



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824269.

This document reflects only the views of the author(s). Neither the Innovation and Networks Executive Agency (INEA) nor the European Commission is in any way responsible for any use that may be made of the information it contains.



Project Acronym: **infra4Dfuture**

Project Title: **Infrastructure for the Future**

Project Number: **824269**

Topic: **MG-2-4-2018 – Coordinating national efforts in modernizing transport infrastructure and provide innovative mobility services**

Type of Action: **Coordination and Support Action (CSA)**

D1.4 – Ready to implement, supported coordination mechanism

Version 1.0

Deliverable:	D1.4– Ready to implement, supported coordination mechanism
Work Package:	WP1: Strengthening transport infrastructure partnerships and alliances
Due Date:	M19 (with EC permission extended to M24)
Submission Date:	30 September 2020
Start Date of Project:	01/10/2018
Duration of Project:	24 Months
Organisation Responsible of Deliverable:	Rijkswaterstaat (RWS)
Version:	1.0
Status:	Final
Author name(s):	Ruud Smit (RWS)
Reviewer(s):	i4Df Governance Board
Nature:	<input checked="" type="checkbox"/> R – Report <input type="checkbox"/> P – Prototype <input type="checkbox"/> D – Demonstrator <input type="checkbox"/> O - Other
Dissemination level:	<input checked="" type="checkbox"/> PU - Public <input type="checkbox"/> CO - Confidential, only for members of the consortium (including the Commission) <input type="checkbox"/> RE - Restricted to a group specified by the consortium (including the Commission Services)

Contents

Glossary of abbreviations	4
1 Executive summary	5
2 Introduction	7
2.1 Purpose of the document	7
2.2 Deviations	7
2.3 Delivery process	8
3 Joint vision for transport infrastructure capabilities	9
3.1 Infrastructure capabilities for 2040 and corresponding innovation focus areas	9
3.2 Rolling programme portfolio until 2025, respectively 2030	11
4 Description of the coordination mechanism	16
4.1 Preamble	16
4.2 The IFA collaboration ecosystems and their context.....	16
4.3 Key structures and instruments for propelling the coordination mechanism.....	20
4.4 Governance of the Coordination mechanism	22
Annex A. Full overview of NTIA innovation topics.....	26
Annex B. Technology Readiness Levels defined	27
Annex C. Scopes of short term NTIA innovation topics	29
IFA 1.1 Integrated Network Performance Management.....	29
IFA 1.2 Responsible and innovative procurement and finance.....	30
IFA 2.1 Decarbonisation of infrastructure management.....	30
IFA 2.2 Preserving the environment.....	30
IFA 2.3 Integrating multi-layer networks and nodes	31
IFA 3.1 Smart data and information ecosystem for accommodating automated and connected transport.....	31
IFA 3.2 Information provision for process optimisation in infrastructure management	32

Glossary of abbreviations

Abbreviation	Full text
ACI-Europe	Airports Council International Europe
ATO	Automatic Train Operation
CCAM	Connected Cooperative and Automated Mobility
CEDR	Conference of European Directors of Roads
CEF	Connecting Europe Facility
EC	European Commission
EFIP	European Federation of Inland Ports
EIM	European Rail Infrastructure Managers
ESPO	European Sea Ports Organisation
INE	Inland Navigation Europe
i4Df	Infra4Dfuture initiative
IFA(s)	Innovation Focus Area(s)
IoT	Internet of Things
ISPIII	infra4Dfuture Stakeholder Platform for Infrastructure Innovation and Implementation
KPIs	Key Performance Indicators
NTIA(s)	National transport infrastructure authority(ies)
PPI	Public Procurement of Innovation
TCO	Total Cost of Ownership
TEN-T	Trans European Network - Transport
ToR	Terms of Reference
TRA	Transport Research Agenda
TRL	Technology Readiness Level

1 Executive summary

The infra4Dfuture initiative (i4Df) was initiated by 19 national transport infrastructure authorities (NTIAs) from 17 countries from Europe, Turkey, and Israel. These NTIAs share the vision that speed, volume and effectiveness of infrastructure innovation and implementation would strongly benefit from closer cooperation and collaboration between infrastructure authorities; on their common innovation needs, across Europe, and across the different modes.

Furthermore, the NTIAs that initiated i4Df considered that public infrastructure authorities in their role and position as procuring clients of innovation would benefit if they would engage in a structured dialogue on common longer term innovation ambitions and needs with relevant stakeholders from industry, research and education, raising mutual awareness, understanding, trust and commitment.

Noting Europe's ambition to create a single transport area over the coming decade(s), and the many well-established innovation activities and ambitions of the different countries and of the individual modes, the NTIAs propose a ready to implement cross-modal coordination mechanism that supports both common national and European ambitions and that enables faster delivery of more, fit for purpose innovation, and deployment up to larger network scales.

The objective of the proposed coordination mechanism is to reinforce effective (public) demand driven innovation collaboration between national and European parties and structures, and to do so by fostering a structured dialogue at the operational level as well as at the strategic level. At the operational level this concerns engagement of advisors from public NTIAs, and experts from relevant stakeholders from industry, research and education. This engagement is clustered in thematic settings that correspond to the common innovation needs referred to as innovation focus areas (IFAs). From their bottom-up, operational activities recommendations for collaborative activities are raised for appropriate top-down endorsement, guidance and commitment from the relevant decision making stakeholder representatives.

In its delivery process, the i4Df initiative organised three high level Stakeholder Conferences, starting off with discussing with national infrastructure authorities the services they expect they need to deliver in 2040 in order to properly address the challenges from economy, society and environment, such as from transport demand, climate change, biodiversity, energy and digitalisation. The resulting common vision for 2040 has been outlined through a series of guiding objectives, and common IFAs that serve as thematic frames for building up collaboration at the activities level (bottom-up), starting already during the runtime of the initiative.

From this common vision for 2040, the i4Df initiative set off to compose the i4Df coordination mechanism under guidance of the i4Df Governance Board and the wider European stakeholder setting.

This document presents the main objective of the i4Df initiative: a full description of the proposed, ready to implement cross-modal coordination mechanism for transport infrastructure innovation and implementation, supported by a wide consortium of NTIAs.

With this main deliverable of the i4Df initiative, further steps towards rolling out the mechanism are in the hands of the relevant stakeholders from public, industry, and research; at their own

chosen action. The initiative recommends the European NTIAs to take the lead in initiating these next steps.

The i4Df initiative considers the European Commission (EC) services are a key stakeholder in effectuating the mechanism's roll-out for several reasons. Firstly, cooperation with the EC is essential in organising effective interfaces through which results from the mechanism's collaborative activities can be brought to the event programming of the intermittent TEN-T days and TRA conferences. These events have been identified as the common anchor points for peer-to-peer exchange on the respective collaboration results along the identified IFAs. In addition, the events provide natural moments in time to organise strategic stakeholder guidance, directions and commitment for future steps.

Secondly, the EC is an important (public) programme owner for innovation (mostly from the Horizon Europe framework) and implementation (mostly from the CEF framework). Therefore, cooperation with the EC can provide significant synergies with the national and trans-national programmes and initiatives from the NTIAs.

Thirdly, the EC is responsible for the TEN-T policy that spans the national transport infrastructure networks of the Member States. Being responsible for the management of the various national sections of the TEN-T, the NTIAs have a strategic interest in this policy, in particular where it is concerned with supporting the NTIAs in their needs and requirements for first deployment of innovative solutions and actions on their appropriate harmonisation and standardisation.

The following sections of this document can be summarised as follows:

- Joint vision of transport infrastructure capabilities and corresponding IFAs. Common NTIAs topics for innovation and implementation until 2030 are presented as well as a rolling portfolio until 2025 and 2030, including approximate timeline for innovation delivery, and necessary measures for their implementation until 2030 (chapter 2).
- Full description of the coordination mechanism including a basic Terms of Reference, and key coordination structures and instruments as well as possible models for NTIA-led governance of the mechanism (chapter 3).

The annexes present more detailed background information on the innovation topics of the NTIAs, such as on scopes, expected timelines in relation to technology readiness levels. Other deliverables (in particular deliverables D1.3 and D2.3) present even further detail.

2 Introduction

2.1 Purpose of the document

This deliverable provides a full description of the cross-modal coordination mechanism developed within the i4Df initiative. It includes a basic Terms of Reference, a joint vision of transport infrastructure capabilities and corresponding innovation focus areas (IFAs), a concerted rolling portfolio of relevant innovation programmes with topics until 2025 and 2030, key coordination structures and instruments such as on gate reviewing process, and measures to drive professional competence building.

2.2 Deviations

Task 1.4 is described as follows in i4Df's 'Description of Action' (DoA):

The aim of this task is to achieve stakeholder endorsement of the overarching coordination mechanism for future demand-driven multimodal infrastructure innovation, including a rolling transport infrastructure innovation portfolio until 2030 in which specific actions are detailed for the years until 2025.

The second expert workshop (M18; under WP4) will assign concrete actions for innovation and implementation for each of the infrastructure capabilities and corresponding innovation focus areas. The actions will be specific to the relevant European and national programmes and initiatives. The result will be the draft concerted rolling portfolio for transport infrastructure innovation, to be endorsed by the fourth and last stakeholder conference. The actions that are planned for the years until 2025 will be of sufficient detail as to allow immediate calls for tender after agreement has been achieved with all respective innovation Programme owners.

The fourth stakeholder conference (M19; during TRA 2020, Helsinki) will aim to secure support of the relevant stakeholders for the fully developed coordination mechanism, infra4Dfuture Stakeholder Platform for Infrastructure Innovation and Implementation (ISPIII), and its key elements and structures as they are developed within WP2 and WP3. This last of four stakeholder conferences is aimed at stakeholders' endorsement of ISPIII. The plan is to have follow-up events of this stakeholder platform at the successive biannual TRA conferences.

D1.4: Ready to implement, supported coordination mechanism [M19]

Providing a full description of the coordination mechanism including the Terms of Reference, a joint vision of transport infrastructure capabilities and corresponding focus areas for innovation, a concerted rolling portfolio of relevant innovation programmes and initiatives until 2025 and 2030, key coordination structures and instruments such as on gate reviewing process and measures to drive professional competence building. Deliverable refers to Task 1.4.

Noting the above presented excerpt from the DoA, following deviations have occurred, resulting in limited loss of quality:

Delayed delivery due to COVID-19. COVID-19 has proven to be a game changer, also to the anticipated process for delivery of this document. Next to an inevitable delay on the due date, physical events that were originally foreseen to capture input from the stakeholder groups had

to be cancelled and replaced by digital solutions. Nevertheless, the quality loss is assessed as limited.

This document was originally planned for M18 (Feb 2020). However, this was rescheduled to maximise input from a second i4Df Expert Workshop (the so-called ‘prelaunch event’, planned for 16-17 March 2020) as well as from a fourth i4Df Stakeholder Conference at TRA 2020 (planned for April 2020). Both events were cancelled due to COVID-19 restrictions. Instead of the second i4Df Expert Workshop, a series of webinars was organised in which the IFA descriptions were updated (except for IFA 1.3; see delivery process). The fourth i4Df Stakeholder Conference was planned as part of the programme of TRA 2020 in Helsinki, April 2020. Due to COVID-19 this event was cancelled as was the Stakeholder Conference. As a consequence the endorsement of key stakeholders (through their European platforms) could not be publicly displayed. This has resulted in limited loss of quality. The delivery date was rescheduled to September 2020 anticipating a more elaborate written interaction with the consortium members on achieving the described scope.

ISPIII. The launch of the i4Df Stakeholder Platform for Infrastructure Innovation and Implementation (ISPIII) has not been achieved. From the three i4Df Stakeholder Conferences, it became clear that the key focus should be on achieving NTIA support for the innovation topics until 2030, and for the structures and workings of the coordination mechanism. Only if this foundation was set, the collaborating NTIAs were able to effectively engage with industry and supporting research on supplying innovative solutions to their common innovation needs. The omission of the ISPIII has resulted in limited loss of quality.

2.3 Delivery process

The following activities have contributed to the preparation of this deliverable:

- **First, Second and Third i4Df Stakeholder Conferences.** On 11 December 2018 (Brussels), 21 May 2019 (Brussels) and on 12 December 2020 (Bonn).
- **Consultation of consortium members.** Besides multiple (written) consultation rounds on the (operationalisation of) the coordination mechanism, a series of IFA dedicated digital workshops was held with the consortium from 23-25 June 2020. These webinars replaced the expert and stakeholder consultation originally planned in March (2nd Expert Workshop in Copenhagen-Malmö), April (4th Stakeholder Conference at TRA 2020) and May (CEF/TEN-T days) that were cancelled because of COVID-19.

3 Joint vision for transport infrastructure capabilities

3.1 Infrastructure capabilities for 2040 and corresponding innovation focus areas

Based on the guidance from three i4Df high level Stakeholder Conferences held, the initiative ultimately has defined three capabilities that transport infrastructure management across the modes will need to deliver to society in 2040, including guiding objectives.

For each of these capabilities seven focus areas for innovation have been identified. Combined, these seven innovation focus areas (IFAs) expectedly span the whole array of strategic issues the NTIAs in Europe need to address. Annex A presents a full overview of these topics. Deliverable D1.3 and D2.3 present a full description of these topics in terms of specific challenges, expected impacts, and scopes.

Capability 1: Infrastructure optimally meeting end user needs

The ability to provide optimal transport infrastructure network capacity in order to accommodate increasing transport needs, and balancing cost, performance, safety and risk to provide infrastructure as a high quality service to end users.

Guiding objectives for 2040:

- Full accommodation of the anticipated development in transport demand across the network, achieving effective alignment between the surface infrastructure networks through interoperability and synchromodality.
- Effective management of resources and assets, and high availability throughout the whole infrastructure lifecycle, from planning and design to end of life.
- Effective, adaptive integration and rapid implementation of innovations across the delivery process chain.
- Significant reduction of Total Cost of Ownership (TCO), e.g. reduction by 30% for infrastructure managers.
- Zero fatalities and severe injuries of infrastructure workers and end users through Vision Zero.
- Resilience to natural and man-made hazards, including adaptation to climate change.
- An affordable high capacity infrastructure that supports end users' service combinations of mobility and logistics.
- Comprehensive and consistent framework of performance indicators for the management of the integrated, multi-modal network, available by 2030.

Innovation Focus Areas:

- IFA 1.1: Integrated Network Performance Management
- IFA 1.2: Responsible and innovative procurement and finance

Capability 2: Infrastructure meeting environmental and social sustainability needs

The ability to embed transport infrastructure networks in their immediate surroundings, optimally balancing interests from economy, society, and environment.

Guiding objectives for 2040:

Compliance with COP21 and Agenda 2030/UN targets for sustainable development in the context of European objectives and targets.

- Minimise carbon footprint of the whole service-life of infrastructure, including the infrastructure delivery process chain. This includes achieving energy neutrality of the infrastructure management operations (e.g. lighting, signalling, data collection, information provision, lifting and ventilation) up to larger network scales.
- Facilitate the transition in the energy pool of the transport modes and supporting measures to improve energy-efficiency of mobility services (passengers, freight).
- Collaborate on the minimisation of the impact on the environment, in particular concerning the impact of noise, vibration and pollutant emissions. This concerns the share of the impact that is contributable to infrastructure management.
- Collaborate on the optimal net benefit from embedding infrastructure in the spatial setting. This concerns the ‘how’ in infrastructure governance, balancing benefits for the economy, society and environment in the planning and approval stage.

Innovation Focus Areas:

- IFA 2.1: Decarbonisation of infrastructure management
- IFA 2.2: Preserving the environment
- IFA 2.3: Integrating multi-layer networks and nodes

Capability 3: Infrastructure achieving added value from digitalisation

The ability to harvest the benefits from digitalisation in internal processes of transport infrastructure management (e.g. planning, design, construction, operation, end-of-life) as well as in the relation between transport infrastructure management and its end user (smart mobility and logistical services, individual end users). Use digitalisation to support the achievement of sustainability targets and provide a better service to infrastructure end users.

Guiding objectives for 2040:

- Facilitate the transition towards smart mobility concepts (freight and passenger) for emerging concepts for automated mobility, e.g. Connected Cooperative and Automated Mobility (CCAM) for road and Automatic Train Operation (ATO) for rail.
- Proactive position of the infrastructure manager within the infrastructure related data driven ecosystem, including clearly defined data flows between multimodal, national and sectoral stakeholders and a clear business model and case for investment in and maintenance of digital and virtual infrastructure.

- Ability to process internal and external raw data into smart data that can optimize infrastructure management processes, including maintenance and construction of infrastructure. Provide seamless data and information use and provision across the transport infrastructure network and logistics chain to the end user.
- Facilitation of the alignment of TEN-T core network with data and energy networks to benefit from multi-purpose digitalised networks that can cater for future digital needs, e.g.
- Internet of Things (IoT) and smart grid based electric mobility.
- Increase the use of automated, semi-automated and remote-piloted solutions for infrastructure maintenance and construction to improve safety for workers and reduce costs.

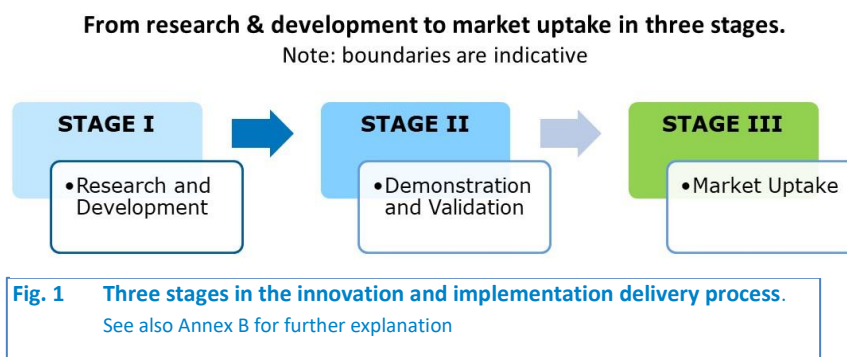
Innovation Focus Areas:

- IFA 3.1: Smart data and information ecosystem for accommodating automated and connected transport
- IFA 3.2: Information provision for process optimisation in infrastructure management

3.2 Rolling programme portfolio until 2025, respectively 2030

3.2.1 Timelines for innovation delivery

Annex A presents the full list of identified NTIA topics for innovation and implementation until 2040, including their expected staged timelines across the innovation delivery process (figure 1).



In line with the updated strategic objectives and impacts of the EC and of member states –in which 2030 is a key milestone year- the i4Df initiative has identified from the full list presented in annex A, those topics that are expected to achieve a technology readiness level by 2030 that makes them fully tested in and documented (i.e. end of stage II: Demonstration and Validation in full operational environment). This implies, the respective innovative solutions are available for voluntary deployment on the infrastructure networks (i.e. stage III: Market Uptake). See table, next page.

IFA	NTIA topics towards 2025	Stage reached until				
		2025	2030	2035	2040	2050
1.2	<i>TEN-T demonstration and validation tracks</i>	II	III			
	<i>Alignment in sustainability targets in infrastructure management</i>	II	III			
	<i>Integrated mobility management systems</i>	II	II	III	III	
1.3	<i>Risk sharing approaches</i>	II	II	III		
	<i>Innovative financing schemes</i>	II	II	III	III	
2.1	<i>Electric road systems: cross-border demonstrators including pre-standardisation</i>	I/II	III			
	<i>Energy Harvesting: Development of a European portfolio of demonstrated/proven technologies</i>	II	III	III		
	<i>Development of new legal and governance models for the emerging new cross-sectoral (e.g. energy and transport) and cross-modal technologies and collaborations</i>	I/II	III			
2.2	<i>Automation of noise mapping</i>	II	III			
	<i>Source measures for noise abatement</i>	II	III			
	<i>Habitat reconnection measures</i>	II	III			
2.3	<i>Data warehouses at the Functional Urban Area (FUA) scale.</i>	I/II	II/III	III	III	
	<i>Integration of transport energy distribution.</i>	I/II	II/III	III	III	
3.1	<i>Large-scale demonstrations focusing on the needs of the infrastructure owners/managers.</i>	I/II	II	III		
	<i>Governance models for infrastructure owners and managers to accommodate CCAM.</i>	I/II	III	III	III	
3.2	<i>Legal and Technical issues around Artificial Intelligence</i>	II/III	III			
	<i>Robotisation: avoiding barriers</i>	II	III			

Annex C presents the scopes of the respective NTIA innovation topics from the table in more detail.

3.2.2 Necessary actions for implementation and deployment of innovation

The NTIAs are pressed for innovative solutions that support their strategic goals, and that they can deploy in their infrastructure management processes¹ on the short term: “*more, faster and fit for purpose*”. As such the emphasis in their structural dialogue with relevant stakeholders from industry, and supporting research including education and training is on driving promising innovation development from higher technology readiness levels² (TRL) to ready-to-deploy, cost-effective solutions that are appropriately documented in order to enable swift adoption in their procurement frameworks. As a consequence, NTIAs should consider necessary measures in their power to remove barriers for innovation and deployment, and to foster

¹ The i4Df initiative focuses on (commonalities in) the management of tangible infrastructure networks for surface transport in which ‘infrastructure’ is defined as the physical (‘hard’) and organisational (‘soft’) structures and facilities needed for the operation of the transport network. This includes the linear links and intersections, the corresponding buildings, the power and data/communication supplies and interconnections to all internal and external stakeholders and end users, as well as the governance and management structures and procedures across the line of sight from ministry to market.

² See also Annex B for more detail on technology readiness level as defined by the European Commission in their Horizon 2020 framework programme.

opportunities to accommodate industry and research in their activities to deliver validated innovative solutions.

In this context the following measures are considered necessary:

- **Broaden NTIA endorsement for the i4Df results:** In the i4Df initiative, NTIAs from 17 member and associated countries collaborated to deliver a common description of innovation needs over the next decade. Though this is a significant setting by itself, the number of NTIAs in Europe is far bigger. It is essential that this wider setting of NTIAs also endorses the delivery of the coordination mechanism and finds it an inspiration to build from, thus providing the continuity and gravitas beyond the runtime of the i4Df initiative (until 30 September 2020). Their endorsement will reinforce necessary confidence from the industry and supporting research to invest in a structured demand and supply side dialogue with the NTIAs as procuring clients for innovation.
- **Emphasise demonstration and validation activities (TRL 8-9):** In their common and concerted innovation agendas and programmes, the NTIAs should emphasise demonstration and validation of innovations picking up from advanced prototyping and preliminary business casing (i.e. TRL 6 to 7), while noticing these activities have a timeframe of 3 to 7 years, depending on the complexity and risk at hand. Picking up from lower TRL levels should not be excluded, but NTIAs should be aware that bringing these to TRL 9 will take many more years.
- **Identify large scale TEN-T testbeds:** A key enabler for demonstration and validation actions up to pre-standardisation (i.e. TRL 9) is providing adequate economy of scales for both the NTIAs as the procuring client, and industry as the lead supplier of innovation.

In order to build these (European) scales, groups of NTIAs should collaborate to identify and commit to providing appropriate sections on their combined (TEN-T) networks that industry and research can use for demonstration and validation.

Such collaborative testbeds can build on the various existing EU-regional cooperation frameworks and initiatives, such as Nordic Council³, the council of the Baltic Sea states⁴, the Benelux Union⁵, etc. Combined TEN-T testbeds should offer a representative image of the possible issues from policy, economy, society, technology, legal and environment in European transport infrastructure management.

- **Converge towards collaborative programme governance and management:** Over time, the innovation collaboration of the NTIAs and their relevant stakeholders in so-called 'IFA collaboration ecosystems (see also paragraph 3.2) will build up a significant portfolio of innovation and implementation activities. Along with their enduring collaboration, mutual understanding and trust will build. In turn this enables a further collaboration, such as on twinning and co-programming as well as for collaborative knowledge exchange, sharing,

³ See also: <https://www.norden.org/en/nordic-council>

⁴ See also: <https://cbss.org/>

⁵ See also: <https://www.benelux.int/nl/benelux-unie/benelux-eeen-oogopslag/>

and transfer through various events. This transition can only be effective if the NTIAs converge towards collaborative programme governance and management that is open, transparent, and agile.

- **(Co-) fund NTIA collaboration from EC framework programmes.** In order to foster the emerging IFA collaboration ecosystems it is important that the Horizon Europe and CEF/TEN-T framework programmes envisage (co-) funding trans-European sharing and transfer of results from demonstration and validation activities (e.g. common frameworks, guidelines, specifications, pooled expertise). For example, this may concern translations into the national language which is key for effective dissemination of the knowledge into the operational processes of infrastructure management across the TEN-T network. Other examples include (co-) funding of travel and lodging of relevant stakeholder experts (in particular from EU-13) in order to ensure the corresponding expenditures are not a barrier for their participation.

Furthermore, (co-) funding may be considered for setting up dedicated scientific and business boards to advise the collaborating NTIAs in their decision making about ensuing stages in the concerted innovation delivery process (e.g. assessing state of the art).

- **Provide European anchor points for high level NTIA and stakeholder support and commitment.** It is imperative that the interlacing CEF/TEN-T days and TRA events serve as tier 1 level anchor points in time for the combined innovation collaboration activities. Together with the previous measure on the required synergies between respectively CEF (implementation) and Horizon Europe (innovation development) on the agenda, this will provide strong incentive for high level management from NTIAs and their relevant stakeholders to attend.

Such set-up would also enable improving synergies and coherence with relevant tier 2 European events (such as on ITS conference), and with relevant tier 3 events on the national and regional level.

- **Build a NTIA coordinated, common information base of proven innovations.** As the innovation activities of the NTIAs across Europe inherently have a relative spread in the state of the art, there is significant benefit in “learning from each other’s strengths”. Therefore, it is key to foster a common information base with relevant results from the IFA collaboration ecosystems activities. In addition such information base can offer broad support for various dissemination, direction and decision making on all levels of activities; from strategic to operational.

In line with the demand driven nature of the i4Df coordination mechanism, this reference basis should be coordinated/governed by the collaborating NTIAs.

- **Align with common initiatives on human capital development.** Already across Europe various (transnational) competence platforms are emerging to share knowledge and sound practices (see also D3.1 and D3.2). Mostly they are on specific domains like tunnel or bridge management. A next step would be to bring these initiatives closer to the activities in the various IFA collaboration ecosystems in order to reinforce the collaboration on the various subjects of the IFA and to provide a dissemination channel for practical application of the new found knowledge. These exchange activities could be further facilitated by

flanking funding initiatives from the European framework programmes, such as from ‘Marie Skłodowska Curie’ and ‘Erasmus’ e.g. when common European curricula on specific knowledge are considered or when there is added value from exchange of experts at larger scales than is currently practice.

In the next chapter, and in particular in paragraph 3.4 in which possible models for governance are presented, these measures are revisited again.

4 Description of the coordination mechanism

4.1 Preamble

The description of the i4Df cross-modal cooperation mechanism has been drafted on the basis of multiple rounds of consultation within the i4Df consortium:

- The original concept for the i4Df coordination mechanism as agreed at the 4th i4Df Governance Board meeting in November 2019 in Vienna.
- The suggestions from the i4Df Governance Board for the further operationalisation of the i4Df coordination mechanism received after the meeting in Vienna.
- The comments received from the i4Df Governance Board members on the further elaborated, refined and detailed operationalisation of the mechanism in May/June 2020.
- Final comments received at and after the final i4Df Governance Board meeting of 9-10 September 2020.

4.2 The IFA collaboration ecosystems and their context

Figure 2 presents the full context of the i4Df cross-modal coordination mechanism with the IFA collaboration ecosystems at its core. In the following sub paragraphs, the main composing elements will be outlined: the principle workings of the IFA collaboration ecosystems at the core of the mechanism (bottom of the figure; par. 3.2.1), and the interface to the two apex research and innovation events that are commonly relevant to all of the IFA collaboration ecosystems (top of the figure; par. 3.2.2).

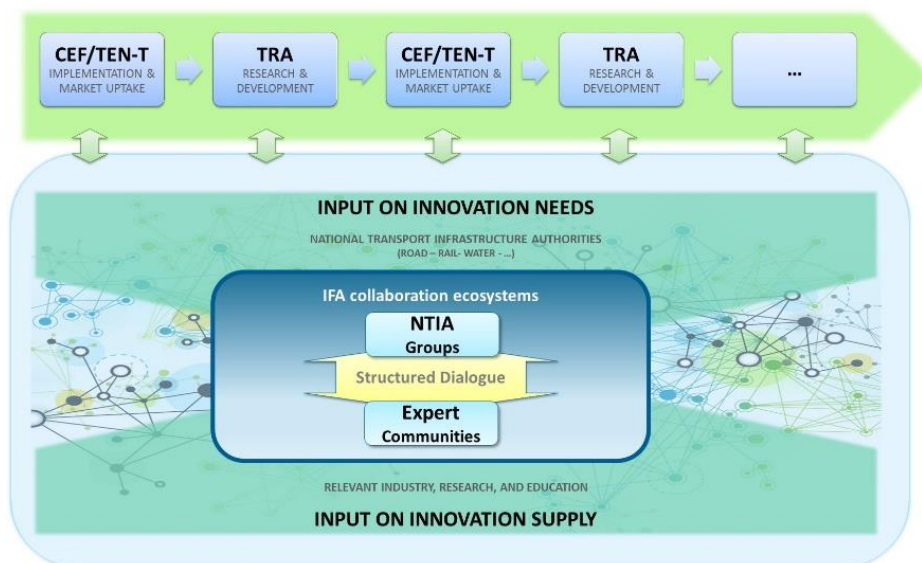


Fig. 2 The i4Df coordination mechanism for demand driven transport infrastructure innovation and implementation (schematic).

The mechanism is centred around a structured dialogue between the (public) national transport infrastructure authorities (NTIAs) as the procuring clients for innovation, and their relevant stakeholders from industry as the lead suppliers of fit for purpose, cost-effective solutions, and from supporting research and education.

Exchange on the outcomes of the coordination mechanism with the wider stakeholder setting will be done through a variety of European, regional and national research and innovation events of which the apex events are shown: CEF/TEN-T days and TRA.

A leading principle is that the coordination mechanism builds up from the innovation activities level, and is centred around a structured dialogue between groups of advisors from the (public)

NTIAs that represent the common public need (demand side) for innovation, and relevant stakeholders experts from industry, research, and education. The latter represent the supply side of the delivery chain, addressing the common demand for appropriate (i.e. fit for purpose and cost-effective) solutions. This structured dialogue builds from a willingness from both groups to explore opportunities for cooperative and collaborative innovation activities that they can subsequently recommend to their strategic representatives for endorsement.

In practice, this dialogue is framed in a series of thematic settings reflecting the common issues the NTIAs need to address in view of their vision for 2040. In that regard, the i4Df initiative has identified seven innovation focus areas (IFAs)⁶ considering the guidance of high level NTIA representatives and the various strategic research agendas from public, industry and research.

As such, the NTIA advisor groups and expert communities engaging in their structured dialogue resemble thematic collaboration ecosystems, i.e. one for each IFA. Each of these IFA collaboration ecosystems are concerned with concerting between a variety of innovation activities from the various European and national programmes and initiatives. Their objective is to identify and scope opportunities for further and closer cooperation and collaboration, all on a voluntary basis.

These IFA collaboration ecosystems can only be successful in coordinating across these opportunities when they experience appropriate, strategic endorsement and commitment from their respective organisations and enterprises, setting a clear need, on a relevant scale, and over a longer time span. Therefore, it is advisable that the results from the IFA collaboration ecosystems are shared with and transferred to the wider European stakeholder setting in order to optimise their effectiveness across the combined European transport infrastructure networks. For this, the IFA collaboration ecosystems will use appropriate European, regional and national events, aiming at the widest outreach across the continent possible.

4.2.1 Principle workings of the IFA collaboration ecosystems

For each of the seven IFAs identified by the i4Df initiative, a collaboration ecosystem should be established from senior advisors from the NTIAs (in figure 3 indicated as ‘NTIA Groups’) and senior experts



Fig. 3 IFA collaboration ecosystems fostering a structured dialogue between advisors from national transport infrastructure authorities (NTIA) and experts from relevant industry, research, and education. The dialogue builds on common (public) needs for innovation and implementation, and a corresponding industrial supply fit for purpose, cost-effective innovative solutions.

⁶ During the runtime of the i4Df initiative the number of IFAs corresponding with the infrastructure capabilities for 2040 was condensed from originally fourteen to ultimately seven.

from relevant industry, education and research (in the figure indicated as ‘Expert communities’)⁷. With endorsement and input from their organisation and enterprises, they can engage in a structured dialogue aiming to coordinate and collaborate on a common portfolio of infrastructure innovation and implementation activities.

The IFA collaboration ecosystems are in essence self-organising and autonomous within the framework of the cross-modal collaboration mechanism. As such, they have great flexibility to define their own working methods, internal procedures, organisation etc. Nevertheless, a certain extent of unity and consistency between the different IFA collaboration ecosystems is essential. Therefore, the ecosystems should respect some common/general elements and requirements to ensure appropriate recognisability and interlinkage in compliance with (the networks of) their organisations. For this, the initiative has drafted some basic terms of reference (ToR). These are primarily concerned with ensuring transparency, internal resourcing (capacity and funding), and compliance to legal and administrative frameworks (e.g. for the pooling of funds), and avoiding conflicts of interest:

- **The IFA collaboration ecosystems are NTIA coordinated.** As the i4Df initiative is about demand driven transport infrastructure innovation and implementation, the groups of collaborating NTIA advisors are in the lead of the workings of the IFA collaboration ecosystems i.e. the NTIA groups set further, specific ToR for the respective IFA collaboration ecosystem. Representing the procuring client for the innovative solutions, resolving their innovation needs, their primary responsibility is on ensuring that the structured dialogue within the IFA collaboration ecosystems appropriately reflects the common innovation needs of the participating NTIAs. As a consequence, the IFA collaboration ecosystems should be chaired from the participating NTIAs.
- **Participation in the open setting of NTIA collaboration groups.** NTIA groups within the IFA collaboration ecosystems are composed of and coordinated by NTIAs, and have an open setting by principle⁸. There is in principle no limit to the number of participants of an NTIA collaboration group, but participation should be relevant to the scope and objectives that are set by the coordinating NTIAs. It is up to the NTIA collaboration groups to determine the manageable number.
- **‘Bring your own programme or initiative’.** In order to build effective collaboration, the structured dialogue within the IFA collaboration ecosystems should build on concrete references to national policy frameworks of the participating NTIAs (‘bring your own programme’). In addition this will reinforce the message that the NTIA participants have firm intent on common cases.

⁷ Whereas seniority is required for effectively shaping the trans-European innovation collaboration, from the perspective of professional competence development, it may be considered beneficial to have junior and medior advisors and experts accompany their seniors to the ecosystems.

⁸ Notice: Currently, the NTIA collaboration groups are composed of i4Df partners. However, membership is open to other NTIAs.

- **In-kind participation by principle.** Participation in IFA collaboration ecosystems by principle is in-kind. This means that all expenses concerned with participation e.g. staff and travel costs, should in essence be covered from own resources. Next to ensuring that participation is driven from sound interest only, this precondition also ensures that the IFA collaboration ecosystems either thrive on addressing the subjects that are of broad interest or wither by a lack of significance.
- **Pooling of funds within the IFA collaboration ecosystem.** An NTIA collaboration group can agree on jointly funding a call for tender. In such cases, the NTIA collaboration group is responsible for bringing together the required funding as well as for ensuring appropriate management of the joint call, in compliance with applicable national, regional or European regulation and legal frameworks.

Co-funding from external bodies, such as from EC framework programmes, may be considered. However, co-funding from external bodies should not be the main driver for collaboration in the NTIA collaboration groups. As a consequence, any external co-financing cannot result in a controlling external vote or a regulatory framework that supersedes the framework as commonly agreed by the collaborating NTIAs themselves.

- **Safeguarding transparency and avoiding conflict of interest.** The NTIA collaboration groups are responsible for safeguarding that the workings of the IFA collaboration ecosystems are transparent, and open/inclusive to all relevant stakeholders, and determine and avoid potential conflicts of interests of participants in order to ensure a level playing field through their activities (e.g. when considering calls for tender).
- **Participation of experts from industry, research and education.** The NTIA advisors participating in the IFA collaboration ecosystems jointly determine which experts from which domains may be involved in the expert communities. Depending on the needs defined by the NTIA collaboration groups and the subjects in question, also experts from sectors other than transport may be engaged.
- **Participation criteria.** Key success factor for building the structured dialogue is a mutual sense of parity on the personal competence level.

The *NTIA participants* are expected to possess the ability to appreciate, translate and appropriately anticipate on the strategic relevance of (developments in) the policy frameworks with respect to the domain of the i4Df IFA collaboration ecosystem they participate in (policy awareness).

The *participants from industry, research and education* should be able to reflect with content competences, have a good understanding of the i4Df IFA domain subjects, possess problem solving abilities and have access to European networks, national research organisations and universities.

- **Collaboration is cross-modal by principle.** The i4Df initiative is about cross-modal cooperation and collaboration on transport infrastructure innovation and implementation. This implies that the IFA collaboration ecosystems have a cross-modal setting by principle. For example, notwithstanding its current description, the scope of IFA 3.1 '*Facilitate the transition towards smart mobility concepts (freight and passenger) for emerging concepts for automated mobility, e.g. Connected Cooperative and Automated Mobility (CCAM) for*

road and Automatic Train Operation (ATO) for rail’ would also include collaboration on concepts for automated inland navigation.

4.2.2 TEN-T-days and TRA as common anchor points

A wide variety of international, national and regional events are related to transport infrastructure innovation and implementation, and can be used by the IFA collaboration ecosystems to share their developments/progress/results, and engage with the wider (multi-sectoral) stakeholder environment. The IFA collaboration ecosystems are responsible for identifying the events relevant to their focus areas and to engage with these events on content.

In order to guarantee common opportunities and preserve a certain coherence between activities in the IFA collaboration ecosystems, there is need for common apex events/anchor points in which the *combined* IFA collaboration ecosystems can share and exchange in a coordinated, coherent way with a representative, cross-cutting and cross-modal, multi-stakeholder setting from transport.

Also such anchor point can serve as opportunities to engage with attending decision making representatives from the organisations participating the IFA collaboration ecosystems, in order to discuss progress made and future needs for innovation collaboration.

In view of their interlaced bi-annual timing and complementary agendas, the i4Df initiative considers the CEF/TEN-T days and TRA



Fig. 4 Intermittent sequence of CEF/TEN-T days and TRA conferences as the common apex events for the IFA collaboration ecosystems.
Where the CEF/TEN-T days provides a strategic setting for the IFA collaboration ecosystems from common national and European objectives and frameworks, the TRA conferences provide the subsequent elaboration into concrete planning and delivery of collaboration activities.

conferences to provide these common anchor points in time (see figure 4). Next to representing a representative, cross-cutting, cross-modal, multi-stakeholder setting from the European innovation arena, both events also recognise the need to drive promising results from research and development implementation and deployment up to larger network scales.

4.3 Key structures and instruments for propelling the coordination mechanism

In the previous paragraph, the context and workings of the cross-modal coordination mechanism were described with the IFA collaboration ecosystems at its heart. This paragraph describes the structures and instruments that are key for propelling the i4Df coordination mechanism. They concern common facilitating services, a common toolbox and interfaces with the common anchor points CEF/TEN-T days and TRA conferences.

4.3.1 Common Facilitating Services and Toolbox

The i4Df cross-modal coordination mechanism envisages common facilitating services in support of the different i4Df IFA collaboration ecosystems. More specific the common services are concerned with:

- Encouragement, coordination and monitoring of the cross-cooperation between the different IFA collaboration ecosystems.
- Accommodation and facilitation of relevant exchange on cross-cutting themes.
- Facilitation and collaboration of the overall workflows of the IFA collaboration ecosystems, such as on common planning, communications.
- Updating and disseminating the common toolbox (guidelines, ToR, programmes, templates, legal and regulatory frameworks, event calendar etc.).

It is imperative that these common services are ‘neutral’ i.e. do not exert direction on the activities in the IFA collaboration ecosystems.

Concerning the common toolbox, the common facilitating services will supply the IFA coordination ecosystems with a common toolbox that is derived from relevant i4Df deliverables and from evolving practices within the IFA collaboration ecosystems. Following list presents a (non-comprehensive) overview of such tools, noticing that they will evolve over time as collaboration progresses:

- Joint innovation pathways until 2040
- Stage gated reviewing process
- Overview of relevant transport related stakeholders
- Expert communities for transport infrastructure innovation
- Overview of national and international transport research programmes
- Recommendations for the operationalisation of the IFA collaboration groups (IFA Continuous Collaboration Life Cycle)
- Human Capital Development, professional competence building for future capabilities and cross-modal approaches, including an evolving overview of collaborative settings for professional competence developments
- Communication and dissemination tools, including collaborative structures for cross-modal, transnational information transfer between innovation programmes

The IFA coordination ecosystems are free to select what they need from the tool box, as well as to adopt any other tool they deem ‘fit for purpose’ in the context of achieving their specific goals and ambitions. However, in order to drive optimal consistency between the different IFA collaboration ecosystems and foster ‘learning from each other’s strengths’, such other/additional tools will be made available to all the IFA coordination ecosystems through the common toolbox.

4.3.2 Interfaces to the common anchor points of CEF/TEN-T days and TRA conferences

The results from the IFA collaboration ecosystems need to be shared and exchanged in the wider European stakeholder community in order to further raise awareness, understanding,

trust and commitment. In addition, the IFA collaboration ecosystems are also in need of strategic guidance on course and future needs from the involved NTIAs.

In view of their transport related programmes, and their objective to foster mutual synergies, the i4Df initiative considers the CEF/TEN-T days and TRA conferences as common apex anchor points for all IFA collaboration ecosystems. Considering that the two anchor point events have well-established but clearly different stakeholder orientations and management structures, it is important to determine appropriate ways to interface the work from the IFA collaboration ecosystems to these structures:

- *The TEN-T days* have a structure in which the EC and representatives from the member states (typically from the policy cores) scope the event programme. Typically, the setup and event programme is driven by DG MOVE together with the host country, which is often the country holding the EU-Presidency at that moment. The target audience for CEF/TEN-T days is mostly middle and higher management and advisors from the policy cores.
- *The TRA conference* works with committees in which the EC (DGRTD and DGMOVE) and representatives from relevant European stakeholder platforms from public, industry and research participate to scope the programme. The organisation is done by a NTIA of one of the member states for which it receives a grant from the EC. The target audience for TRA is mostly (senior) experts from research and education although increasingly experts from industry and public also participate.

4.3.3 The coordination mechanism in the wider European context

The i4Df cross-modal coordination mechanism builds on voluntary actions from national, regional and European transport innovation programmes and initiatives that find their specific context and direction in the associated national and European transport policies and objectives. Against this diverse but increasingly consistent European context, the i4Df initiative has defined a first draft common vision for 2040, outlined by guiding objectives and related IFAs.

Successful collaboration on innovation typically results in common guidelines, specifications etc. delivered from demonstration and validation (TRL 8-9). Being brought forward from transnational collaboration, these common results can be considered a form of pre-standardisation, and may be an incentive for NTIAs to (voluntary) initiate first deployment of innovative solutions up to larger network scales (market uptake).

A further stage in innovation delivery concerns European standardisation and regulation, for example when the first deployment activities from various countries clearly show benefit 4. However, such standardisation activities follows formally established procedures that are out of scope of the i4Df mechanism. Nevertheless, the NTIAs may consider assessing the results from their innovation collaboration on benefits from further standardisation or regulation, and come to recommendations to the corresponding national and European structures (e.g. EC, CEN).

4.4 Governance of the Coordination mechanism

In considering possible governance structures for the effectuation of the coordination mechanism, the key guidance from the three i4Df Stakeholder Conferences is that additional

or even overarching structures next to the ones that already exist, should be avoided as much as possible.

However, as the mechanism is cross-cutting to the existing structures, and notwithstanding its emphasis on voluntary, self-organising and in-kind resourcing (capacity and funding) of collaborative activities, and on the optimal synergies with and utilisation of existing facilities and structures in the European arena, there is need for a bare minimum of additional supporting structures, instruments and terms of reference.

This paragraph describes possible models for these additional supporting structures while acknowledging that final choices will have to be made during the roll-out stage following end-of-project.

4.4.1 Concerning the i4Df coordination mechanism as a whole

A successful roll-out of the i4Df coordination mechanism for infrastructure innovation collaboration requires strategic ownership and direction from appropriate management levels in the participating NTIAs. This top-down framework is needed to empower the bottom-up collaboration activities of the NTIA advisors and experts from industry and research engaging in the IFA collaboration groups. Furthermore, it is a pre-requisite to establish effective links with their organisations' European strategies, programmes and initiatives, and memberships. This includes various initiatives and platforms on human capital development.

During the i4Df initiative, the three Stakeholder Conferences have served this aim. The result is a clear vision for 2040 on end-user centric, sustainable and digitalised transport infrastructure services outlined through a first set of guiding objectives and innovation focus areas (see also deliverable D1.2). In the roll-out stage following end of project, a similar 'governance conference' approach could be considered among the NTIAs participating in the IFA collaboration ecosystems e.g. to be organised in conjunction with the CEF/TEN-T days event in 2021.

Depending on the issues to address and the ambition of the decision makers involved, the first governance conferences could already include relevant stakeholders from industry, research, and education. This could particularly be relevant for discussing collaboration on demonstration and validation of promising innovative solutions (TRL 8-9) and their ensuing deployment (by voluntary action) up to larger network scales where economy of scales is a key interest for stakeholders from industry, research and education.

Such 'conference' model does not need to be formalised in the very first stages of the roll-out of the mechanism, in particular as the collaboration is voluntary and most likely to be aimed at learning from each other's strategies, programmes and initiatives and at identifying possible synergies and quick wins. Most likely the agenda will be driven bottom-up from the various IFA collaboration ecosystems, requesting appropriate sense of endorsement and direction for taking the collaboration activities to the next level, for example concerning collaborative input to the CEF/TEN-T and TRA anchor points in time.

Over time, the NTIA -led governance conference can evolve its structure in order to address comprehensiveness and cohesiveness of the evolving portfolio of results from the active IFA collaboration ecosystems.

Notwithstanding this gradual model, a short term issue to address is the resourcing and governance of the facilitating services (see also par. 3.3.1). Although at the early stages of the roll-out the respective resources involved will be very limited, their allocation requires explicit agreement, commitment and mandating.

4.4.2 Concerning the collaboration activities within the IFA collaboration ecosystems

As stated previously, the IFA collaboration systems are self-funding and self-organising by principle. The majority of activities are in-kind and do not require any transfer of resources or decision making.

The extent and scope of activities within the IFA collaboration ecosystems are basically aimed at twinning⁹ and co-programming¹⁰ of the represented national programmes and initiatives on a voluntary base; harvesting synergies. Therefore, the governance model is that of a regular working group. The key principle in this model is that the lead i.e. chairmanship must be in hands of NTIAs in order to preserve the demand driven nature of the mechanism (see also paragraph 3.2.1).

This situation does not change in cases where NTIAs participating in the ecosystem agree to pool resources in a common pot to fund innovation activities. In that case the pooled fund is subject to a specific agreement that by principle automatically makes it a distinct, closed collaboration ecosystem by itself i.e. independent from the open setting that initiated it.

4.4.3 Concerning the common facilitating services and the common tool box

The governance of the activities concerning the provision of common facilitating services -and related to these activities the provision of the common toolbox- is particularly concerned with appropriate requirements for accountability, transparency, avoiding conflict of interests, and synergising with existing European structures and bodies.

The leading principle is that the NTIAs that resource the common facilitating services in capacity and funding, also have ownership responsibility. Key governance issues for them to address are:

- Assigning principle secretarial responsibility over the facilitating services as well as assigning appropriate oversight from the NTIAs participating in the IFA collaboration ecosystems within the context of the overall governance of the coordination mechanism.
- Acquiring the appropriate professional competences either from in-kind resourcing or from outsourcing (avoiding conflict of interests). Whether or not to solicit for external

⁹ Twinning concerns sharing relevant information between individual projects and programmes with the objective to learn from each other's strengths and avoid duplication of (or gaps in) the scope.

¹⁰ Co-programming concerns the alignment of scope, timing, information, and resources (without any transfer of power or resources) between individual projects or programmes with the objective to maximise synergies.

co-funding (e.g. from EC, industry) to cover the required resourcing, taking into account the additional complexity that managing such hybrid funding may bring.

- Reconciling the activities of the common facilitating services with similar standing activities in other settings. The activities within the IFA collaboration ecosystems are cross cutting to corresponding activities of the various national, regional and European platforms, structures and bodies. Reconciliation between both is therefore essential in order to avoid conflict of interest, in particular considering the common memberships of the participating stakeholders, and the commonalities of the various collaboration models and tools.

4.4.4 Concerning the interfaces to the common anchor points CEF/TEN-T days and TRA conferences

The i4Df cross-modal coordination mechanism strongly builds on a situation in which the CEF/TEN-T days and TRA conferences have dedicated strategic programme slots for transport infrastructure innovation in the context of the event's overall objectives and themes. The delivery of content from the coordination mechanism to these strategic and technical programming slots require appropriate NTIA-led governance sub-structures that are in compliance with the overall governance and management structures of the respective events.

In order to achieve these dedicated strategic programme slots, and the corresponding governance sub-structures, requires engagement with the relevant stakeholders currently involved in the overall management and organisation of the respective events (see also paragraph 3.3.2).

Annex A. Full overview of NTIA innovation topics

The following overview presents the full list of identified NTIA topics for innovation and implementation, including their expected staged timelines across the innovation delivery process. In paragraph 2.2.1 the topics from this are shown for which TRL9 can be achieved by 2030, making them available for voluntary deployment on the infrastructure networks. See also Annex C for further definition of technology readiness levels.

IFA	Overall NTIA topics for innovation	Stage reached until				
		2025	2030	2035	2040	2050
1.2	<i>TEN-T demonstration and validation tracks</i>	II	III			
	<i>Common 'line of sight' for the TEN-T core</i>	I	II	III		
	<i>Alignment in sustainability targets in infrastructure management</i>	II	III			
	<i>Building digital twins on the EU-regional scale</i>	I	II	III		
	<i>Integrated mobility management systems</i>	II	II	III	III	
	<i>Future proofing of infrastructure planning</i>	I	II	II	III	III
1.2	<i>Life-cycle costs analysis in innovative contracting</i>	I	II	III		
	<i>Risk sharing approaches</i>	II	II	III		
	<i>Simulation models in procurement</i>	I	II	III	III	
	<i>Innovative financing schemes</i>	II	II	III	III	
2.1	<i>Electric road systems: cross-border demonstrators including pre-standardisation</i>	I/II	III			
	<i>Energy Harvesting: Development of a European portfolio of demonstrated/proven technologies</i>	II	III	III		
	<i>Development of new legal and governance models for the emerging new cross-sectoral (e.g. energy and transport) and cross-modal technologies and collaborations</i>	I/II	III			
2.2	<i>Automation of noise mapping</i>	II	III			
	<i>Next generation impact assessment tools</i>	I	II	III		
	<i>EU-regional scale monitoring network</i>	I	II	III		
	<i>Improved understanding of dose-response relationships</i>	I	II	III		
	<i>Source measures for noise abatement</i>	II	III			
	<i>Next generation noise abatement techniques</i>	I	III	III		
	<i>Introduction of drones in monitoring, inspection</i>	I	II	III		
	<i>Common pricing techniques</i>	I	II	III		
	<i>Assessment of natural water treatment solutions</i>	I	II	III		
<i>Habitat reconnection measures</i>	II	III				
2.3	<i>Data warehouses at the Functional Urban Area (FUA) scale.</i>	I/II	II/III	III	III	
	<i>Mobility labs at the Functional Urban Area (FUA) scale.</i>	I	II/III	III	III	
	<i>Multi-scalar infrastructure planning.</i>	I	II/III	III	III	
	<i>Integration of transport energy distribution.</i>	I/II	II/III	III	III	
3.1	<i>Large-scale demonstrations focusing on the needs of the infrastructure owners/managers.</i>	I/II	II	III		
	<i>Physical and digital infrastructure.</i>	I	II/III	III	III	
	<i>Governance models for infrastructure owners and managers to accommodate CCAM.</i>	I/II	II/III	III	III	
3.2	<i>Dynamic Asset Management Systems</i>	I	II	III		
	<i>Synthetic digital twin.</i>	I	II/III	III		
	<i>Dynamic and Automated AMS for network maintenance decisions.</i>	I	II	III		
	<i>Legal and Technical issues around Artificial Intelligence</i>	II/III	III			
	<i>Robotisation: avoiding barriers</i>	II	III			

Annex B. Technology Readiness Levels defined

In her Horizon 2020 framework programme, the European Commission provided a working definition of the various technology levels along the innovation delivery chain:

Level	Description
TRL 1	basic principles observed
TRL 2	technology concept formulated
TRL 3	experimental proof of concept
TRL 4	technology validated in lab
TRL 5	technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 6	technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 7	system prototype demonstration in operational environment
TRL 8	system complete and qualified
TRL 9	actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

The i4Df initiative builds on that definition, in particular in the various tools, such as the staged gate reviewing process (deliverable D 2.1). However, in outlining the concept and principles of the coordination mechanism, the detailed description of the various readiness levels is aggregated to show the general nature of the activities rather than to provide a precise demarcation (see also fig. 5).

In practice, the coordination mechanism is conceived to have innovation collaboration pick up at TRL 4 when innovations are taken from the laboratory to the field for the first time. The mechanism then recognises a first research and development stage

From research & development to market uptake in three stages.

Note: boundaries are indicative



Fig. 5 Three stages in the innovation and implementation delivery process.
 Stage I, concerning Research and Development, typically spans from TRL 4 to TRL 7. Stage II, concerning Demonstration and validation, typically spans TRL 8 and TRL 9 activities. Resulting in common guidelines, specifications and (testing) facilities, this stage is the basis for further market uptake – stage III in the innovation delivery process. In that stage, fit for purpose and cost-effective innovations can be deployed up to larger network scales by NTIAs own chosen action e.g. through launching customer or PPI schemes.

that ultimately delivers the innovation at a TRL 7 i.e. the readiness is demonstrated by prototyping in an operational environment (of transport infrastructure management). After this

the mechanism recognises a second stage of demonstration and validation of the innovations in real life, full scale operational environment. This stage delivers innovations at the highest readiness level, TRL 9. This includes the provision of all relevant documentation (e.g. guidelines and specifications) required to accommodate the innovation in procurement frameworks. Once accommodated in these frameworks the innovation can be procured from the market, for example through public procurement of innovation (PPI) schemes in which the public authorities are launching customers for innovations.

Annex C. Scopes of short term NTIA innovation topics

This annex presents the aggregated descriptions of the NTIA topics for innovation and implementation presented in paragraph 2.2.2 ‘Timelines to innovation delivery’. They concern the NTIA topics that envisage demonstration and validation activities in the years until 2025. The full descriptions of the corresponding IFAs are presented in deliverables D1.3 and D2.3.

For reference, following overview presents the persons and organisations from the i4Df consortium that are currently coordinating the content of the IFAs.

IFA	coordinator	organisation	country
1.1	Mats Karlsson	Trafikverket	Sweden
	Arjan Hijdra	Rijkswaterstaat	The Netherlands
1.2	--	--	--
2.1	Markus Auerbach	BASf	Germany
2.2	Patrizia Bellucci	ANAS S.p.A.	Italy
2.3	Sjaak van der Werf	Rijkswaterstaat	The Netherlands
3.1	Andreas Blust	BMK	Austria
3.2	Janis Barbars	LVC	Latvia

Note: For IFA 1.2 ‘Responsible and innovative procurement and finance’, there was no coordinator available from the consortium. Therefore, there has not been an expert consultation in the webinar series from 23-25 June 2020 on this IFA. Lacking updates, the innovation description presented here has been copied from the deliverable D1.2 ‘*Joint vision on transport infrastructure innovation until 2040*’

IFA 1.1 Integrated Network Performance Management

- **TEN-T demonstration and validation tracks.** The first action is for groups of willing NTIAs to demarcate several demonstration and validation track on connecting sections across the TEN-T. These serve as a concrete geographical setting in which NTIAs can exchange and share their infrastructure governance frameworks and practices in search of common denominators that enable compatibility between the nationally defined service levels and associated Key Performance Indicators (KPIs).
- **Alignment in sustainability targets in infrastructure management.** Across Europe infrastructure managers are evaluating the impact of the Green Deal package on their primary processes, and their subsequent actionable management perspectives. A coordination action is in order to share these exercises among peers and to identify commonalities. The objective is to deliver a common correlated portfolio of service levels and KPIs as well as practical steps across the ‘line of sight’ from needs to market in order deliver on these.

- **Integrated mobility management systems.** As the EU-regional testbeds would typically encompass populated economic areas in Europe, these digital twins can subsequently be used to deliver optimised, integrated mobility management systems for these areas.

IFA 1.2 Responsible and innovative procurement and finance

- **Risk sharing approaches:** Building on recent (national) work, common innovative risk sharing and management approaches could be established to provide suitable models to share risk between infrastructure owners, end users, designers (e.g. design-build tenders) and contractors.
- **Innovative financing schemes:** Linked to procurement processes are also innovative financing approaches to raise funds for new infrastructure investments through direct payment of the infrastructure by e.g. the user including the relations between users, mobility providers, and contractors.

IFA 2.1 Decarbonisation of infrastructure management

- **Electric road systems: cross-border demonstrators including pre-standardisation:** Further development of Electric Road Systems need cross-border demonstrators involving relevant stakeholders from other sectors, such as from energy, which would provide the knowledge and financial capacities to build and operate such systems at deployment.
- **Energy Harvesting: Development of a European portfolio of demonstrated/proven technologies:** An assessment of the impact and cost-effectiveness building on the current abundance of separate projects. The study will provide the NTIAs with an overview on a European scale. This overview can facilitate an analysis of the reasons why most of the technologies haven't entered the market yet.
- **Development of new legal and governance models for the emerging new cross-sectoral (e.g. energy and transport) and cross-modal technologies and collaborations:** Legislation often lags behind fast technologic evolution and therefore new concepts and models for the (legal) implementation, governance models or more specifically business cases have to be developed. This is especially important for the cross-modal and cross-sectoral context these emerging technologies will have to be built and operated in.

IFA 2.2 Preserving the environment

- **Automation of noise mapping,** considering the possibility of using mobile phones, to improve the accuracy of mandatory noise maps, speed of delivery, and reduce the cost of the process. The Environmental Noise Directive requires Member States to produce strategic noise maps on a 5-years basis for all major roads, railways, airports and urban agglomerations. Noise mapping activities are quite expensive and require highly qualified personnel. Therefore, advanced noise mapping procedures and tools are claimed in order to speed up the process and reduce their economic impact. This goal can be achieved by automating the noise mapping process.
- **Source measures for noise abatement.** Innovative solutions to abate noise at the source (roads, railways, vessels). Noise mitigation measures typically are based on passive

solutions, such as noise barriers or facade treatment. These solutions are quite expensive and their effectiveness is usually limited in space. Therefore, it is imperative to improve solutions to abate noise at the source, in order to reduce costs and drastically decrease the number of people exposed to noise.

- **Habitat reconnection measures.** Based on a common understanding of what the habitats are and how they are affected by infrastructure (and transport), it is necessary to connect the whole habitats, to allow the migration of species. Integrated solutions need to be taken into account reflecting the various aspects related to environmental impacts. Opportunities of the existing space belonging to the infrastructure have to be investigated to preserve and improve biodiversity.

IFA 2.3 Integrating multi-layer networks and nodes

- **Data warehouses at the Functional Urban Area (FUA) scale.** Optimal transport system collaboration at the Functional Urban Area scale needs dedicated data warehousing, including models for sustainable cooperation and collaboration between public and private sector. A first step in this process is establishing common data architectures and standards that enable exchange of historical as well as real-time data between relevant stakeholders, such as public authorities, freight operators, infrastructure and traffic managers. From this foundation, cooperation models can be developed to enable effective and secure mobility data and capacity sharing. The approach would be from the TEN-T scale down into the relevant supporting networks with a particular focus on the peri-urban settings in the FUA. In case of larger, cross-border scale FUAs, the respective national access should ensure appropriate harmonisation and standardisation.

Additional research development should focus on the transport/mobility interfaces, such as of freight/persons, intra-/inter-urban, last-mile/long-distance transport as well as on generic spatial-economic assessment approaches that enable integrated public-private business casing in Functional Urban Areas.

- **Integration of transport energy distribution.** The hubs and terminals in the FUA setting are interfacing 'last-mile' and long-distance transport. Therefore, they are particularly suited for reinforcing the energy transition by introducing energy distribution infrastructures for alternative fuels and electricity at low marginal additional cost. This requires careful planning and development through strategic public-private alliances. Key is to facilitate the development and dissemination of good practices and standards that enable the required technical and organisational compatibility between the involved energy, mobility, and transport infrastructure sector.

IFA 3.1 Smart data and information ecosystem for accommodating automated and connected transport

- **Large-scale demonstrations focusing on the needs of the infrastructure owners/managers.** The role of infrastructure owners and managers is essential in large-scale demonstrations of CCAM solutions. Demonstrations of the interaction between CCAM solutions for passenger and freight and the infrastructure can create infrastructure focused knowledge that enables the development of business cases for infrastructure

owners and managers to move along the ISAD levels. The necessity for cross-border elements is the strong need to harmonisation and interoperability of technologies and methodologies also for infrastructure owners and managers.

- **Governance models for infrastructure owners and managers to accommodate CCAM.** Data and connectivity is an essential resource for the deployment of CCAM. Creating a strategic vision for the role of the infrastructure owner and manager in the evolving eco-system that clearly highlights the benefits of data sharing for internal and external. This includes the development of new governance models that enable cooperation initiatives across institutional, modal and national boundaries. The integration of legacy systems for data management into the evolving multimodal and transnational data ecosystem requires also consideration.

IFA 3.2 Information provision for process optimisation in infrastructure management

- **Legal and Technical issues around Artificial Intelligence.** Development of legal and organisational frameworks for use of AI in infrastructure management. Common systems and procedures for data acquisition, validation, calibration and exchange.
- **Robotisation: avoiding barriers.** An assessment of the barriers for the use of robotisation (and its enabling activities – digital twins, modular construction, mobile factories, 3-D printing, gaming, and Augmented Reality and Virtual Reality) in the construction processes.