INFRASTRUCTURE & MOBILITY
AN ECTP COMMITTEE

ECTP Infrastructure and Mobility

FP9 2021-2027 POSITION PAPER

This document was developed by ECTP's (European Construction, built environment and energy efficient buildings Technology Platform) Infrastructures & Mobility Committee in particular with the support of Miguel Segarra (DRAGADOS), Clemente Fuggini (Rina Consulting), Thierry Goger (FEHRL), David Gerber (ARUP), Jesús Isoird (Tecnalia) and Alain Zarli (CSTB/ECTP).

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INDEX

1. INTRODUCTION

The Transport sector is one of the major drivers for economic growth and its reach into every aspect of society cannot be overstated. An efficient and effective transport system not only supports the economy with the movement of people and goods, but its influence is much deeper. Yet, it has a major impact on the environment and on the communities. Most activities in scientific disciplines such as chemistry, physics, computing, economics, psychology, logistics, as well as engineering, such as mechanical, civil, electrical, electronic, are directly or indirectly associated with applications in transport.

The European transport infrastructure network is a shared heritage of great economic value, enabling wealth to be generated across the continent. The magnitude of Europe's transport infrastructure is indeed quite high – in terms of (1) Roads, with a total road network of approximately 5 million km in the 28 EU Member States (60,000 km are motorways), (2) Railways, with a total length of lines around 215,000 km (107,500 km are electrified), and (3) Waterways, with 41,000 km of navigable inland waterways.

1.1 An existing infrastructure to be strengthened and transformed

Europe has an ambitious investment programme to build and complete the EU core and comprehensive transport network that connects East and West, North and South[1]. Besides, Europe possesses one of the densest and most developed infrastructure networks in the world, a huge legacy and accumulated investment inherited from its long history. It owns the oldest road networks, the first ever underground trains and the railway networks, ports and airports that facilitated its prosperity. Most of these infrastructures were constructed in the period 1960-1970 and were designed for a working life of 50 years. Now these infrastructure networks are often strained far beyond their intended capacities in terms of traffic flows and traffic loads. Large sections already require significant refurbishing. Furthermore, climate change may also have altered the climatic conditions considered at the design stage. Consequently, many of the existing infrastructures no longer fulfil the current functional requirements and today's safety and quality standards.

We now faced the issue that, with a 50-years design life at an end, a large part of the existing infrastructure reaches the end of its lifetime. Is it still safe enough to continue being used? Will it have to be demolished, strengthened and/or put under structural behaviour monitoring? The ensuing reconstruction works will inevitably create an important disturbance of traffic with associated economic consequences. The cost of replacing the existing European infrastructure is considerably high, and massive coordinated investment and funding is necessary.

[1] https://ec.europa.eu/transport/themes/infrastructure/ten-t-guidelines_en

European Transport Infrastructure (TI) needs modernising[2]. As stated in the Transport European First Semester 2016 Thematic Fiche prepared by the Commission, "European transport network infrastructures, and in particular the trans-European transport network (TEN-T), require a proper level of investment (to support) new infrastructure, refurbishment and modernisation of the existing network, as well as an increased coordination between Member States affected by cross-border infrastructure projects"[3]. Financially now is a good time for the EU TI to be brought up-to-date; as stated by Economic Science Nobel Prize recipient Paul Krugman[4], European Member States should seize the current opportunity of low interest rate on bank loans to renew an old and quickly degrading transport infrastructure. Waiting too long will increase the price of renewal or maintenance[5] (as shown in Figure 1), while reducing the performance and affecting relevant aspects such as security, safety, resilience and environmental impact of the transport system.

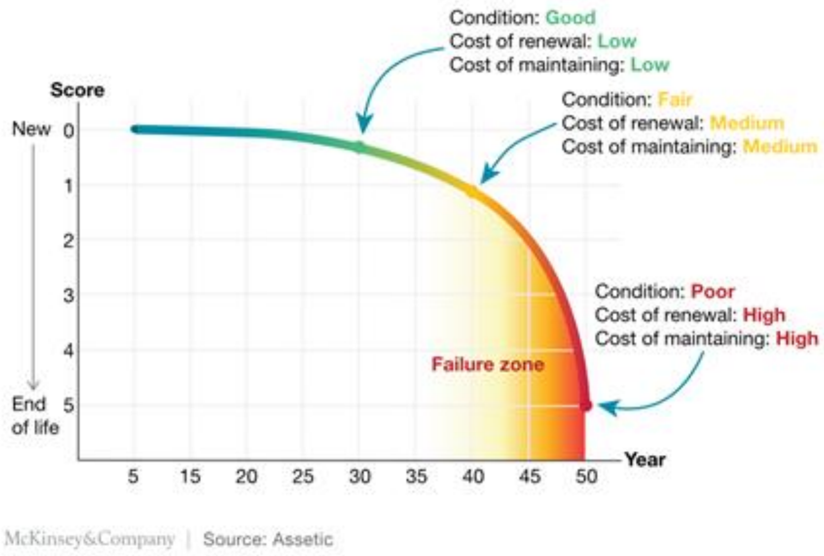

Fig. 1.1 Extracted from McKinsey "Using 'asset genetics' to unlock hidden capital

However, investments at public level across European Member States have been decreasing over the last ten years due to an unfavourable economic climate and a focus on other more urgent priorities. Indeed, challenges at global level are putting pressure on our societies and on the infrastructure of transportation of goods and people

[2] See For a detailed analysis of the state of European TI, see REFINET D3.4 "Strategic Implementation Plan (SIP)" and REFINET D4.1"Strategy for the Deployment of the SIP". Both available at: http://refinet.eu/resources/publications
[3] Source: http://ec.europa.eu/europe2020/pdf/themes/2016/transport_201605.pdf
[4] Source: Internazionale, July 2016, http://www.internazionale.it/
[5] Source: "Using 'asset genetics' to unlock hidden capital", http://www.mckinsey.com/industries/infrastructure/our-insights/using-asset-genetics-to-unlock-hidden-capital?cid=other-soc-lkn-mip-mck-oth-1607&kui=IDn5kwzg83LVR1keZHYk3Q

1.2 A new infrastructure to be developed

As result of the different socioeconomic development in the European regions during the second half of the last century, in some of them, the transport infrastructure still need to be deployed. This is high priority for many European regions, as "building a new regional transport infrastructure, extension and enhancing existing networks and removing transport bottlenecks therefore contributes directly to the fulfilment of the EU Cohesion policy goals"[6]. This need at global European level is also explicated by the TEN-T initiative[7], which promotes and strengthens seamless transport chains for passenger and freight, while keeping up with future technological trends.

Without innovation and research supporting infrastructure construction and renovation, the only option is to keep on building infrastructure the 20th century way – high carbon, low innovation and at high cost – all very wasteful and inefficient, and **with no way or hard ways to support innovative transport modes**. It is therefore vital to improve infrastructure delivery for people and freight, moreover becoming globally competitive. Across Europe there is an urgent need to modernise construction delivery, and industry will not do it on its own – the risks, the structure of the industry and the implementation of EU procurement aligns against innovation. Given the complexity of existing and future infrastructures, 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 and performance of the existing network.

1.3 Why is it important to invest in transport infrastructure?

Deteriorating infrastructure, long known to be a public safety issue, has a cascading impact on the economy, negatively affecting business productivity, gross domestic product, employment, personal income and international competitiveness. The economic consequences of continued underinvestment in infrastructure and the economic gains that could be made if we choose to invest in infrastructure are astronomical[8].

Aged Infrastructure Networks often need to operate beyond their design lifetime or in combination with other heterogeneous systems. For the European community, the utilization of these Infrastructure Networks beyond their design life is, in many cases, essential to keep the European system of systems functional. Furthermore, there is an increasing demand for better asset management of transport infrastructure in order to meet the so-called "grand challenges" defined by the EU (sustainability, energy consumption, environment, employment and social cohesion) in a cost-efficient way.

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6 Evaluation of transport infrastructure in regions of the Czech Republic
7 Infrastructure - TEN-T - Connecting Europe Facility
8 ASCE, American Society of Civil Engineers (2011), Failure to Act, The economic impact of current Investment Trends in surface Transportation Infrastructure

A paradigm shift is needed 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 considerations about availability and cost of energy, new uses of infrastructure, new products and new regulations, etc. need to be taken into account as well.

In addition, new threats like climate change will directly affect the efficiency and robustness of the transport network. Roads and other highway infrastructure elements are already subject to extreme weather events, such as storms, heat waves and freezing weather that are part of natural weather variations, as well as seasonal differences where it is hotter, colder, wetter or dryer than average seasons or years. Climate projections indicate that climate change will further increase the frequency and severity of extreme weather events in the future as well as having more usually longer-term effects related to change in average temperatures and rainfall.

In order to maintain competitiveness, the European transport networks need to be resilient to the impact of climate change at reasonable operating costs, ensuring safety and sustainability, achieving 100% reliability under extreme events and, especially in freight corridors, with limited congestion. Some research projects[9] have already been funded to assess the risk and the impact of the developing climate upon transport infrastructure. Some of them even attempt to define mitigation measures. However, the technology to mitigate, prevent or withstand the effect of this future climate is still to be developed.

An ageing society poses a new concern on the variety of users' needs that will necessitate a new approach to the design of infrastructure. Transport demand is strongly driven by demand growth in, to and between large cities and other urban areas. The demand for long distance journeys is already growing in many countries and is expected to increase. Elderly people will use transportation networks more frequently, particularly in urban areas and for long distance journeys. Besides, the patterns for younger people are expected to change in favor of multimodal travel patterns with fewer car owners. In any case, the current growing number of vehicles and mobility trends in the world, the challenges presented by transportation, which are global concerns, such as congestion, safety, security, energy efficiency and the environment, are coming high in the agenda for the near future.

Digitalisation of the construction and transport sector will also bring new opportunities for research and innovation in construction delivery, operation and maintenance. Adoption of new digital technologies have an enormous potential for increasing the competitiveness of European companies, including SMEs. Technologies, such as Internet

[9]http://ec.europa.eu/research/transport/news/items/eu_projects_say_transport_networks_vulnerable_to_climate change_en.htm

of Things & monitoring technologies, Robotics, Virtual and augmented reality, Big Data, Building / Infrastructure Information Modelling and many other will allow a smart management of transport infrastructure to ensure safety / security, predict events, failure and cascade effects while increasing performance and user satisfaction.

As mentioned above, without investment on research and innovation the sector transformation into an integrated, inclusive, seamless, safe and sustainable mobility system as envisaged in the White paper will hardly happen.

2. BACKGROUND

There have been several European initiatives that share this vision partially or in its entirety. Examples are **FORx4** from ERTRAC or **Shift2Rail** from ERRAC.

A major initiative has been ECTP's **reFINE**[10] that advocates the need for developing **High-Level Service Infrastructures** (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 infrastructures 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 infrastructures, 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 infrastructures.

The **ERTRAC-ERRAC-Waterborne-ACARE-ECTP Joint 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.

A consolidated **shared European vision** of how the multimodal European transport infrastructure network of the future (including, but not only, cross-modal aspects) should be specified, designed, built or renovated, and, maintained and upgraded in order to enhance the effectiveness of the sector must still be further developed. One of the most

[10] European Construction Technology Platform (ECTP) – reFINE: Research for Future Infrastructure Networks in Europe. The reFINE initiative is now managed in the context of the existing "Infrastructures & Mobility" Committee within the ECTP – http://www.ectp.org.

recent activities in this direction has been the **REFINET** CSA, which has delivered this shared vision and the REFINET Strategic Innovation Plan further detailed later in the document, where the different levels of development of the transport infrastructures in the European countries have been addressed and where two complementary scenarios have also been considered:

- Maintenance and upgrading of already exiting transport infrastructures,
- Development of new transport infrastructures.

REFINET has also produced the TI-Tech Mapper Platform (a web tool to analyse and map Transport Infrastructure Technologies across Europe) which is publicly available. It makes use of data collected related to best practices, high-potential and incoming technologies; innovations from R&D projects, etc. and presents them in a format that can be used to provide a support in analysis, decision-making, planning to stakeholders such as contractors and construction companies, TI operators and managers, public bodies such as ministries, policy makers, research and academia.

During the timeline of the REFINET other activities have been taking place, such as the **Infrastructure Cloud** initiative bringing together stakeholders from all transport modes belonging to all lifecycles of the infrastructure.

Two other Horizon 2020 CSA projects, **USE-iT** (Users, Safety and security and Energy in Transport infrastructure) and **FOX** (Forever Open Cross (X) modal infrastructure) have been developing in parallel with **REFINET**. The USE-iT project focuses on the operation of transport infrastructure across modes and cross modal transfer, whilst FOX focusses on the life cycle of the physical transport infrastructure covering all modes. Current work is directed to make the results of these three projects converge and feed back into the **FORx4 programme**, thus **delivering an integrated roadmap with the results of the three projects**.

In addition to the three projects outlined above, a fourth project, **SETRIS**, follows-up on previous works undertaken by the five European Technology Platforms[11] (ETPs) by updating and completing their existing Strategic Research and Innovation Agendas (SRIAs), roadmaps and implementation plans using a new coordinated and integrated approach.

[11] The five ETPs are: ERTRAC (European Road Transport Research Advisory Council); ERRAC (European Rail Research Advisory Council); ALICE (Alliance for Logistics Innovation through Collaboration in Europe); ACARE (Advisory Council for Aviation Research and Innovation in Europe); and Waterborne (Maritime and Inland Waterway Research ETP).

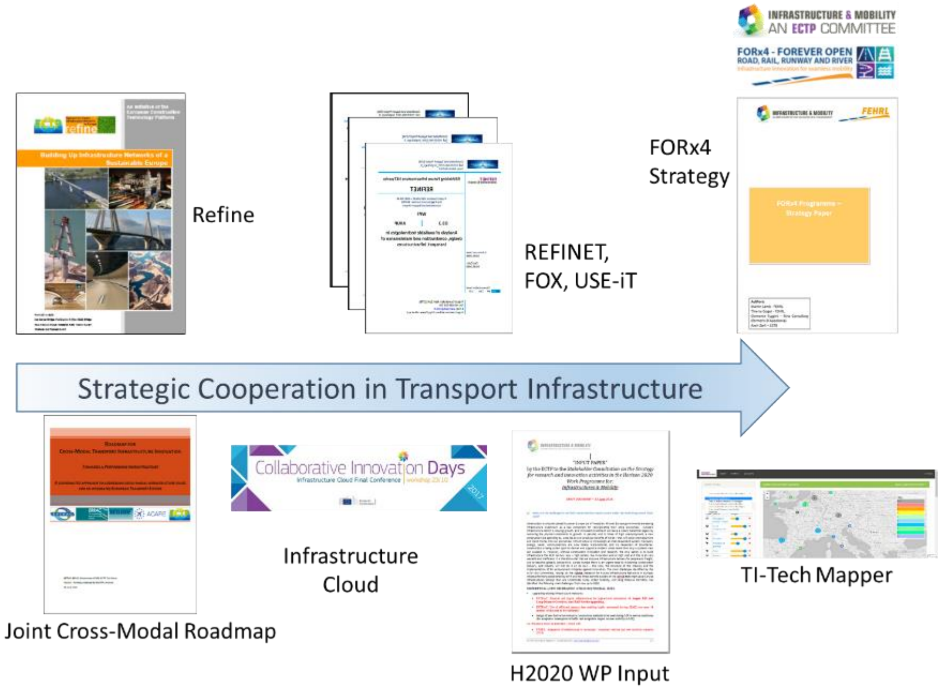

Fig.2.1 ECTP's strategic cooperation in Transport infrastructure

3. FUTURE OF TRANSPORT AND MOBILITY

Future of Transport is oriented to develop systems more focused in the citizens ensuring accessibility and inclusiveness while reducing the environmental impact and pollution, in particular improving quality of life of European cities.

As an example, **Mobility as a Service** and seamless mobility is the vision where users will not own modes of transport but will consume mobility services. The **integration between transport infrastructure and digital technologies** will provide personalized seamless journeys across different transport modes.

Autonomous vehicles advocate for a more efficient traffic management, increased safety, less climate impact and more available free space in cities that can be used for other purposes which also opens **additional possibilities for upgrading the transport infrastructure in the built environment of cities**. However, **these prospects can be rather volatile** as autonomous vehicles might stimulate the demand of transportation of those who currently do not travel on their own (i.e. the elder). There is also **no clear consensus on the impact of autonomous vehicles on energy consumed and emissions** to the atmosphere (GHGs) which could vary in the range from -50% to +100%. On the other hand, **trends like teleworking with a slow development could catch up in the future**. Some studies indicate that transport externalities (emissions, disturbances, jams, etc.) could be cut up by 90% just by teleworking five days a week. An intermediate step would be for companies to have **decentralized office spaces** (e.g. provided or rented by municipalities) nearby were workers' homes are placed, accessible by active transport means (walking, cycling) and were workers could develop their work activities in a high connectivity environment. Again, this is another opportunity for upgrading and improving the built environment and decarbonizing transport.

Walking and cycling have today and will continue to have a bigger presence in cities and urban planning. This also means reshaping the urban landscape, **reclaiming in many cases for these types of transport infrastructure that was previously used by motorised vehicles**. For instance, flexible streets can be designed or existing parking space can be redesign for vehicle loading and drop-off as less parking space would be needed.

In order to make real and feasible the implementation of new and radical sustainable transport systems**, Infrastructure needs to be physically and technologically upgraded and adapted**. For example:

- **Intelligent Infrastructure**, allowing to collect and analyse data in real time will provide increased operational efficiency for infrastructure as well as for mobility.
- **Reduced operation and maintenance** costs for the assets can be achieved by making better informed decisions.
- New **non-disruptive techniques for upgrade and maintenance** of infrastructure will help to achieve steady traffic flows.
- **New materials** (e.g. self-healing materials) to provide cost-effective strengthening capabilities to old infrastructures
- Infrastructure needs to **be resilient to the effects of climate change and man made hazards.**

In addition, and as an overarching feature, an **efficient Asset Management process is needed** to ensure cost-effectiveness in planning, design, delivery, operation and maintenance of large infrastructures or infrastructure networks. Indeed, infrastructure asset management generally focuses on the later stages of a facility's life cycle, specifically maintenance, rehabilitation and replacement; risk-based approaches are not always integrated, and network resilience perspective is not implemented throughout the lifecycle, etc. and once such services are provided, there is not is not a harmonised approach for infrastructure asset management. A coherent and multi-modes framework is needed in combination with lean procurement methodologies, financial, economic and risk assessment modules: technological solutions and tools for smart governance, and risk-based delivery and management of TI.

In this sense, Innovative Infrastructure Financing methods are needed for the transport infrastructure of the future. Public and private collaboration within innovative funding schemes are needed to construct High Level Services Infrastructure able to serve tomorrow's mobility and to upgrade the existing one to the new service standards.

4. ECTP'S REFINET MULTI-MODAL TRANSPORT INFRASTRUCTURE MODEL (RMMTI)

REFINET's main output, the **RMMTI Model**, is a high-level non-transport-mode specific model that serves as a living reference for objectives and sustained criteria for defining the design & operation specification of infrastructure projects in Europe, based on ECTP's High Level Service Infrastructure concept, for each transport mode. The model itself can be exploited in two main ways, as an infrastructure performance index and as guiding principle and strategy for the European multimodal transport infrastructure network for defining a long-term research and innovation programme for the European transport infrastructure. The RMMTI model is a 3-tier model with the following layered levels:

- **Level 1** aims to identify which key features should be considered to define the European Multi-modal Transport Infrastructure of the future. Which are the desired performance parameters for the RMMTI model of the future from the point of view of all stakeholders (end-users, operators/owners, construction companies, engineering firms, public administration)?
- **Level 2** helps identify the key aspects to be considered when implementing a multimodal systemic approach, that is, from the perspective of the transport network as a whole. Which are the targets to focus on when implementing a systemic approach? The second level of the structure of the REFINET model considers the systems of systems nature of the transport infrastructure networks, throughout the design, construction, operation and maintenance stages.
- **Level 3** aims to identify which key technologies/knowledge need to be developed in the short/medium/long term. Which projects are necessary to boost the sector?

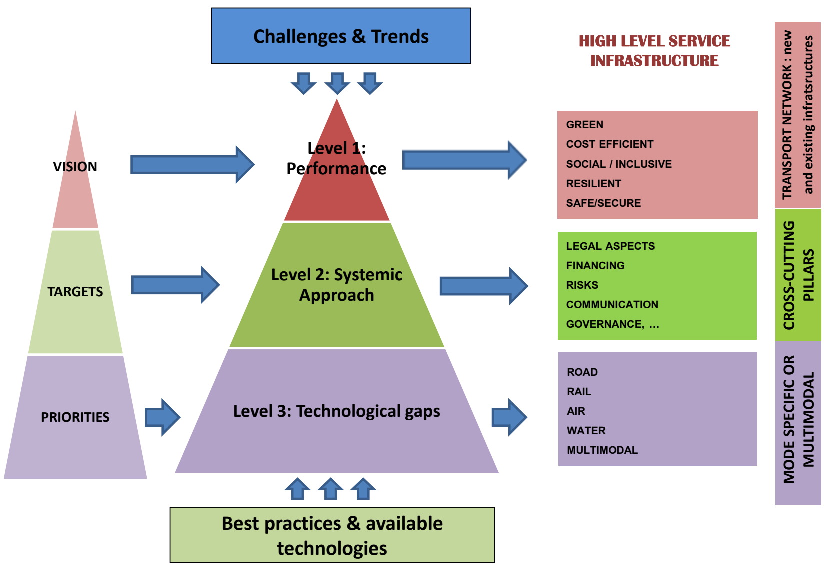

Fig. 4.1 ECTP's RMMTI model structure

5. KEY R&D AND INNOVATION AREAS FOR 2021-2027

		Connection to RMMTI Model	R&D priorities on transport infrastructures	PRIORITY LEVEL		
			PRIORITY AREA A: Urban mobility	SHORT-TERM	MEDIUM TERM	LONG-TERM
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) - Superabsorbent surface materials (CO_2, NO_x)			
A	2	G	Adaptation technologies for sustainable energy harvesting and recovery for future sustainable urban transport infrastructure - Heat removal - solar road -inductive technology - electrification			
A	3	G	Flexible and adaptable transport infrastructure to favor 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			
A	4	G	Optimization of construction materials for prefabrication and development of advance production techniques, including additive manufacturing, improving recycling and reuse.			
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.			
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 upgradability, retrofitting.			

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.			
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, cyber physics) - 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			
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 cyber-security.			

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

		Connection to RMMTI Model	REFINET priority on transport infrastructures	**PRIORITY LEVEL**		
			PRIORITY AREA B: Multimodal hubs	**SHORT-TERM**	**MEDIUM TERM**	**LONG-TERM**
B	**1**	**G**	Application of new technologies, new materials to the design of multimodal hubs enabling low-carbon and resource efficient green hubs.			

B	**2**	**G**	Development of tools to analyse whole-life whole-system energy and carbon impacts, considering multimodal hubs as energy producer centers.			
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			
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).			
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)			
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, …)			
B	**7**	**S/S**	Security against man-made extreme events in transit environments (preparedness, prevention, robustness and recovery)			
B	**8**	**S/S**	Security by design: including proven and effective measures to prevent, mitigate or detect man-made extreme events.			
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			

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

		Connection to RMMTI Model	REFINET priority on transport infrastructures	PRIORITY LEVEL		
			PRIORITY AREA C: Long distance corridors	SHORT-TERM	MEDIUM TERM	LONG-TERM
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.			
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 infrastructure facilities and networks. Surface infrastructures are covering large areas and connecting cities and industries, therefore infrastructure with the ability of resource harvesting could profit to the infrastructure system and nearby residential or industrial areas.			

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.			
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 fiber, 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.			
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 fiber, 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.			
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.			
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.			
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.			
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).			
C	**10**	**R**	Infrastructure adaptation to climate change increasing the resilience against natural hazards considering service performance and related costs balance.			
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 synchromodality.			

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).			
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 centered 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			

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

		Connection to RMMTI Model	REFINET priority on transport infrastructures	PRIORITY LEVEL		
			PRIORITY AREA D: Systemic approach	SHORT-TERM	MEDIUM TERM	LONG-TERM
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.			
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.			

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.			
D	**6**	**L/S**	Codes: lack of multimodal standards and tools related to multi-hazard resilience, considering the government and private organisation collaboration, in order to achieve a seamless transport.			
D	**7**	**L/S**	Standards for multimodal transport data aggregation in a common format for the development of multitude potential services from multimodal approach.			
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 services, 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).			
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. 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.			
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.			
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.			
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.			
D	**15**	**L/S**	Standards and service quality assurance - interoperability: legislation and standards.			

D	**16**	**L/S**	Rules and Regulations - to facilitate and stimulate recycling and re-use in the field of infrastructure.			
D	**17**	**R/I**	Undesired traveler's behaviour to respond emergency situations.			
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.			

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