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REFINET Multi-modal Transport Infrastructure framework

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Abstract

Most European transport infrastructure was built in the 1960-1970s and was designed for a working life of 50 years. This infrastructure is now reaching the end of its lifetime and it is often strained far beyond intended capacities in terms of traffic flows and loads. In addition to aging, infrastructure networks will eventually face new challenges such as climate change impacts, demographic trends, and cross-modal requirements. Across Europe there is therefore an urgent need to modernise and future-proof existing infrastructure and to deliver new infrastructure in an innovative and efficient way. A pan-European, coordinated approach to the development and delivery of innovative concepts and solutions for design, construction, maintenance and upgrade of transport infrastructure would help the EU transport network remain globally competitive. This paper argues that the REFINET Multi-Modal Transport Infrastructure (RMMTI) framework provides a simple but powerful vision, which resonates with transport sector stakeholders across all modes. The RMMTI framework aims to be an open, active and quality reference that can 1) help infrastructure managers from strategic planning to operational level, 2) inform research and innovation priorities for transport infrastructure; and, 3) be used as a benchmark for future multi-modal transport infrastructure.

Keywords: Multi-modal transport; Transport Infrastructure, Management Framework.

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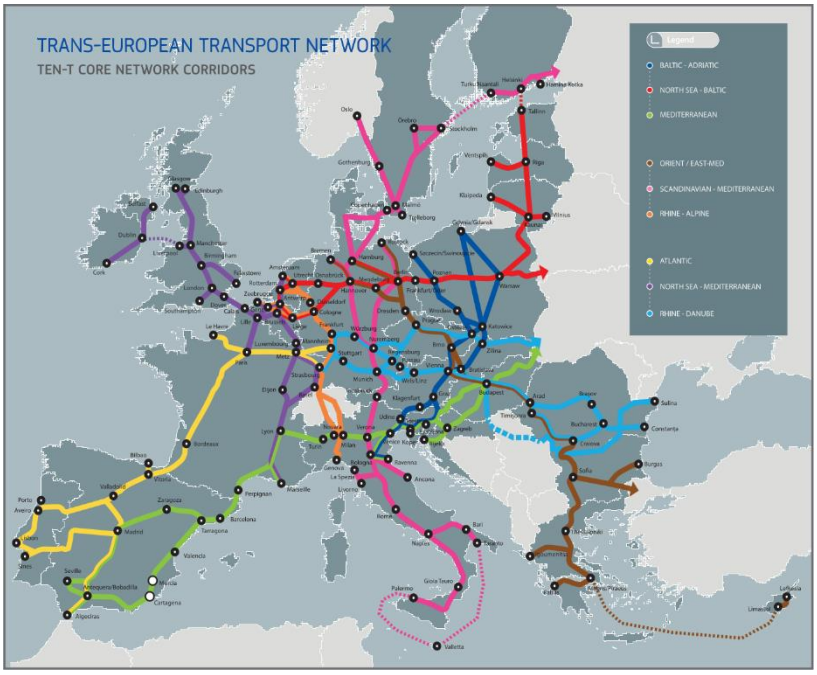
1. Introduction

Without a doubt, the transport sector is one of the major enablers of economic growth, supporting mobility of passengers and goods and directly impacting on both the environment and society at large. The European Commission's *Single European Transport Area,* European Commission (2011), envisions future mobility of people and goods at European scale to be based on integrated and optimized services provided by Global Operators, and supported by Intelligent Transport Systems (ITS). The European vision and strategy for Mobility as a Service (MaaS) require a transport infrastructure network able to fulfil present requirements, withstand future demands, deliver a quality, safe and efficient service, and to adapt to future challenges and trends.



The European transport infrastructure network is a shared heritage of great economic value, enabling wealth to be generated across the continent. The extent of Europe's transport infrastructure is impressive – in terms of (1) Roads, with a total road network of approximately 5 million km in the 28 EU Member States, (2) Railways, with a total length of lines around 215,000 km, (3) Waterways, with 41,000 km of navigable inland waterways and (4) 7450 airports in Europe.
Europe possesses one of the densest and most developed infrastructure networks in the world, but most of this infrastructure was constructed in the period 1960-70s and was designed for a working life of 50 years.

Figure 1 Trans-European Transport Network (TEN-T).

With a large proportion of these infrastructure networks approaching the end of their design life, it is often the case that they strained far beyond their intended capacities in terms of traffic flows and loads. A worrying amount of existing infrastructure no longer fulfils current functional requirements and today's safety and quality standards and therefore needs to be strengthened and modernised. The ensuing maintenance and modernisation works will inevitably create disruption to traffic flows, with associated economic consequences.

The cost of replacing and upgrading the existing European infrastructure is considerably high, and massive coordinated investment and funding are necessary. Construction and renovation activities of transport infrastructures today represent around $4bn world-wide, and it is anticipated that this figure will be doubled by 2025. Without adequate investment on research and innovation the sector will struggle to get beyond traditional practice of building infrastructure 'in the 20th century way' – high carbon, wasteful, inefficient and at high cost. This means that the required business adaptation process to transform the transport sector into an integrated, inclusive, seamless, safe and sustainable mobility system, as supported by the Transport "White Paper", European Commission (2011), will hardly happen if innovation is not considered at the heart of the strategy.
Across Europe there is an urgent need to modernise infrastructure, be it in the design, construction, maintenance or operation life cycle stage. The industry will not do it on its own – the risks, the way the industry is structured and the implementation of EU procurement are some of the barriers to innovation. A pan-European, coordinated approach to the development and delivery of innovative concepts and solutions for design, construction, maintenance and upgrade of transport infrastructure would help the EU transport network and the European Transport Infrastructure Construction Industry remain globally competitive .

The vision for a seamless integrated transportation system required to achieve a competitive and connected EU has been explored at length by several EU research projects in the past decade. However, without a functioning physical infrastructure, the transport network would simply not exist.

The Horizon 2020-funded Coordinated Support Action (CSA) REFINET has focussed on transport infrastructure, giving prominence to the fact that a vision, strategic plan and coordinated, targeted investment in research and innovation are all needed for transport infrastructure as much as for mobility services.

This paper aims to present the REFINET Multi-Modal Transport Infrastructure (RMMTI) framework, one of the outputs generated by the REFINET project.
The paper goes on to argue that RMMTI framework would provide a simple but powerful vision that can resonate with transport sector stakeholders across all modes. Immediate benefits of the RMMTI framework include visualisation and the integration of different approaches previously developed by European Technology Platforms, transport sector organisations, the European Commission and national governments of the European transport infrastructure in the medium (2030) and long term (2050).
Finally, recommendations are provided on how the RMMTI framework can be successfully utilised as a reference by a range of transport stakeholders and become a benchmark for the development and delivery of future transport infrastructure.

2. Background

Aging, climate change and demographic trends are most likely to affect the European Transport network in the future. Global mobility trends, congestion, safety, security, energy efficiency and the environment will all present challenges for transportation networks in the short term. Resilience to external shocks and stresses, as in reliability of performance, adaptation or rapid recovery from an adverse event are increasingly considered by decision makers in investment plans for buiding new or upgranding existing transport infrastrucure. The European Road Transport Research Advisory Council (ERTRAC), European Rail Research Advisory Council (ERRAC), Waterborne Technology Platform (WATERBORNE), Advisory Council for Aviation Research and Innovation in Europe (ACARE) and & European Construction Technology Platform (ECTP) Task Force (2013) identified research and innovation actions as high priority to enable an improvement of 50% in infrastructure performance, risk and cost versus a 2010 baseline as well as enabling seamless door-to-door services for passengers and freight by 2030.

Several Strategic Research Agendas, Roadmaps, and documents: USDOT (2015), ERRAC (2014), ERTRAC (2010) or Shift2Rail Joint Undertaking (2015) – to name a few have elaborated on the above transportation challenges. However, the reFINE initiative (reFINE (2012) and (reFINE (2013)), was the first one to focus specifically on the needs of the transport infrastructure sector. Further to the reFINE initiative, the European Commission (EC) recognised the importance to undertake further research on multi-modal transport infrastructure and to promote collaboration among relevant actors across all transport modes These include transport infrastructure owners, operators, engineering and construction companies, academia and research organisations and other stakeholders.

A sustained investment by the EC has allowed, quite uniquely, three broadly complementary H2020-funded CSAs to be undertaken in parallel:

- REFINET: Rethinking Future Infrastructure Networks (2015); delivering a shared European vision of how to specify, design, build or renovate, and maintain the multi-modal European transport infrastructure as well as deploy this vision to support European competitiveness.

- USE-iT: Users, Safety, Security and Energy in Transport Infrastructure (2015); developing a roadmap describing the research challenges and implementation steps to achieve greater cooperation and co-modal operations in the areas of users, safety, security and carbon/energy.

- FOX: Forever Open Infrastructure across (X) all Transport Modes (2015); defining a comprehensive cross modal approach in the area of construction, inspection, maintenance and recycle & reuse of transport infrastructure, that would serve primarily infrastructure owners/operators in anticipating the future.

The RMMTI framework model discussed in the following sections is one of the outputs of the REFINET project, completed in April 2017.

3. Methodology

The first step in developing the RMMTI model was to undertake a literature review of outputs from relevant projects funded by the EC, which had explored transport infrastructure at a strategic level. The review has

included work undertaken by relevant organisations such as National Technology Platforms, national governments, infrastructure managers at regional/national/EU level, Conference of European Directors of Roads (CEDR), Forum of European National Highway Research Laboratories (FEHRL), and other transport sector associations.

A large volume of documents was reviewed and analysed by the research team. A particularly useful document was the the roadmap for cross-modal transport infrastructure innovation developed by the ERTRAC-ERRAC-Waterborne-ACARE-ECTP Task Force (2013).

This 'top-down' literature review identified key candidate characteristics for the European multi-modal model for transport infrastructure.

As well as a 'top-down analysis' of high level strategy documents, a 'bottom-up approach' was adopted to gather information, analyse and map research and innovation (R&I) projects relevant to the transport infrastructure sector. A template was developed to standardise information capture and facilitate the analysis, see Figure 2 below.

Catalogue of R&I projects	
Field	**Description**
Technology title and keywords	Title of the technology and main keywords
Source of technology	Project Title and Funding Scheme (Ganº)
Lifecycle stage	Design/ Construction/Maintenance/Operation /Renovation
Type of infrastructure	Road, Rail, Air, Water, Multi-modal
Component of infrastructure	Bridge, tunnel, pavement, etc.
Short Description	Scenario for application of the technology (IF INFORMATION IS PUBLICLY AVAILABLE)
Maturity	TRL
Link to REFINET high Level Service Infrastructure	Selection among the five performances: GREEN, COST-EFFICIENT, RESILIENT, SOCIAL/INCLUSIVE, and SAFE/SECURE
Key performance Indicators	quantitative indicator according the definition of RMMTI model that help assess the efficiency of the technology
Year of project ends	year of project ends
Further information	project website

Figure 2 Template used in the analysis of the European Research and Innovation projects in Transportation.

Outputs from both analyses described above have been used to design consultation with transport experts through workshops events. Workshops are a well established technique to elicit feedback and input from a range of stakeholders in a short period of time. The content and format of the workshop were carefully designed so that the ouput could inform development of a framework model.

As a starting point for consultation in the workshop and in order to capture information in a structured way, the preliminary framework developed in the reFINE initiative, precursor of REFINET, was used. This preliminary framework was built around the concept of High Service Level Infrastructure (HLSI) and supported by three 'pillars', defined as follows.

- Multi-modal Hubs: defined as infrastructure networks that support the European social and territorial cohesion. Infrastructure networks are integrated, efficient and well connected, thanks to multi-modal 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.

- Urban Mobility: defined as infrastructure networks that support a high quality of life in sustainable European cities by ensuring a continuous and safe circulation of life, water and food and by providing the physical means for mobility to live and work.

- Long Distance Corridors: defined as 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 the rest of the world.

A successful workshop event held in Madrid in 2015 was used to identify the major trends and key challenges within the transport infrastructure sector, main technological gaps and key characteristcs of the ideal multi-modal transport infrastructure network.
The template used in the workshop, designed to include findings from the literature review, analyses of R&I projects and the reFINE preliminary framework, is shown in Figure 3 below.

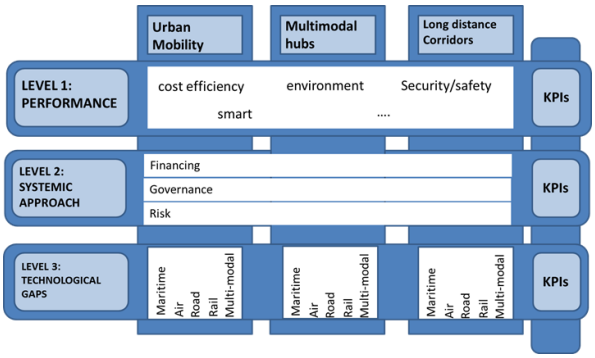


Figure 3 Template used in the workshop held in Madrid on December 2015.

Consultation was absolutely key in eliciting high quality information but so was the breadth of knowledge and experience of the transport experts that were consulted throughout the REFINET project. Importantly, experts included relevant stakeholders from all transport modes (road, railway, maritime, aviation).
The REFINET research consortium included a diverse range of organisations representing infrastructure contractors, designers, transport research institutions, and National Technology Platforms. In addition, the REFINET project has been a joint effort not just of individual research organisations but, more widely, of communities such as ECTP, European Network of Construction Companies for Research and Development (ENCORD), Union Internationale des Chemins de fer (UIC) and Plataforma Tecnológica Española de la Construcción (PTEC), which will continue share common interests in the transport infrastructure field and will be key in ensuring that the RMMTI framework model and other outputs from the REFINET projects are disseminated to potential users. Finally, synergies across the 'CSA cluster' (i.e. the three CSAs introduced in Section 2) have been exploited to maximise dissemination of the outputs of each project and broaden the community of interested stakeholders in this area of knowledge have been taken into account, exchanging information and producing common documents.

Finally, to provide a sound foundation to the RMMTI model, the project team reached out to its wide network of experts and carried out an extensive review of best practices and available and emerging technologies review in design, construction and maintenance of transport infrastructure using a similar template to that shown in Figure 2 to gather information. Best practices and technologies were collated in two catalogues, which are helpful to identify technology gaps and can inform priorities for research and innovation to close such gaps.

Outputs from the consultation, combined with the top-down and bottom-up analyses and technologies and best practices review described above, have fed into the RMMTI model further discussed in Section 4 below.

4. The RMMTI framework model

The RMMTI framework model was developed as an evolution of the preliminary framework from the reFINE initiative, using results from the literature review, analyses of R&I projects, best practices and technologies review and consultation undertaken as part of the REFINET project as described in Section 3.

The following propositions were used in developing the RMMTI framework:

- is relevant to both existing and new infrastructure;
- has a multi-level structure;
- is mode agnostic;
- aims to integrate different sectorial or modal approaches; and
- aims to incorporate technological gaps and demands as an element for continuous improvement

The RMMTI framework model is shown on Figure 4 overleaf. The RMMTI, with a three level structure, aims at delivering a high level of service infrastructure, through a systemic approach, supported by best practices and technologies acting as the foundations of the model. Each level is described in detail below.

Figure 4 The RMMTI framework model.

Level 1, PERFORMANCE, corresponds to the key features that should be considered in order to define the European Multi-modal Transport Infrastructure from a range of stakeholder perspectives (end-users, operators/ owners, construction companies, engineering firms and administration). These key performance features should align with the transport system strategy regardless whether the transport system is at a local, regional or global scale. The key characteristics or features identified by the analysis and consultation described in Section 3 are:

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

Level 2, SYSTEMIC APPROACH, corresponds key aspects that should be considered in order to have a cross-cutting 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. Mode-specific models will feed and will be interconnected within the systemic approach level. As discussed in Section 3, a review and analysis of Strategic Research Agendas (SRAs), Roadmaps, and other documents addressing the way forward for transport was undertaken as part of the REFINET project. The following aspects, transcending those of integrated design, construction and operation of the infrastructure, have been identified as cross-cutting and should be considered when adopting a systemic approach:

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

Level 3, TECHNOLOGICAL GAPS, corresponds to the key technologies/knowledge which should be developed or adapted in the short/medium term 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 (defined in Section 3): urban mobility, multi-modal hubs and long-distance corridors, as components of the

transport network. However, it is true that some technologies or knowledge can be cross-cutting through modes or the transport network. Techological gaps need to be continuously assessed and updated.

Good practices and available technologies in design, construction and maintenance of transport infrastructure were analysed with aim to provide an informed view on the current state of the art and future trends in the field. They constitute the foundation to the 3rd level of the model.

As a differentiation in comparison to other transport infrastructure models, the RMMTI introduces a systemic multi-modal approach. If followed through, this ambitious approach would enable the redefinition of cross-modal performance targets for the transport system, allowing the identification of interdependencies and vulnerabilities, and mainly focusing on:

- Asset management
- Financial and multi-modal transport infrastructure Business Model
- Standards, communication and dissemination channels
- Intelligent transportation system (ITS)

It is important to note that this model needs to be dynamic and it requires continuous updating. If widely adopted, the proposed RMMTI model could provide a common framework to align research and innovation strategies for the transport infrastructure sector, which are currently dis-jointed and developed in siloes. 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. The REFINET MMTI model should help to guide the research and innovation investments of the infrastructure sector for the next period with the support of EU, national and regional bodies.

If heavily disseminated and promoted by the wide combined networks and communities described in Section 3, the RMMTI framework model could serve as a reference, against which the gradual shift to multi-modal networks could be benchmarked and measured against Key Performance Indicators (KPIs). These KPIs should be user-defined and aligned to the key features or characteristics identified in Level 1 of the model. The RMMTI framework model will not work witout a Strategic Implementation Plan, which needs to be agreed at an appropriate scale.

A pan-European programme coordinating investments and efforts of all member states in the field of transport infrastructure would deliver substantial benefits and go a great length towards delivering a greener, more cost efficient, more resilient and safer multi-modal transport infrastructure.

5. Conclusion and next steps

This paper highlighted the recognised need for a common pan-European 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. The REFINET Multi-modal Transport Infrastructure (RMMTI) model and framework has the ambition to be a major step towards addressing the tremendous challenges of the European infrastructure networks.

Multiple uses have been discussed for the RMMTI framework model.

The RMMTI multi-level structure is ideally suited to address the following issues:

- 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.

In addition, the described model could be used for structuring the R&I priority areas and actions of the Strategic Implementation Plan, around the identified five key performance features defining 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 five key performance features related to Systemic approach (Level 2 of the model).

The RMMTI framework intends to be an open**,** active and quality reference for the future multi-modal transport infrastructure. This model is the first of its kind to be specifically focussed on transport infrastructure. In the

short-term, it could be adopted to assess existing transport infrastructure and to develop new multi-modal infrastructure, with introduction of suitable KPIs and thresholds.

The need for level-specific and user-defined KPIs has been identified and, in the first instance, could be aligned with the key characteristics or features relevant to Levels 1 and 2. However, further work is required to fully develop multi-modal KPI metrics. Next steps could include, for example, the development of a system, in the form of a weighed matrix that would allow labelling of multi-modal infrastructure networks.

Finally, as any framework tool, it must be promoted, updated and supported by transport infrastructure organisations and, most importantly, the EC if it is to survive the test of time and deliver maximum benefits to all stakeholders and, ultimately, to society as a whole.

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