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Publishable Executive Summary

The framework architecture for smart governance of infrastructure networks can be considered as a generic canvas that enables agencies to find common ground. The National Infrastructure Agencies have to deal with political dynamics and policy ambitions related to new infrastructure, which is a different action arena than provision of service and maintenance and operation of available networks.

Secondly, although some infrastructure agencies have multiple modalities in their portfolio, many agencies mange and assign responsibilities for different modes in isoloation. a sectoral assignment. National or international institutional frameworks do not currently optimise the entire system of networks holistically. The provided framework architecture does recognise the interlinkages and provides an entry to take synergetic behavior of networks into consideration.

Thirdly, contemporary infrastructure ambitions include a variety of concepts that need to be incorporated. These concepts, like commonly shared data, network resilience and sustainability, have wide implications. These are not restricted to a single activity or physical element. These concepts need to be embedded in systems and processes and are therefore shown in the framework architecture to include all around.

The framework architecture, as shown, offers a way to see all these interconnected elements and concepts in a coherent way. It connects new investments to available networks, it includes cross border and cross-modal considerations and it relates to policy ambitions and generic concepts to be pursued. The framework architecture is not a detailed guideline ready for use for infrastructure agencies. It does provide a very generic overview of the coherence of decision making and optimisation of networks in order to provide best value. Such a generic overview is useful to support a common dialogue and common learning processes. This framework will be followed by specific guidelines that are far more detailed and will be more diversified towards specific challenges or network issues.

Along with the guidelines, the framework architecture will be tested and validated in living labs. These living labs will focus on regional contexts where a variety of interlined network problems play out and where investments, maintenance and operation play a role for different modalities.

Contents

1 Purpose of the document

1.1 PURPOSE OF THE DOCUMENT

This document describes the conceptual design of the common framework. As such de document is closely related to deliverables D2.1 (Whole Life Cycle and Risk Based models) and D3.1 (Asset Data Dictionary) that define two key elements of the conceptual framework

1.2 DOCUMENT STRUCTURE

In chapter 2 the context of the conceptual design of the common framework is outlined. A key element in that is the explanation of the added value of the framework.

In chapter 3 the common principles of the common framework design are explained. As the common asset management framework is about optimising economic and societal value of the assets and the networks, the chapter outlines the methods for service optimisation, for maximising societal value of investments, and for determining the resiliency and sustainability of the networks.

Chapter 4 presents the actual framework architecture design.

1.3 DEVIATIONS FROM ORIGINAL DESCRIPTION IN THE GRANT AGREEMENT ANNEX 1 PARTA

1.3.1 DESCRIPTION OF WORK RELATED TO DELIVERABLE IN GA ANNEX 1 – PARTA

Task 1.1 Develop a framework architecture for smart governance of transportation networks. (M1-12) [leader: RWS;participants: HE, ANAS, TII, CERTH, WI]

The framework architecture should address the difficulties and complexity of decision making to maximize societal value. Objectives from stakeholders at policy level (European and national), asset owners, asset managers, service providers, users and public are to be accommodated in an optimized way. Therefore the framework architecture has to accommodate a push forward in cross-modal and cross-border optimization of transport networks.

The framework is based on identification of common principles and methodologies for decision-making and prioritization of infrastructure investments and actions. It helps to act and decide crossing political, institutional and network borders.

The framework should include enhancement of resilience of the transportation systems. The following subtasks are foreseen to realize this task:

- Identification and classification of principles and methods used by (or within) authorities of the consortium participants and affiliated members in order to optimize investments and action beyond borders and singular modalities.
- Projecting these identified principles and methodologies in a societal value scheme to visualize the commonalities, gaps and overlaps.

- Work out a framework on resilience of infrastructure networks on the basis of elements defined in scientific literature: robustness (resistance to disturbances), redundancy (in assets, in modality and cross modal redundancy), rapidity (speed of recovery) and resourcefulness (capacity of agencies to recover systems after disturbance)
- Define common principles for maximizing societal value in a framework of sustainable developments which can guide and support cross agency discussion and decision making.

- Determine generic hindrances and opportunities for broad optimization and building resilience
- Provide a framework to assess the effectiveness and efficiency of interventions
- Analyze and discuss results and build a framework architecture which supports (interlinked) network optimizations.

1.3.2 TIME DEVIATIONS FROM ORIGINAL PLANNING IN GA ANNEX 1 – PART A

No deviations from the original planning occurred.

1.3.3 CONTENT DEVIATIONS FROM ORIGINAL PLANNING IN GA ANNEX 1 – PART A

No deviations from the original planning occurred.

2 Framework architecture for smart governance of transportation networks

2.1 INTRODUCTION

Transport infrastructure is the backbone of national economies, providing connections for people and goods, access to jobs and services, and enabling trade and economic growth. Efficient transport infrastructure enhances market accessibility and productivity by creating employment and connecting the continent between East and West, North and South. This highlights the role of infrastructures as one of the main pillars of European society and economy. Transportation networks are indispensable for the smooth functioning of society, acting as important lifelines linking communities and goods. A coherent transport network should include cross-border combined transport services, establishing common acceptable standards and considering also regional planning objectives, as well as social and environmental factors and criteria. However, transport networks are fragile and vulnerable to natural and man-induced disasters, which can disrupt their vital functionality.

Based on the White Paper on Transport from 2011, the European Commission sets the target of a functional core network on all modes by 2030. This trend is also enhanced by the recent economic recession. As a result, innovative cost-effective and environmental friendly solutions attract the attention of European transport ministries and National Infrastructure Authorities (NIAs). Higher efficiency and increased productivity of transport infrastructure constitute major challenges that asset management (AM) has to deal with. AM is a core activity for sustainable development because it offers a better understanding to NIAs of their assets, describing how they perform and determining the funding they need (Department for Transport, 2013).

2.2 WHY DO WE NEED A FRAMEWORK?

Developing and managing infrastructure to serve the transportation needs of society is a challenging task. Infrastructure serving transportation comes in a variety forms (road, rail, waterways and more), spans large time frames (sometimes up to 100 years), is capital intensive (single projects can easily exceed € 100 mln), is both physically inert and part of relatively inert institutions (ministries, agencies, long term contracts), is widely linked (cross-modal, central-regional- local networks, cross border, regional context), is rich in externalities affecting many stakeholders, and is extremely resource intensive (natural resources in infrastructures). Transport and transport infrastructures play a central role in many policy fields beyond transportation, e.g. environmental and climate policy, social policy, cohesion, innovation policy, economic and industry policy and has to respond to respective demands. Decisions about these networks will inevitably have a variety of effects, short- and long-term, and will in their turn influence the use of these networks. The design of infrastructure influences choices of transportation modes and thus is closely linked to social issues such as availability and affordability of mobility, to environmental aspects such as greenhouse gas emissions, emissions of nitrogen oxide, or nature protection, or to health issues.

For mentioned reasons infrastructure networks can be considered as complex. From a societal perspective, all stakeholders need to be involved (a participatory approach), aiming at satisfying the wide set of interests with minimum consumption of resources. Due to the high number of parameters in play and uncertainties about current state or future situation, this is a challenging task. Practice, however, has delivered a variety of tools and methods to face this challenge. These tools and methods can optimise current networks according to specific aspects and optimize the value proposition for new infrastructure investments. Such optimisation needs to be placed in a wider context of policy ambitions covering a wider set of issues including concepts like resilience and sustainability.

To avoid a high degree of 'muddling through' and ensure effective and efficient use of resources, a framework could be instrumental. Such a framework could help balancing efforts, avoid losses by network incompatibilities and push symbiotic functioning of networks. In this document the most elemental set of building blocks is described in order to create a common basis for European NRAs, NIAs and alike. In the follow-up guidelines of this framework, these elements will be described in more detail. For deliverable D1.1, this document, the focal point is building a common core to facilitate communication and alignment between agencies.

3 Common principles and methods for maximizing economic and societal value

In this section the fundamental elements for valued infrastructure networks are discussed briefly. As mentioned, in deliverable 1.2 (the guidelines) these will be described in more detail. Basically, transport networks need to address four key elements in order to suit contemporary needs. First, the networks in place need to deliver an optimised service to the users in terms of balancing performance, costs and risk (section 3.1). Second, all investments in new infrastructure need to consider the broad context in which these investments take place, and need to achieve maximum returns on the resources employed. These returns benefit not only a single asset owner, but a variety of owners, users and affected stakeholders in a broad sense (Pareto[1] efficient investments)(section 3.2. Thirdly, disruptions of all sorts can take place in these networks, exceeding anticipated design conditions. To cope with the nature of these events, and reduce risk for people and first and second order economic damage, resilience is to be enhanced. Especially as climate change might be an additional stressor. Fourth, sustainability is vital for durable solutions and the prosperity of generations to come. In all activities taking place at and around transport infrastructure, these concepts need to be taken into account (section 3.3).

3.1 LEVEL OF SERVICE OPTIMIZATION

In general, Level of Service (LoS) is a NIAstated commitment to deliver a specific service at a specified level of quality and reliability. The LoS can be performance-related or customer/regulatory-related. Three major costs that come into play when responding to services levels are: capital costs, operational and maintenance costs, risk costs and costs related to environmental awareness and specific mitigation activities.

In order to maximize LoS, it is required to evaluate the best way to operate, maintain, or renew/replace specific groups of assets for a continuing provision of the targeted LoS at the lowest possible cost. By measuring the cost and risk of achieving the service level throughout the life cycle, the asset manager can continuously improve the way it goes about achieving its service level goals.

On various transportation modes, LoS is evaluated using the speed, convenience, comfort and security of transportation facilities and services as experienced by users. Infrastructures thus should provide for a minimum throughput of passengers and/or freight with an acceptable level of density (e.g. traffic density and or seats per passenger) and avoid overdesign, which is associated with additional costs. Within road transportation, traditionally the traffic flow is rated according to the most desired to undesirable level of service for users, which are (a) free flow traffic, (b) steady traffic, (c) steady traffic but limited, (d) steady traffic at high density, (e) traffic at saturation, and (f) congestion[i].This rating system defines transportation problems and prioritises transportation system improvements, resulting in resources being directed at infrastructure expansion, which can be more

[1] Pareto efficiency is defined in literature as 'no stakeholder position can be improved without a negative effect other stakeholder positions'. In the extended variant as meant here it also includes the option of inter-stakeholder compensation to push value even further. This is a qualitative rational economic optimum from a micro-economic perspective.

of the same. But to maximize LoS, it is required to rethink options on how a specific service (transportation of a certain number of people and/or freight) can be achieved, for example via strengthening alternative modes of transportation or more efficient use of existing infrastructure.

According to the CEDR report (Conference of European Directors of Roads, 2013), life cycle costs (LCC) constitute the basis of a comprehensive AM approach since different planning phases require different actions to be taken (Davis, 2012). It involves phases from recognition to disposal and describes that assets have a life cycle even though their duration is not the same. AM planning of a transport system specifies short- and long- term decision making. Short-term decisions of AM include prioritisation of daily operations and their corresponding data collection improving utilisation and maintenance phases. Reductions in the maintenance frequency result in significant short-term benefits to the NIAs. On the other hand, long-term decisions assess the overall system in a long-term horizon for appreciating the full impact of an asset and developing a future plan. In a case of failure, the long term cost to the organization might be substantial, related to short-term benefits gained. For these reasons, we can recognize AM in quality management, project management, engineering, finance and accounting.

AM could support NIAs to accomplish their strategic goals more efficiently and effectively with limited funds. Therefore, NIAs should have a clearly defined mission and relevant strategic goals and objectives that decision making tools and methods could support (FWHA, 2013). Both staff and external stakeholders should work towards achieving them by setting tactical objectives for periodic management at high-level as well as operational objectives for management on a daily basis.

Figure 1 depicts the different levels of AM objectives and their interrelation for achieving a high Level of Service (LoS) in the most cost effective manner for present and future stakeholders.

Figure 1: AM objectives

The key points could be summarised as follows:

1. Correlate both operational and tactical AM objectives with strategic (socio-economic) objectives to cover the lifecycle phases.
2. Well-defined objectives are critical for successful AM, allowing their easy quantification using performance measures.
3. High quality information is a basic component for resource allocation and utilisation, identifying factors that affect the objectives.

4. Multiple frameworks could be considered for successful management of different processes at any level.
5. LoS should be developed in a hierarchy that reflects the increasing level of detail of planning activities (strategic, tactical and operational).

The LoS covers both **technical** (i.e. routine operations, routine maintenance, preventive maintenance, network improvement and development etc.) and **organisational** issues (i.e. funding schemes, communication with users, investment strategies, service level agreements, risk analysis, gap analysis etc.) that could be translated into appropriate KPIs to assess both the performance and the condition of an asset.

3.2 MAXIMIZE SOCIO-ECONOMIC VALUE OF NETWORK INVESTMENTS

As stated in the EU white paper and Trans-European Transport Network (TEN-T), infrastructure development is an important way to enhance market integration, improve trade and foster development to strengthen regional cohesion in Europe. This requires high-quality and safe infrastructure that includes all transport modes, and allowance for the optimal use of existing capacities by either creating new, or upgrading existing infrastructure beyond borders and for different modes of transport ii.

Among the EU Member States, however, there are still competing ideas for specific investments (e.g. on transport modes or specific technologies) that may negatively impact the connectivity of Member States' infrastructures. To optimize the investment, i.e. to maximise its economic and societal value, performance of assets and infrastructure development should be monitored at a regular basis and adjustments made at the appropriate stage in an asset life cycle to achieve an acceptable balance between cost, level of service (i.e., performance), and consequential risks. The maximisation of economic and social value, however, requires taking into account harmful effects (direct and indirect) of transport systems. This requires using a life cycle perspective and risk based management of transport infrastructure. Risk factors include parameters such as financial, environmental, health, and safety. Negative externalities, such as the cost of disruption and delay, including climate change and (selected) disturbances, and social and environmental degradation also need consideration.

Thus, benchmarks for the optimisation of infrastructure investments will not only be derived from intrinsic variables (connectivity, transport volume and reliability etc) but also from external policy fields such as environmental and climate policies (e.g. GHG emissions, fostering environmentally friendly transport modesiii, impacts on biodiversity), social policy (e.g. accessibility of transport, health effects), cohesion policies, the economy, or innovation policies.

To address these kind of multi-issue, multi-stakeholder optimisation processes a dedicated 5-step approach has been developed by Hijdra et al (2017) on the basis of best practices encountered in the field. Basically, this model aggregates the rational economic core elements of value creation in negotiation theory, transaction cost theory and design theory. Negotiation theory elegantly shows how to increase value in situations with a wide variety of actors and interests, transaction cost theory provides a way to economise on the institutions involved and design theory helps moulding a physical reality delivering maximum results. In practice, steps will blend together to some extent, but for clarity purposes these have been framed in 5 steps.

In step 1, the starting point is identified. Although many perspectives are available on how capital investments are initiated, practice shows that for the vast majority there needs to be a significant problem calling for action. Often it is the asset manager signaling such problem, but the asset owner or service provider (sometimes pushed or encouraged by other stakeholders) could also ignite the process of seeking adaptation/expansion/improvement of the network.

- What is the issue moving an agency towards action?;
- what is the formal interest to be served in order to make the asset owner, asset manager and service-provider successful?
- how is this interest related to interests of others in the context? are questions to be answered here.

In step 2, the process of optimisation takes place. Network adaptations do not take place isolated from their context, and will inherently relate to other networks, their immediate surrounding and a wide set of other interests. This calls for a set of agreements (with municipalities, provinces, water-floodprotection agencies, , ministries of environment, cities, and other infrastructure operators) to realise well-embedded, well-balanced and integrated solutions. The available options are to be identified and evaluated upon potential for delivery of service, appreciation in a broad sense and (negative) externalities. These agreements can, for instance, include cross modal or cross border institutional arrangements involving municipalities, provinces or national agencies. Both benefits and costs of transactions for potential mutual gains are to be taken into account.

In step 3, the design process, is defined which design has the potential to deliver most value and value-capturing opportunities as emerging from the deals made in step 2. Fundamental different design approaches exist (adaptive design, participatory design, value engineering, architectural/landscape design to name a few) that lead to different outcomes on the basis of the same input.

In step 4, the value capturing process is realised. In the end, each involved agency seeks to get maximum return on the resources invested. Usually the majority of resources invested come from the asset owner with the intent to solve a specific problem (e.g. NRA, NIA). However, contemporary infrastructure projects commonly use sources of co-funding from all sorts of actors (with the intent to get a return on this, monetary or non-monetary). Value capturing opportunities largely depend on both step 2 and step 3. Going back and forth through these steps with a light approach would be a practical way to gain understanding of effective routes to investigate more thoroughly.

In step 5, the realism of potential value and cooperative options is checked. Mutual gains are often identified on paper, but willingness of partners to join in depends on more issues than a projected mutual gain alone. These partners might, for instance, have limited resources, which restrict them from entering into a partnership. Or in other cases, they just have better opportunities for which they would like to use their resources.

This 5-step process will be described in detail in Deliverable 1.2.

3.3 RESILIENT AND SUSTAINABLE NETWORKS

The environmental, economic, and social impact of the transport system is immense. Transport systems and infrastructure has become a crosscutting political issue. It is related to energy and economic policy, social policy, health policy, environmental and climate policies, among others. Thus, sustainable infrastructure development needs to balance the respective policy objectives in order to avoid trade-offs and to enhance synergies and co-benefits between these policies. On the other hand, this means that transport systems may also be targeted by environmental, economic and social policies. A forward-looking management of infrastructure assets needs to anticipate potential demands from these policy fields.

Availability of reliable transport systems is vital for the functioning of the increasingly interdependent economy and the maintenance of cross-border supply chains. With technological development and an increasing degree of complexity, transport systems themselves have become even more vulnerable to disruptions – be it natural and man-made disasters such as the effects of climate change, disruptions in power supply or disturbances of ICT systems. Thus, transport systems have become more vulnerable to disasters, and at the same time, the potential impact of disasters has grown.

The **resilience** of the transportation networks can be defined as ‘‘the intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions’’ (Hollnagel, 2011). In other words, it is the ability of transportation systems to retain performance during and after disasters, undergoing little to no loss of performance, and their ability to return to the normal state of operation quickly after disasters, that defines their resilience. Hollnagel (2011) phrases this in terms of four cornerstones of resilience (Figure 2): knowing what to do, what to look for, what to expect, and what has happened.

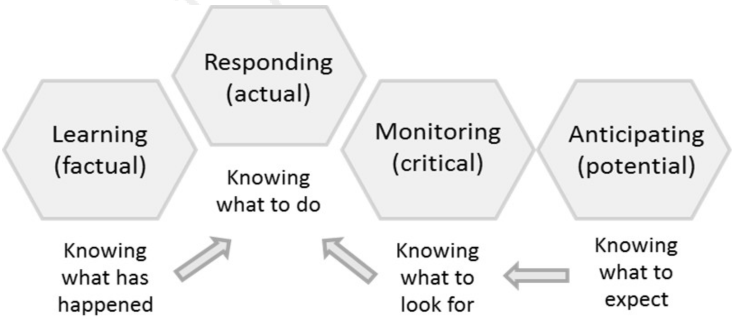

Figure 2: The four cornerstones of resilience, Hollnagel (2011)

Hence, the concept of resilience is broad and from the transport system’s perspective may cover various factors, extending from natural disasters to covering the capacity of public, private and civic sectors to withstand disruption, absorb disturbance, act effectively in a crisis, and adapt to changing conditions, including climate change, and growth over time. Two main dimensions could be identified according to Bruneau et al. (2003):

1. **Technical dimension:** The ability of the physical system(s) to perform to an acceptable/desired level when subject to a hazard event.
2. **Organizational dimension:** The capacity of an organization to make decisions and take actions to plan, manage and respond to a hazard event in order to achieve the desired resilient outcomes.

Each dimension has three core principles (with a range of indicator subsets) that help define resilient organisations,which are proposed to form the basis of the framework to measure the resilience of the transport system. These principles are described in Table 1 below. Furthermore, a resilient organisation is one that is *'still able to achieve its core objectives in the face of adversity'* (Seville et al., 2006). There are three aspects to building resilience in organisations: a) reducing the size and frequency of crises (vulnerability), b) improving the ability and speed of the organization to manage crises effectively (adaptive capacity), and c) an acute awareness of risk and an ability to manage strategic risks as a process and not an event.

Table 1: Proposed principles of resilience for the transport system

Dimension	Principle	Definition
Technical	Robustness	Strength, or the ability of elements, systems and other units of analysis, to withstand a given level of stress or demand without suffering degradation or loss of function
	Redundancy	The extent to which elements, systems, or other infrastructure units exist that are substitutable, ie capable of satisfying functional requirements in the event of disruption, degradation, or loss of functionality
	Safe-to-fail	The extent to which innovative design approaches are developed, allowing (where relevant) controlled, planned failure during unpredicted conditions, recognising that the possibility of failure can never be eliminated. This may involve new approaches to design, to complement traditional, incremental risk-based design
Organisational	Change readiness	The ability to sense and anticipate hazards, identify problems and failures, and to develop a forewarning of disruption threats and their effects through sourcing a diversity of views, increasing alertness, and understanding. . Also involves the ability to adapt (either via redesign or planning) and learn from the success or failure of previous adaptive strategies.
	Networks	The ability to establish relationships, mutual aid arrangements and regulatory partnerships, understand interconnectedness and vulnerabilities across all aspects of supply chains and distribution networks, and promote open communication and mitigation of internal/external silos.
	Leadership and culture	The ability to develop an organisational mind-set/culture of enthusiasm for challenges, agility, flexibility, adaptive capacity, innovation and opportunity taking.

Source: Hughes and Healy (2014)

Resilience of infrastructures may also comprise the adaptability to technological innovation., and changing societal needs and political environments (e.g. political regulations). This is especially important since the environmental, economic, and social impact of the transport system is immense. Consequently, transport systems and infrastructure has become a crosscutting political issue. It is related to energy and economic policy, social policy, health policy, environmental and climate policies among others. In the medium- to long-term, infrastructure systems that do not correspond to the external demands from civil society and politics may become obsolete (e.g. replaced by other systems) or their adaptation may be cost-intensive. On the other hand, infrastructures can also foster innovations (by avoiding lock-in effects) and thus contribute to social value creation. Thus, a sustainable and resilient infrastructure development needs to anticipate and balance the respective policy objectives in order to avoid trade-offs and to enhance synergies and co-benefits between these policies.

4 Framework architecture

In the previous sections, major elements of a framework architecture have been described. These issues address both existing networks as well as capital investments. The concepts are not exclusive for a specific type of transport network, but relate to all types like roads, rail and waterways. These systems also provide vital linkages for ports and airports, linking all surface and non-surface modalities together. These elements have been structured in a framework (figure 3). The logic of the framework follows the elements as described in Chapter 3:

1. Asset management is the foundation of the system. By balancing performance, costs and risk the aim is to optimise the service to the public given the available resources. By defining an asset owner, an asset manager and service provider role, responsibilities and tasks are clear. At some point, the owner, the asset manager or the service provider may encounter a situation that requires new investment. Preliminary studies, cost benefit analysis and other commonly used methods can determine a rational background; politicians could be following a path parallel to this rationality.

2. When, according to (national) regulations, it is determined that the problem needs to be tackled, the scoping of the project will take place. This is a crucial step in the process, where the scope determines to what extend elements of the problem, the entire problem, or the wider context of a problematic region, are addressed. Here lies the opportunity to determine the best value proposition for the agency and for society in a broader sense (see 5-steps in section 3.2), ensure mobility and transport is efficiently and effectively accommodated, (negative) externalities are minimised and effective institutional arrangements are selected.

3. Common concepts like use of data, resilience and sustainability will have to be taken into account in all steps of network management, network enhancement and network expansion.

The above mentioned three elements are shown in a generic framework architecture in figure 3.

In a more generic way the framework can be seen as: there needs to be a problem to initiate action, integrated planning taking into account synergies delivers value, and sectoral (by road, waterway of railroad agencies) implementation and operation (for each individual sector) spurs effectiveness and efficiency.

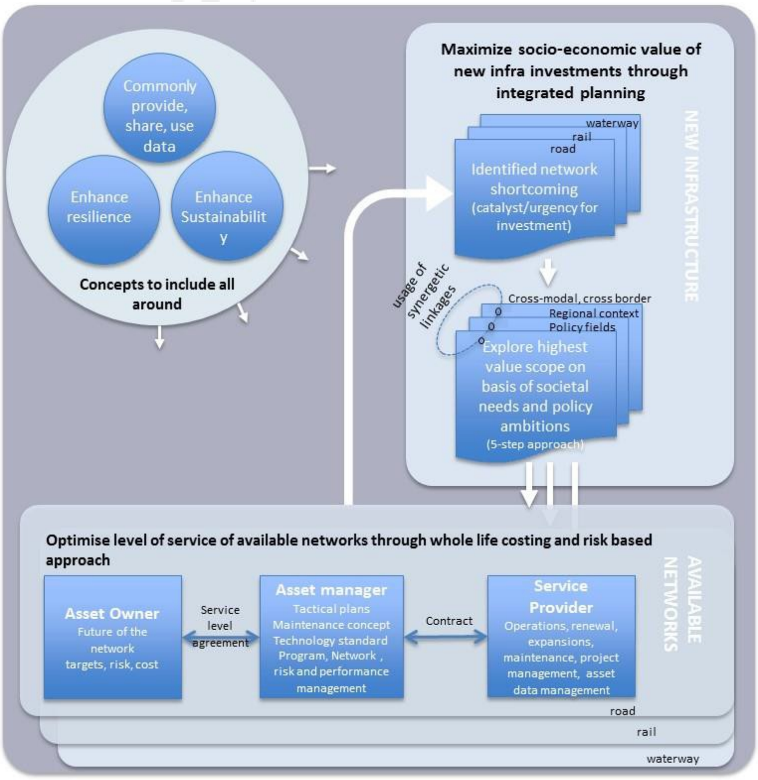

Figure 3: Framework architecture 1

5 Concluding remarks

The framework architecture for smart governance of infrastructure networks can be considered as a generic canvas that enables agencies to find common ground. The National Infrastructure Agencies have to deal with political dynamics and policy ambitions related to new infrastructure, which is a different action arena than provision of service and maintenance and operation of available networks.

Secondly, although some infrastructure agencies have multiple modalities in their portfolio, many agencies mange and assign responsibilities for different modes in isoloation. a sectoral assignment. National or international institutional frameworks do not currently optimise the entire system of networks holistically. The provided framework architecture does recognise the interlinkages and provides an entry to take synergetic behavior of networks into consideration.

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[i] https://people.hofstra.edu/geotrans/eng/methods/levelservice.html

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iiihttp://www.eea.europa.eu/downloads/5a048b3109c14d6e9357c54ec4be6902/1480583876/assessment-3.pdf