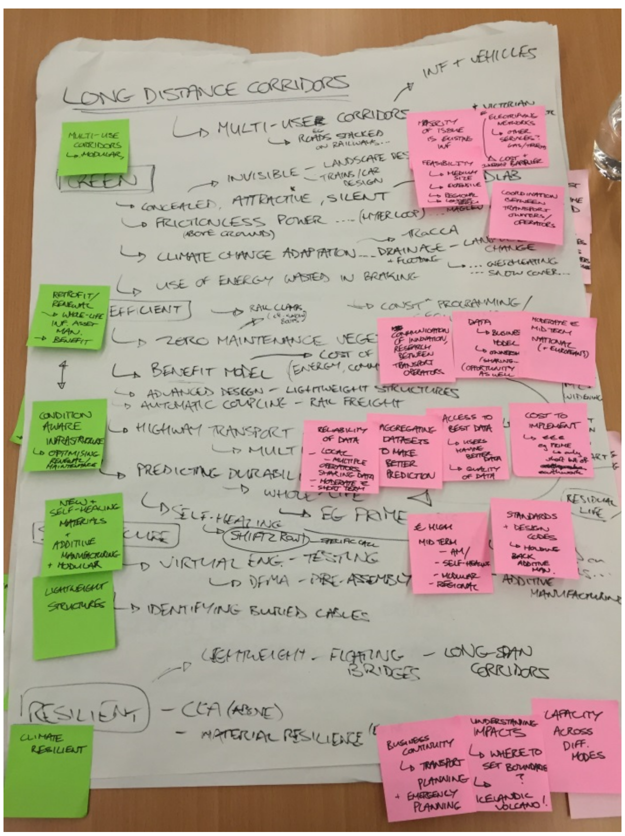
All contributions gathered in the two workshop sessions, will be used, among other activities, for the collection of specific actions regarding with research needs taking into account the framework previously defined in D3.1REFINET multi-modal transport infrastructure (RMMTI) model and the identified four priority areas (URBAN MOBILITY, MULTIMODAAL HUBS, LONG-DISTANCE CORRIDORS and SYSTEMIC APPROACH).

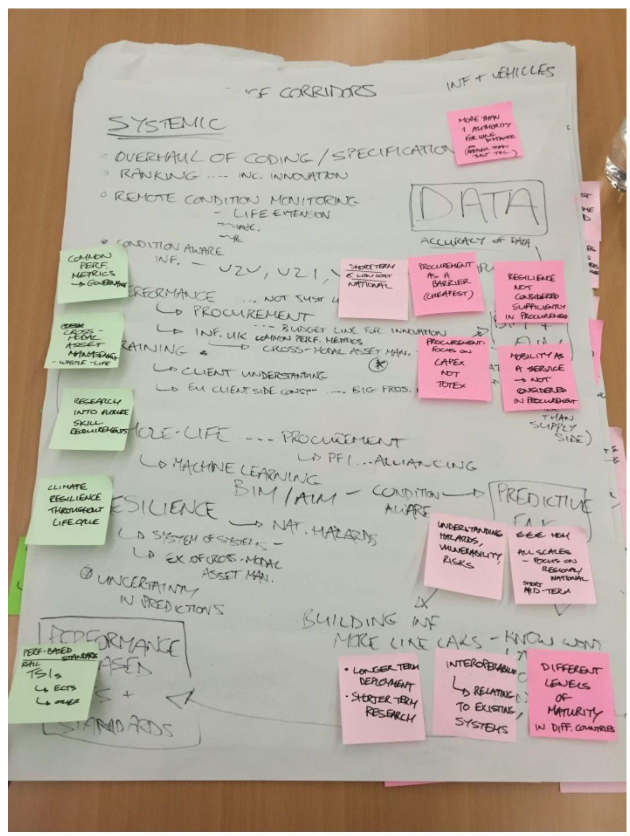
The specific actions and priority areas will structure the research and development needs to improve the future of European multimodal transport infrastructure and to strengthen the specific performances, which had already been defined in REFINET multimodal transport infrastructure framework in order to contribute the achievement of High Level Service Infrastructure.

6. ANNEX I


URBAN MOBILITY
PASSENGER
GREEN
ELECTRIFICATION
RENEWABLES
AUTONOMOUS VEHICLES
RAIL SIGNALLING
COST-EFFICIENT
ROBOTICS
RESILIENCE
INTERDEPENCIES ACROSS INF. SYSTEMS
SECURITY
DATA, CYBERSECURITY


MULTI-MODAL HUBS
ADAPTIVE STRUCTURES
MULTI-FUNCTIONAL SPACES
COST-EFFICIENT
VERTICAL HUBS
SOCIAL
SAFE / SECURITY
AIRPORTS
GREEN
RESILIENT
CLIMATE RESILIENCE
NETWORK OF APPS


LONG DISTANCE CORRIDORS
INF + VEHICLES
MULTI-USER CORRIDORS
GREEN
EFFICIENT
BENEFIT MODEL
RESILIENT
LIGHTWEIGHT STRUCTURES
CLIMATE RESILIENT


SYSTEMIC
INF + VEHICLES
DATA
PROCUREMENT
MACHINE LEARNING
BIM / AIM
PREDICTIVE
BUILDING INF
PERFORMANCE BASED
STANDARDS

7. References

- reFINE Initiative document: *"Building up Infrastructure Networks of a Sustainable Europe – Strategic targets and expected impacts"- October 2012.*
- *Deliverable 3.1: Definition of the REFINET multi-modal transport infrastructure (RMMTI) model*

ANNEX 4: REFINET RESEARCH & DEVELOPMENT NEEDS TABLE

<table>
<tr><th colspan="4">RESEARCH & INNOVATION NEED # 1</th></tr>
<tr><td>PRIORITY AREA</td><td>URBAN MOBILITY</td><td>PERFORMANCE</td><td>GREEN</td></tr>
<tr><td>TRL LEVEL</td><td>RESEARCH
TRL<5</td><td>ID</td><td>R1.1</td></tr>
<tr><th colspan="4">TOPIC DESCRIPTION</th></tr>
<tr><th colspan="4">Specific Challenges</th></tr>
<tr><td colspan="4">Delivery of new technology is uncertain. Relying on one technology can mean that unintended consequences are difficult to mitigate and therefore a holistic system approach should be taken. Air quality is a high profile topic that can receive intense external scruitiny. There is a significant body of vehicles within circulation that will not be out of use for some time, and retrofitting is expensive and slow. Therefore change may be difficult to achieve quickly. Air quality is highly impacted by transport mode e.g. aviation, road transport. A shift to multimodal transport will help but these transport modes will still be heavily used</td></tr>
<tr><th colspan="4">Scope</th></tr>
<tr><td colspan="4">Advanced technologies and materials to improve air quality, noise and vibration in cities through smart infrastructure</td></tr>
<tr><th colspan="4">Expected Impact</th></tr>
<tr><td colspan="4">Deaths and illness due to air quality issues with oxides of nitrogen and fine particulate matter would be reduced.
Noise and vibration can have a negative impact on wellbeing, reducing these could improve environment adjacent to transport infrastructure</td></tr>
<tr><td>Required Level of Investment</td><td>High</td><td>Priority Level</td><td>medium term</td></tr>
<tr><td>Geographic Scale</td><td colspan="3">Regional</td></tr>
</table>

RESEARCH & INNOVATION NEED # 2			
PRIORITY AREA	URBAN MOBILITY	**PERFORMANCE**	GREEN
TRL LEVEL	RESEARCH TRL<5	**ID**	R1.2
TOPIC DESCRIPTION			
Specific Challenges			
Delivery of new technology is uncertain. No one technology should be relied upon to deliver. Unintended consequences can occur and therefore a whole system approach should be taken. Extensive new infrastructure and adaptation of current transport infrastructure may be required Scalability and timing: alternative energy source must be supplied in the time frame needed, in the volume needed, and at a reasonable cost Intermittency: e.g. solar power produces energy only intermittently, it requires suitable storage technologies and possibly needs to be used in combination with other alternative energy sources Efficiency and energy density: larger amounts of materials or resources are needed to produce equivalent amount of energy of traditional fossil fuels. Mant alternative energies are characterised by low enegy densities and efficiency resulting in higher levels of resource consumption			
Scope			
Adpatation technologies for sustainable energy harvesting and recovery for future sustainable urban transport infrastructure - Heat removal - solar road -inductive technology - electrification			
Expected Impact			
Energy harvesting and recovery would reduce energy demand overall, thereby reducing carbon emissions and costs. Inductive technology that would charge electric cars "on-the-go" would expand the distance they could travel, and reduce the need for additional infrastructure of charging points.			
Required Level of Investment	Medium	**Priority Level**	medium term
Geographic Scale	Regional		

RESEARCH & INNOVATION NEED # 3			
PRIORITY AREA	URBAN MOBILITY	**PERFORMANCE**	GREEN
TRL LEVEL	RESEARCH TRL<5	**ID**	R1.3
TOPIC DESCRIPTION			
Specific Challenges			
It requires extensive integration between transport modes. Seamless integration requires travel data availabiliy and reliability. Data sharing and cyber-security issues. It may be difficult to influence people to change transport modes Modal shift may lead to unpredictable user behaviour The impacts of changes in travel habits e.g. less commuting to work or change in car ownership are difficult to predict			
Scope			
Flexible and adpatable transport infrastructure to favour sustainable transport mobility - increasing soft transport modes - automated mobility- underground mobility and parking			
Expected Impact			
Increased access to alternative transport modes would encourage mode change to more sustainable modes of transport that have fewer emissions (carbon and others).			
Required Level of Investment	Medium	**Priority Level**	medium term
Geographic Scale	National		

RESEARCH & INNOVATION NEED # 4			
PRIORITY AREA	URBAN MOBILITY	**PERFORMANCE**	GREEN
TRL LEVEL	RESEARCH TRL<5	**ID**	R1.4
TOPIC DESCRIPTION			
Specific Challenges			
The design, development and validation of new materials, processes and constructive solutions which are more sustainable and durable constitute a very relevant challenge in order to mitigate the effects of climate change and other environmental impacts. New developments can increase the added value of European industry in the field of materials and construction products by 1) increasing the sustainability of processes and products, reducing waste generation and metabolizing waste of other sectors; 2) incorporation of new nanostructured materials that enable building systems provide new features and 3) adoption of new intelligent production processes by combining evolutionary algorithms and additive manufacturing systems for the development of multifunctional and ultralight prefabricated components. Additive manufacturing (AM), its possibilities, feasibility and advantages over existing techniques lay on the development of suitable materials. i) optimizing the use of alternative raw materials with special emphasis on resources from CDW; ii) lighten up of structural components; iii) reduction of carbon footprint along the value chain .; iv) reducing manufacturing and assembly cost throughout the different stages of the value chain; v) selective incorporation of new high-value functions.			
Scope			
Optimization of construction materials for prefabrication and development of advance production techniques, including additive manufacturing, improving recycling and reuse:			
Expected Impact			
*Designing and manufacturing concrete pieces of very complex geometries that develop architectural and most ambitious infrastructure projects in terms of design and incorporate new features in prefabricated parts in a more optimized way, ensuring at least 15% cost reduction. *Incorporate at least 50% of raw materials valued from CDW. *Optimization of benefits in infrastructure designs. The new challenges of reducing the use of resources in buildings and infrastructures and the subsequent reduction of greenhouse gases, established in Europe for the period 2020-30, are leading the demand for lighter and structurally efficient prefabricated products. Lighten at least 15% of the piece by topology optimization. *Optimizing performance in infrastructure. With regard to the structural strength, structural integration in early stages of project ensures not only more resistant effectiveness, but also expand the suitable solutions and formal possibilities beyond conventional structural types, creating complex shapes with different branches and thicknesses and wherein the material is inhomogeneous, using different materials in different areas of the part, according to the required functional performance. This			

technique will lighten the pieces of concrete without losing structural performance, optimize manufacturing costs, minimize the use of resources and reduce carbon footprint.			
Required Level of Investment	High	**Priority Level**	short term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 5			
PRIORITY AREA	URBAN MOBILITY	**PERFORMANCE**	COST-EFFICIENT
TRL LEVEL	RESEARCH TRL<5	**ID**	R2.1
TOPIC DESCRIPTION			
Specific Challenges			
The adaptation of existing infrastructure to future requirements is on of the major challenges today due to several factors such as costs and also the negative impact that upgrading and construction projects generate in the operation of transport system, in particular in urban environment. Technologies lik 3D printing at large scale, techniques for decreasing time scales and improvement of modular construction including prefabrication with advanced systems for inspection and operation management like robotics, augmented and virtual reality, ... are needed to radically improve infrastructure upgrading projects at urban level.			
Scope			
New construction processes and techniques for low intrusive, fast and cost-efficient infrastructure adaptation			
Expected Impact			
* Reduction of life cycle costs in upgrading, maintenance and operation of infrastructure. * Faster and less intrusive maintenance operations * Improvement of ifranstructure performance levels and resilience. * Safer and greener maintenance operations			
Required Level of Investment	Medium	**Priority Level**	medium term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 6			
PRIORITY AREA	URBAN MOBILITY	**PERFORMANCE**	COST-EFFICIENT
TRL LEVEL	RESEARCH TRL<5	**ID**	R2.2
TOPIC DESCRIPTION			
Specific Challenges			
Advanced materials are needed to improve infrastructure performance and impact in its whole life cycle. Through an increased durability the cost of the infrastructure will be significantly reduced from a whole life cycle perspective, while improving its performance levels in terms of security (structural behaviour, resilience to man-made or natural events), safety of users and environmental impact. Added value functionalities could be incorporated for example for energy harvesting, CO2 absorption, selfcleaning and selfrepairing properties, as well as the integration of embedded sensors that can generate services and valuable information.			
Scope			
Advanced materials for urban infrastructure			
Expected Impact			
* Increased durability and reduction of life cycle costs. * Improvement of ifranstructure performance levels and resilience. * Multifunctional and added value products. * Improving security, safety and resilience			
Required Level of Investment	Very High	**Priority Level**	Long term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 7			
PRIORITY AREA	URBAN MOBILITY	**PERFORMANCE**	SOCIAL / INCLUSIVE
TRL LEVEL	RESEARCH TRL<5	**ID**	R3.1
TOPIC DESCRIPTION			
Specific Challenges			
New approaches and mobility planning strategies need to be developed to ensure that ALL citizens can use urban transport modes and its connections to multimodal hubs and long distance corridors. Security, evacuation and emergency planning aspects need to be adapted too.			
Scope			
Accessibility for All			
Expected Impact			
The main impact will be a multimodal transport system accessible for all. All destinations at urban level are accessible for all people, involving several transport modes.			
Required Level of Investment	Medium	**Priority Level**	short term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 8			
PRIORITY AREA	URBAN MOBILITY	**PERFORMANCE**	SOCIAL / INCLUSIVE
TRL LEVEL	RESEARCH TRL<5	**ID**	R3.2
TOPIC DESCRIPTION			
Specific Challenges			
New systems and technologies are needed to support users of the urban transport system, ensuring accessibility, seamless travel, ticcketing and information exchange. systems need to be adapted to future accesibility requirements.			
Scope			
Adaptation of a Smart Urban infrastructure			
Expected Impact			
Main impacts will be: * seamless door to door travel * real time and accurate information to users * Sensors and communication for real-time transport information (ex. geolocalised information to cars, passengers, users,..) *Assessing HCD aspects of urban mobility + modeling - simulation - accuracy			
Required Level of Investment	Medium	**Priority Level**	short term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 9			
PRIORITY AREA	URBAN MOBILITY	**PERFORMANCE**	RESILIENT
TRL LEVEL	RESEARCH TRL<5	**ID**	R4.1
TOPIC DESCRIPTION			
Specific Challenges			
Low and ultra-low maintenance regimes will be achieved using a combination of technologies that may have high costs associated with them. Cost-benefit analyses and whole lifecycle cost considerations will be required to justify more costly interventions. Self-healing materials - challenge still exists for turning self-healing concept into practical applications at different conditions (temperature, pressure, humidity, light, vacuum, etc.) and this has to be considered carefully during design phase of a self-healing material in order to achieve not only to long term but also high healing performance throughout the service life			
Scope			
Technologies for durable and long lasting infrastructure - Self healing materials			
Expected Impact			
Improved technologies involved in the construction of infrastructure assets will increase their resilience, leading to less requirement for maintenance and allowing them to continue operating under conditions beyond design specifications. Reduced maintenance will also result in reduced workforce exposure to other potential risks.			
Required Level of Investment	Medium	**Priority Level**	short term
Geographic Scale	Regional		

<table>
<tr><th colspan="4">RESEARCH & INNOVATION NEED # 10</th></tr>
<tr><td>PRIORITY AREA</td><td>URBAN MOBILITY</td><td>PERFORMANCE</td><td>RESILIENT</td></tr>
<tr><td>TRL LEVEL</td><td>RESEARCH
TRL<5</td><td>ID</td><td>R4.2</td></tr>
<tr><td colspan="4">TOPIC DESCRIPTION</td></tr>
<tr><td colspan="4">Specific Challenges</td></tr>
<tr><td colspan="4">Uncertainty of climate change projections.

Relative inability to accurately predict the temporal and spatial nature of natural hazards (e.g. earthquakes, landslides, volcanoes and Tsunamis).

Aging infrastructure assets which require extensive and costly adaptation/reconstruction to increase their resilience to the hazards identified.

Infrastructure assets which have not been designed with future climate change in mind.</td></tr>
<tr><td colspan="4">Scope</td></tr>
<tr><td colspan="4">Increasing the resilience and adapting urban infrastructure to the impacts of environmental and man-made hazards, including:
- Self-sufficient technologies to ensure day-to-day activities under exceptional circumstances
- Understanding the impacts of severe weather events on infrastructure networks
- Adaptation to both incremental and abrupt increases of weather and longer-term climate change
-Terrorist attacks (explosions, cyberphysics)
- Understanding the impacts of floods, earthquakes, landslides, volcanoes (could incorporate real time response, recovery technologies etc.)</td></tr>
<tr><td colspan="4">Expected Impact</td></tr>
<tr><td colspan="4">Being able to anticipate the impacts of both environmental and man-made hazards will increase the resilience of infrastructure networks. Prioritisation of areas which require particular investment, adaptation or the implementation of recovery measures will ultimately result in increased safety standards and reduced service disruption to end users.</td></tr>
<tr><td>Required Level of Investment</td><td>High</td><td>Priority Level</td><td>short term</td></tr>
<tr><td>Geographic Scale</td><td colspan="3">Regional</td></tr>
</table>

<table>
<tr><th colspan="4">RESEARCH & INNOVATION NEED # 11</th></tr>
<tr><td>PRIORITY AREA</td><td>URBAN MOBILITY</td><td>PERFORMANCE</td><td>SAFE / SECURE</td></tr>
<tr><td>TRL LEVEL</td><td>RESEARCH
TRL<5</td><td>ID</td><td>R5.1</td></tr>
<tr><th colspan="4">TOPIC DESCRIPTION</th></tr>
<tr><th colspan="4">Specific Challenges</th></tr>
<tr><td colspan="4">New and future threats are arising to the urban transport system. Some are coming from new technology trends and others are related to man made hazards.

In terms of safety, the challenges are focused to the introduction of new technologies for mobility related to autonomous dirving concepts. Urban infrastructure needs to be adapted to this new vehicles and also to the interaction between traditional systems and new vehicles.
In parallel, security aspects are becoming very relevant, in particular those related to cyber security and terrorist attacks related to structural resilience. Technologies are needed to protect urban transport systems and response to threats while protecting users and passengers.</td></tr>
<tr><th colspan="4">Scope</th></tr>
<tr><td colspan="4">Safe and Secure Urban Infrastructure</td></tr>
<tr><th colspan="4">Expected Impact</th></tr>
<tr><td colspan="4">Increased safety and security of urban infrastructure towards new and future threats.
* safer urban infrastructure for users.
* more secure infrastructure agains man made hazards</td></tr>
<tr><td>Required Level of Investment</td><td>Medium</td><td>Priority Level</td><td>Long term</td></tr>
<tr><td>Geographic Scale</td><td colspan="3">European</td></tr>
</table>

RESEARCH & INNOVATION NEED # 12			
PRIORITY AREA	URBAN MOBILITY	**PERFORMANCE**	GREEN
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I1.1
TOPIC DESCRIPTION			
Specific Challenges			
Delivery of new technology is uncertain. Relying on one technology can mean that unintended consequences are difficult to mitigate and therefore a holistic system approach should be taken. Pilots may not be successful in demonstrating value/performance of the technologies Encouraging uptake of whole life carbon costing may have to be regulatory instead of optional Extensive new infrastructure and adaptation of current transport infrastructure may be required Scalability and timing: alternative energy source must be supplied in the time frame needed, in the volume needed, and at a reasonable cost Intermittency: e.g. solar power produces energy only intermittently, it requires suitable storage technologies and possibly needs to be used in combination with other alternative energy sources Efficiency and energy density: larger amounts of materials or resources are needed to produce equivalent amount of energy of traditional fossil fuels. Mant alternative energies are characterised by low enegy densities and efficiency resulting in higher levels of resource consumption			
Scope			
Small and large scale pilot projects to demonstrate infrastructure transformation for low carbon, efficient and sustainable energy use Low carbon whole -life costing - integration of charging infrastructures for electrical vehicles in urban regeneration - Electric buses - Movement energy harvesting - Inductive technology - electrification - rapid-charging of electric vehicles-deployment and usage in cities			
Expected Impact			
Pilot projects can highlight issues early before roll out. Whole life costing prioritises the solution with lowest overall carbon instead of focusing on the capital carbon alone.			
Required Level of Investment	Medium	**Priority Level**	medium term
Geographic Scale	National		

<table>
<tr><th colspan="4">RESEARCH & INNOVATION NEED # 13</th></tr>
<tr><td>PRIORITY AREA</td><td>URBAN MOBILITY</td><td>PERFORMANCE</td><td>GREEN</td></tr>
<tr><td>TRL LEVEL</td><td>INNOVATION
6<TRL<8</td><td>ID</td><td>I1.2</td></tr>
<tr><th colspan="4">TOPIC DESCRIPTION</th></tr>
<tr><th colspan="4">Specific Challenges</th></tr>
<tr><td colspan="4">Delivery of new technology is uncertain. Relying on one technology can mean that unintended consequences are difficult to mitigate and therefore a holistic system approach should be taken. Pilots may not be successful in demonstrating value/performance of the technologies Commecialisation: there may be high costs associated with these materials and their deployment It may require higher upfront investment for new build and renewals. There will be increased pressure to demontrate efficiency
Uncertainty linked to climate impact over the long life span of transport infrastructure</td></tr>
<tr><th colspan="4">Scope</th></tr>
<tr><td colspan="4">Small scale demonstration projects of advanced materials and processes e.g. selfhealing materials, durable, sustainable, multifunctional,…</td></tr>
<tr><th colspan="4">Expected Impact</th></tr>
<tr><td colspan="4">Self healing, durable and sustainable materials can reduce the amount of maintenance as asset must undergo during its life cycle. These qualities, as well as multifunctional materials, all fit into the idea of the circular economy i.e. keeping materials and resources in use and retaining their value rather than consuming and disposing of them. In addition it reduces risk of people being put harms way when maintenance needs to be carried out.</td></tr>
<tr><td>Required Level of Investment</td><td>High</td><td>Priority Level</td><td>medium term</td></tr>
<tr><td>Geographic Scale</td><td colspan="3">National</td></tr>
</table>

RESEARCH & INNOVATION NEED # 14			
PRIORITY AREA	URBAN MOBILITY	**PERFORMANCE**	GREEN
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I1.3
TOPIC DESCRIPTION			
Specific Challenges			
Delivery of new technology is uncertain. Relying on one technology can mean that unintended consequences are difficult to mitigate and therefore a holistic system approach should be taken. Pilots may not be successful in infuencing user behaviour It requires extensive integration between transport modes. Seamless integration requires travel data availabiliy and reliability. Data sharing and cyber-security issues.			
Scope			
Piloting actions to demonstrate new approaches, management strategies and technologies to achieve a flexible and adpatable transport infrastructure to favour sustainable transport mobility			
Expected Impact			
Increased access to alternative transport modes would encourage mode change to more sustainable modes of transport that have fewer emissions (carbon and others).			
Required Level of Investment	Low	**Priority Level**	short term
Geographic Scale	National		

RESEARCH & INNOVATION NEED # 15			
PRIORITY AREA	URBAN MOBILITY	**PERFORMANCE**	GREEN
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I1.4
TOPIC DESCRIPTION			
Specific Challenges			
Delivery of new technology is uncertain. Relying on one technology can mean that unintended consequences are difficult to mitigate and therefore a holistic system approach should be taken. Air quality is a high profile topic that can receive intense external scruitiny There is a significant body of vehicles within circulation that will not be out of use for some time, and retrofitting is expensive and slow. Therefore change may be difficult to achieve quickly. Air quality is highly impacted by transport mode e.g. aviation, road transport. A shift to multimodal transport will help but these transport modes will still be heavily used			
Scope			
Large Scale pilots to demonstrate effieent integration of technologies for air quality, noise and vibration reduction in urban infrastructure Noise & pollution reduction - Integration of nature-based solutions (both GREEN & SOCIAL / INCLUSIVE) - Superabsorbing surface materials (CO2, Nox)			
Expected Impact			
Deaths and illness due to air quality issues with oxides of nitrogen and fine particulate matter would be reduced. Noise and vibration can have a negative impact on wellbeing, reducing these could improve environment adjacent to transport infrastructure			
Required Level of Investment	High	**Priority Level**	short term
Geographic Scale	National		

RESEARCH & INNOVATION NEED # 16			
PRIORITY AREA	URBAN MOBILITY	**PERFORMANCE**	COST-EFFICIENT
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I2.1
TOPIC DESCRIPTION			
Specific Challenges			
Large scale pilots involving the demonstration of several technologies and different approaches at real scale in European cities. Replication activities are required to ensure an expansion to other EU cities. Standardisation activies need to be considered.			
Scope			
Demonstration of new construction processes and techniques for low intrusive, fast and cost-efficient infrastructure adaptation			
Expected Impact			
* Reduction of life cycle costs in upgrading, maintenance and operation of infrastructure. * Faster and less intrusive maintenance operations * Improvement of ifranstructure performance levels and resilience. * Safer and greener maintenance operations			
Required Level of Investment	Very High	**Priority Level**	Long term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 17			
PRIORITY AREA	URBAN MOBILITY	**PERFORMANCE**	COST-EFFICIENT
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I2.2
TOPIC DESCRIPTION			
Specific Challenges			
Large scale pilots involving the demonstration of several technologies and different approaches at real scale in European cities. Replication activities are required to ensure an expansion to other EU cities. Standardisation activies need to be considered.			
Scope			
Demonstration of Advanced materials for urban infrastructure			
Expected Impact			
* Increased durability and reduction of life cycle costs. * Improvement of ifranstructure performance levels and resilience. * Multifunctional and added value products. * Improving security, safety and resilience			
Required Level of Investment	Very High	**Priority Level**	Long term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 18			
PRIORITY AREA	URBAN MOBILITY	**PERFORMANCE**	SOCIAL / INCLUSIVE
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I3.1
TOPIC DESCRIPTION			
Specific Challenges			
Large scale pilots involving the demonstration of several technologies and different approaches at real scale in European cities focusing on measuring the accessibility and seamless travel for all. innovative approaches are needed to increase the acceptability and use of sustainable transport modes by the society. Replication activities are required to ensure an expansion to other EU cities. Standardisation activies need to be considered.			
Scope			
Demonstration of Accessible for All urban infrastructure favouring multimodality Adaptation of urban environment to deploy safe and friendly routes for vulnerable population (children, ageing...) - Informing custome - providing choice-traveller needs - Vwide spread technology APP			
Expected Impact			
The main impact will be a multimodal transport system accessible for all. All destinations at urban level are accessible for all people, involving several transport modes.			
Required Level of Investment	Very High	**Priority Level**	Long term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 19			
PRIORITY AREA	URBAN MOBILITY	**PERFORMANCE**	SOCIAL / INCLUSIVE
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I3.2
TOPIC DESCRIPTION			
Specific Challenges			
Pilots of sustainable and multtimodal urban transport approaches are needed. Demonstration projects that monitor and evaluate those systems in terms of accesibility, use and acceptance.			
Scope			
Demonstration of more efficient transport approaches Autonomous vehicles/hybrid systems - Transport links info on delays across modes			
Expected Impact			
The main expected impact is to increase the social acceptance of sustainable transport modes at urban level.			
Required Level of Investment	High	**Priority Level**	medium term
Geographic Scale	National		

RESEARCH & INNOVATION NEED # 20			
PRIORITY AREA	URBAN MOBILITY	**PERFORMANCE**	RESILIENT
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I4.1
TOPIC DESCRIPTION			
Specific Challenges			
The use of real-time information to environmental hazards could still result in people being caught up in a particular event. Requirement to close particular sections of a network prior to a forecasted event may be necessary. Uncertainty as to peoples travel habits and how they use the information which is provided to them.			
Scope			
Innovative management and techonologies increase infrastructure resilience to environmental and man made hazards - Real-time travel options to users - Use of real-time info to forecast environmental hazards			
Expected Impact			
Using real-time information can allow infrastructure service providers and emergency responders to redirect transport users in order to reduce the exposure to a particular hazard and reduce the overall impact of an event.			
Required Level of Investment	Low	**Priority Level**	medium term
Geographic Scale	National		

RESEARCH & INNOVATION NEED # 21			
PRIORITY AREA	URBAN MOBILITY	**PERFORMANCE**	RESILIENT
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I4.2
TOPIC DESCRIPTION			
Specific Challenges			
Political cycles and regulatory demands will affect infrastructure budgets and priorties for infrastructure design and maintenance			
Scope			
Demonstration of innovative technologies to extend service life in optimum performance of transport infrastructure - Prioritisation of asset maintenance + investment - Addictive manufacturing (3D printing) - Design for upgradebility, retrofiting			
Expected Impact			
Prioritising the maintenance of assets will increase the resilience of particularly vulnerable assets to specific natural and man-made hazards. Moreover, incorporating upgradeability into design will ensure continued resilience (e.g. allowing flood defences levels to be raised in light of climate change projections)			
Required Level of Investment	High	**Priority Level**	medium term
Geographic Scale	National		

RESEARCH & INNOVATION NEED # 22			
PRIORITY AREA	URBAN MOBILITY	**PERFORMANCE**	SAFE / SECURE
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I5.1
TOPIC DESCRIPTION			
Specific Challenges			
Pilots and real scale demonstration projects are needed to show how infrastructure responses to new and future threats such as autonomous driving and man made hazards such as terrorist attacks. Aspects such as public communication & awareness, development of responsive infrastructure, lighting, management of crisis and emergencies,...			
Scope			
Demonstration projects to increase safety in existing infrastructure			
Expected Impact			
Increased safety and security of urban infrastructure towards new and future threats. * safer urban infrastructure for users. * more secure infrastructure agains man made hazards			
Required Level of Investment	Medium	**Priority Level**	Long term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 23			
PRIORITY AREA	URBAN MOBILITY	**PERFORMANCE**	
TRL LEVEL	DEPLOYMENT 8<TRL	**ID**	D1
TOPIC DESCRIPTION			
Specific Challenges			
Development of activities focused on reducing the gap from research to the market. Promoting activities related to: * Public procurement for innovation * Sinergies between H2020 and research programmes with projec development programmes like CEF *Standardisation			
Scope			
Deployment and roll out of urban infrastructure innovation			
Expected Impact			
* Faster and more efficient integration of innovations in the transport system. * More cost efficient development of innovations			
Required Level of Investment	High	**Priority Level**	Long term
Geographic Scale	National		

RESEARCH & INNOVATION NEED # 24			
PRIORITY AREA	URBAN MOBILITY	**PERFORMANCE**	
TRL LEVEL	DEPLOYMENT 8<TRL	**ID**	D2
TOPIC DESCRIPTION			
Specific Challenges			
Development of awareness campaigns of new transport systems and innovations in order to convince the benefits for the users.			
Scope			
Public acceptance of major infrastructure works.			
Expected Impact			
Social acceptance of new and more sustainable transport systems.			
Required Level of Investment	Low	**Priority Level**	Long term
Geographic Scale	Local		

RESEARCH & INNOVATION NEED # 25			
PRIORITY AREA	MULTIMODAL HUBS	**PERFORMANCE**	GREEN
TRL LEVEL	RESEARCH TRL<5	**ID**	R1.1
TOPIC DESCRIPTION			
Specific Challenges			
Delivery of new technology is uncertain. Relying on one technology can mean that unintended consequences are difficult to mitigate and therefore a holistic system approach should be taken. Air quality is a high profile topic that can receive intense external scruitiny. There is a significant body of vehicles within circulation that will not be out of use for some time, and retrofitting is expensive and slow. Therefore change may be difficult to achieve quickly. Air quality is highly impacted by transport mode e.g. aviation, road transport. A shift to multimodal transport will help but these transport modes will still be heavily used			
Scope			
Application of new technologies, new materials to the design of multimodal hubs enabilng low-carbon and resource efficient green hubs			
Expected Impact			
Reduced environmental impact: include noise and vibration in early design stage, design to avoid energy use			
Required Level of Investment	Medium	**Priority Level**	medium term
Geographic Scale	National		

RESEARCH & INNOVATION NEED # 26			
PRIORITY AREA	MULTIMODAL HUBS	**PERFORMANCE**	GREEN
TRL LEVEL	RESEARCH TRL<5	**ID**	R1.2
TOPIC DESCRIPTION			
Specific Challenges			
Solving the "last mile" issue i.e. that most of the carbon on a journey is emitted in the last mile. Requires coordination between model providers and different stakeholders			
Scope			
Development of tools to analyse whole-life whole-system energy and carbon impacts, considering multimodal hubs as energy producer centers .			
Expected Impact			
improved energy management of existing infrastructure, trial for innovation to reduce energy use and carbon footprint			
Required Level of Investment	Medium	**Priority Level**	medium term
Geographic Scale	National		

RESEARCH & INNOVATION NEED # 27			
PRIORITY AREA	MULTIMODAL HUBS	**PERFORMANCE**	COST-EFFICIENT
TRL LEVEL	RESEARCH TRL<5	**ID**	R2.1
TOPIC DESCRIPTION			
Specific Challenges			
Holistic view of the system must be taken to avoid reliance on one technology			
Scope			
New designs and construction techniques for multimodal hubs in order to optimise the structure repair, maintenance and life extension processes -prefabrication and automatisation processes -use of the underground - vertical designs specially in urban environment			
Expected Impact			
improved maintenance efficiency, reduced overall costs, extended component life time			
Required Level of Investment	High	**Priority Level**	short term
Geographic Scale	National		

RESEARCH & INNOVATION NEED # 28			
PRIORITY AREA	MULTIMODAL HUBS	**PERFORMANCE**	SOCIAL / INCLUSIVE
TRL LEVEL	RESEARCH TRL<5	**ID**	R3.1
TOPIC DESCRIPTION			
Specific Challenges			
The commission Regulation EU No 1300/2014 on the accessibility of the Union's rail system persons with reduced mobility defines mandatory accessibility requirements for all new stations and accessibility in existing infrastructures should be progressively improved through: improvement of mobility inside hubs, design of new multi modals hub with step-free access, tactile paths or tactile walking surface indicators, wheelchair accessibility of ticket counters, innovative accessibility solutions to adapt existing hubs to persons with reduced mobility. It may require modification of standards and implementation costs for existing infrastructure.			
Scope			
Friendly environments for inclusive mobility and accessibility for persons with reduced mobility.			
Expected Impact			
Accessibility of multi modal hub to all passengers, whatever their social category, age and life characteristics and their possible physical impairment.			
Required Level of Investment	Medium	**Priority Level**	Short term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 29			
PRIORITY AREA	MULTIMODAL HUBS	**PERFORMANCE**	RESILIENT
TRL LEVEL	RESEARCH TRL<5	**ID**	R4.1
TOPIC DESCRIPTION			
Specific Challenges			
Ability to predict the likelihood, magnitude and severity of a particular weather and/or climatic event. Changes in the way people travel. Introduction of new risks and hazards to the transport networks (e.g. autonomous vehicles).			
Scope			
Adaptive design. Increase flexibility to interchange route or transport mode adaptable for increasing demand of future population adaptable for climate change events link with other hubs (network of hubs)			
Expected Impact			
Increasing the resilience of transport networks will lead to reduced disruption to customers and an improved safety performance.			
Required Level of Investment	Medium	**Priority Level**	long term
Geographic Scale	National		

RESEARCH & INNOVATION NEED # 30			
PRIORITY AREA	MULTIMODAL HUBS	**PERFORMANCE**	RESILIENT
TRL LEVEL	RESEARCH TRL<5	**ID**	R4.2
TOPIC DESCRIPTION			
Specific Challenges			
Historically, consideration of transport infrastructure has been siloed. Currently, significant understanding of respective networks, but not enough understanding of how infrastructure networks are intrinsically interconnected. Often no regulatory incentives to consider interdependencies in the prioritisation of infrastructure maintenance/renewal. Issues of security when identifying particualrly vulnerable locations where key interconnections between infrastructure networks may exist.			
Scope			
Modelling of consequences via different scenarios assessment and preparedness to disruptive events, study of interdependencies, cascade effects and other consequences			
Expected Impact			
There are an increasing number of natural and man-made hazard events which have the potential to impact on our transport networks. Transport infrastructure aims to increase its resilience to such events by taking into account business continuity approach and the safety of its users. Thus, it is needed more efective strategies to: 1)prevent the occurence of this dramatic events 2)mitigate the effect both in the risk scenario as well as the reprecussion in the net 3)better response the crisis taking into account mobility of both people and goods and 4)better recovery strategies taking into account both redesign, reconstruction approaches.			
Required Level of Investment	Medium	**Priority Level**	medium term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 31			
PRIORITY AREA	MULTIMODAL HUBS	**PERFORMANCE**	SAFE / SECURE
TRL LEVEL	RESEARCH TRL<5	**ID**	R5.1
TOPIC DESCRIPTION			
Specific Challenges			
Require collaboration between transport stakeholders, technology providers and law enforcement agencies.			
Scope			
Security against terrorism attacks in transit environments (preparedness, prevention, robustness and recovery)			
Expected Impact			
Security in transit environments refers to the security of buses stops, stations and interchanges, to the immediate vicinity of transport stops and stations and to the 'en route' travel (on board of different modes). Criminal acts are a result of 1) the environment of the transport node itself (e.g., design of platforms, CCTVs, dark corners, hiding places) and, 2) the social interaction within those environments (e.g., poor guardianship, crowdedness). A multi- and interdisciplinary approach is required to tackle transit security and demands more integrated, holistic and cross-disciplinary approach. Also, the identification and assessment of transport infrastructure vulnerabilities regarding man-made threats can contribute to the strengthening of the resilience of the European Transport Network against various man-made hazards, by providing road owners and operators with an easy to manage, practice-oriented tool for the assessment of the infrastructure.			
Required Level of Investment	Medium	**Priority Level**	Short term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 32			
PRIORITY AREA	MULTIMODAL HUBS	**PERFORMANCE**	SAFE / SECURE
TRL LEVEL	RESEARCH TRL<5	**ID**	R5.2
TOPIC DESCRIPTION			
Specific Challenges			
There is a considerable scope in the design and planning of station infrastructure to include proven and effective security measures to prevent, mitigate or deter attacks from terrorists.			
Scope			
Security by design			
Expected Impact			
The measures to improve security include the implementation of appropriate physical secure stations/terminals against bomb blast, CBRN (Chemical, Biological, Radiological and Nuclear) attacks involving particle dispersion and fire events); security procedures (screening, materials detection, intrusion detection systems, and tracking applications) should be considered at all stages of station development. The containment (where possible) of building services and power supplies, locating public car parks as far away from station buildings, creating a distinct separation with other 'crowded places' are examples of possible measures.			
Required Level of Investment	Medium	**Priority Level**	medium term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 33			
PRIORITY AREA	MULTIMODAL HUBS	**PERFORMANCE**	SAFE / SECURE
TRL LEVEL	RESEARCH TRL<5	**ID**	R5.3
TOPIC DESCRIPTION			
Specific Challenges			
Jeopardization of security should be prevented			
Scope			
Minimise Security Barriers to mobility without decreasing the overall system security level (security controls, ...)			
Expected Impact			
faster mobility, improved customer service and satisfaction			
Required Level of Investment	Medium	**Priority Level**	Medium term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 34			
PRIORITY AREA	MULTIMODAL HUBS	**PERFORMANCE**	GREEN
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I1.1
TOPIC DESCRIPTION			
Specific Challenges			
Delivery dates of new technologies are very unceratin Pilots may not be successful in infuencing user behaviour			
Scope			
Pilot case for the application of new technologies, new materials to the design of multimodal hubs			
Expected Impact			
Reduced environmental impact: include noise and vibration in early design stage, design to avoid energy use			
Required Level of Investment	High	**Priority Level**	short term
Geographic Scale	National		

RESEARCH & INNOVATION NEED # 35			
PRIORITY AREA	MULTIMODAL HUBS	**PERFORMANCE**	GREEN
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I1.2
TOPIC DESCRIPTION			
Specific Challenges			
Holistic view of the system must be taken to avoid reliance on one technology			
Scope			
Test case of tools to analyse whole-life whole-system energy and carbon impacts.			
Expected Impact			
improved energy management of existing infrastrure, trial for innovation to reduce energy use and carbon footprint			
Required Level of Investment	Medium	**Priority Level**	short term
Geographic Scale	National		

RESEARCH & INNOVATION NEED # 36			
PRIORITY AREA	MULTIMODAL HUBS	**PERFORMANCE**	COST-EFFICIENT
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I2.1
TOPIC DESCRIPTION			
Specific Challenges			
Novel designs and construction techniques in early stage of commercialisation may have high costs associated with them. Cost-benefit analyses and whole lifecycle cost considerations will be required to justify more costly interventions.			
Scope			
Pilot with new designs and construction techniques for multimodal hubs			
Expected Impact			
improved maintenance efficiency, reduced overall costs, extended component life time			
Required Level of Investment	High	**Priority Level**	short term
Geographic Scale	National		

RESEARCH & INNOVATION NEED # 37			
PRIORITY AREA	MULTIMODAL HUBS	**PERFORMANCE**	SOCIAL / INCLUSIVE
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I3.1
TOPIC DESCRIPTION			
Specific Challenges			
Nowadays user information systems are not customerised and the dynamic and user-center tools are not used in general.			
Scope			
Pilot case : Improvement of mobility inside hubs Adaptation of solutions and services already available for inclusive mobility (disabled people to elder population)			
Expected Impact			
Ease for passenger to move in the hub thanks to digital info on his/her smartphone, tablet, augmented reality.Easy access/mobility for all			
Required Level of Investment	Medium	**Priority Level**	medium term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 38			
PRIORITY AREA	MULTIMODAL HUBS	**PERFORMANCE**	RESILIENT
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I4.1
TOPIC DESCRIPTION			
Specific Challenges			
Access to data is not guaranteed and data protection laws would have to be complied with.			
Scope			
Implementation of Real-time data acqusition tool to prepare for disruption (SHM, …)			
Expected Impact			
This would allow evidence based iterventions to be made in order to prevent disruption.			
Required Level of Investment	medium	**Priority Level**	short term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 39			
PRIORITY AREA	MULTIMODAL HUBS	**PERFORMANCE**	SAFE / SECURE
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I5.1
TOPIC DESCRIPTION			
Specific Challenges			
Require collaboration between transport stakeholders, technology providers, law enforcement agencies and public adminstration for design of multi modal hubs supporting security without jeopardizing activities (architecture adapted to video surveillance, blast resistant materials, control of flows and gates, …), Integrated technological solutions for passengers and goods protection and assessment of related ethical and legal issues, human factor approaches for crowd control and profiling, development of tools for situation awareness and decision making for security center.			
Scope			
Devlopment of prototypes and methodologies to increase resilience (preparedness, prevention, robustness, …) against terrorist attacks.			
Expected Impact			
Improved prevention, investigation, mitigation capabilities; prevention of more terrorist endeavours; increase the feeling of security of citizens			
Required Level of Investment	Medium/low	**Priority Level**	Medium/short term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 40			
PRIORITY AREA	MULTIMODAL HUBS	**PERFORMANCE**	SAFE / SECURE
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I5.2
TOPIC DESCRIPTION			
Specific Challenges			
Ensure the compliance with ethics, health and privacy requirements			
Scope			
Development of fast & non intrusive safety controls in accordance with ethics, health and privacy requirements : biometric identification, non radioactive scanning and detection and identification of dangerous material			
Expected Impact			
Advance toward seamless travel for passengers and goods			
Required Level of Investment	Medium/low	**Priority Level**	Medium/short term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 41			
PRIORITY AREA	MULTIMODAL HUBS	**PERFORMANCE**	
TRL LEVEL	DEPLOYMENT 8<TRL	**ID**	D1
TOPIC DESCRIPTION			
Specific Challenges			
Development of activities focused on reducing the gap from research to the market. Promoting activities related to: * Public procurement for innovation * Sinergies between H2020 and research programmes with projec development programmes like CEF *Standardisation			
Scope			
Deployment and roll out of multimodal hub innovation			
Expected Impact			
* Faster and more efficient integration of innovations in the transport system. * More cost efficient development of innovations			
Required Level of Investment	High	**Priority Level**	Long term
Geographic Scale	National		

RESEARCH & INNOVATION NEED # 42			
PRIORITY AREA	MULTIMODAL HUBS	**PERFORMANCE**	
TRL LEVEL	DEPLOYMENT 8<TRL	**ID**	D2
TOPIC DESCRIPTION			
Specific Challenges			
Development of awareness campaigns of new transport systems and innovations in order to convince the benefits for the users.			
Scope			
Public acceptance of major infrastructure works.			
Expected Impact			
Social acceptance of new and more sustainable transport systems.			
Required Level of Investment	Low	**Priority Level**	Long term
Geographic Scale	Local		

RESEARCH & INNOVATION NEED # 43			
PRIORITY AREA	LONG DISTANCE CORRIDORS	**PERFORMANCE**	GREEN
TRL LEVEL		**ID**	R1.1
TOPIC DESCRIPTION			
Specific Challenges			
If the electricity can be produced from largely renewable sources, the electrification of (parts of) the transport network offers significant opportunities for the reduction of carbon emissions and energy savings for vehicles. Research and innovation is required to identify the best solutions to provision of renewable energy for road infrastructure, as well as new technologies, materials and systems to increase energy efficiency and reduce carbon intensity.			
Scope			
Adaptation of road infrastructure to new sustainable energy sources: Rapid electric charging infrastructure linked to renewable energy sources To encourage the uptake of electric vehicles, innovative approaches to the planning and design of rapid electric charging infrastructure are required. New technologies and systems are required that utilise renewable energy sources, while maintaining levels of safety, security and resilience, including in rural locations. Low energy bound materials (LEBM) for pavements Develop and test new methodologies for adoption of LEBM, including laboratory testing and design of analytical approaches to pavement design with LEBM. Full-scale site trials with detailed analysis and generation of data are required to inform future design specifications and development of industry good practice and standards. Energy efficient lighting, ICT and remote sensing equipment With increased use of remote condition monitoring sensors and smart signage and ICT systems on highways, the demands for energy increases. New efficient technologies and systems are required to increase the energy efficiency, harvest energy from vehicles, and reduce the carbon intensity of the infrastructure as a whole, while maintaining levels of safety, security and resilience. Energy generating road surfaces The use of Piezoelectric devices within the road infrastructure will lead to the harvesting of vibrational energy from vehicle movement. Such devices can produce electrical energy that is predictable (based on traffic patterns), and locally storable.			
Expected Impact			
New materials, technologies, tools and techniques for increased the use of renewable energy sources for transport infrastructure, increased energy efficiency and reduced carbon intensity.			
Required Level of Investment	Very High	**Priority Level**	Long term

Geographic Scale	European

<table>
<tr><th colspan="4">RESEARCH & INNOVATION NEED # 44</th></tr>
<tr><td>PRIORITY AREA</td><td>LONG DISTANCE CORRIDORS</td><td>PERFORMANCE</td><td>GREEN</td></tr>
<tr><td>TRL LEVEL</td><td></td><td>ID</td><td>R1.2</td></tr>
<tr><th colspan="4">TOPIC DESCRIPTION</th></tr>
<tr><th colspan="4">Specific Challenges</th></tr>
<tr><td colspan="4">Attract investors with solid business plans and cost benifit analysis</td></tr>
<tr><th colspan="4">Scope</th></tr>
<tr><td colspan="4">Innovative solutions and concepts for ressource harvesting, such as integrated energy harvesting, heat recovery or rain collection systems should be explored in order to take advantages of surface transport infrastructures. Diverse technologies are currently used and developed for city buildings, but rarely applied to insfrastructure facilities and networks. Surface infrastructures are covering large areas and connecting cities and industries, therefore infrastructure with the ability of ressource harvesting could profit to the infrastructure system and nearby residential or industrial areas.</td></tr>
<tr><th colspan="4">Expected Impact</th></tr>
<tr><td colspan="4">Provide energy and utilities to infrastructures, industries or nearby towns, increase the level of acceptance of infrastructure construction project.</td></tr>
<tr><td>Required Level of Investment</td><td>Low</td><td>Priority Level</td><td>Long term</td></tr>
<tr><td>Geographic Scale</td><td colspan="3">Europe</td></tr>
</table>

RESEARCH & INNOVATION NEED # 45			
PRIORITY AREA	LONG DISTANCE CORRIDORS	**PERFORMANCE**	GREEN
TRL LEVEL		**ID**	R1.3
TOPIC DESCRIPTION			
Specific Challenges			
Removal of freight from road network is difficult and requires infrastructure such as logistics centres at strategic locations that are also multimodal hubs to allow local distribution via low carbon transport.			
Scope			
New transport infrastructure with low environmental impact New improved design of corridors, such as vertical or/and underground corridors or multi-utility routes, should be considered to include the increasing future demands on autonomous and electric vehicles with the minimum environmental impact. New and recycled materials and improved construction techniques should be included in these new designs to minimise acoustic, water, soil and air contamination. Not only in design and construction stages, the environment should be taken into account, but also modelling tools to analyse whole-life system energy and carbon impacts are crucial in order to ensure the environment is always taken in to account.			
Expected Impact			
All of these would improve heath and well being of users and nearby residents.			
Required Level of Investment	Very high	**Priority Level**	Long term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 46			
PRIORITY AREA	LONG DISTANCE CORRIDORS	**PERFORMANCE**	COST-EFFICIENT
TRL LEVEL		**ID**	R2.1
TOPIC DESCRIPTION			
Specific Challenges			
Europe is facing a relevant challenge related to the maintenance and management of infrastructure assets due to ageing, extreme events and budget constraints. A performance based approach for infrastructure maintenance is needed to ensure a cost effective maintenance and operation process, enabling an adequate and safe level of service.by means of the risk control.			
Scope			
Performance based approach for maintenance of transport infrastructure: New methods and tools for monitoring and assessing (the status of) existing structures, relatively to structural loading and deterioration potential. New (non-destructive) testing methods (radar, ultrasound, optical fibre, wireless smart sensors...) for diagnostic, early damage detection and maintenance of the infrastructures; Smart inspection and robotics for maintenance. Integration of terrestrial and satellite systems for the structural health monitoring of key infrastructures located in a natural risk prone area (earthquakes, landslides, floods). Risk control by means of monitoring Different causes may lead to the non-compliance of a particular requirement relating to an existing infrastructure. Many of the causes may be traced back to deviations from expected actions or resistances. The quantification of parameters relating to such influences may provide evidence about the degree of compliance of a given structure with a particular serviceability or safety requirement. Such parameters may therefore be called indicators and associated threshold values can be established on a risk basis, as well as admissible average frequencies for outcrossing. Indicators may be monitored and the measured values can continuously be compared to the threshold values previously established. Alarm systems may be installed which are activated in the event of outcrossing. Safety measures can therefore be adopted depending on the consequences of the observed non-compliance. Based on such an approach, and by using modern information technology, inspections of large infrastructures may be automated and optimized.			
Expected Impact			
*Cost effective maintenance process, based on infrastructure performance assessment and risk control. *New methods for infrastructure performance monitoring and assessing.			
Required Level of Investment	Medium	**Priority Level**	Medium term

Geographic Scale	European

RESEARCH & INNOVATION NEED # 47			
PRIORITY AREA	LONG DISTANCE CORRIDORS	**PERFORMANCE**	COST-EFFICIENT
TRL LEVEL		**ID**	R2.2

TOPIC DESCRIPTION
Specific Challenges
Europe is facing a relevant challenge related to the maintenance and management of infrastructure assets due to ageing, man-made and climate change actions. An integrated approach for ensuring safety and infrastructure performance is needed to ensure a cost effective maintenance process.
Scope
Extending the life time of existing infrastructure New methods and tools for monitoring and assessing (the status of) existing structures, relatively to structural loading and deterioration potential. * New (non-destructive) testing methods (radar, ultrasound, optical fibre, wireless smart sensors...) for diagnostic, early damage detection and maintenance of the infrastructures; * Smart inspection and robotics for maintenance * Integration of terrestrial and satellite systems for the structural health monitoring of key infrastructures located in a natural risk prone area (earthquakes, landslides, floods). Developing alternative structural models for deteriorating structures * The resistance of an ageing structure is dependent on the condition of the materials of which it is composed, for example the level of degradation of reinforcement bars. However, there is limited knowledge on how and in what form to include material degradation in structural models. **a. Develop probabilistic models for local and global deterioration. **b. Perform small- and large-cale experiments on deteriorating structural elements. **c. Couple deterioration to reliability assessment over a certain (remaining) lifetime. * Development of a better understanding of damage and deterioration mechanisms and their effects on asset performance and residual life; Strengthening and life extension solutions * Regarding the strengthening and life extension solutions adapted for relevant assets, such as bridges in case of fatigue, development of the following aspects is proposed: **Create new renovation techniques that use simple and cost-effective on-site technologies and/or advanced, industrialised solutions in offsite. **Find and qualify the life enhancement of post-weld treatments on existing structures and determine the boundaries of application and new welding techniques. **Develop ‘cold’ (i.e. non-weld) repair techniques for short, medium and long-term structured life extension. **Find low intrusive repair techniques that can be carried out with ongoing traffic.

**Self-healing materials for better reinforcing capabilities of the aging infrastructures.			
Expected Impact			
*Reduce cost for maintenance and infrastructure upgrading. *Life extension of critical infrastructure. *Improved transport service and safety.			
Required Level of Investment	Medium	**Priority Level**	Medium term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 48			
PRIORITY AREA	LONG DISTANCE CORRIDORS	**PERFORMANCE**	COST-EFFICIENT
TRL LEVEL		**ID**	R2.3

TOPIC DESCRIPTION

Specific Challenges

Europe is depending on the existence and availability of complex infrastructure. Important critical infrastructure is indispensable in the supply chain of energy, in transportation and in protection against water flooding. Massive investments in critical infrastructures have been made to reach the current level of economic and social development.The integrity of this infrastructure is becoming a serious issue. Most of our transportation (infra)structure has been built in the years 60-70 (water management structures on the average 30 years earlier) and approaches the end of design life time. Moreover, loads are increasing (varying from heavier traffic to more extreme climate events). Consequently, structural integrity can no longer be taken for granted.Premature and unpredictable failure of structures, with undesirable and unacceptable consequences can be disastrous for industry and society. However, in many cases inspection is difficult or even impossible today because defects are embedded deep in the material or structure. And our ability to forecast a structure's integrity is limited because our understanding of the process of degradation and its impact on the structure is still limited. With this state-of-the art, maintenance costs are sharply increasing, and proper levels of maintenance are under threat of becoming unaffordable.Condition-Based Maintenance (CBM) based on monitoring and forecasting the integrity of structures, is the most effective way to safeguard structural integrity while reducing maintenance costs, maximizing the "up-time" of the structures and allowing utilization in a different way than a structure was originally designed for. The successful development of a CBM capability will require the further development and integration of many technology areas including non-destructive measurement, sensing/data processing/telemetry, and a variety of deterministic and probabilistic predictive modelling capabilities with the ability to quantify the uncertainty in the predictions. The multi-disciplinary and challenging nature of the problem, its current embryonic estate of development, and its tremendous potential for safety and economic benefits qualify CBM as a 'grand challenge' problem in the twenty-first century.

Scope

Smart Infrastructures enabling condition based Maintenance
It is important that the sensing and inspection technology as well as the models for degradation and structural integrity are developed in projects combining the two elements. The output of sensing and inspection is input for modelling. Hence, the input data that models require and the information that sensing and inspection can produce must fit. This program will have wide application for maintenance of large structures. To safeguard the applicability of the results in practice, field tests of the technology need to be organized for different types of application with active participation of stakeholders. The program focusses on concrete and on steel structures.
Develop advanced sensing and inspection technology
Advanced intelligent imaging, ultrasonic systems, acoustics (sonar) and radar, fiber optic sensors, earth

observation, distributed sensor systems and data management platforms connecting sensor data to models will be (further) developed and tailored to the specific requirement for inspection and monitoring e.g, steel bridged or concrete tunnels. The development will be tuned to different requirements of the applications. Important requirements derive from the specific circumstances in which the equipment need to be employed. In that context robotic techniques for inspection will be developed. Develop (multi-scale, multi-physics, probabilistic) models Material degradation models, e.g. describing the intrusion of chloride and carbon dioxide through concrete and the chemical rust process of re-bar in time, combined with models for predicting of the associated pressure development on concrete and local fracture of cover due to re-bar corrosion. Or for steel structures, models describing corrosion fatigue, fracture initiation and propagation. The ambition is to develop toolboxes that will predict material degradation under relevant load conditions. In addition, there is a need to know how the limit states beyond which a structure is considered to be not safe, are related to the local states of the components and materials. To assess this and the present structural safety and remaining service life, adequate models for (global) response of the structural system affected by local degradation are needed. Game changing approaches are required to develop multi-scale and multi-physics models for reliable prediction the remaining life time, and the related financial and other risks. There is currently no measure/model that can predict with sufficient accuracy the probability of failure or the remaining lifetime. Integrated structure and network management. The above innovations need to be validated and demonstrated in field test with active participation of stakeholders. The innovations need to be incorporated in coordination approaches that take into account all actors that own, operate, manage individual structures and networks to provide end users with accessible, flexible and reliable infrastructures condition based maintenance services. Data-driven decision support for maintenance Recent advances in the areas of Big Data, Machine Learning and Aritifical Intelligence will significantly improve the intelligence gathered from the vast amount of data collected from fixed and mobile infrastructure sensing devices and systems. Such data combined with Expert Knowledge will lead to impovement in the infrastrucutre maintenance processes and enbale the transition to preventive maintenance.
Expected Impact
This program aims at breakthroughs with respect to the grand CBM challenge which enable: “detection and monitoring of (precursors of) degradation inside steel/cement/concrete structures” and use this information for: “diagnosis of their structural health and forecast the service life for various intervention options" The required knowledge can also be used at the design stage to minimize the total life cycle costs of assets. The program will have wide application for maintenance of large structures and networks, in particular in the transportation infrastructure but it can be linked to similar developments initiated e.g for offshore wind structures, industrial installations, pipelines and sewage systems, oil &gas and geothermal wells. The economic benefits (cost reduction, reduced down time, new innovative enterprises) will be very large.

Required Level of Investment	Medium	**Priority Level**	short term

Geographic Scale	National

RESEARCH & INNOVATION NEED # 49			
PRIORITY AREA	LONG DISTANCE CORRIDORS	**PERFORMANCE**	COST-EFFICIENT
TRL LEVEL		**ID**	R2.4
TOPIC DESCRIPTION			
Specific Challenges			
Scope			
New infrastructure technologies. This will include new track forms, switches and crossings, and their potential for commercial development. Development of intelligent infrastructure maintenance and inspection and defect detection technologies carried out at commercial speeds.			
Expected Impact			
System infrastructure should be designed to be intelligent and self-learning. It should adopt relevant infrastructure technologies from different transport sectors.Intelligent infrastructure will be fatigue and wear resistant; system components will be monitored autonomously in real time. The use of new operational and track engineering techniques across the network will reduce the need for intrusive maintenance and greatly improve the train/infrastructure interaction at conventional and high speeds, such as the wheel/rail interface. A focus on intelligence provided by the system (remote condition monitoring and autonomous analysis and decision support) will enable the establishment of timely and right first time maintenance. This will ensure that there is minimisation of system interruption and maximisation of product availability to the customer.			
Required Level of Investment	Medium	**Priority Level**	Medium term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 50			
PRIORITY AREA	LONG DISTANCE CORRIDORS	**PERFORMANCE**	COST-EFFICIENT
TRL LEVEL		**ID**	R2.5
TOPIC DESCRIPTION			
Specific Challenges			
Scope			
Seamless cross borders transport operations, Freight Competitiveness via co-operation and co-ordination across Europe with technology and innovation, including: cross-European means of coordinating, managing and exploiting freight operations; Focus on corridors and create network dedicated to rail freight and strengthen the international corridors (TEN-T freight network)			
Expected Impact			
Connected and sustainable Pan-European freight TEN-T infrastructure			
Required Level of Investment	High	**Priority Level**	Medium/long term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 51			
PRIORITY AREA	LONG DISTANCE CORRIDORS	**PERFORMANCE**	SOCIAL / INCLUSIVE
TRL LEVEL		**ID**	R3.1
TOPIC DESCRIPTION			
Specific Challenges			
Scope			
Acceptance & approval process of new routes			
Expected Impact			
Required Level of Investment		**Priority Level**	
Geographic Scale			

RESEARCH & INNOVATION NEED # 52			
PRIORITY AREA	LONG DISTANCE CORRIDORS	**PERFORMANCE**	SOCIAL / INCLUSIVE
TRL LEVEL		**ID**	R3.2
TOPIC DESCRIPTION			
Specific Challenges			
Crossing and interventions need to be designed minimising disruption to travel whilst ensuring that vulnerable users can safely cross the network or are adequately secluded from it (e.g. cycling paths). This will probably translate in numerous new structures.			
Scope			
Ensuring new LD corridors has minimal impact on Accessibility (e.g. cycling and walking routes)			
Expected Impact			
By ensuring accessibility to vulnerable users (e.g. pedestrians, cyclists) there will be a positive impact on neighbouring communities and it will help promote more active transport modes.			
Required Level of Investment	High	**Priority Level**	short term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 53			
PRIORITY AREA	LONG DISTANCE CORRIDORS	**PERFORMANCE**	RESILIENT
TRL LEVEL		**ID**	R4.1
TOPIC DESCRIPTION			
Specific Challenges			
Different risk appetites of different infrastructure operators/governments/regulators etc. Difficulty in predicting the temporal nature and magnitude of natural and man-made hazard events.			
Scope			
Innovative solutions for preparedness, prevention, robustness and recovery from the occurrence of emergency situation based on disruptive events (natural and man-made hazards)			
Expected Impact			
It is imperative for a well-defined and managed transport infrastructure to be able to anticioate to emergency situations from disruptive events, like flooding, landslide or terrorist attacks.This will allow: 1) Reduced level of risk of users. 2) To manage potential corridors cuts as well as to reduce time of these cuts. 3) To manage emergency resources under more effective approach 4) Reduce both direct and indirect costs 5) Enhancement of the communication among infrastructure end-users and operators.			
Required Level of Investment	Medium	**Priority Level**	Medium term
Geographic Scale	European		

<table>
<tr><th colspan="4">RESEARCH & INNOVATION NEED # 54</th></tr>
<tr><td>PRIORITY AREA</td><td>LONG DISTANCE CORRIDORS</td><td>PERFORMANCE</td><td>RESILIENT</td></tr>
<tr><td>TRL LEVEL</td><td></td><td>ID</td><td>R4.2</td></tr>
<tr><th colspan="4">TOPIC DESCRIPTION</th></tr>
<tr><th colspan="4">Specific Challenges</th></tr>
<tr><td colspan="4">Require collaboration between infrustructure managers, construction sector and technology providers (climate services, IT services etc)</td></tr>
<tr><th colspan="4">Scope</th></tr>
<tr><td colspan="4">Infrastructure adaptation to climate change</td></tr>
<tr><th colspan="4">Expected Impact</th></tr>
<tr><td colspan="4">Adverse weather conditions have a negative impact on transport service performance and related costs. These costs are expected to increase because of changing climate patterns resulting in an increase in the intensity and frequency of extreme weather events. Weather conditions also affect the ageing of railway infrastructure. In order to mitigate the impact of climate change on transport systems there is a need for infrastructure resilient to climate change.</td></tr>
<tr><td>Required Level of Investment</td><td>High</td><td>Priority Level</td><td>Medium term</td></tr>
<tr><td>Geographic Scale</td><td colspan="3">European</td></tr>
</table>

RESEARCH & INNOVATION NEED # 55			
PRIORITY AREA	LONG DISTANCE CORRIDORS	**PERFORMANCE**	RESILIENT
TRL LEVEL		**ID**	R4.3
TOPIC DESCRIPTION			
Specific Challenges			
Scope			
Resilient transport and logistics networks by design Real Time Traffic Management enable control, command and communication systems runs across the whole European Rail network; Infrastructure resilience via technology innovation and governance, management and finance of the infrastructure; Transport chain design and operation for synchromodality			
Expected Impact			
Reduction in lineside equipment based on more in-cab signaling, sopled with benefits from deploying and exploiting 'intelligent infrastructure' are likely to result in significant operational and capital cost savings; increased diversity and resilience of transport services, more intermodality			
Required Level of Investment	Medium	**Priority Level**	Short/mmedium term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 56			
PRIORITY AREA	LONG DISTANCE CORRIDORS	**PERFORMANCE**	RESILIENT
TRL LEVEL		**ID**	R4.4
TOPIC DESCRIPTION			
Specific Challenges			
There is considerable uncertainty in the future of transport (i.e. autnomous vehicles/electric vehicles etc.) Uncertainty in climate change projections and how it may impact on transport systems.			
Scope			
Harmonised cost-benefit assessment approaches for short, medium and long term decision making against operation changes, such as climate change, long term shift in vehicle type s or upgrading			
Expected Impact			
Transport infrastructures are demanding harmonised cost benefit assessment when integrating climate change adaptation into decision making process. For that purpose, it is needed to develop a multi-scale method able to assess not only the economic cost of implementing different adaptation measures, but also the quantification of social and performance impacts. Both direct and indirect effects should be considered taking into account a system of systems approach.			
Required Level of Investment	Medium	**Priority Level**	Medium Term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 57			
PRIORITY AREA	LONG DISTANCE CORRIDORS	**PERFORMANCE**	SAFE / SECURE
TRL LEVEL		**ID**	R5.1

TOPIC DESCRIPTION

Specific Challenges

Automated Driving is seen as one of the key technologies and major technological advancements influencing and shaping our future mobility and quality of life. Automated Driving must therefore be considered as a key aspect for the European Transport policy, able to support several objectives and societal challenges, such as road safety, decarbonisation, smart cities, social inclusiveness, etc. In technological terms, the advancement towards highly Automated Driving is seen as an evolutionary process to ensure that all involved stakeholders can develop and evolve with the adequate pace. The European community is nevertheless facing important challenges to enable or implement higher levels of Automated Driving in all environments. Among them, the physical infrastructure that is required to enable/support higher levels of automated driving is utmost important and the challenges within must be tackled.

Scope

Future infrastructure for all users' safety:
Road infrastructure, both in urban and in rural areas, needs to be adapted to the requirements of new vehicle technologies, in particular automated driving functions, and its performance needs to be guaranteed by intelligent maintenance and monitoring. Also for pedestrians and cyclists a focus should be on their dedicated infrastructure to avoid amongst others single vehicle / road user accidents. Infrastructure design should take into account the need for interactions with all kinds of road users (human factors). In order to meet these challenges, proposals should address one or several of the following aspects, according the specific situation addressed:
*Re-engineering/re-design methods to adapt the network to new needs and ensure higher efficiency;
*Innovative design and construction methods that are fast, cost-efficient, low disturbance, using low maintenance and environment-friendly materials and flexible enough to accommodate increasing/changing demand;
*Integration of IV/VI and the relation between infrastructure performance and sensor requirements/vehicle dynamics.

Expected Impact

Actions are expected to contribute to re-defining the transport infrastructure network to accomodate an increasing demand for Automated Driving Vehicles and the possible sharing space with human driving vehicles. Impact assessment regarding safety, efficiency and environmental benefits shall provide evidence for a costs/benefit. Safety measures for users should be located at the heart of the projects, including direct and indirect measures.

Required Level of Investment	Medium	**Priority Level**	Medium term
Geographic Scale	European		

<table>
<tr><th colspan="4">RESEARCH & INNOVATION NEED # 58</th></tr>
<tr><td>PRIORITY AREA</td><td>LONG DISTANCE CORRIDORS</td><td>PERFORMANCE</td><td>SAFE / SECURE</td></tr>
<tr><td>TRL LEVEL</td><td></td><td>ID</td><td>R5.2</td></tr>
<tr><th colspan="4">TOPIC DESCRIPTION</th></tr>
<tr><th colspan="4">Specific Challenges</th></tr>
<tr><td colspan="4"></td></tr>
<tr><th colspan="4">Scope</th></tr>
<tr><td colspan="4">Improved management of critical interfaces with others modes and smart methods for monitoring road-rail intersections with the use of advanced solutions (GNSS systems, advanced CCTV tools, etc.) and analysis (collaborative tools) integrated by new human centred safety measures . eg Level crossing for rail/road with the aim to minimize risks at and around level crossings by developing a fully integrated cross-modal set of innovative solutions and tools for the proactive management and new design of level-crossing infrastructure.Properly adapted technical solutions deployed within an appropriate human, legal and organisational framework are necessary.</td></tr>
<tr><th colspan="4">Expected Impact</th></tr>
<tr><td colspan="4">Mitigation of human error at rail road interface/level crossing will lead to the reduction in number or elimination of accidents (29 % of railway accidents 2010-2012 , European Union Agency for Railways, RAILWAY SAFETY PERFORMANCE) but also foster the implementation of multimodal network with the increase of connections and interchanges.</td></tr>
<tr><td>Required Level of Investment</td><td>Medium</td><td>Priority Level</td><td>Medium term</td></tr>
<tr><td>Geographic Scale</td><td colspan="3">European</td></tr>
</table>

RESEARCH & INNOVATION NEED # 59			
PRIORITY AREA	LONG DISTANCE CORRIDORS	**PERFORMANCE**	GREEN
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I1.1
TOPIC DESCRIPTION			
Specific Challenges			
Materials would have to be tested extensively to ensure they are robust			
Scope			
Durable and energy-efficient materials - increasing the lifetime of assets			
Expected Impact			
Durable, energy-efficient materials with minimal maintenance needs have as key advantage a significant reduction of the delays caused by maintenance works such as traffic jams, train delays, delayed or cancelled aircraft operations, etc. As a conse-quence, society and infrastructure users benefit from a diminution of external costs. On the other hand, since maintenance works wouldn't have to take place so often and infrastructure would remain operative for longer periods of time, operators would reduce their costs. Explicitly to name here are the inclusion of nanomaterials and technology for the increase of the material durability. Finally, a general improvement of the understanding on material durability and behaviour and the development of deterioration models would enable better planning and scheduling of the maintenance works.			
Required Level of Investment	High	**Priority Level**	medium term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 60			
PRIORITY AREA	LONG DISTANCE CORRIDORS	**PERFORMANCE**	GREEN
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I1.2
TOPIC DESCRIPTION			
Specific Challenges			
Focus should be on ensuring high quality recycled materials are created, this will ensure sustainable use of these prodicts. Circular econmy concept is relevant, but needs to be focused on a geographically specific area i.e. reuse of materials is low carbon only if transporting it long distance is not required.			
Scope			
Recycling and reuse by design - to ensure R&R aspects in designing new products			
Expected Impact			
Traditionally, recycling and reuse are not thought of when a product is designed. However, thinking about second life of materials and products in the design phase will ensure sustainable, cost efficient and responsible use of R&R. Development and experience from other industries could be examples for the application in the field of infrastructure. Especially additives in asphalt and concrete should be clearly and fully assessed on their long term (R&R) consequences, which at the moment is not regular practice. The application and use of R&R materials in combination with concepts like prefab elements and modular design could complement each other. Modular building elements will make it easier and less costly to produce and maintain products, a high and defined degree of quality can be guaranteed, material streams can be easily traced, quality and performance test methods can be implemented. R&R by design, including continuous improvement, will make it easier to realize its implementation because of the continuity of product delivery and return and defined product characteristics.			
Required Level of Investment	Medium	**Priority Level**	medium term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 61			
PRIORITY AREA	LONG DISTANCE CORRIDORS	**PERFORMANCE**	COST-EFFICIENT
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I2.1
TOPIC DESCRIPTION			
Specific Challenges			
Current practices include fine-milling or diamond grinding of surfaces and the use of asphalt rejuvenators or the inductive heating of asphalt pavements. Further techniques are used to control the temperature of the assets during extreme hot or cold weather events by storing the energy generated during the summer to be used for heating in winter.			
Scope			
Techniques and materials for fast maintenance measures - fewer maintenance operations mean fewer interruptions of the infrastructure network			
Expected Impact			
Materials durability can be enhanced through a broad range of physical and chemical methods. A number of measures allow a quick improvement of the material's properties. Other technical options are the use of geothermal energy or the use of groundwater energy to achieve the desired effect. It is necessary to further develop and improve these techniques that have been tested in pilot applications so far to achieve a good economical and ecological efficiency.			
Required Level of Investment	Medium	**Priority Level**	Medium term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 62			
PRIORITY AREA	LONG DISTANCE CORRIDORS	**PERFORMANCE**	COST-EFFICIENT
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I2.2
TOPIC DESCRIPTION			
Specific Challenges			
As previously mentioned (see Urban Mobility R1.4) the precast industry is a huge industry across Eurpose therefore consistent uptake of improvements in precast design or construction could be challenging			
Scope			
Precast elements _ Quick and efficient maintenance measures			
Expected Impact			
Precast elements enable maintenance measures in a very short time. This allows for fast maintenance operations scheduled in detail, e. g. overnight construction measures avoiding long closures of the infrastructure during highly frequented times and thereby minimizing major disturbances of the traffic flow. These elements achieve a higher quality than its in-situ built counterparts due to the fact that the product is manufactured in a con-trolled environment independently from weather conditions (temperature, precipitation). Due to their modular character, it is possible to implement and test innovations quickly and easily. It is necessary to further improve the characteristics as well as the installation processes and to define regulations to assure a high, long-lasting, and constant quality of the performance.			
Required Level of Investment	Low	**Priority Level**	short term
Geographic Scale	National		

RESEARCH & INNOVATION NEED # 63			
PRIORITY AREA	LONG DISTANCE CORRIDORS	**PERFORMANCE**	SOCIAL / INCLUSIVE
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I3.1
TOPIC DESCRIPTION			
Specific Challenges			
Pilots of sustainable and mulltimodal long distance corridors approaches are needed. Demonstration projects that monitor and evaluate those systems in terms of accesibility, use and acceptance.			
Scope			
Demonstration of more efficient transport approaches Autonomous vehicles/hybrid systems/ Long distance Corridors links and adaptation - Transport links info on delays across modes			
Expected Impact			
The main expected impact is to increase the social acceptance of sustainable transport modes at long distance corridors.			
Required Level of Investment	High	**Priority Level**	medium term
Geographic Scale	National		

RESEARCH & INNOVATION NEED # 64			
PRIORITY AREA	LONG DISTANCE CORRIDORS	**PERFORMANCE**	RESILIENT
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I4.1
TOPIC DESCRIPTION			
Specific Challenges			
There are potential issues with storage, validation and management of data collected through the Internet of Things. Data protection and security issues. Requires understanding of how the data is to be used before data collection begins.			
Scope			
Using sensor-based technology to monitor transport fleets			
Expected Impact			
Fleet probing (using low cost probes on public or private road & rail vehicles, aircrafts; less suitable for vessels) can be a source of information about the quality and level of damage of infrastructure condition. Data can be aggregated into a single database and properly interpreted. The idea for this type of "simplified" road inspection methods is to use classical passenger cars equipped with sensors, and with smartphones for data acquisition and transmission and for evaluation of road networks. Vehicle sensor data could be transmitted by V2X (vehicle to infrastructure) to detect changes in road condition in real time (for example, detect ice patches or sudden potholes). Internet of things (IoT) is an opportunity for infrastructure inspection to be connected with inspection devices and vehicles using electric sensors and the Internet.			
Required Level of Investment	Low	**Priority Level**	medium term
Geographic Scale	National		

RESEARCH & INNOVATION NEED # 65			
PRIORITY AREA	LONG DISTANCE CORRIDORS	**PERFORMANCE**	SAFE / SECURE
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I5.1
TOPIC DESCRIPTION			
Specific Challenges			
The infrastructure inspection may times has to be carried out often in difficult and dangerous working conditions. A work under the bridge and the tunnels are more difficult due to high altitude and difficult access to the meat measurement. Also inspection work on the road, runway, rail and in ports influence on the traffic sped and expose workers to the dangerous situations.			
Scope			
Inspection robots/self-repairing robots			
Expected Impact			
In these cases, they are very suitable replacement robots. The use of robots for inspection work would contribute to greater security for workers who carry out the inspection work in the field. Also, would the robots were available for the less accessible parts of the infrastructure and the different facilities of the infrastructure. For example sealing cracks in roadways ensures a road's structural integrity and extends the time between major repaving projects, but conventional manual crack sealing operations expose workers to dangerous traffic and cover a limited amount of roadway each day. Automated Pavement Crack Detection and Sealing System could at the same time detect the cracks and repair them with the new sealing material. Also the concept of swarm robotics is a relatively new paradigm for the coordination of multiple robots solely based on local interactions using simple individual robotic nodes.			
Required Level of Investment	Medium	**Priority Level**	Medium Term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 66			
PRIORITY AREA	LONG DISTANCE CORRIDORS	**PERFORMANCE**	SAFE / SECURE
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I5.2
TOPIC DESCRIPTION			
Specific Challenges			
An important issue limiting the uptake of using recycled materials nowadays is the uncertainty about the exact composition and quality of the recycled material. For instance it could contain contaminations or undesired materials, or even dangerous substances such as asbestos.			
Scope			
Traceability of materials & products - to ensure the performance and durability of materials and hence, the user´s safety			
Expected Impact			
Development of systems to trace the materials and products to where they come from could help to provide the trust needed for construction companies to use recycled materials. Additionally, development of the proper risk methods, test protocols and measurement equipment could help to reduce the probability of using contaminated or bad quality materials.			
Required Level of Investment	Medium	**Priority Level**	Medium Term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 67			
PRIORITY AREA	LONG DISTANCE CORRIDORS	PERFORMANCE	
TRL LEVEL	DEPLOYMENT 8<TRL	ID	D1
TOPIC DESCRIPTION			
Specific Challenges			
Development of activities focused on reducing the gap from research to the market. Promoting activities related to: * Public procurement for innovation * Sinergies between H2020 and research programmes with projec development programmes like CEF *Standardisation			
Scope			
Deployment and roll out of long distance corridors innovation			
Expected Impact			
* Faster and more efficient integration of innovations in the transport system. * More cost efficient development of innovations			
Required Level of Investment	High	Priority Level	Long term
Geographic Scale	National		

RESEARCH & INNOVATION NEED # 68			
PRIORITY AREA	LONG DISTANCE CORRIDORS	**PERFORMANCE**	
TRL LEVEL	DEPLOYMENT 8<TRL	**ID**	D2
TOPIC DESCRIPTION			
Specific Challenges			
Development of awareness campaigns of new transport systems and innovations in order to convince the benefits for the users.			
Scope			
Public acceptance of major infrastructure works.			
Expected Impact			
Social acceptance of new and more sustainable transport systems.			
Required Level of Investment	Low	**Priority Level**	Long term
Geographic Scale	Local		

<table>
<tr><th colspan="4">RESEARCH & INNOVATION NEED # 69</th></tr>
<tr><td>PRIORITY AREA</td><td>SYSTEMIC APPROACH</td><td>PERFORMANCE</td><td>GOVERNANCE</td></tr>
<tr><td>TRL LEVEL</td><td>RESEARCH
TRL<5</td><td>ID</td><td>R1.1</td></tr>
<tr><th colspan="4">TOPIC DESCRIPTION</th></tr>
<tr><th colspan="4">Specific Challenges</th></tr>
<tr><td colspan="4">Development of PLM (Product Life-cycle Management) concepts, methods and tools for managing HLSI product information from conception to service. In particular, information models and tools for sustainability and LCA (Life-Cycle assessment), including environmental impact, and resilience to changes. Definition of common performance indicators.
Data integration for New (non-destructive) testing methods (radar, ultrasound, optical fibre, wireless smart sensors...) for diagnostic, early damage detection and maintenance of the infrastructures.
Data Integration of terrestrial and satellite systems for the structural health monitoring of key infrastructures located in a natural risk (earthquakes, landslides, floods) prone area.
Data management for advanced sensing, smart inspection & robotics for maintenance.</td></tr>
<tr><th colspan="4">Scope</th></tr>
<tr><td colspan="4">Integrated information system for asset management</td></tr>
<tr><th colspan="4">Expected Impact</th></tr>
<tr><td colspan="4">Asset management needs in the future up-to-date data supply to ensure proper decision-making. If the future infrastructures will be constructed with built-in sensors that allow the remote monitoring of performance, such data could be complemented with data from remote sensing and in-car data or train data. Combined they would inform network managers and operators about the behaviour of the infrastructure, as well as inform designers on how to improve the next generation of infrastructure. There is a danger to open all the data to the public. Possibilities to wrong interpretation. In different countries there’s attention for BIM and geoinformation in the whole lifecycle of the railway network: from feasibility study, design and construction to the maintenance and management phase. Also the quantum revolution takes quantum theory to its technological consequences. It is leading to devices with fundamentally superior performance and capabilities for sensing, measuring, imaging, communication, simulation and computing. Some of them are still require years of careful research and development.</td></tr>
<tr><td>Required Level of Investment</td><td>Low</td><td>Priority Level</td><td>medium term</td></tr>
<tr><td>Geographic Scale</td><td colspan="3">European</td></tr>
</table>

RESEARCH & INNOVATION NEED # 70			
PRIORITY AREA	SYSTEMIC APPROACH	**PERFORMANCE**	GOVERNANCE
TRL LEVEL	RESEARCH TRL<5	**ID**	R1.2
TOPIC DESCRIPTION			
Specific Challenges			
New methods and tools integrated in BIM-based Cloud-based AMS for monitoring and assessing (the status of) existing structures, e.g. relatively to structural loading and deterioration potential. This includes better understanding of damage and deterioration mechanisms and their effects on asset performance and residual life. Development of new advanced methods for characterization and assessment of the safety of existing structures, taking into account economic considerations and limits for human safety. Development of structured sets of performance indicators and performance based design closely connected to probabilistic modelling and prediction. Development of BIM extensions and related MVDs for infrastructure and network management. Development of enriched information-based interfaces integrated to infrastructures assets. Establish European information network of databases for maintenance / costs of MH (taking into account occupational safety and health).			
Scope			
Network assessment through asset management including BIM			
Expected Impact			
Maintenance actions have to be prioritized to achieve maximum performance. An Asset Management System (AMS) gives support to the operator, enables him to get a clear overview of the status of its network and objectively decide when and where operations have to be made. Decisions are then taken based on a set of infrastructure evaluation criteria that can be defined individually to appropriately allocate the financial resources for maintenance measures. On a different matter, albeit initially conceived for construction, BIM has the potential to be further enhanced to include maintenance criteria and parameters such as a database of past and current damage and repairs and can be embedded into existing AMS. Combined with “augmented” or virtual reality “wearables”, it may allow the use of a real-time view of the infrastructure’s status and damage and even watch a virtual representation of the repair works. It is necessary to unify and define common data standards as well as to agree on the criteria of the data to be determined and the historical data.			
Required Level of Investment	Medium	**Priority Level**	short term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 71			
PRIORITY AREA	SYSTEMIC APPROACH	**PERFORMANCE**	COMMUNICATION
TRL LEVEL	RESEARCH TRL<5	**ID**	R2.1
TOPIC DESCRIPTION			
Specific Challenges			
Development of accurate information systems (integrated with predictive urban and LD traffic models) for decision making in multi-modal infrastructures traffic inter-connection, with link to real-time information and mobility services, e.g. in relation to network maintenance operations, to inform end-users on traffic conditions, and suggest alternatives adapted to the mobility demands, based on co-modality principles (variable signalling panels, innovative communication methods etc.). Development of predictive urban traffic models for decision making in traffic regulation, and for providing accurate information and recommendations to users. Development of automatic incident detection systems with capacity to provide early warnings to the traffic control system. Development of holistic (multi-aspects, context-based, passenger/freight-aware) methodology and tools for D2D services deployment and performance based on new infrastructure networks that factor in appropriate indicators, information models, simulation and decision-making tools, to achieve a comprehensive set of performance levels for continuous D2D transport for passengers and freight. Devlopment of ICT-based information systems (using e.g. widespread real-time monitoring) to inform users on traffic conditions, incidents, traffic disruption, etc., including the suggestion of best travel routes, to optimize traffic and serviceability.			
Scope			
Coordinated Travel Process - Multimodal Information Platforms			
Expected Impact			
There is an emerging need for multimodal information platforms both physical and virtual. Increased demand for mobility and fast and accurate information are creating todays' research and innovation trends, thus satisfying these needs is critical. This concept assumes that airports, ports, railway, metro and bus stations should increasingly be linked and transformed into multimodal connection platforms for passengers (both physical and virtual). Online information and electronic booking and payment systems integrating all means of transport should facilitate multimodal travel.			
Required Level of Investment	Very High	**Priority Level**	medium term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 72			
PRIORITY AREA	SYSTEMIC APPROACH	**PERFORMANCE**	COMMUNICATION
TRL LEVEL	RESEARCH TRL<5	**ID**	R2.2
TOPIC DESCRIPTION			
Specific Challenges			
Development of required communication infrastructure for real-time information and mobility services, e.g. in relation to network maintenance operations, to inform end-users on traffic conditions, and suggest alternatives adapted to the mobility demands, based on co-modality principles. Development of standards, best practices, and quality training for transport operators and workers. Development of "infostructures" leaning against physical HLSI, formed by an Integrated set of information services for the passenger, providing a Facilities-Services continuum as well as ensuring quality of services for accessibility and affordability by all to high-quality services and HLSI.			
Scope			
Active Integrated Transport Infrastructure: Data /Information systems			
Expected Impact			
User information on multimodal facilities such as: park and ride, bus terminals, airports, rail stations, water ports for passengers and goods, multimodal hubs. Data input from vehicles, trains, ships, airplanes: how can this be used across modes and how this can be made available for users in clear and not confusing format. This concept goes hand in hand with smart infrastructure: smart/intelligent roads, intelligent rail, airports and water ports: smart cars with revision/inspection warnings, computer onboard for (pre)diagnosis, smart passenger trains/locomotives with diagnosis tools, smart road vehicles and planes. Communication protocols and standards for data exchange need to be established as well as information channels.			
Required Level of Investment	Very High	**Priority Level**	medium term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 73			
PRIORITY AREA	SYSTEMIC APPROACH	**PERFORMANCE**	FINANCIAL/ECONOMIC
TRL LEVEL	RESEARCH TRL<5	**ID**	R3.1
TOPIC DESCRIPTION			
Specific Challenges			
The current lack of regulation on the reuse and recycling of materials and products hinder the incorporation of waste materials as raw materials,enabling other business models, adding GREEN and COST-EFFICIENT aspects to the new material and products.			
Scope			
Supply and demand - to make an overview of the streams of materials and products			
Expected Impact			
The current knowledge situation in infrastructure lacks a clear view on supply and demand of materials and of material life from cradle to grave. Such an overview (life-cycle aspects) will help to address opportunities for improvement and increase of R&R. A better understanding of the material streams will help to support decisions on governmental R&R support measures and company investments. “Waste” should be seen as material and is available to be functional elsewhere. The amount and quality could be derived roughly from this kind of information.			
Required Level of Investment	High	**Priority Level**	medium term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 74			
PRIORITY AREA	SYSTEMIC APPROACH	**PERFORMANCE**	FINANCIAL/ECONOMIC
TRL LEVEL	RESEARCH TRL<5	**ID**	R3.2
TOPIC DESCRIPTION			
Specific Challenges			
Moving to the as a service will require massive changes in the procurement processes and procedures currently implemented. Furthermore, suppliers need to be able to provide such services.			
Scope			
As a Service supply model			
Expected Impact			
Many sectors are currently moving towards the as a service supply model with examples in the IT sector such as Infrastructure as a Service (IaaS), Software as a Service (SaaS) and Platform as a Service (PaaS). Such supply models bring a number of advantages to the operator such as scalability and improved services. It is envisioned that such supply models can be adopted in the transport industry. An example would be procuring for traffic information instead of traffic sensors.			
Required Level of Investment	Medium	**Priority Level**	medium term
Geographic Scale	National		

<table>
<tr><th colspan="4">RESEARCH & INNOVATION NEED # 75</th></tr>
<tr><td>PRIORITY AREA</td><td>SYSTEMIC APPROACH</td><td>PERFORMANCE</td><td>LEGAL / STANDARD</td></tr>
<tr><td>TRL LEVEL</td><td>RESEARCH
TRL<5</td><td>ID</td><td>R4.1</td></tr>
<tr><th colspan="4">TOPIC DESCRIPTION</th></tr>
<tr><th colspan="4">Specific Challenges</th></tr>
<tr><td colspan="4">This requires effort at the national and international levels and from both government and private organisations</td></tr>
<tr><th colspan="4">Scope</th></tr>
<tr><td colspan="4">Codes: lack of multimodal standards and tools related to multihazard resilience</td></tr>
<tr><th colspan="4">Expected Impact</th></tr>
<tr><td colspan="4">Improved, efficient interfaces between different modes at transhipment points for achieving seamless transport.</td></tr>
<tr><td>Required Level of Investment</td><td>High</td><td>Priority Level</td><td>medium term</td></tr>
<tr><td>Geographic Scale</td><td colspan="3">European</td></tr>
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<tr><th colspan="4">RESEARCH & INNOVATION NEED # 76</th></tr>
<tr><td>PRIORITY AREA</td><td>SYSTEMIC APPROACH</td><td>PERFORMANCE</td><td>LEGAL / STANDARD</td></tr>
<tr><td>TRL LEVEL</td><td>RESEARCH
TRL<5</td><td>ID</td><td>R4.2</td></tr>
<tr><th colspan="4">TOPIC DESCRIPTION</th></tr>
<tr><th colspan="4">Specific Challenges</th></tr>
<tr><td colspan="4">This requires effort at the national and international levels and from both government and private organisations. Furthermore, the existence and support of legacy systems and the advent of new sensors and systems will present a challenge to the application of such standards.</td></tr>
<tr><th colspan="4">Scope</th></tr>
<tr><td colspan="4">Standards for multimodal transport data aggregation a format</td></tr>
<tr><th colspan="4">Expected Impact</th></tr>
<tr><td colspan="4">The development of standards for multimodal transport data is essential for the development of multi-modal information systems and can unlock a multitude of potential services</td></tr>
<tr><td>Required Level of Investment</td><td>High</td><td>Priority Level</td><td>medium term</td></tr>
<tr><td>Geographic Scale</td><td colspan="3">European</td></tr>
</table>

RESEARCH & INNOVATION NEED # 77			
PRIORITY AREA	SYSTEMIC APPROACH	**PERFORMANCE**	RISKS / INTERDEPENDENCIES
TRL LEVEL	RESEARCH TRL<5	**ID**	R5.1
TOPIC DESCRIPTION			
Specific Challenges			
The integration, aggregation and dissemination of data/information across sectors (transport operators, weather information providers, emergency services and members of the public) is faced with challenges in relation to data formats, access rights, security, and information models			
Scope			
Advanced traveler information - cross modal emergency evacuation/events/weather user information			
Expected Impact			
Emergency and evacuation information needs to be quickly and effectively conveyed to users. Even though emergency situations do not happen often, but with rapid climate change and emerging man made (terrorist attacks) or natural caused events/threats it becomes an increasing issue. Exchanging information with emergency services (EMS) as well as with the users and operators of other transport modes is covered in this topic. Another aspect is ensuring consistency in the messages provided to the public by different organizations, e.g. port operators, airports, rail and highway operators with police and EMS.			
Required Level of Investment	Very High	**Priority Level**	Long term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 78			
PRIORITY AREA	SYSTEMIC APPROACH	**PERFORMANCE**	RISKS / INTERDEPENDENCIES
TRL LEVEL	RESEARCH TRL<5	**ID**	R5.2
TOPIC DESCRIPTION			
Specific Challenges			
New sophisticated modelling tools are required for the assessment of such hazards (natural and/or man-made). These tools should have the ability to aggregate and process a wide variety of data sources and provide validated and verified assessment of the impact of different hazards on the transport system. Such tools should also have the ability to adapt to new threats as well as new and emerging data sources.			
Scope			
Systemic multi-scale approach for assessment of the performance of transport infrastructure against multi-hazard risk			
Expected Impact			
Natural hazards and man-made events are a concern for critical infrastructure operators. These events has dramatical influence on both the risk scenario and the performance of the network (local, regional, national and European). A harmonised and systemic approach to evaluate both the new risks as well as to repercussions at different scales are needed and it will support in investment strategies and selection of adaptation measures.			
Required Level of Investment	Very High	**Priority Level**	Long term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 79			
PRIORITY AREA	SYSTEMIC APPROACH	**PERFORMANCE**	GOVERNANCE
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I1.1
TOPIC DESCRIPTION			
Specific Challenges			
Barriers to inclusion include the lack of sufficent data on carbon emitted for different methods and materials. Research should ensure that a wide range of data is available. In addition there may be a lack of incentives: if there is no regulatory backing to inclusion of carbon it could be excluded.			
Scope			
Inclusion of carbon in procurement decisions			
Expected Impact			
Sustainable procurement for vehicles and infrastructure construction/ maintenance contracts can be a powerful tool in reducing carbon with the impact cascading down the supply chain. Various innovative approaches can be taken to support this for example the Dutch rail operator Pro-rail developed a system called the CO2 ladder to reduce carbon in its supply chain. This research area also includes influencing procurement decisions through vehicle taxes related to the level of CO2 emissions generated and providing information on fuel efficiency. Research to develop and trial different methods of embedding consideration of carbon in procurement decisions is required to support implementation and provide the evidence for more wide-spread use.			
Required Level of Investment	Low	**Priority Level**	short term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 80			
PRIORITY AREA	SYSTEMIC APPROACH	**PERFORMANCE**	GOVERNANCE
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I1.2
TOPIC DESCRIPTION			
Specific Challenges			
Interconnections among transport infrastructures is more and more needed. An open, active, quality framework for future multimodal transport infrastructure needs to be developed to help assess existing transport infrastructures and set standards for new ones, defining the different KPIs and their thresholds, specifically for each transport mode.			
Scope			
Identification of Operational, Tactical and Strategy Key Performance Indicators for securing the uptake of transport infrastructures innovation in TEN-T projects/networks: *Ensure efficient transport of goods and passengers using the High Level Service Infrastructure concept throughout needs relating to urban mobility, multimodal hubs and long-distance corridors. *Emphasising characteristics such as GREEN, COST-EFFICIENT, SOCIAL/INCLUSIVE, RESILIENT and SAFE/SECURE, OPEN, ACTIVE and QUALITY as a reference framework for any new multimodal transport infrastructure. *Identification of Key Performance Indicators for securing the uptake of transport infrastructures innovation in TEN-T projects/networks			
Expected Impact			
* Strategic: Guiding the evolution of the transport infrastructure (TI) in the whole of the EU towards the completion of the current TEN-T policy and the launch of the policy which will sustain an European Multi-Modal Transport Infrastructure (MMTI) Network. *Tactical: Accelerate the completion of the TEN-T Network, especially for the countries with a slow rate of development of Transport Infrastructure. *Operational: Specific deployment plans and roadmaps, including the proposal of ad hoc solutions through a consistent and resourceful dialogue with key national stakeholders and agreed KPIs.			
Required Level of Investment	Medium	**Priority Level**	Medium Term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 81			
PRIORITY AREA	SYSTEMIC APPROACH	**PERFORMANCE**	COMMUNICATION
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I2.1
TOPIC DESCRIPTION			
Specific Challenges			
In order to unleash the potential of innovative technologies and ensure the deployment in transport infrastructures, overcoming non-technical barriers is more than necessary. Among the others, an important step is to achieve the full acceptance of transport operators and especially a consolidated awareness about the benefits on their practical operations, in compliance to their real needs and future trends.			
Scope			
Increasing awareness of transport (multi-modal) operators on high-potential technologies and future trends in design, construction, operation and maintenance of the future (after 2020) European infrastructure network: Widespread, shared and agreed roadmap on high-potential technologies and future trends for an European infrastructure network, taking into account of key partnership roles from sectors such as energy and ICT.			
Expected Impact			
*Provide an effective framework for sharing best practices in different transport infrastructures, in such a way that unleashes innovation potential in multi-modal infrastructures and related operators *Consolidate a common taxonomy for each infrastructure, lifecycle stage (i.e. design, construction, operation, maintenance) and related high-potential technologies. *Facilitate cost-benefit evaluations to the wide community of transport (multi-modal) operators, in such way to be as understandable and useful as possible for setting strategic and business goals.			
Required Level of Investment	Medium	**Priority Level**	Medium Term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 82			
PRIORITY AREA	SYSTEMIC APPROACH	**PERFORMANCE**	COMMUNICATION
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I2.2
TOPIC DESCRIPTION			
Specific Challenges			
User expectations and acceptance of new technologies depend on a number of factors related to the individual (age, sex, background) and to the community as a whole (e.g. culture aspects). Such factors need to be assessed as the country or even regional levels.			
Scope			
Transport user Expectations and Acceptance factors across modes			
Expected Impact			
This concept deals with understanding and accepting information received from various information providers and on various devices by the end users. Human perception of information is limited and most efficient ways of communicating and yet not overloading users with unnecessary information needs investigation. Privacy issues such as traceability, profiling, and sharing private data with various providers ofering user information services can sometimes act as a stopper towards spreading new technologies. Fragmentation of information and tailoring user information services in such ways that it takes human behavior and perception limits into consideration is part of this concept.			
Required Level of Investment	Medium	**Priority Level**	medium term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 83			
PRIORITY AREA	SYSTEMIC APPROACH	**PERFORMANCE**	FINANCIAL/ECONOMIC
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I3.1

TOPIC DESCRIPTION

Specific Challenges

Transport budgets remain constrained, yet Europe's transport infrastructure continues to age and faces demands for increased capacity together with requirements for safety, efficiency and environmental sustainability. Dealing with the magnitude of infrastructure spending needs, to meet increased demands for reliability of service, in the coming decades is daunting. Innovations in infrastructure funding and financing are therefore much needed, that balance construction and maintenance costs and time versus whole-life costs, while engaging users.

Scope

Better funding and financing methods:
Innovative funding methods
On the funding side, tax revenues will continue to be the primary funding sources in the foreseeable future and innovative approaches are required to draw upon these sources, for example through value capture or from developer revenues. In addition, because user charges will play an increasingly important role to supplement tax revenues, there is a need to consider innovative user engagement methods such as crowdfunding or multi-jurisdictional and pooled approaches. Improved social and environmental impact assessment methdologies are required, encompassing both positive and negative influences, in order to improve existing financial assessments such as Discounted Cash-Flow (DCF) analysis, Net Present Value (NPV) calculations and Internal Rate of Return (IRR) analyses.

Innovative financing methods
On the financing side, institutional investors are critical actors and there is a need to develop innovative financing models to involve them more directly and actively. Linked to this is the reality that little standardisation currently exists for evaluating whether infrastructure projects have met their expected outputs and outcomes. Application and testing of the suitability of different emerging common performance metrics and key performance indicators is required, through collaboration with the financial sector. Analysis of the effectiveness of 'pipelines' of proposed infrastructure projects published by government and other agencies in creating market stability will also help to encourage further development of long term infrastructure investment plans. New approaches are also required to the assessment and management of risk and resilience, through collaboration with the insurance industry.

Whole-life and circular economy business models for infrastructure
Circular Economy business models are beginning to be adopted in a number of different sectors, however there are a limited number of examples of adoption in the built environment and infrastructure sectors. With typically long life cycles for infrastructure assets, new innovative business models are required to implement adaptable infrastructure assets and components that enable better whole-life

management and reverse the trend for decreased maintenance and operational expenditure (despite increased capital expenditure). Linked to this is the need for procurement methods to be aligned with new and emerging performance metrics to enable whole-life management of infrastructure to be included.
Expected Impact
*Evidence to promote increased adoption of long term infrastructure investment 'pipelines'. *Development of new innovative user engagement methods to supplement tax revenues. *Development of flexible financing and funding models that can be tailored to different needs. *Demonstration of new workable circular economy business models for infrastructure.

Required Level of Investment	Medium	**Priority Level**	Medium Term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 84			
PRIORITY AREA	SYSTEMIC APPROACH	**PERFORMANCE**	LEGAL / STANDARD
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I4.1
TOPIC DESCRIPTION			
Specific Challenges			
The current practice is that in most cases pan-European user information services cover one mode and one area, so it's not possible to plan a multi-modal journey across Europe with one journey planner/service. Once the regulations are in place and services have developed, then it should be much easier to plan such journeys.			
Scope			
Standards and service quality assurance - interoperability: legislation and standards.			
Expected Impact			
Interoperability means data standards, legislation standards and rules enabling smooth data exchange between service providers and infrastructure and services operators. This concept relates to a need for common standards on data exchange between transport operators and user information providers and also for legislation allowing sharing of user information data across modes. Quality assurance process of obtaining and exchanging only good quality data needs to be established via appropriate KPI's that need to be adapted by service providers and infrastructure owners.			
Required Level of Investment	Medium	**Priority Level**	Medium Term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 85			
PRIORITY AREA	SYSTEMIC APPROACH	**PERFORMANCE**	LEGAL / STANDARD
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I4.2
TOPIC DESCRIPTION			
Specific Challenges			
Currently, recycling and reuse are generally not actively supported by policy makers in Europe. On a high level a European driven approach to further develop and apply R&R is necessary for further steps.			
Scope			
Rules and Regulations - to facilitate and stimulate recycling and re-use in the field of infrastructure			
Expected Impact			
The differences between countries can be reduced, knowledge sharing can be supported, countries can learn and implement good practices from other EU countries. Harmonized approaches are needed on a more practical and performance based level. E.g. clear and unambiguous European guidelines for characterization and performance of materials and products.			
Required Level of Investment	Medium	**Priority Level**	Medium Term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 86			
PRIORITY AREA	SYSTEMIC APPROACH	**PERFORMANCE**	RISKS / INTERDEPOENDENCIES
TRL LEVEL	INNOVATION 6<TRL<8	**ID**	I5.1
TOPIC DESCRIPTION			
Specific Challenges			
Transport operators while sharing data about their networks, need to provide such data in a way that encourage positive travellers behaviours and ensure that such data is used for the benefits of the travellers, the network operators objectives and the community as a whole			
Scope			
Undesired travellers behaviour			
Expected Impact			
Influencing travellers can have a significant positive impact on the transport network. Examples include encouraging the use of more sustainable modes of transport, travelling at specific times to minimise impact on congestion. On the other hand, encouraging a specific set of traveller behaviours can have negative consequences on the transport network.			
Required Level of Investment	Very High	**Priority Level**	Long term
Geographic Scale	European		

RESEARCH & INNOVATION NEED # 87			
PRIORITY AREA	SYSTEMIC APPROACH	**PERFORMANCE**	
TRL LEVEL	DEPLOYMENT 8<TRL	**ID**	D1

TOPIC DESCRIPTION

Specific Challenges

The recent establishment of a large-scale European network of stakeholders including buildings and infrastructures sector as well as transport systems sector companies and researchers, has led to define a pan-European futuristic vision towards "HLSI 2040", identifying the upcoming research and innovation challenges and topics for multi-modal infrastructures. There is today a crucial requirement to increase awareness about the need for a transition from current infrastructures to drastically innovative concepts of HLSI in a holistic dimension, and to promote a living and regularly updated vision and associated R&I roadmap through continuous community building activities among the various complementary communities of transport infrastructures, in terms of roadmapping and visionary scenarios, support to planning the implementation and deployment of innovative large-scale pilots and demonstrations, devising strategies influencing on the long term public policy and strategic management and business in companies, along with a comprehensive well-structured communication about the outcomes of all these activities.

Scope

Spreading innovation and research in smart high-level service infrastructure:

Leveraging on the continuous development of a multi-modal infrastructures European stakeholders network for dialog and consultation between all actors, and to update and enhance a pan-European vision and approach towards the needs for collaborative R&D covering products, systems & services for HLSI development, operation & management, the above challenge should imply the completion of the following main activities:

*Achieve foresight activity leading to continuous prediction and forecasting of futuristic needs and breakthrough innovation, so as to update views on short-term, medium-term and long-term priorities in terms of applied RDI, based on the current state-of-the-art and ongoing European and national research projects;
*Devise and deploy a detailed plan for coordination of information exchange and dissemination between all infrastructures projects and initiatives, e.g. H2020 & INFRAVATION ongoing projects, etc. – including at an international level in relationships with policy makers and funding agencies, e.g. US DoT. this should allow a comprehensive dissemination of the innovative know-how and technologies - increasing awareness of transport (multi-modal) operators on high potential technologies and future trends in design, construction, operation and maintenance of the future (after 2020) European infrastructure network;
*Identify operational, tactical and strategy Key Performance Indicators for securing the uptake of transport infrastructures innovation, especially in TEN-T projects/networks;

*Facilitate the (demonstrator/pilot) project generation – thanks to awareness raising of all different kinds of actors, networking coordination, and greater access for industry and research organisations to funding and partnership – and along with mechanisms to achieve relays in each country through national strategic alliances. *Achieve cross-fertilisation (e.g. reporting of technological progress; exchange or licensing of IPR; joint efforts towards continuous improvements in standards & potential regulations) and identification of value chain elements required for industrial success. *Develop new organisational and funding/financing approaches (including green procurement schemes) for the development, deployment, experimentation and assessment of innovation-based cost effective and highly performing technologies and systems leading to future smart, green and cost-efficient HLSI – including provision for exploitation of new business models and new market opportunities.			
Expected Impact			
*Support the future provision of innovative and cost-saving approaches to the development and use of green, safe and low-cost multi-modal infrastructures for transport - to meet cost-effectiveness and sustainability goals. *Speeding up the industrial exploitation and take up of the results of European (H2020, Infravation…) projects. *Stimulation of alliances for further RTD and industrial innovation in the addressed technology and application areas, with additional added value by exploiting synergies and sharing best practice. *Increased industry and public presence and awareness of R&I activities in the fields of multi-modal infrastructures for ITS. *More effective execution of activities of common interest, such as IPR management and standardization.			
Required Level of Investment	Medium	**Priority Level**	Medium Term
Geographic Scale	European		

REFERENCES

- reFINE Initiative document: *"Building up Infrastructure Networks of a Sustainable Europe – Strategic targets and expected impacts"- October 2012.*