Orchestra

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ORCHESTRA Project Deliverable: D3.1

Initial use cases for multimodal traffic management

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About ORCHESTRA

The long-term vision of the ORCHESTRA is a future where it is easy to coordinate and synchronise the traffic management of all modes to cope with diverse demands and situations. Also, to facilitate optimal utilisation of transport networks and efficient multimodal transport services, both in rural and urban areas.

The project will:

- Establish a common understanding of multimodal traffic management concepts and solutions, within and across different modes, for various stakeholders and multiple contexts
- Define a Multimodal Traffic Management Ecosystem (MTME) where traffic managements in different modes and areas (rural and urban) are coordinated to contribute to a more balanced and resilient transport system, bridging current barriers and silos
- Support MTME realisation and deployments, through the provision of tools, models, and guidelines – including support for connected and automated vehicles and vessels (CAVs)
- Validate and adjust MTME for organisational issues, functionality, capability, and usability
- Maximise outreach and uptake of project results through strong stakeholder involvement

The project will provide a Polycentric Multimodal Architecture (PMA) that specify how diverse system components collaborate and interact, taking into account smart infrastructures, technical and organisational aspects and polycentric governance. The PMA will be supported by: 1) Enabling toolkit, 2) Deployment toolkit, 3) Documented lessons learned.

The project will validate the PMA and related tools and toolkits in two Living labs (in Norway and Italy), collectively covering both road, rail, water, and air transport. The Italian Living lab is focusing on traffic orchestration for the mobility of people, while the Norwegian Living lab is focusing on traffic orchestration for freight. The Living labs will be supported by simulations to enhance evaluations.

Legal disclaimer

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Executive Summary

The report covers initial parts of the ORCHESTRA Polycentric Management Architecture (PMA) and specifies how the concept of multimodal traffic management (MTM) and the multimodal traffic management ecosystem (MTME) fit into the transport domain. The PMA is a Reference Architecture. This means that it aims to guide the creation of individual system architecture for a family of systems that fit into the ecosystem.

The PMA is intended to specify a full-fledged implementation for the MTM concept. Being the initial version of the PMA, this report aims to support the understanding of the MTM concept and the related functionality.

The System of Interest, in this case the family of systems that are specified in the PMA, is defined as well as its overall concerns, which are sustainability, polycentricity, multimodality, resilience, and business neutrality. An overall concepts model is also provided to support an initial understanding of what MTM is about.

The initial version of the PMA includes two viewpoints - the motivation view and an initial version of the context view. The latter will be further elaborated in the next versions of the PMA (ORCHESTRA deliverables D3.2 and D3.3)

The motivation view includes ArchiMate motivation models that describe the rationale for the PMA. The content of the models is established in collaboration with real stakeholders and experts in the transport domain. The stakeholder archetypes directly involved in the System of Interest as well as other stakeholder archetypes in the MTM ecosystem are identified and defined. Motivation models address the motivations for a change towards MTM for the main stakeholders. These are

- Transport Service Provider: Provides transport services to transport users. A service may integrate transport legs from several modes.
- Fleet Operator: Operates a fleet and manages the transport operations needed the transport chains composed by the transport service provider.
- Network User: The transport means and/or its operator. Carries out transport operations managed by the Fleet Operator.
- Traffic Orchestrator: Responsible for the multimodal traffic management.

For each main stakeholder type, a motivation model identifies the drivers for a change towards MTM and performs assessments of the status with respect to the drivers. Another model provides an overview of the goals liked to the drivers. Altogether, the motivation view provides insight into concrete motivations that as far as possible should be met in successful implementation of MTM.

The initial version of the context view describes the functionality of the System of Interest, from the view of the main stakeholders. For the Transport Service Provider, Fleet Operator, and Network User, the functionality is limited to the interactions with the Traffic Orchestrator. The functionality of the Traffic Orchestrator is emphasized since this is the functionality that supports the multimodal traffic management. It includes:

- Data management and governance: Real-time data, plans, and predictions (for transport operations included) are monitored to create a basis for traffic orchestration decisions. Data is also shared with other stakeholders so that they can adapt their plans and operation to current and foreseen situations.
- Decision support and decision making: Based on the monitoring, decisions are supported in different ways – predictions, simulations, artificial intelligence, dashboards, etc. Decisions for the handling of current and upcoming situations, accidents and disruptions are taken to facilitate resilience.
- Traffic orchestration: The transport demand management and demand capacity balancing measures decided are linked to the network and the smart infrastructure to facilitate automatic, semi-automatic, and manual measures. When needed, the use of capacity is coordinated across networks and modes. Transport operations may be transferred to other networks and modes, and the Transport Service Providers and Fleet Operators are also involved in the coordination.

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List of Abbreviations

Table 1: List of abbreviations

Abbreviation	Explanation
ATM	Air Traffic Management
CAV	Connected and automated vehicle/vessel
C-ITS	Cooperative Intelligent Transport Systems
CoP	Community of Practitioners
IEEE	Institute of Electrical and Electronic Engineers.
MaaS	Mobility as a Service
MTM	Multimodal Transport Management
MTME	Multimodal Transport Management Ecosystem
NGO	Non-governmental organization
OEM	Original Equipment Manufacturer
PMA	Polycentric Multimodal Architecture
UBL	Universal Business Language
UML	Unified Modelling Language
UTM	Unmanned Aircraft System Traffic Management

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List of Definitions

Table 2: List of definitions

Definition	Explanation
Mode	Road, sea, rail, or air. Within some of these, there might be sub-modes. In general, the traffic orchestrator address one mode, which may include sub-modes (e.g., bike, bus, car, etc. for road). If a sub-mode (e.g., light rail) is managed as a separate network, the sub-mode is considered as a mode.
Network	A transport network has a mode and the traffic in the network is managed in one or more governance areas.
Reference architecture	An architecture description being a blueprint guiding the creation of individual system architecture descriptions for a family of systems. Will among other define the reference functionality.
Reference functionality	Reference functionality is core functionality that should be addressed by system instances compliant with the System of Interest. The detailed functionality (e.g., the user interface) may however vary depending on the realisation. The reference functionality can be used as a blueprint to make a starting point for the definition of the more detailed functionality to be implemented by real system components.
Resilience	The definition we use in this report is: *"A system is resilient if it can adjust its functioning prior to, during, or following events (changes, disturbances, and opportunities), and thereby sustain required operations under both expected and unexpected conditions*." [2]
Use case	The term "use case" is used in the title of this deliverable according to the convention within software engineering. In this context, a "use case" describes how a system will be used and its functionality. Such "use cases" specify (and model) the functionality of a system. Since the above definition deviates from the use of the "use case" term in other contexts (where the term is used about an example implementation or a pilot), *we avoided to use the "use case" term in the content of this deliverable. Instead, we use the term "functionality".*

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1 About this Deliverable

1.1 Why would I want to read this deliverable?

This report covers initial parts of the ORCHESTRA Polycentric Management Architecture (PMA). It describes the system of interest with respect to a multimodal traffic management (MTM). This includes the stakeholders involved and their concerns, the context of the system, and the functionality needed by the stakeholders.

In MTM, the traffic is managed and orchestrated within as well as across network and modes, to be optimal to the society. This means that the traffic flows and the network capacities are coordinated and balanced in a holistic and resilient way across the networks and modes. The resilience is about an adaptable capability to prevent and early detect abnormalities and disruptions, as well as to response to and recover from perturbations in the traffic. The use of Automated and Connected Vehicles/Vessels (CAVs) in such a setting is also emphasized.

This initial version of the PMA will constitute a basis for the intermediate and final versions of the PMA deliverables (D3.2 and D3.3).

1.2 Intended readership/users

This report is relevant to all project partners of ORCHESTRA involved in the conceptualization and implementation of MTME. In addition to defining the most important concepts and terms of relevance to multimodal traffic management, the models outline the relations between them. Thus, the models presented may be of interest to academia from diverse disciplines focusing on aspects of a socio-technical system.

The report may be of interest to the Community of Practitioners (CoP) members in ORCHESTRA, constituting relevant stakeholder types. The CoP is engaged in workshops to endure the relevance of elements of the ecosystem. They have also provided input to the report. Further, the report may be of interest for significant stakeholders in all transport modes (sea, rail, road, and air), e.g. service providers, traffic managers, infrastructure managers, regulators, technology providers.

1.3 Other project deliverables that may be of interest

The deliverable has relations to other ORCHESTRA deliverables.

Inputs are used from:

- D2.1 "Initial target vision"
- D2.2 "Pre-Studies on environment analysis and drivers"

Outputs will be to:

- D2.3 " Initial scenarios for multimodal traffic management "
- D3.2 "Intermediate Polycentric Multimodal Architecture (PMA) for multimodal traffic management"
- D3.3 "Final Polycentric Multimodal Architecture (PMA) for multimodal traffic management"
- D4.1 " Initial version of technical tools"
- D5.1 " Simulation Architecture"

The most recent version of the models is available in a HTML version at the following link. Note that these may have been updated since the publishing of this report:

https://h2020-orchestra.github.io/TrafficManagementArchHTML/

The version corresponding to this deliverable is available at:

https://h2020-orchestra.github.io/TrafficManagementArchHTML/v1.0.html

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1.4 Involvement in work

Partners involved in this report are SINTEF, ITS Norway (ITSN), TU Delft (TUDELFT), the Norwegian Public Roads Administration (NPRA), and HES-SO.

SINTEF has been leader of the work and the main author of the deliverable. ITS Norway has provided input regarding the functionality needed by the Fleet Operator. TU Delft has provided input on the functionality needed by the Transport Service Provider, and they have also provided much of the content on resilience. HES-SO has provided input on the functionality needed by the Network User. NPRA has provided input on the functionality needed by the Traffic Orchestrator and the traffic management in general. All participants have comments upon the content of the deliverable.

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2 Background

2.1 Purpose of the architecture

Purpose of architectural descriptions: Every system has an architecture. The purpose of an architectural description is to document important parts of the architecture and its background, so that it can be understood by developers and others that has an interest in the system. To this end, the architectural description should describe the elements of the architecture, their relationships and properties, but also the stakeholders, motivation, context, functions, concepts, and principles behind the architecture that explains why it is designed like it is. Architectural descriptions can be used to document an existing system, but they can also be used to describe and agree upon blueprints for new concepts or as part of standardisation efforts for domains or systems such as multimodal traffic management.

Purpose for the domain: The architecture description provided in this deliverable specify how the concept of multimodal traffic management (MTM) and the multimodal traffic management ecosystem (MTME) fit into the transport domain. The architecture description also supports the understanding of the MTM concept and the realisation of it by means of the new and/or added aspects that facilitate the implementation of the system of systems that realise the MTM concept.

The architecture description shall serve as a blueprint for further work on the MTM concept and planning and construction of systems and/or system components (new as well as modifications and extensions of existing systems) that together realise the concept. *The architecture described by this deliverable is a **Reference Architecture** and not a system architecture for a specific system*. The Reference Architecture aims to guide the creation of individual system architecture to arrange for integrations into the ecosystem.

It is important to note that the architecture content cannot enforce a particular structure on the systems participating in the ecosystem. The main issue is to describes how the systems should collaborate to implement the concept. Details for the individual systems (e.g., internal databases, the functionality of the user interfaces, design choices, etc.) are not covered, as such decisions are taken by individual system providers.

Purpose for the project: The architecture description specifies MTM solutions in terms of modified and/or added responsibilities and collaboration patterns needed. It supports a common understanding of the MTME and the MTM concept that is crucial to the project. It also supports the realisation of new tools and models that support the implementation of the concept.

The architecture description addresses a full-fledged implementation for the MTM concept. ORCHESTRA will not implement such solutions, just tools that support aspects of the solution. The full-fledged scope of the architecture description is necessary for the ability to serve as basis for future exploitation and deployment of the MTM ideas.

2.2 Use of existing models and architecture frameworks

The ORCHESTRA architecture addresses a multimodal traffic management (MTM) and the ecosystem in which it operates. The system of interest is not one particular system but a family of systems. A search for literature of relevance to such an architecture is carried out (SCOPUS search in titles, abstracts and keywords on: *architecture AND multimodal AND "traffic management")*. Five scientific articles were identified as interesting, of which none were of relevance to this project. In general, the focuses of the articles were on limited and technical problem areas and not on an architecture for the MTM ecosystem. A wider google search was also done, but no relevant results were found except for a few of those mentioned below (which we already know about)

- ARKTRANS [ARKTRANS] is a reference architecture for the transport domain. It is multimodal, meaning that the specifications provided are common to all modes, and is covers both freight and person transport. The development of our architecture is based the conceptual specifications of the transport domain.

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- Common Framework [Common Framework] is the Common architecture for ICT in transport and logistics, and it builds upon ARKTRANS. It is also multimodal, and it provides detailed specifications for freight transport that we can build upon and develop further.
- "ISO/IEC19845 Information technology — Universal business language version 2.1 (UBL v2.1)" includes the information models defined in the Common Framework and define messages that support a digitalisation of the transport chain management. The information models provide details on transport chains, transport operations, and the cargo transported, and will be considered for re-use in the work on the PMA.

3 Approach

3.1 Methods for data collection and analysis

3.1.1 Workshops providing input on the Motivation view

The content of the motivation view in Chapter 5 is established from input from several workshops:

1. **Stakeholder types -** Internal, online workshop. Work package participants provided input on stakeholders of relevance to the multimodal traffic management ecosystem (MTME). The online tool Miro was used to collect input on stakeholders of relevance to the MTME regarding the transport of freight and passengers, traffic management, and societal issues.
2. **Motivational models -** Internal, online workshop with work package participants. Initial motivation diagrams include four stakeholder types (Traffic Orchestrator, Transport Service Provider, Fleet Operator, and Network User) were presented, discussed, and refined.
3. **Freight transport (Norwegian Living Lab)** – Face-to-face workshop at the Herøya with external participants (from the CoP and others). The World Café approach were used to collect input on motivation diagrams. There were one café table for each stakeholder type (Traffic Orchestrator, Transport Service Provider, Fleet Operator, and Network User). A table host managed the activity at each table and collect the input provided. The workshop participants were divided into four groups. Each group started at one table and work there for 20 minutes before they moved to the next table, and so on until all groups had visited all tables and discussed the motivation diagrams for all stakeholder types. The table host started each session by summing up the results achieved so far. In the following sessions, the results from the previous group(s) included.
4. **Passenger transport (Italian Living Lab) –** Face-to-face workshop in Milan with external participants (from the CoP and others). The approach was the same as for workshop 3 at the Norwegian Living Lab.

3.1.2 Data analysis

The input from the internal stakeholder workshops was analysed, and the generic stakeholder types in section 5.1 were identified. It was verified that the generic types covered all suggested stakeholders, and the result was also verified through an alignment with related work (the ARKTRANS and Common Framework architecture descriptions).

After each of the freight and passenger workshop, the results were analysed, and the generic stakeholder types and motivation diagrams were updated to cover all relevant aspects. The results from the freight and passenger workshops (workshop 3 and 4) were harmonised into one set of diagrams. Concerns regarding the inclusion and exclusion of the input provided were:

- Only input of relevance to the target stakeholder type were included.
- Input targeting issues already addressed were, if possible, merged with existing content.
- Input regarded as comments were included in descriptions of existing elements.
- Input that could not be interpreted were excluded.

Input that was out of scope of the system of interest (see section 4.1.1) were excluded. This was content not targeting traffic orchestration, and related data governance, network management, and traffic orchestration supporting fleet operators and transport service providers.

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3.2 Approach for architecture description

To structure and guide the architectural description, we have decided to use the open architectural description framework ARCADE[1] and the standard "ISO/IEC/IEEE 42010 Systems and software engineering - Architecture description".

3.2.1 Assets used in this architecture description

This architectural description uses and/or relates a set of existing assets that has structured, assisted, or otherwise guided the work. These assets are described in the following table.

Asset	Description of the asset	Use / relation to this work
	Architectural Description Frameworks	
ARCADE	ARCADE is a domain and technology independent architectural description framework for software intensive systems. ARCADE is based on IEEE 1471-2000, and defines a set of viewpoints and models http://arcade-framework.org/	This architectural description builds on the ARCADE framework. The document structure, and the viewpoints and models used are based on ARCADE as further described in section 3.2.3.
	Standards for Architectural Description	
IEEE 1471-2000	IEEE 1471-2000 Recommended Practice for Architectural Description for Software-Intensive Systems. Defines a set of concepts for architectural descriptions, such as stakeholder, system, viewpoints, architectural description. https://standards.ieee.org/ieee/1471/2187/	The architectural concepts of this document build on its successor, IEEE 42010. ARCADE is based on this IEEE 1471-2000.
ISO/IEC/ IEEE 42010	ISO/IEC/IEEE 42010 Systems and software engineering - Architecture description. This revises and extends IEEE 1471-2000 and define a set of concepts used for architectural description. https://standards.ieee.org/ieee/42010/5334/	The architectural concepts used in this document build on IEEE 42010. This is further described in section 3.2.2.
	Modelling Language Standards	
ArchiMate	ArchiMate is a standard of The Open Group and specifies the ArchiMate Enterprise Architecture modelling language. The modelling of aspects of relevance to enterprise architectures is supported by a graphical modelling notation. https://pubs.opengroup.org/architecture/archimate3-doc/	ArchiMate is applied as a modelling notation for the motivation view and context view in this document.
UML	The Unified Modelling Language (UML) is a modelling language standardized by the Object Management Group (OMG). UML includes 13 diagram types for modelling structure, behavior and interaction, including Use Cases Diagrams, Class Diagrams, Component Diagrams, Activity Diagrams and Sequence diagrams. https://www.uml.org/	The motivation and context viewpoints provided in this document use ArchiMate, and not UML, for the models. The next iteration of this work will add other viewpoints from ARCADE, and for these UML is planned to be used.

[1] http://arcade-framework.org/

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3.2.2 Architecture concepts

The ORCHESTRA architecture description follows the guidelines provided by the standard "ISO/IEC/IEEE 42010 Systems and software engineering - Architecture description". This includes a set of concepts depicted in Figure 1 and Figure 2.

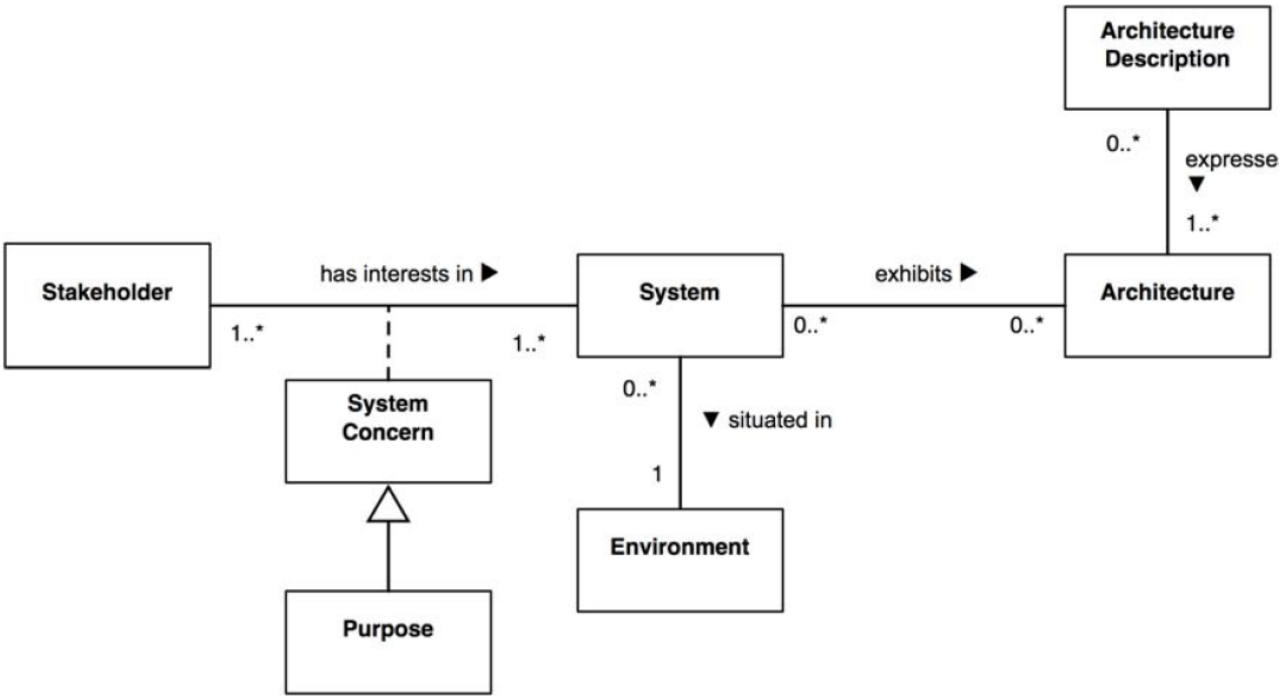

Figure 1: Context of architecture description [IEEE 42010-2011]

The concepts defining the context for architecture descriptions in general (Figure 1) include:

- A **system** is man-made and consists of one or more of the following: hardware, software, data, humans, processes, procedures, facilities, materials and naturally occurring entities [IEEE 42010-2011].
- A **stakeholder** is an individual, team, organization, or classes thereof, having an interest in a system [IEEE 42010-2011].
- A stakeholder's interest in a system is linked to the **purpose** the stakeholder ascribes to the system [IEEE 42010-2011]. The purpose is a sort of **system concern**, i.e., an interest in a system**.**
- A system operates in an **environment.** The environment is the context determining the setting and circumstances of all influences upon a system [IEEE 42010-2011]. It includes everything that is not a part of the system, and which interfaces the system of interest directly. This includes both stakeholders and other systems. A system acts upon its environment and vice versa.
- A system always has an **architecture**. It is the "fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution" [IEEE 42010-2011].
- The architecture is expressed in an **architecture description** [IEEE 42010-2011]. All systems have an architecture, but they may not have an architecture description.

In ORCHESTRA, the system is not one specific system but a family of systems doing and supporting traffic orchestration, and the system and its environment constitute a multimodal traffic management ecosystem (MTME). The stakeholders are archetypes – thus we talk about stakeholder types.

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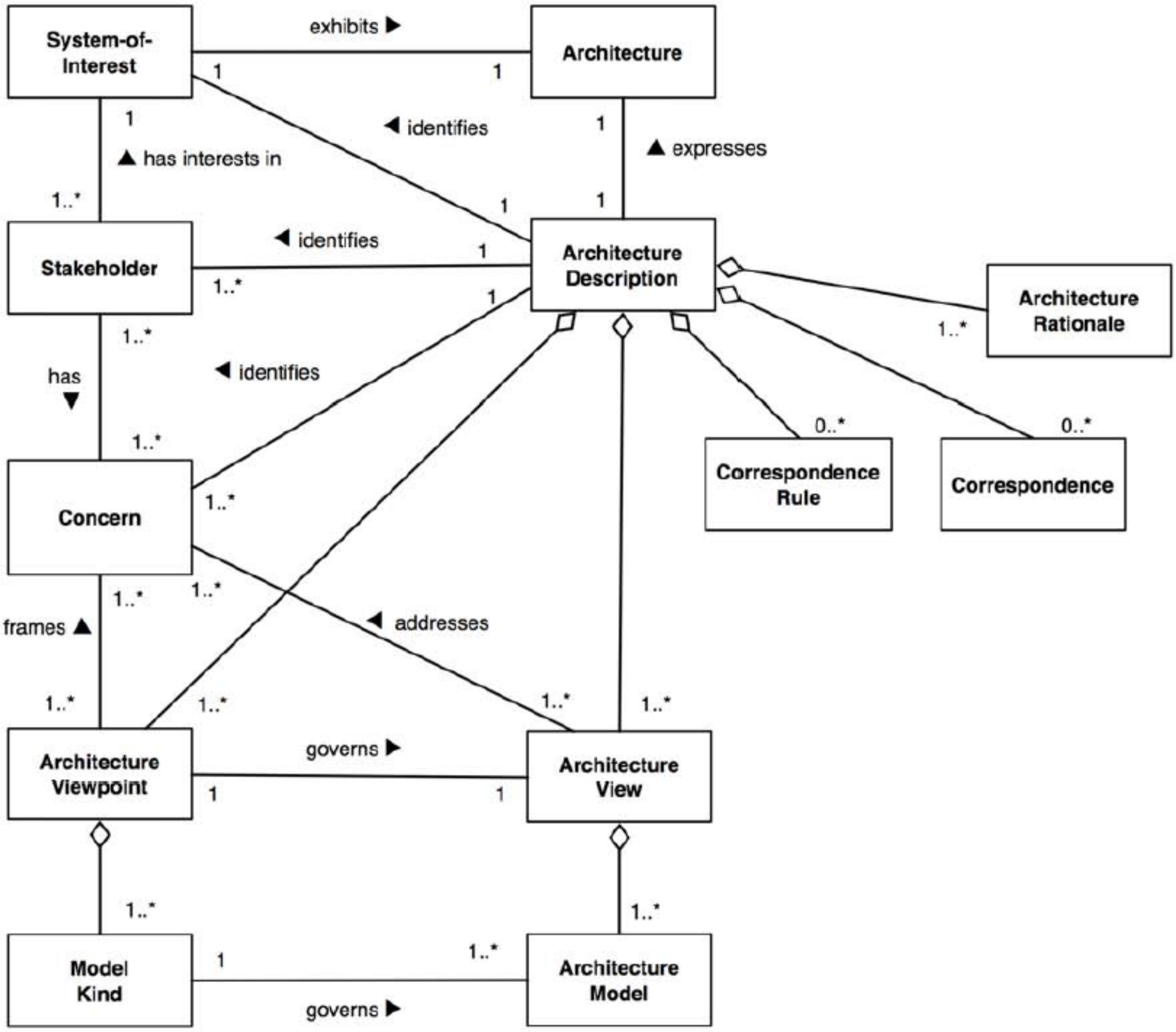

Figure 2: Architecture concepts [IEEE 42010-2011]

Figure 2 provides additional architecture concepts, building on those in Figure 1. The architecture description contains:

- Description of the **system of interests**. This is the system (see above definition) whose architecture is expressed in the architecture description
- Descriptions of relevant **stakeholders** (see above definition)
- Descriptions of relevant **concerns**. A concern is an "interest in a system relevant to one or more of its stakeholders" [IEEE 42010-2011].
- **Architecture views** expressing the architecture of a system from the perspective of specific system concerns [IEEE 42010-2011]. An architecture view consists of one or more architecture models to address aspects of relevance in an architecture view. An **architecture model** uses modelling conventions established by its model kind [IEEE 42010-2011].
- A **model kind** defines "conventions for a type of modelling" [IEEE 42010-2011]. This may for example be the notations and languages to be used.

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- **Architecture viewpoints** specifying the conventions for constructing, interpreting, using, and analysing one type of architecture view [IEEE 42010-2011]. It identifies the model kinds to be used to frame the relevant set of concerns.
- **Architecture rationale** explains and justify the architecture decisions.

The ORCHESTRA architecture will include several viewpoints and model kinds, as described in section 3.2.3. The system of interest and overall concerns are described in Chapter 4. The stakeholders are defined in section 5.1.

3.2.3 ARCADE and viewpoints used in this document

ARCADE (http://arcade-framework.org/) is an architectural description framework developed by SINTEF. It has been applied and refined through several EU and national research projects. ARCADE is based on the architectural description standard IEEE 1471-2000.

ARCADE defines a set of viewpoints and can be regarded as a kind of template for what to include and how to structure an architectural description. The viewpoints currently defined by ARCADE are:

- *Context*: Together with the requirements viewpoint, the Context viewpoint focus on the *"what"*-part of the architecture. The viewpoint describes the functionality needed by the stakeholders interacting with the system of interest, environment systems of relevance for the system of interest, and mapping of which functionality belongs to the system of interest and environment systems.
- *Requirements*: This describes the functional and quality related requirements of the system. The requirement view is usually described using tables containing requirement id, description, priority, and acceptance test (when relevant). UML diagrams can be used to provide further details, e.g. of interfaces to environment systems.
- *Component*: This covers the *"how"*-part of the architecture. Describes how the system of interest can be decomposed into components, the interface between these components, the information handled by the system and its components, and interactions between the components. Various UML diagrams are used, including component diagrams, class diagrams, sequence diagrams and activity diagrams.
- *Distribution*: This describes the *"where"* of the architecture. Logical distribution of components and roles are described, typically using UML deployment diagrams.
- *Realisation*: This describes more details on how and where, including mapping to realisation technology and concrete deployment. This viewpoint is out of scope for ORCHESTRA.

Viewpoints used in this document:

- *Motivation*: The Motivation viewpoint has of focuses on the *"why"*-part of the architecture. It describes the stakeholders involved, their drivers with assessments of these, and high-level goals. It can also play a role in describing the architecture rationale. A Motivation viewpoint is a not yet defined in ARCADE. In this document the viewpoint uses the motivational elements of ArchiMate for its description and corresponds to the Stakeholder viewpoint of ArchiMate. (See Annex A for more details on ArchiMate).
- *Context*: In this document, the context view of the main stakeholders identified in the Motivation view, using ArchiMate Business Layer model elements. ArchiMate was chosen to have a good continuation from the Motivation view. The Business Layer model elements of ArchiMate cover some of the same aspects as Use Case models would do in UML, but also with some differences. In the context view models of this document, we have in the functionality models for the main stakeholders also identified the mapping for which functionality is inside and outside the scope of the system of interest. Description of environment systems and mapping to these will be considered in later versions of the architecture.

In later versions, the ORCHESTRA architecture described in this document will be revised and extended to also include the following viewpoints: Requirements, Component, and Distribution. The Realisation viewpoint is out of scope for the ORCHESTRA reference architecture.

ARCADE is currently being updated and revised. The planned updates include revisions to use IEEE 42010-2011 in place of its predecessor IEEE 1471-2000, addition of a motivation viewpoint, and revisions to

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recommend use ArchiMate as a supplement to UML for some of the viewpoints. Experiences from developing the motivation view and context view in this document will be used as input for the revision of ARCADE.

4 System and architectural overview

4.1 System of interest

It is important to notice that the System of Interest (SoI) addressed by the specifications of this deliverable is not a physical system. As described in section 2.1, the architecture description is a Reference architecture for a Multimodal Traffic Management Ecosystem (MTME) that can be used as a blueprint for many different systems. Thus, *the System of Interest is a family of systems that together constitute a MTME.*

4.1.1 System of Interest in MTME

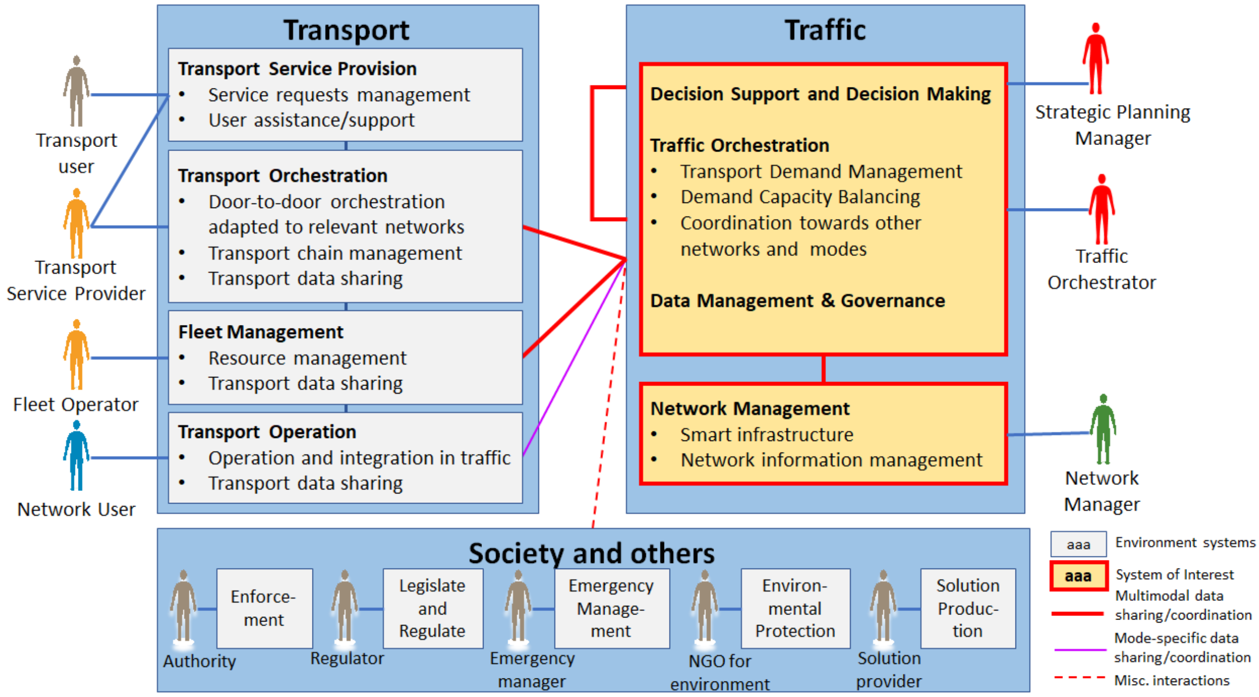

Figure 3: Multimodal Traffic Management Ecosystem (MTME) with System of Interest in its environment

Figure 3 provides an overview of the MTME. The System of Interest is the boxes with red boarders in the traffic part of the ecosystem and the red and purple links towards the transport part. The other parts of the MTME constitute the environment in which the System of Interest operates.

As shown in Figure 3, the **ecosystem** is divided into three areas with activities, described below: (1) Transport, (2) Traffic, and (3) Society and others. There may be many system instances for each activity. Many of them will have a defined governance area that for example will encompass one network and one mode. The governance areas will however interact to arrange for a more optimal transport system as a whole.

The **stakeholder** types depicted in the figure are further described in section 5.1. It is important to notice that one actor may cover several stakeholder types. A freight forwarder being a Transport Service Provider may for example also be a Fleet Operator operating own vehicles/vessels. A Mobility as a Service (MaaS) provider is a Transport Service Provider but may for example also be a Fleet Operator for a fleet delivering public transport.

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(1) Transport

Transport is about the transport of persons and/or goods from a start location to a destination by means of one or more transport legs that may be accomplished by several modes and in several networks. Many activities are involved and include:

Transport Service Provision: The Transport User has a transport demand (a travel or cargo transport) and selects the services needed. Several services from several Transport Service Providers may have to be combined to satisfy the demand. Composite and multimodal services are however emerging, and door-to-door transport chains may in principle be delivered by one service and one Transport Service Provider. The Transport Service Provider manages requests from Transport Users and supports the Transport Users during the transport. The Transport Service Provider also has dialogues with Transport Users, for example to agree on the transport alternatives to use and to provide support in case of deviations.

Transport Orchestration: The Transport Service Provider orchestrates transports requested by Transport Users. The preferred transport options are selected and combined into a transport chain that is needed to fulfil demands. This is done before the transport starts or dynamically on the way in case of deviations or changed demands. The demands from several Transport Users may be combined to arrange for more optimal transports. Cargo from several Transport Users may for example be consolidated (they are transported together), and passengers (that are Transport Users) will share the same bus or airplane. The transport chains are managed. Planned transport operations are initiated and followed up. Unplanned situations and deviations are handled, and in some cases the chains must be fully or partly re-planned.

Fleet Management: The Fleet Operator manages resources like personnel, vehicles/vessels, and space in vehicles/vessels and load units, and the resources are in transport operations that are legs in transport chains. The use of resources is planned to be as optimal as possible. One transport operation may for example handle transports requested by several Transport Service Providers and Transport Users. Optimal routes and possibilities for return loads are considered.

Transport Operation: A Network Users may be a pedestrian or an operator of a vehicle/vessel. With automation, the Network User may partly of fully be a system, e.g., a person supported by systems or a connected and automated vehicle (CAV). The Network Users may be on a private journey or carry out a freight or person transport operation on behalf of a Fleet Operator. Thus, Network Users may have different aims and preferences with respect to the journey. In any case, the use of the network must be adapted to the network regulations and conditions and to the traffic situation.

Links to other parts of the ecosystem: Transport Service Providers, Fleet Operators, and Network Users share data with the traffic part of the ecosystem. In return they will get information and support, and the transports will be influenced by the traffic orchestration to arrange for the best possible use of the whole transport system. The society and others will also affect the transports. Laws and regulations, and enforcement will for example influence the transport related tasks.

(2) Traffic

Traffic is caused by transports, and the aim is to influence, support and manage the traffic caused by transports to make it resilient, safe, and efficient, and to minimise the negative impacts on the planet, environment, and society. Activities involved include:

Traffic Orchestration: The traffic orchestration is managed by the Traffic Orchestrator and extends traditional traffic management with new measures for:

- *Transportation Demand Management* (TDM): The aim is to maximize the sustainability (efficiency, climate neutrality, inclusivity, profitability in coherence/balance/relation) of the transport system by discouraging/restricting unnecessary vehicle use and promoting/enabling more effective, profitable, healthy and environmentally friendly transport across all modes and infrastructure owners/Transport Networks.

- *Demand Capacity Balancing*. The aim is to cope with a current or upcoming situation with imbalance between the transport demand and the capacity of the network. Measures are taken to re-establish the balance.

The use of the transport network in general is managed as well as the use of limited network resources accessible by just one or a few Network Users at a time, e.g., loading bays, parking spaces, holding area, is also managed.

The traffic orchestration is supported by new tools and technologies, and the interactions with Network Users are to a large extent digital. Also in road transport, individual vehicles are controlled and not just the traffic flows.

To arrange for an optimal transport system as a whole, decisions and actions are coordinated across modes and networks. This is for example important in the case of deviations and disruptions in one part of the system. In such cases, other parts of the transport system may step in. The traffic orchestration must also facilitate smooth, efficient, and safe introduction of CAVs in the traffic, and thereby arrange for an acceptance of CAVs.

Decision Support and Decision Making: The Traffic Orchestrator will arrange for resilience using decision support that facilitate informed and pro-active decisions that will ensure normal deviations in addition to avoid or limit the effects of undesired events and accidents. In case of undesired situations and disruptions, such decisions are the basis for measures that support the transport part of the ecosystem to maintain the desired mobility of freight and persons.

Data Management and Governance: Data are the basis for the resilient and multimodal traffic orchestration described above. The Traffic Orchestrator manages historical traffic data as well as data about ongoing and upcoming transports received from the transport part of the ecosystem. Data from the Network Management (e.g., on network conditions and traffic situations) and external sources (e.g., for meteorological and hydrological data) will also be used. The Traffic Orchestrator uses the data in the traffic orchestration and shares relevant data and information with other modes, networks, and other governance levels, and also with the transport part of the ecosystem.

Network Management: The Network Manager manages the physical network infrastructures as well as digital, smart infrastructures. Static data describing the infrastructure is managed as well as dynamic, real-time data provided by the smart infrastructure. The latter collects data from sensors and Network Users. The data are used in the operation of the network (maintenance, etc.) and shared with others. Traffic orchestration decisions are to a large extent based on the data.

(3) Society and others

The MTM must collaborate with other domains and professional actors of the society to minimise the negative effects of the traffic and to handle situations and to align with the societal and technological development. This is also important for the general societal acceptance of MTM. Governance, laws, and regulations define the premises, and the laws and regulations area also enforced. The emergency management is handled in many different governance areas (local, regional, national, health, research and rescue, etc.), and preparedness/emergency plans and operations are coordinated across these areas. Environmental protection also has different governance areas (local, regional, national, public, private, sea, land, different types of emissions, etc.). Many solutions will support the transport and traffic parts of the ecosystem, e.g. solutions for smart infrastructures, technology and digital solutions for data collection, management and sharing, artificial intelligence for decision support, etc.

4.2 Overall concerns

The System of Interest (SoI) operates, as illustrated in section 4.1.1, has some overall concerns that must be addressed: Sustainability, polycentricity, multimodality, and resilience.

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4.2.1 Sustainability

The architecture must arrange for sustainability. This means that the architecture must include:

- **Properties expressing sustainability related aspects.** The architecture must support the expression of characteristics or properties of entities (vehicles/vessels, network segments, areas, etc.) in a way that facilitate decision according to policies.
- **Traffic measure mechanisms**. The measures must facilitate the implementation of policies regarding sustainability, e.g. transport demand management according to policies, reduced emissions of Co2 and other pollutions, and improved air quality.
- **Generic solutions**. The mechanisms specified must be generic so that measures can be defined and taken according to local policies.

4.2.2 Polycentricity

The SoI operates, as illustrated in Figure 3 in section 4.1.1, in a larger environment. The architecture must support environments with many different perspectives such as the perspectives of different:

- **Stakeholder types.** They have different aims and business models.
- **Transport modes.** In general, there are road, sea, rail, air and inland waterway transports. Within each of these modes there may also be sub-modes like for example private car, taxi, bus, bike, scooter, and so on.
- **Networks.** They are heterogeneous with respect to size, mode, type of traffic, traffic volumes, regulations, business models, topography, climate, etc.
- **Governance levels.** Networks and decisions may be taken by private and/or public stakeholders at local, regional, national, or international levels.
- **Transport types.** The transports may be public (e.g., public transport), private (e.g., people going to work or on holidays), commercial (e.g., taxies and freight transport), and there are person transport and freight transport.
- **Technologies and digitalisation.** The network may for example to different degrees have smart infrastructures and they may support different levels of automation and digitalisation.

4.2.3 Multimodality

The SoI addresses all transport modes, and the traffic part of the ecosystem described in section 4.1.1 requires multimodal solutions. Thus, the architecture description must specify solutions in a way that applies for all modes. The concerns to be addressed are:

- **Legacy systems.** The System of Interest will extend the current traffic and network management done within silos in each transport mode. The extension should as far as possible be multimodal (i.e., harmonised across and common to all modes).
- **Common understanding.** To arrange for the above extensions, it is crucial to have a common understanding across modes and stakeholder types. Thus, the concepts and solutions supported by the System of Interest must as far as possible be specified in a neutral (multimodal) language that can be understood by all modes.
- **Harmonisation whenever possible.** As far as possible, multimodal protocols, common to all modes, should support digital coordination, collaboration and support across modes, networks, and stakeholders. In particular, this accounts for the coordination between Traffic Orchestrators, which may belong to any mode or network; and for the communication between Traffic Orchestrators and Transport Service Providers, who may work with all modes. Fleet Operators will in many cases just belong to one mode but not always. Thus, the communications between Traffic Orchestrators and Fleet Operators should also be multimodal.
- **Learning across modes.** Network Users belong to just one mode, and for sea, rail and air transport, there are today frequent communication between traffic managers and Network Users. Different mode-specific initiatives are also working on mechanisms that can be used in traffic orchestration, e.g., the work on C-ITS (Cooperative Intelligent Transport Systems) for road transport and ATM (Air Traffic Management)

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for air transport. The overall concepts of traffic orchestration towards Network Users will however include many new concepts, for example concept for adaption to resilient transport – monitored and controlled by the Traffic Orchestrator. Such concepts should be specified in a multimodal, mode-independent way to facilitate learning across modes.

- **Communication.** As a consequence of the above, multimodal communication is needed between Traffic Orchestrators and between Traffic Orchestrators, Transport Service Providers and Fleet Operators. The communication between Traffic Orchestrators and Network Users may be specific for each mode, implemented by the mechanisms already defined or being defined.

4.2.4 Resilience

Resilience is one of the four strategic orientations for EU research and innovation for 2021-2024 [1]. The definition (see List of Definitions, page 8) emphasises the adaptive capacity of a system *prior to, during,* and *after* changes and disturbances in order to sustain required functions under both *expected* and *unexpected* conditions. The ORCHESTRA architecture description must address resilience in the SoI, including the connections between the network components.

The overall concerns that the architecture description must support are:

- **Resilient planning and management approaches.** Anticipatory management and stochastic planning must incorporate possible randomness in the pre-perturbation stage.
- **Pro-active actions.** Possible perturbations should if possible be detected before they happen, and actions should be taken at an early stage to avoid the perturbations totally or to limit or mitigate the effects.
- **Adaptive actions during the perturbations.** The aim will be to diminish the caused negative effects and corresponding propagations in the multimodal network.
- **Efficient recovery** back to the normal stage and develop the ability to adapt to future surprises as they unfold.
- **Learning from collected data.** Historical data on situations and effects of actions should support the above action points.

The architecture description must support architecture resilience. This is about the vulnerability of a fully connected and digitalised transport system. The main concerns to be addressed by the architecture description are:

- **Security issues.** Information security must be maintained, and cyber security attacks must be avoided, and if they happen such attacks must be detected and stopped.
- **Loss of connectivity.** Back-up solutions to be applied in case of loss of connectivity with Network Users must be specified.
- **Flexibility in governance and organisation**. It must be possible to implement the responsibilities and structures described in a flexible way and implement the to hand over responsibilities when this is needed.

4.2.5 Business neutrality

New means introduced in SoI (e.g. to resolve other concerns) need to ensure that fairness and accessibility to the system is maintained (or improved). This includes:

- **Openness for new players.** Ensuring that changes do not result in extensive barriers for new players to enter the market. Such barriers may for example include extensive capital requirements, access to enabling technologies (licenses, patents etc.), and network effects.
- **Openness for new business models.** This includes flexibility to support new and innovative business models for stakeholders both in the transport and traffic domain.

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4.3 Domain concepts

This section describes concepts of relevance in traffic orchestration and the MTM ecosystem. Figure 4 provides an overview of concepts. As indicates by the stereotypes and colours used, there are different types of concepts. The stereotypes are:

- **Stakeholder** (yellow): These concepts refer to the stakeholder archetypes defined in 4.1.
- **Spatial** (grey): These concepts are spatial objects and might be a point, a boarder, an area, or another spatial object (road, fairway, railway, air space, etc.). They represent smaller or larger parts of physical transport network infrastructures or locations within the infrastructures.
- **Context** (light blue): These concepts constitute or establish a context for the traffic orchestration.
- **Resilience** (green): These concepts facilitate resilient traffic orchestration and will address anticipatory management, stochastic planning, deviation handling, and efficient recovery back to the normal stage.
- **Measure** (pink): These concepts represent groups of measures that facilitate traffic orchestration.
- **Rules** (beige): These concepts represent the rules to be followed in the traffic orchestration.
- **Orchestration** (blue): These concepts represent the transport orchestration with a network and a mode.

A MTME may consist of several *Transport Networks. A Transport Network has one* mode and operates under one or more *legislations* that may be adapted to *international agreements.* The traffic within a Transport Network may affect or be affected by the *traffic orchestration.* The traffic orchestration may also affect the *traffic orchestration in neighbouring networks and modes,* as their traffic volumes and traffic types may be related.

A transport network may have *network segments, network resources* and *zones.* A *network segment* is a part of a transport network (e.g., road segments, fairway segments, railway segments, air corridors, etc.). A *network resource* is a part of the transport network that can be used by just one Network User at a time, e.g., a parking slot, a charge point, a quey in a seaport, a gateway in an airport, etc. A *zone* has a set of *regulations* and a spatial extension that may include a *geofence*, *network segments* and *network resources*. A geofence is a border in the Transport Network and may define an area, a space, or a dividing line.

A zone has several specialisations that facilitate different types of traffic orchestration measures:

- *Governance area* defines the area or space with respect to some authority and is the zone in which the traffic orchestration takes place.
- *Critical zone* is a zone where the network capacity is critical. An imbalance in the transport demand and the capacity of the network in such a zone may have serious effects. The mobility of persons and the transport of goods may be hindered to an extend that causes long delays or other problems.
- *Control zone* is a zone where the traffic flow in general or individual Network Users are monitored, controlled, or guided.
- *Access zone* is a zone with access restrictions. Just certain Network Users are allowed to enter such a sone zone.
- *Priority zone* is accessible for Network Users in general, but certain Network Users have priority and will gain access and may use the zone prior to other Network Users.
- *Monetary zone* has a payment regime.

Zones may be predefined or dynamically established based on traffic situations or needs. They may partly or fully overlap to facilitate the traffic orchestration measures needed. An access zone and a monetary zone may for example overlap to facilitate access for Network Users that have paid a fee and to stop other Network Users.

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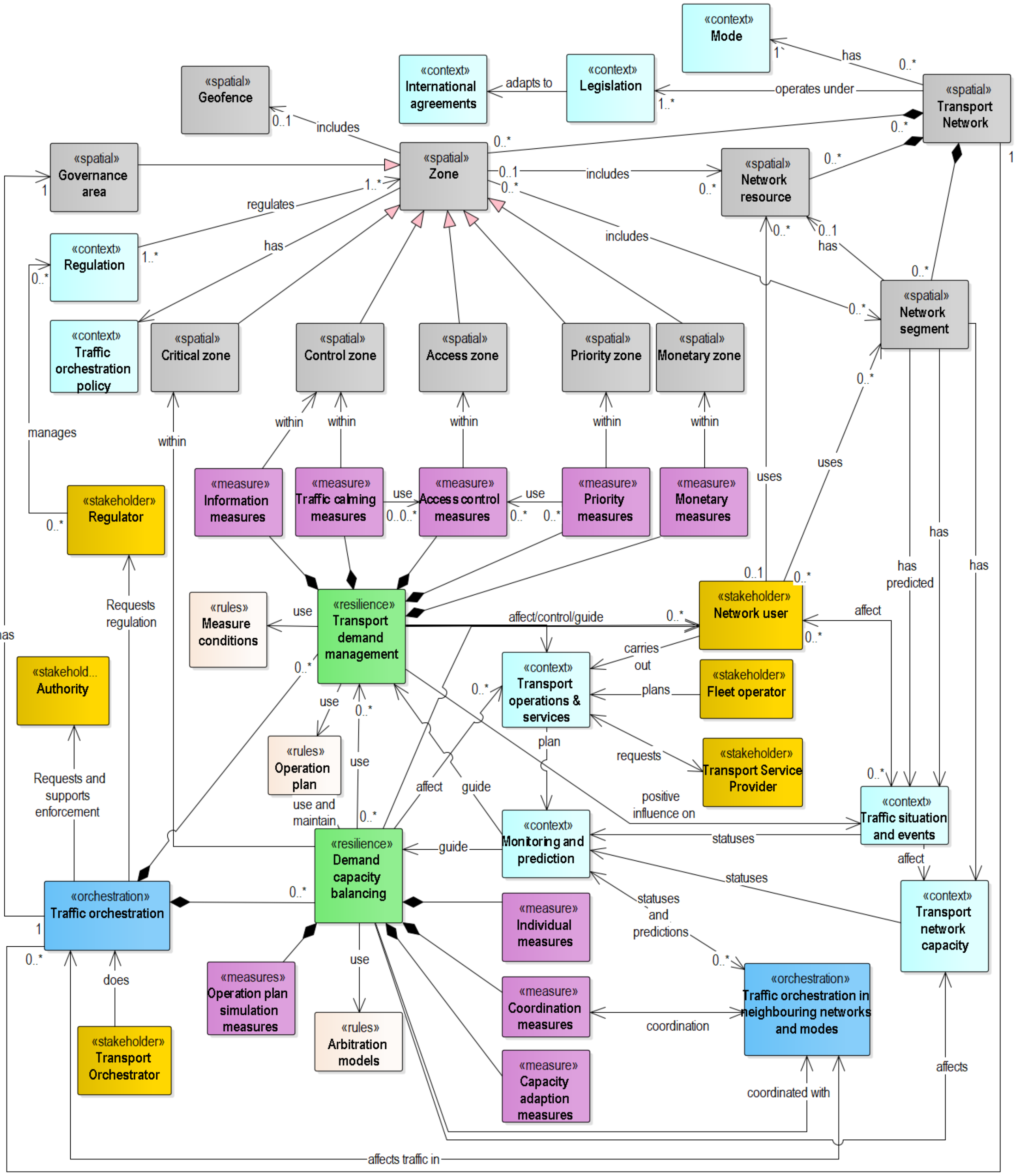

Figure 4: MTM concept model

Traffic orchestration is done within a governance area through transport demand management and demand capacity balancing. Both are guided by the monitoring and predictions of traffic situations and events, transport network capacity, and the statuses and capacities provided by the Traffic orchestration in neighbouring networks and modes. Whenever needed, the Regulator may be asked to adapt regulations (traffic regulation), and Authorities may be asked to the enforce regulations. The enforcement may also be supported, e.g., through

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the provision of data that documents regulation violations. Both transport demand management and demand capacity balancing take decisions according to an operation plan, and demand capacity balancing will manage this plan to ensure the best possible utilisation of the network capacity.

Transport demand management aims to have a positive influence on the current and upcoming traffic situations through managing the use of the transport network. The measures taken affect *Network Users* as well as planned and ongoing *Transport operations and services*. The Network Users may also be controlled and/or guided. Several measure types are supported, and *measure conditions* define how the measures shall target the different network users. The measure types are:

- *Information measures* provide information services that may affect the transport demand.
- *Traffic calming measures* target control zones and aims to reduce traffic volumes or the negative effects of the traffic.
- *Access control measures* target access zones and supports access control.
- *Priority measures* target priority zones and do prioritising among Network Users.
- *Monetary measures* target pricing zones and facilitate billing and payment or other monetary transactions (earning of points, use of points, etc.).

Demand capacity balancing aims to balance the capacity of the transport network with the demand and also to coordinate the capacity and demand balancing with the *traffic orchestration in neighbouring networks and modes*. This overall goal is a more optimal transport system as a whole. Critical zones are identified, and measures are taken towards both *Network Users* and planned as well as ongoing *Transport operations and services*. The Network Users may also be controlled and/or guided. Transport demand management may also be used to balance the network. The monitoring and prediction carried out can facilitate explorations (e.g., simulations) of "what if"-scenarios regarding tactical decisions, and *arbitration models* can guide decisions that are trade-offs between different needs. The decisions taken are integrated in the operation plan for the critical zone. Several mechanisms support the demand capacity balancing:

- *Operation plan simulations* explore "what if" scenarios to investigate the effects of different measures. The findings will guide the updates of the operational operation plan.
- *Individual Transport Network measures* controls or guides individual Network Users.
- *Capacity adaption measures* are measures that may increase the network capacity through use of relevant mechanisms (speed regulation, adapt the use of network segments, re-route, etc.).
- *Coordination measures* coordinates the distribution of traffic to and from *other networks and modes*.

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5 Motivation view

The motivation view describes:

- The stakeholder types of relevance to the SoI
- Drivers, assessments, and goals for the main stakeholders that are users of the SoI.

ArchiMate motivation diagrams are used along textual descriptions of the elements. Annex A.1 provides a description of the notation used.

In the motivation view, the overall concerns described in section 4.2 are met as follows:

- **Polycentricity**: The strategies for the perspectives identified are as follows:
    - *Stakeholder types*: The stakeholder types are identified and described, and motivation diagrams are defined for the stakeholder types that are users of the SoI. All motivation diagrams are linked to specific stakeholder types.
    - *Transport modes, networks, governance levels, and transport types*: Unless nothing is said about particular issues, the entries in the motivation diagrams are common to all modes, networks, governance levels, and transport types.
    - *Technology and digitalisation*: The technology to be used in the realisation are not addressed in the motivation diagrams.
- **Multimodality**: The aspects and principles related to multimodality are addressed as described above. The motivation diagrams are as far as possible harmonized across modes. Assessments of the situation in one model may however be included to support learning. The mode-independent motivation diagrams support a common understanding and communication across modes.
- **Resilience**: Some motivation diagrams may include aspect of relevance to resilience, or they may also address issues that can be solved through resilience. The mapping towards resilience is however not done here.

5.1 Stakeholder overview

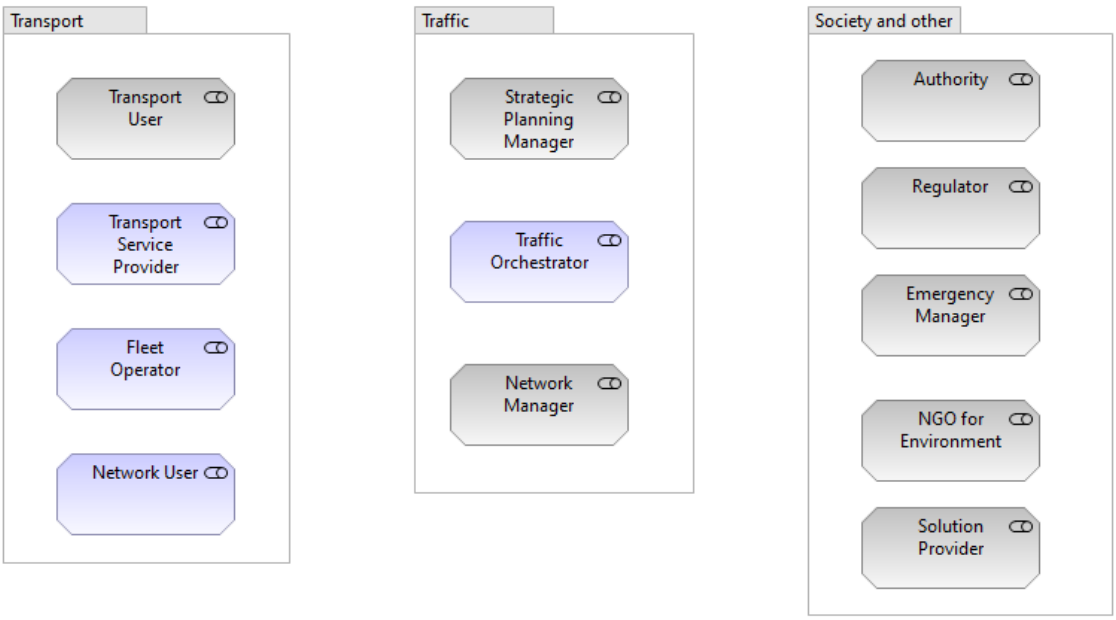

Figure 5: Generic stakeholder types.

Figure 5 provides an overview of the generic stakeholder types in the MTME.

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The stakeholder types are divided into three groups: transport, traffic, and society and other. The groups corresponding to the three parts of the MTME described in section 4.1. Four stakeholder types are directly related to the System of Interest: Transport Service Provider, Fleet Operator, Network User, Traffic Orchestrator. The other stakeholder types are however a part of the total picture.

The stakeholder types are described below.

Note: The stakeholder archetypes represent non-overlapping responsibilities for a certain governance area. Depending on the governance area, a stakeholder type may operate on a local, regional, national, or international level, or the governance area may be at different levels of a business.

Note: Real actors may represent one or more stakeholder types. Some examples on how real stakeholders may take the role of different stakeholder type are as follows:

- A freight forwarder operating own vehicles/vessels will be both a Transport Service Provider and a Fleet Operator.
- A freight forwarder booking services from another Transport Service Providers for some of the transport legs will also be a Transport User.
- A private person planning travelling from A to B may use a Transport Service Provider or be his/her own Transport Service Provider. In case of the latter, the person will, as a Transport Service Provider, plan the chain from A via C and D to B and book the different legs from Transport Service Providers and/or Fleet operators.
- A private person using his/her own car will be both a Fleet Operator and a Network User. If the private car is use on one leg of a chain with several legs and modes, the person will also be a Transport User.

The examples with private persons as Transport Service Providers and Fleet Operators illustrate that benefit of using stakeholder archetypes. Transport Service Providers and Fleet Operators will report their transport operations to the Transport Orchestrator and get support in return. Private persons may also report their planned operations and get similar support. They may for example be notified about foreseen problems along the planned route and be able to replan in time. When all Transport Service Providers and Fleet Operators (private persons included) report about their planned and ongoing operations, the Traffic Orchestration will get more information and will be able to make better predictions and decisions.

5.1.1 Transport

Transport User

The Transport User searches for a relevant transport service, books a service, and follows up the execution of the service. The Transport User may request services for freight transport, person transport, or a combination. The Transport User provides detailed information about the transport demand to the Transport Service Provider.

Transport Service Provider

The Transport Service Provider provides transport services to the Transport User. This includes customer support and information, decisions how the service is to be provided, and the follow up. In person transport, Transport User usually will influence the decisions (e.g., select the modes and routes to be used). In freight transport, the Transport Service Provider quite often takes decisions on behalf of the Transport User. The decisions will affect which Fleet Operators to use. One or more Fleet Operators may be needed to cover the desired transport chain. The actual transport operations will be managed by the Fleet Operator.

Fleet Operator

The Fleet Operator executes transport operations. One operation may carry out transports requested by one or more Transport Service Providers and may cover the transport demand of one or more Transport Users. Time

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schedule are planned, resources are allocated, and operations are followed up to ensure that they are carried out according to rules, regulations, and agreements. When relevant, the Transport Service Providers are informed about the progress.

Network Users

The Network User operates a vehicle/vessel (micro mobility included), or he/she may be a pedestrian. The Network User is responsible for an integration into the traffic in compliance with laws and regulations and for safety issues related to behaviour and operation of the vehicle/vessel.

The Network User may be a person, a person supported by systems, or a system (e.g. a Connected and Automated Vehicle - CAV).

5.1.2 Traffic

Strategic Planning Manger

The Strategic Planning Manager takes strategic decisions related to traffic management and orchestration. This includes plans and strategies for automated vs manual measures, transport demand management, demand capacity balancing, access control, priorities, etc. The Strategic Planning Manager is also responsible for the overall strategies regarding the collaboration and coordination with other modes, networks, and governance areas.

Traffic Orchestrator

The Traffic Orchestrator aims to arrange for sustainable transport from an environmental, economic/socio-economic, and societal point of view according to the directions of the Strategic Planning Manager as well as operational laws and regulations. This is done through:

- Traffic management. The traffic flow and the movement of vessels/vehicles/pedestrians is guided or controlled to arrange for safety, efficiency, and optimal utilisation of the network. This includes interactions with Network Users related to transport demand management, capacity demand balancing, access control, traffic control/guidance, information sharing, etc.
- Transport network resource management. The access to and use of limited resources like parking spaces, loading bays, waiting areas, etc. is managed.
- Coordination towards other modes, networks, and governance areas. Information is exchanged and decisions and actions are coordinated to contribute to a more optimal transport system as a whole.

Network Manager

The Infrastructure Manager plans and operates a transport network. This includes the physical infrastructure enabling the movement of transport means as well as equipment and the smart infrastructures linked to the network.

5.1.3 Society and others

Authority

This Authority is responsible for monitoring and inspections of a aspects of interest in the transport domain, and whenever this is required, for interventions and sanctions adapted to enforce envisioned situations.

Regulator

The Regulator is responsible for legislative issues (European and national) or regulations (national and local). The latter must be in accordance with the legislation and includes regulations affecting the traffic orchestration.

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Emergency Manager

The Emergency Manager is responsible for emergency preparedness, capability, and response related to transport. Depending on the governance area, this may be at a national, regional, or local level. The with other levels will be a part of the responsibility.

Non-Governmental Organization (NGO) for Environment

The NGO for Environment contributes to environmental protection. This may be through environmental monitoring, activities for protection of the environment, knowledge generation on environmental protection, etc.

Solution Provider

The solution provider contributes to the realisation of the MTME through design, production, and roll out of solutions needed in the MTME. This may for example be software and hardware needed in the transport network infrastructure or in vehicles/vessels, software needed by the traffic orchestrator, or software needed by the transport service provider or fleet operator for better communication with the traffic orchestrator. The solution providers may provide their solutions according to many different business models.

5.2 Drivers and Assessments

In the sections below, each of the main stakeholder types is described by their *Drivers* for a change towards resilient and multimodal traffic orchestration, and the associated *Assessments* of the current situation.

The stakeholder types addressed are: The Transport Service Provider, the Fleet Operator, the Network User, and the Traffic Orchestrator.

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5.2.1 Transport Service Provider

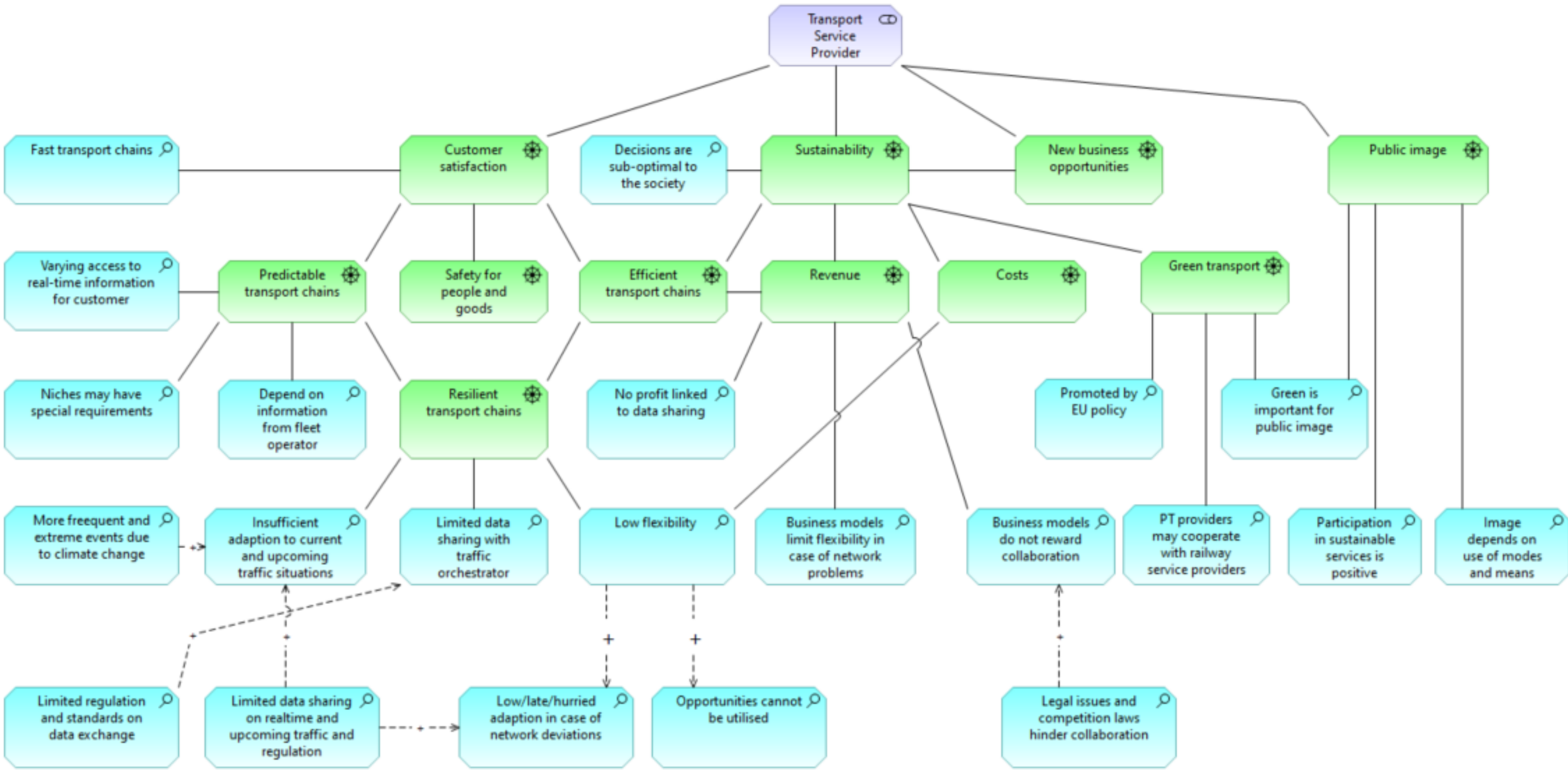

Figure 6: Transport Service Provider Motivation Diagram: Drivers and Assessments

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The table below provides descriptions of the Drivers and Assessments in the motivation diagram in Figure 6.

Drivers	Assessments
Customer satisfaction: The aim is to provide competitive services that fulfil the expectations of the customers. Deviations must also be handled in a good way.	**Chains adapted to transport demands:** Transport services fulfil different types of demands, e.g., the shortest or cheapest travel time.
Predictable transport chain: It is important to be aware of issues that may affect the transport chains, in real time and if possible, also in advance, to be able to take mitigating measures.	**Varying access to real-time information for customer:** For freight transport, some Transport Service Providers provides real-time tracking information, but usually, the tracking is about the arrival/departure from certain checkpoints, or there may be no tracking. For public transport, real-time information has become quite common, but usually the traveller must handle the consequences of delays by himself/herself. For other types of person transport (e.g., air transport), information on delays or deviations is usually reported in retrospect. **Niches may have special requirements:** The Transport Service Provider may e.g. specialise on a niche of transporting goods that require a special environment (temperature, humidity, etc.) or require security (high value, dangerous, etc.), or on transport of passenger with special needs or preferences (e.g. elderly, disabled, persons needing protection). For these cases there can be special requirements (or even regulations) for end-to-end predictability. **Depend on information from fleet operator:** The Transport Service Provider depends on status and tracking information from the Fleet Operators. The quality of the services provided to the customer can never be better than the service offered by the Fleet Operator. The Fleet Operator must have equipment and services for real-time monitoring.
Safety for people and goods: The aim is to provide services that that are recognised as safe.	Not further addressed as the safety issues of relevance to the Transport Service Provider is outside the scope of the SoI.
Efficient transport chains: The aim is to provide transport chains that appear efficient to the customer in a way that is cost-effective for the Transport Service Provider.	Further addressed through the **Resilient transport chains** driver.
Resilient transport chains: Resilience will increase the ability to deliver cost-effective services according to plans, in addition to improve the deviation handling. Informed actions can be taken at an early stage, opportunities can be utilised, and deviations can be	**Insufficient adaption to current and upcoming traffic situations:** Information on the current traffic situation may cause a re-planning of transport chains if the agreements allow it. However, it is quite common that the planned legs are not changed. In such cases, the execution of the current leg must adapt to the traffic situation. If the next leg cannot be executed as planned due to delays, later departures may be used. Information on predicted traffic situation is not available or not commonly used.

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avoided, or the effects can be mitigated.	It is not common to switch to alternative routes and modes during the execution of a transport chain unless the option is a part of a portfolio of existing agreements. More frequent and extreme events due to climate change: Weather conditions cause disruptions and delays. **Limited data sharing on real-time and upcoming traffic and regulation:** For all modes, information on the current traffic situation and regulations is available to some extent. The Transport Service Providers do to a little extend use this information when the transport chains are planned. The current situation may however cause re-planning during the execution of the chains. Forecasts regarding upcoming traffic situation are available indirectly. The weather forecast may for example to some extend indicate how the traffic situation will be in the future. For some transport chains, this may cause a re-planning. **Limited data sharing with traffic orchestrator:** Transport Service Providers do in general not interact directly with traffic managers. The traffic information is usually accessed via public channels. In many cases it is not sufficient to just relay on limited information regarding one leg. A more holistic picture is required as the access to partial information would not be effective or efficient. Some providers of public transport have in collaboration with traffic managers got proprietary solutions. Buses may for example get priority in traffic lights. The data exchange is in this case with the buses. The solutions are negotiated and elaborated at a local level. **Limited regulation and standards on data exchange:** Today, Transport Service Providers do not provide data to Traffic managers, and there are no regulations and standards addressing such information exchange. **Low flexibility:** Long-term contracts may restrict the flexibility. The transport Service Provider may not be in a position to choose alternative routes and operators. On the contrary, contracts with many fleet operators may increase the flexibility. **Low/late/hurried adaption in case of network deviations:** Disruptions and deviations in the transport networks and traffic flows may cause the need for changes in transport chains. This quite often happens at a late stage or during the transports. In such cases, it is difficult to find optimal solutions. **Limited data sharing on real-time and upcoming traffic and regulation:** See above **Opportunities cannot be utilised:** Long-term contracts and business models may restrict the possibility to utilise opportunities, e.g., the use of available capacity in transport means operated by other operators. As a result, more vehicles/vessels may have a low load factor. There

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	is also a lack of services that support the utilisation of such opportunities.
Sustainability: Sustainability with respect to environmental, economic, and societal issues is crucial.	**Decisions are sub-optimal to the society:** Today, all actors involved in the transport chain do optimisation from their own point of view. This is also the case for Transport Service Providers. Their use of modes, networks, routes, and operators may turn out to be less optimal to the society.
Revenue: Sustainable return of investment and cost coverage are needed for most transport service providers.	**No profit linked to data sharing:** Today, Transport Service Providers will get nothing in return for data sharing. Data sharing also has a cost (e.g., effort wise with respect to data security). This cost may proportionally be high compared with the revenue. **Business models limit flexibility in case of network problems:** Business models usually have just a limited support for dynamic adaption of transport chains in case of disruptions, deviations, and new opportunities. Full flexible for transhipments to other modes, networks and operators may not be possible in case of network problems. Investments done or flexibility provided by one actor may also benefit others but may not always be compensated. Lack of marketplace for flexible transport brokering reduces the flexibility. **Business models do not reward collaboration:** Several vehicles with low load factor may operate the same routes. The business models may not reward or push for collaboration & data sharing for new services. Some cooperation exists in international shipping **Legal issues and competition laws hinder collaboration:** There are laws and regulations that hinder collaboration among big actors. However, in general collaboration may also be beneficial for small actors.
Costs: The cost must be proportional to revenue level of each stakeholder	**Low flexibility:** See above
Green transport: The provision of green transport may be a desire as well as a strategic tool to reach costumers.	**Promoted by EU policy:** European policy about Green Deal and related strategies push green solutions. This policy promotes the development of technology, solutions, and services that support green transport services. **Some collaboration for green alternatives:** In general, this is mainly the case when public actors are in the lead, since they are motivated by societal economics and not just business economics. Public transport providers may for example cooperate with railway service providers. **Green is important for public image:** To many Transport Service Providers, it is important to have a green image. Transparency to help people understand who is actually helping the planet and who is actually only “greenwashing” becomes more relevant.

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New business opportunities: New technology and a focus on green services may open new business opportunities. This may be transport services as well as digital services.	Covered by the **Sustainability** driver.
Public image: A good image will generate more customers and may also influence the willingness to pay for the services provided.	**Green behaviour is important for public image:** See above **Participation in sustainable services is positive:** The provision or participation in services that have a green image may influence the public image. One such service may for example be MaaS. **Image depends on use of modes and means:** The public image is influenced by operators and routes used. The use of operators operating in green modes and with green vehicles/vessels may for example support a green image.

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5.2.2 Fleet Operator

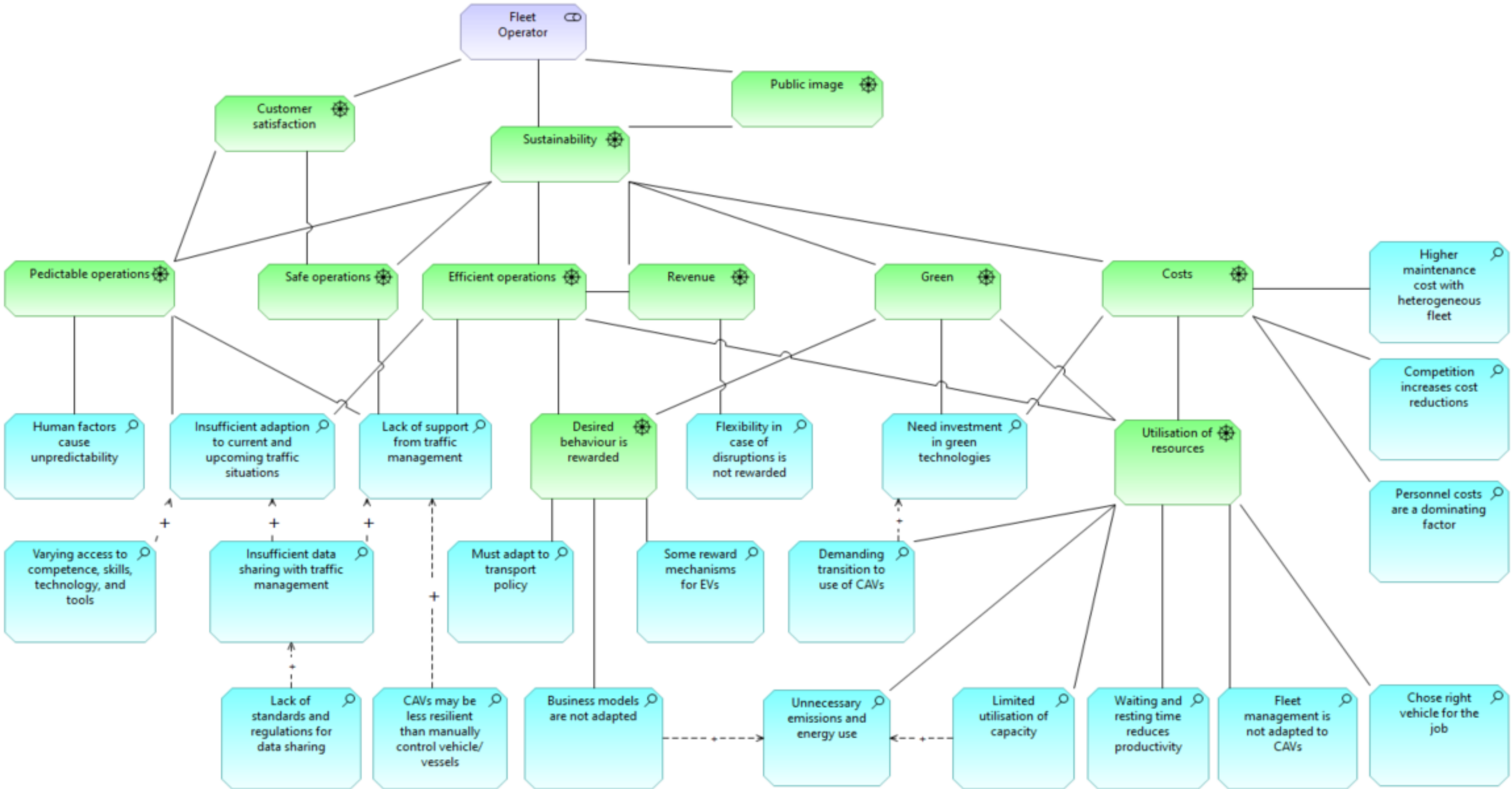

Figure 7: Fleet Operator Motivation Diagram: Drivers and Assessments

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The table below provides descriptions of the Drivers and Assessments in the motivation diagram in Figure 7.

Drivers	Assessments
Customer satisfaction: The aim is to be a preferred transport provider and to carry out transport operations that fulfil the expectations of the customers. Deviations must be avoided or handled in a good way.	Covered by the following drivers: **Predictable operations** and **Safe operations**
Predictable operations: Fleet operators want information and services that make the operations more predictable and allows pro-active measures to avoid or reduce deviations.	**Human factors cause unpredictability**: Uninformed decisions and human errors causes deviations. The deviation may for example be caused by the traffic situation along the route (congestion, driving conditions, sailing conditions, etc.), temporarily regulations or situations (reduced speed limit, road works, etc.), incidents or accidents hindering the flow, and own involvement in incidents and accident. **Insufficient adaption to current and upcoming traffic situation:** The optimisation done by the fleet operator may be sub-optimalisation due to lack of information and lack of the ability to consider the totality. **Varying access to competence, skills, technology, and tools:** It is resource demanding (investments, effort and time) to invest in new technology and tools and to build new competence and skills. Fleet operators have varying investment willingness and capability. Fleet operators must also ensure employer satisfaction. Employers may not appreciate changes in technology and tools and new requirements to skills and competence. The trade unions may play an important role with respect to the acceptance of changes. **Insufficient data sharing with traffic management:** Today, fleet operators share few details on the transport operations with the traffic manager. In some modes, information on for example dangerous cargo, is shared. Details on type of cargo, type of engine, load factor, etc. are not shared. Many details on the transports are considered as business sensitive information. Fleet operators may be willing to share data on capacities if they by doing so may get more freight/passengers due to disruptions in other networks. Fleet operators aim for customers satisfaction and may be willing to share data if they can get advantages that will benefit their customers. **Lack of standards and regulations for data sharing:** The information sharing with the traffic management is according to rules and regulations within the specific modes. This does not cover details such as for example the load factor.

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	There are no regulations and standards across modes regarding information sharing with traffic management. **Lack of support from traffic management:** In some modes there is a peer-to-peer dialogue between the traffic management and the vehicle/vessel. There is however no or a very limited information exchange with the fleet operator. Thus, the planning of the fleet operations and the fleet management mainly depend on information of general interest, and not on information targeting individual operations. Fleet operators may for example not get early warnings from the traffic managers. Information of general interest like traffic messages, messages to mariners, etc. are available.
Safe operations: Safe operations are crucial. Accidents may harm the customers – passengers may get hurt and cargo damaged. The reputation may also be damaged. Accidents may also harm the vessel/vehicle and the crew and cause unforeseen costs.	**Lack of support from traffic management:** See above.
Sustainability: This is about economy, environment, and society. Traditionally, good economy is the main driver for private fleet operators. Public fleet operators traditionally also focus on support societal sustainability. For both types of operators, environmental sustainability has or is now becoming important, and their customers also request environmental sustainability.	Covered by the following drivers: **Predictable operations, Safe operations, Efficient operations, Revenue, Green,** and **Costs**
Efficient operations: Time is money, and efficiency is crucial. If the operations are efficient, more operations can be caried out with by the available resources.	**Lack of support from traffic management:** See above. See also the following drivers: **Desired behaviour is rewarded** and **Utilisation of resources.**
Desired behaviour is rewarded: Whenever feasible, fleet operators in general try to adapt to rules and regulations and societal norms. The motivation increases if desired behaviour is rewarded. Different reward mechanisms	**Must adapt to transport policy:** European transport policy address safety issues, environmental protection, and societal aspects. This affects the transport sector, and vehicles, vessels, regulations, and services are adapted to the policy. Thus, fleet operators my indirectly be supported in the adaption to the policy. OEMs do for example equip new vehicles with clean engines. If the economy allows, fleet operators may contribute to the transition by buying new equipment (vehicles, vessel, etc.).

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may motivate – economic, access rights, priorities, etc.	**Business models are not adapted:** Today, business models adapted to traditional transport chains. Long term contracts may reduce the flexibility. In case of disruptions, the main strategy in many cases is to wait until the problem is solved. Alternatives and opportunities that may support more effective transports cannot be utilised. In most cases, the business models do not support that one fleet operator may take over from another in case of disruptions. In is not clear how the money flows should be distributed. The business models are not green. Collaboration between fleet operators and other mechanisms that may reduce emissions are not rewarded. The use of available capacity across fleets and other measures that may reduce the total emissions are not supported. **Unnecessary emissions and energy use:** The use of fossil fuel is becoming more and more outdated for some vehicle/vessel types (private cars, taxies, utility vehicles, buses ferries, etc.), and even for aircraft seagoing vessels the technology is changing. New engine requirements are coming. At sea, engines must be updated by 2026, and on road, the transition towards e-mobility is also regulated. For freight transport, the load factor in general is about 50%. The consolidation of the cargo is sub-optimal. Trials and theories for synchro-modality and Physical Internet show that savings are possible if the approaches is more holistic, and if the business models arrange for flexibility. **Some reward mechanisms for EVs**: In some countries, electric vehicles (EVs) get advantages, and such incentives seam to speed up the transition to e-mobility.
Utilisation of resources: The capacity of transport means, personnel resources, and other resources must the utilised	**Demanding transition to use of CAVs:** CAVs are used in many trials and in some operative setting. The CAVs are however in general not sufficiently roadworthy - they cannot operate in normal traffic together with manually operated vehicles. The speed is too low, and they will not tackle all situations. The technology is however rapidly improving. There are many challenges related to the transition to CAVs. They must tackle mixed traffic, regulations must define rules and responsibilities, business models must support different ownership models, etc. **Unnecessary emissions and energy use:** See above **Business models are not adapted:** See above **Limited utilisation of capacity:** The capacity may be space for passengers, cargo load capacity, the number of vehicles/vessels of different types, and personnel. The greenness of transport does among others depend on the load factor. For freight transport on road, the average load factor is too low, about 50%. New concept like synchro-modality and the Physical Internet may in the future increase the load factor. There is a lack of marketplaces supporting transport brokering, and the load factor

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	becomes low if it is difficult to get return load. There is also a lack of transport hubs where cargo from different chains can be consolidated. Load factor is also a challenge for all types of person transport – from private cars to air transport. During peak hours, and in case of disruptions, lack of capacity is a problem, and there is a need for better support for the distribution of the passengers across modes and services to limit the accelerations of extreme peaks. Outside peak hours, the utilisation of the capacity may be too low. The lack of flexibility is a problem, and CAVs may open for more demand driven services where the capacity is adapted to the needs by means of CAVs with different sizes and types. The utilisation of personnel must be adapted to skills and competence, and for vehicles/vessels to the type of transport operations. Some modes are vulnerable due to a lack of skills and competencies as there may be a dependency with the vehicle/vessel type. **Waiting and resting time reduces productivity:** Transports may not go according to plans. At all stages of the transports (departure, arrival, and enroute) there may be waiting times that reduces the productivity. The resting time requirements may also affect the productivity. The drivers rest according to the regulations. If possible, the resting time is adapted to the route, traffic situation, driving conditions, etc. The driver may for example rest during rush hours to save time. The traffic management does not support just in time arrivals, smooth transport operations, and adaption of the resting time. **Fleet management is not adapted to CAVs:** The providers of CAVs also provide fleet management tools, but so far, the use of CAVs in fleet operations is limited. The fleet management tools for CAVs are do little extend communicate with the traffic management. Probably, it is not easy to combine fleet management for CAVs and traditional vessels/vehicles. **Chose right vehicle for the job:** Fleet operator with a heterogeneous fleet may benefit from using the best fitted vehicle/vessel in operations. This is due to differences in capacity, functionality, engine, etc. Today, the choose of vehicle/vessel type does to a little affects the traffic management. However, use of electric vehicles may in some countries get privileges.
Revenue: Sustainable return of investment and cost coverage are needed.	See also the **efficient operation** driver. **Flexibility in case of disruptions is not rewarded:** Due to business models, the flexibility in case of disruptions may be limited. Network problems may for example not be solved by transhipments between modes and networks.
Green: The provision of green transport may be both a defined	See the following drivers: **Desired behaviour is rewarded** and **Utilisation of resources.**

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strategy and a competitional advantage.	**Need investment in green technologies:** OEMs are developing vehicles/vessels that meet the green policy. The fleet operators need to invest in such technologies. The ability to do such investments varies. The advantages achieved with use of green technologies varies between modes and networks. **Demanding transition to use of CAVs:** See above.
Costs: The cost must be proportional to the revenue level.	See also the **Utilisation of resources** driver. **Need investment in green technologies:** See above **Higher maintenance cost with heterogeneous fleet:** A heterogeneous fleet makes it possible to adapt the use of resources to the transport operation, traffic regulations, and traffic management strategies. The operation cost may however be higher as maintenance, training of personnel, flexible use of personnel, etc. may be more challenging. **Competition increases cost reductions:** In general, completions may be a driver for more cost-effective operations. **Personnel costs are a dominating factor:** For many fleet operators, the personnel costs are high, and it is difficult to reduce these costs and maintain a high level of satisfaction among the employees. As for other sectors, the use of smart technology supporting planning and operations may reduce costs.

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5.2.3 Network User

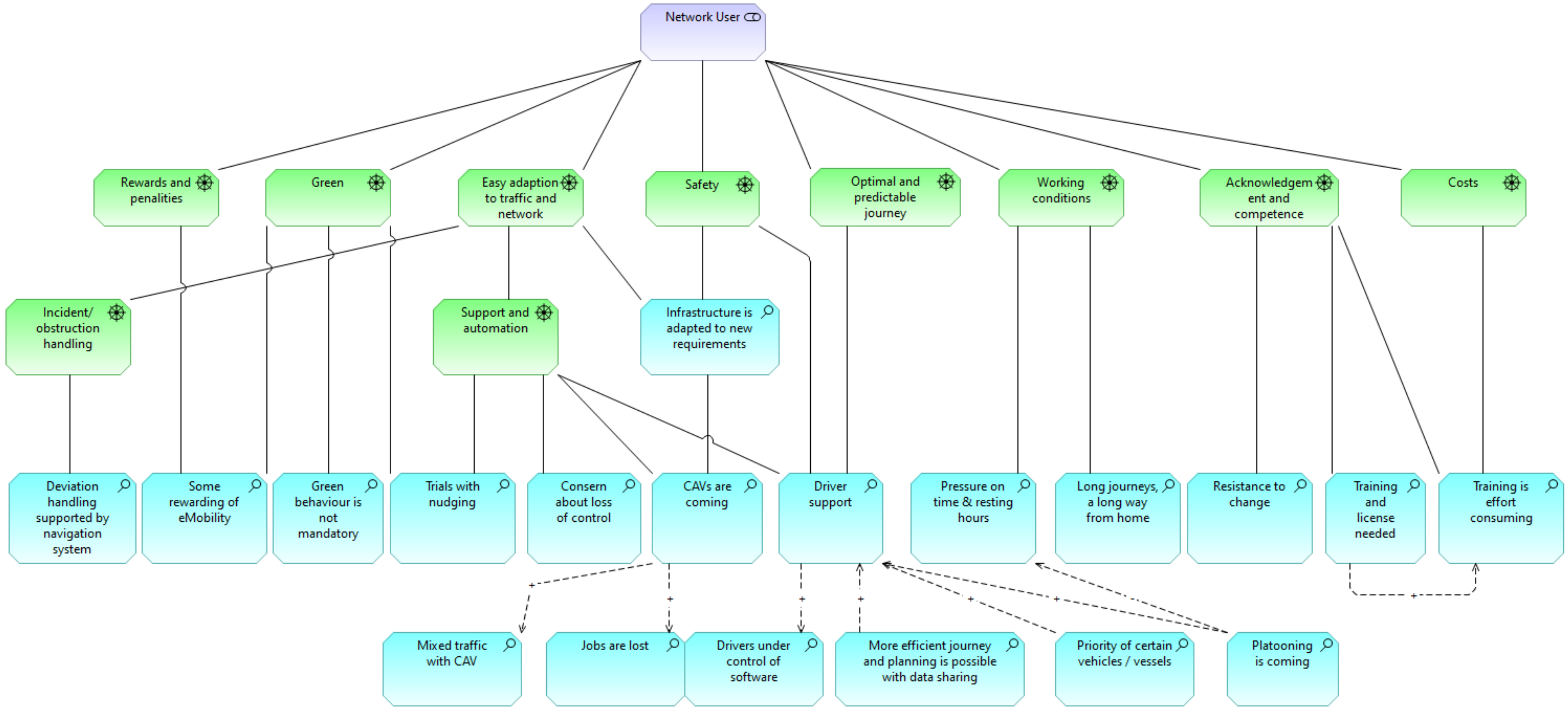

Figure 8: Network User Motivation Diagram: Drivers and Assessments

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The table below provides descriptions of the Drivers and Assessments in the motivation diagram in Figure 8.

Drivers	Assessments
Rewards and penalties: Network Users may be motivated to desired behaviour by means of rewards and penalties.	**Some rewarding of e-mobility:** Some countries have incitements for use of electric vehicles. This may for example be economic incentives like reduction of taxes or access incentives like right to use lanes dedicated to electric vehicles.
Green: Many network Users are motivated by the ability to be greener.	**Some rewarding of e-mobility:** See above **Green behaviour is not mandatory:** Today, Network Users are not obliged to a green behaviour. It is voluntary to take green decisions. **Trials with nudging:** There has been some trials where Network Users have been nudged in a green direction. Green choices have for example been suggested by travel planners.
Easy adaption to traffic and network: Network Users want to travel as easily as possible. They want to use the easiest route and to easily find alternatives in case of deviations.	**Infrastructure is adapted to new requirements:** The transport network infrastructure is improving. Information on traffic situations, new regulations, etc. may for example be sent to navigations systems and speed adaption systems. Variable signs may arrange for optimal speed, etc. **CAVs are coming** Standards and services for CAVs and communication with CAVs are being developed. **Mixed traffic with CAVs:** A mix of CAVs and traditional vehicles/vessel may make the operation of Vessels/vehicles more complicated. **Jobs are lost:** With CAVs, some drivers may lose their job.
Incident/obstruction handling: Network users will benefit from a better handling of deviations.	**Deviation handling supported by navigation systems:** There may be a lack of transparency with respect to deviations, reasons for deviations, and decisions on how they are handled. Information may also be delivered too late. Traffic messages, messages to mariners, etc. are provided. Data on planned/ongoing journeys may not be shared. Thus, information adapted to the journey cannot be delivered.
Support and automation: On-board systems can support the operator of the transport means, and different levels of automation may be deployed.	**Trials with nudging:** See above **Concerns about loss of control:** For some, automation means loss of control. Users may not like that they have to share data. **CAVs are coming:** See above. **Driver support:** The vehicle/vessels are getting more advanced. They support semi-automated driving and take safety measures. If Network Users share data, they can get journey planning support and during the journey they may get better support. They may for example get information on delays and why there are delays.

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	Drivers under control of software: With automation or semi-automation, drivers will be replaced by software. **More efficient journey and planning is possible with data sharing:** If better support is needed, the Network Users must also provide more data. **Priority of certain vehicles/vessels:** Some vehicles/vessels are prioritised today. They may get access to green areas of the city or to specific lanes. The priority rules are usually manually manged. The priority must be fair and according to well defined rules. **Platooning is coming:** Trials with platooning are carried out.
Safety: The Network Users aims for safe journeys.	**Infrastructure is adapted to new requirements:** See above. **Driver support:** See above.
Optimal and predictable journey: The Network Users aims for optimal journeys according to preferences and with predictable departures/ arrivals/durations, comfort, etc. They want less stress, and they want to save money and time and to have more comfort.	**Driver support:** See above.
Working conditions: Professional Network users (e.g. truck drivers) aim for improved conditions	**Pressure on time and resting hours:** Journey may be stressful. Time schedules must be kept, also when there are challenging driving conditions. Resting hours must be adapted to traffic conditions. **Platooning is coming:** See above **Long journeys, a long way from home:** Drivers must live in the car for days during long journeys.
Acknowledgement and competence: Network users may receive positive appreciations due to their skills and competence.	**Resistance to change:** Many humans do not like changes. They do not know what the new situation will be like, and they must spend effort on changing. **Training and licence needed:** Requirements and training are changing **Training is effort consuming:** This may be costly and a burden.
Costs: Network users are motivated by cost reductions.	**Training is effort consuming:** See above.

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5.2.4 Traffic Orchestrator

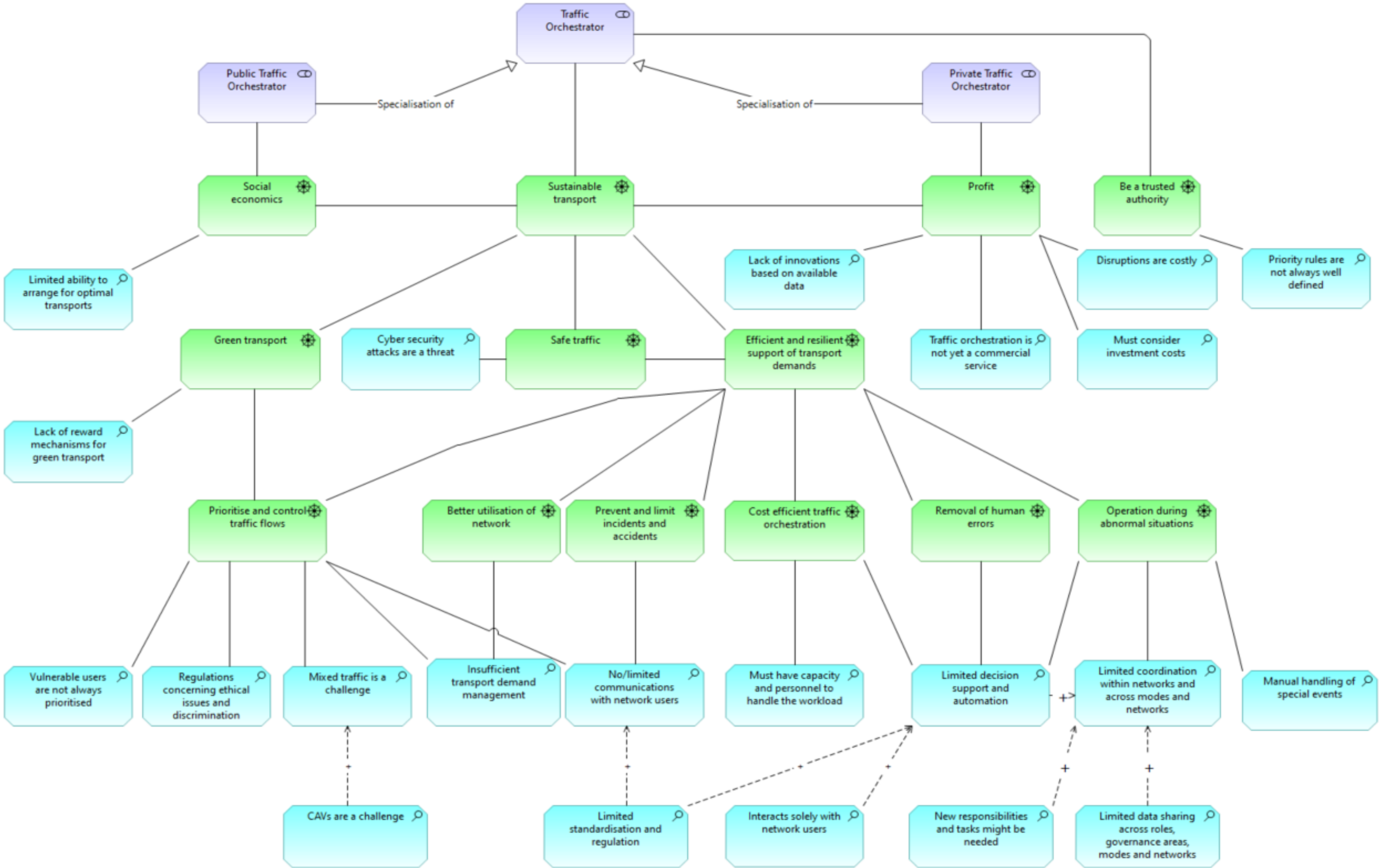

Figure 9: Traffic Orchestrator Motivation Diagram: Drivers and Assessments.

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The Traffic Orchestrator has two specialisations, the Public Traffic Orchestrator, and the Private Traffic Orchestrator, as depicted in the diagram. To some extent they have different drivers but also much in common.

The table below provides descriptions of the Drivers and Assessments in the motivation diagram in Figure 9.

Drivers	Assessments
Social economics: The Public Traffic Orchestrator is obliged to aim for a good society. They manage the traffic in a way that contributes to efficient and safe traffic flows..	See also the **Sustainable transport** driver. **Limited ability to arrange for optimal transports:** Transport service providers may manage transport chains with legs carried out by several Fleet Operators. The plans and requirements to be met are defined but the executions may deviate from plans due to unforeseen circumstances, traffic situations included. The fleet operators may decide how the transport operations are carried out and how upcoming situations are handled. Thus, the transport service provider cannot always ensure that all requirements are met.
Sustainable transport: Both public and private Traffic Orchestrators aim for sustainable transport. This is about economy, environmental protection, and societal issues.	See the following drivers: **Social economics, Green transport, Safe traffic, Efficient and resilient support of transport demands,** and **Profit.**
Green transport: Green transport is one of the main drivers for the public traffic orchestrator due to policy goals. Also for the private traffic orchestrator this is an important driver, either due to their own motivation and/or due to regulations and public image.	See also the **Prioritise and control traffic flows** driver. **Lack of reward mechanisms for green transport:** It is not easy to measure the greenness of a transport chain composed of many legs, and transport service providers are not rewarded if the promote green transport. Transport service providers may improve their public image if the service provider and out as a green and thereby they may increase their market share among customers aiming for green transports.
Prioritise and control traffic flows: The Traffic Orchestrator is motivated by the ability to prioritise and the traffic flows in an easy, efficient, and correct way according to well defined rules and regulations. The aim is to contribute to safe and efficient transport and to minimise the negative effects of the traffic.	**Vulnerable users are not always prioritised:** Some network users, e.g., pedestrians and cyclists, are more vulnerable than others. Their needs are not always considered. **Regulations concerning ethical issues and discrimination:** Such regulations address among others privacy issues (GDPR), inclusion, exist, and fairness. Traffic authorities aims to comply with them, and the work on standards and technical solutions also adapt to these regulations. In many cases there is however a conflict between a compliance to the regulations and realisation of smart, digital solutions. **Mixed traffic is a challenge:** All network users must be safe, respected, and be able to fulfil their mobility demand. Mixes traffic (e.g., with pedestrians, cyclists, and cars) is a challenge, and with the emerge of CAVs, this challenge will be even larger. The transport network infrastructure may arrange for good solutions, but parts of the network may not be adapted to all needs.

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	CAVs are a challenge: The emerge of CAVs raise new questions regarding responsibilities. The regulations are unclear, or regulations are also missing. **Insufficient transport demand management:** Traffic volume varies depending on time and situation. Today, traffic management centres know the current situation, but they are not able handle the situation. The transport demand management and capacity balancing mechanisms are not sufficient. **No/limited communications with network users:** For some modes, e.g., road transport, the communications with network users does not exist or it is very limited. Peer-to-peer communication channels may be used as well as generic mechanisms like signs and signals. Thus, the ability to support or influence on the operation of vehicles/vessels may be limited. When the communication is between humans and not systems, the response times may be too long in emergency situations, and human errors may also affect both the communication and the responses. **Limited standardisation and regulation:** Within all modes, technical solutions are used to improve the safety, and the work on digital support for the improved safety is continuous. Standards and ongoing standardisation specify how digital services and communication protocols can be used, e.g., the work on C-ITS for road transport. The work on automation may also improve the safety. Tools and mechanisms for CAVs may also improve the safety in traditional vehicles/vessels. In some mode the exchange of selected data on the transport operations is regulated. In sea transport, data on dangerous cargo must for example be reported. There are however no regulations on the exchange of data that may support transport demand management and capacity balancing within and across networks and modes.
Safe traffic: Safety is the principal concern of the Traffic Orchestrator. The aim is to take the right decisions in time to prevent or minimise the effect of accidents.	See also the **Efficient and resilient support of transport demands** driver. **Cyber security attacks are a threat:** With connected vehicles/vessels and digitalisation of the traffic control, cyber-attacks become a threat. The communication protocols, e.g. those for C-ITS, use mechanisms to improve the security, but still this is a concern to address.
Efficient and resilient support of transport demands: Traffic orchestrators aims to satisfy the transport demand, within the framework of current regulations, and to minimise the negative effects on the traffic in case of incidents and accidents.	See the following drivers: **Prioritise and control traffic flows**, **Better utilisation of network**, **Prevent and limit incidents and accidents**, **Cost efficient traffic orchestration**, **Removal of human errors,** and **Operation during abnormal situations.**

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Better utilisation of network: Traffic Orchestrators are motivated by the possibility to control the traffic in such a way that the transport network capacity is utilised in an optimal way.	**Insufficient transport demand management:** See above
Prevent and limit incidents and accidents: Traffic Orchestrators are motivated by the possibility to detect potentially dangerous situations and to take actions that can prevent or limit accidents.	**No/limited communications with network users:** See above. **Limited standardisation and regulation:** See above.
Cost efficient traffic orchestration: The complexity in the traffic management is increasing at the traffic grows. CAVs will also cause new challenges. Traffic Orchestrators aim for the ability to manage this complexity in a cost-effective way.	**Must have capacity and personnel to handle the workload:** As the traffic volumes and complexity increase, the capacity of traffic management centres must adapt. Tools are to some extend used to detect upcoming incidents, and the tools may also issue alarms. **Limited decision support and automation:** Today, traffic management is in general done by humans. They are supported by digital tools, and some tools may also detect upcoming incidents and issue alarms. It is the human that, more or less supported by digital tool, take decisions and actions. Human errors may influence decisions and actions, but some safety mechanisms are implemented. Automated decisions and control mechanisms are not widely deployed. Big data analysis and artificial intelligence (AI) is to a little extent used, neither in predictions of upcoming situations, nor in decision support. Services that may support the Network users during normal situations are implemented. This is for example the navigation systems used in cars. They collect and presents open information about the traffic situation. Navigation services also exist for air transport and sea transport. **Limited standardisation and regulation:** See above. **Interacts solely with network users:** The traffic management controls the use of the transport network through direct communication with the Network Users. The communication and collaboration with Transport Service Providers and Fleet Operators is limited of not existing. The planning and management of transport chains and operations are for influences.
Removal of human errors: Human error are always a threat when decisions and actions are taken by humans. The Traffic Orchestrator is motivated by the ability to remove such errors.	**Limited decision support and limited automation in decisions:** See above

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Operation during abnormal situations: The traffic orchestrator aims for flexible and resilient handling of obstructions. In case of incidents and accidents, flexibility in the transport system should be utilise so that vehicles/vessels and travellers can find alternative routes and services.	**Limited decision support and limited automation in decisions:** See above **Limited coordination within networks and across modes and networks:** Today, the coordination between modes is very limited, and is such coordination happens, it is manual. There is coordination between networks and governance areas with some modes, e.g., air transport. Coordination also exists in air traffic: ATM (Air Traffic Management) and UTM (Unmanned Aircraft System Traffic Management, e.g. drones). In sea transport, there are handovers when one vessel leaves one governance area and enters another. In general, the existing coordination is done as a part of normal operations. In case of disruptions, it is very difficult or not possible to see the total picture across modes, and to decide which actions to take. **New responsibilities and tasks might be needed:** Today, the responsibilities for a coordination between modes and related procedures are not defined. **Limited data sharing across roles, governance areas, modes and networks:** The data sharing between traffic management and Transport Service Providers and Fleet Operators are not defined. Likewise, there are no data sharing between the traffic management within modes. Even for networks within the same mode, the data sharing is restricted to traffic control issues. Data sharing about capacities and statuses that may support a better capacity balancing between modes and network does not exist **Manual handling of special events:** Today, abnormal situations and special events in the transport network are to a large extend handled manually.
Profit: Private Traffic Orchestrators are motivated by the ability to generate profit.	**Lack of innovations based on available data**: Traffic Orchestrators will get much data about the traffic. Such data can be used in new services and smart solutions. There are however few innovations that are based on such data today. **Traffic orchestration is not yet a commercial service:** So far, traffic orchestration is not provided as a service to third parties. Business models for such services are also needed. **Must consider investment costs:** The willingness to invest in new traffic orchestration solutions may vary. The benefits are so far not documented. **Disruptions are costly:** In private transport network, the cost of disruptions will influence the willingness to invest.
Be a trusted authority: Traffic Orchestrator depend on the willingness to share data of transport services and operations. Thus, they must be independent,	**Priority rules are not always well defined:** Some vehicles and vessels get priority with respect to access and use of the transport networks. The rules to such priorities are not always clear. It may be difficult to know which behaviour and which measures that can be taken to get the advantages.

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transparent, and trusted party that orchestrates the traffic according to fair principles.	Clarity in rules create trust in the Traffic Orchestrator and thus also increase the willingness to share data.

5.3 Drivers and Goals

In the sections, each of the stakeholder types are described by the *Goals* linked to their *Drivers* defined in section 5.2. The Goals are influenced by the "delta" between the *Drivers* and the associated *Assessments* in section 5.2.

Note: The Goals represent the perspective of the associated stakeholder type.

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5.3.1 Transport Service Providers

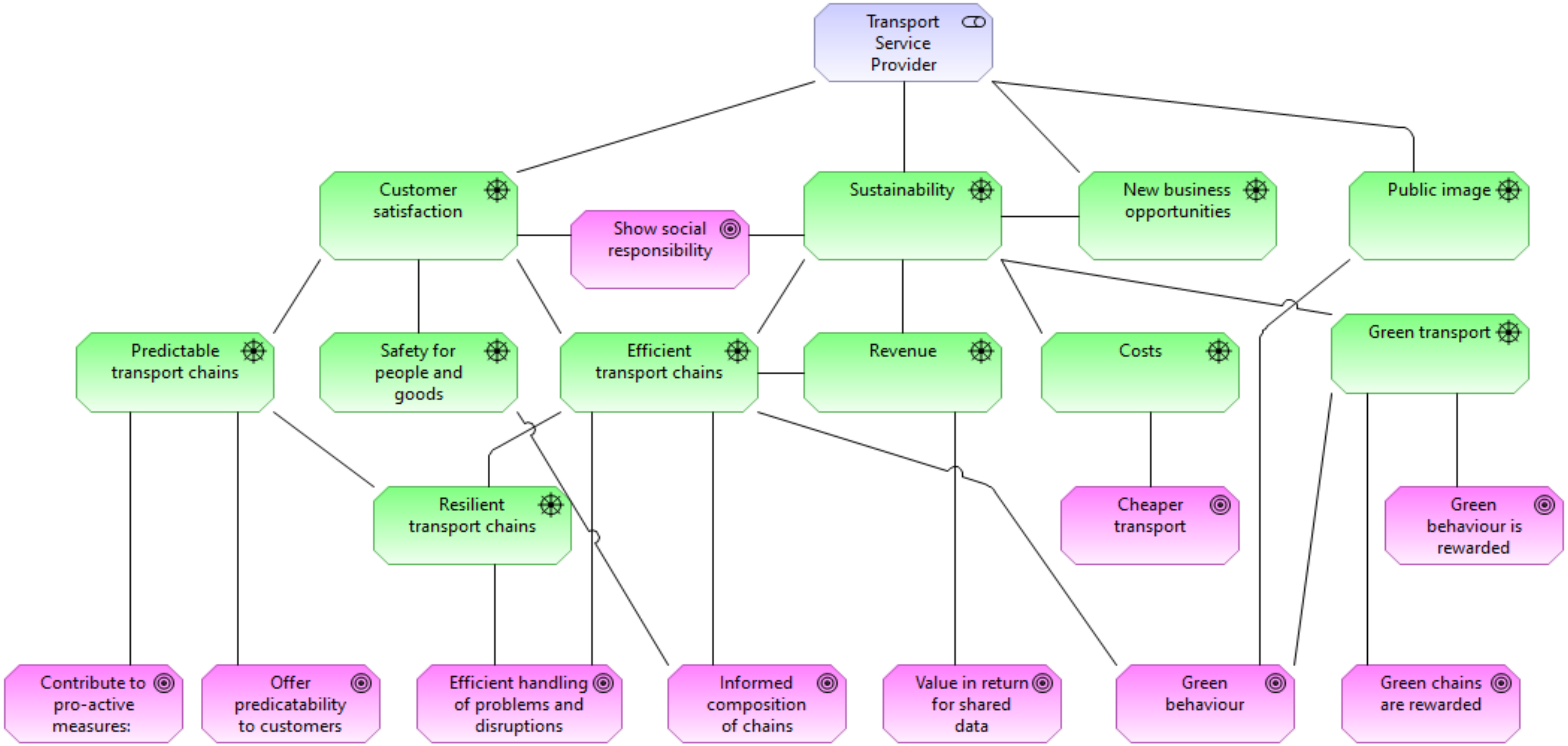

Figure 10: Transport Service Provider Motivation Diagram: Drivers and Goals

The Goals of the Transport Service Provider are, as illustrated in Figure 10:

- **Show social responsibility:** Transport Service Providers may want to appear as contributors to sustainable transport. Thus, they are willing to contribute to a traffic orchestration that aim to optimise the transport within as well as across modes and network, to the best of the society.
- **Contribute to pro-active measures:** As a consequence of the above, and providing that this is likely give more optimal transports, Transport Service Providers should be willing to share data with the traffic orchestrator, and to adapt their transport chains to requests from the traffic orchestrator as a pro-active measure (e.g., when congestions are predicted).
- **Offer predictability to customer:** The customers of Transport Service Providers are affected by traffic problems, and transports are more often affected by the climate changes. To offer predictability to their customer, Transport Service Providers should get support for predictability from the traffic orchestration.
- **Efficient handling of problems and disruptions:** Transport Service Providers must dynamically re-plan and adapt the transport chains to current and upcoming situations. They should get early notification and warnings about predicted, occurred, unforeseen situations (accidents, disruptions, etc.), and transport orchestration measures that may affect ongoing/planned chains. They should also get support for informed decisions on how to handle situations, e.g., information on the expected duration of the problem, etc.
- **Informed composition of chains:** Transport Service Providers should compose the transport chains based on knowledge about current and predicted network and traffic situations. The transport chains should in the future be composed in a more dynamic way. The next leg may be planned when the previous leg is ongoing or finalised. Customised real-time information, predictions, early notifications, and warnings should give Transport Service Providers time to look for the best possible transport opportunities for the next leg.
- **Value in return for shared data:** Transport Service Providers should as far as possible not have to share business sensitive information and data about their customers. They should however be willing to share some data and anonymous data due to their societal responsibility and the benefits the sharing of the data may give. Metadata on planned and ongoing transport chains should be shared with the Traffic Orchestrator to facilitate holistic and informed management of traffic flows. In return, the Transport Service Providers should get customised support during normal and abnormal traffic situation.
- **Cheaper transport:** Transport Service Providers buy transports from Fleet Operators. Traffic orchestration services should make the transport operations more reliable, predictable, and cost efficient. This should directly or indirectly also reduce the costs for the Transport Service Providers.
- **Green behaviour:** Transport Service Providers should prefer green modes. Such transport services should be available and accessible and not more expensive than other alternatives.
- **Green chains are rewarded:** The use of green modes and services should be rewarded, and transport chains with legs transporting cargo or passengers to/from such modes should also get benefits.

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5.3.2 Fleet Operator

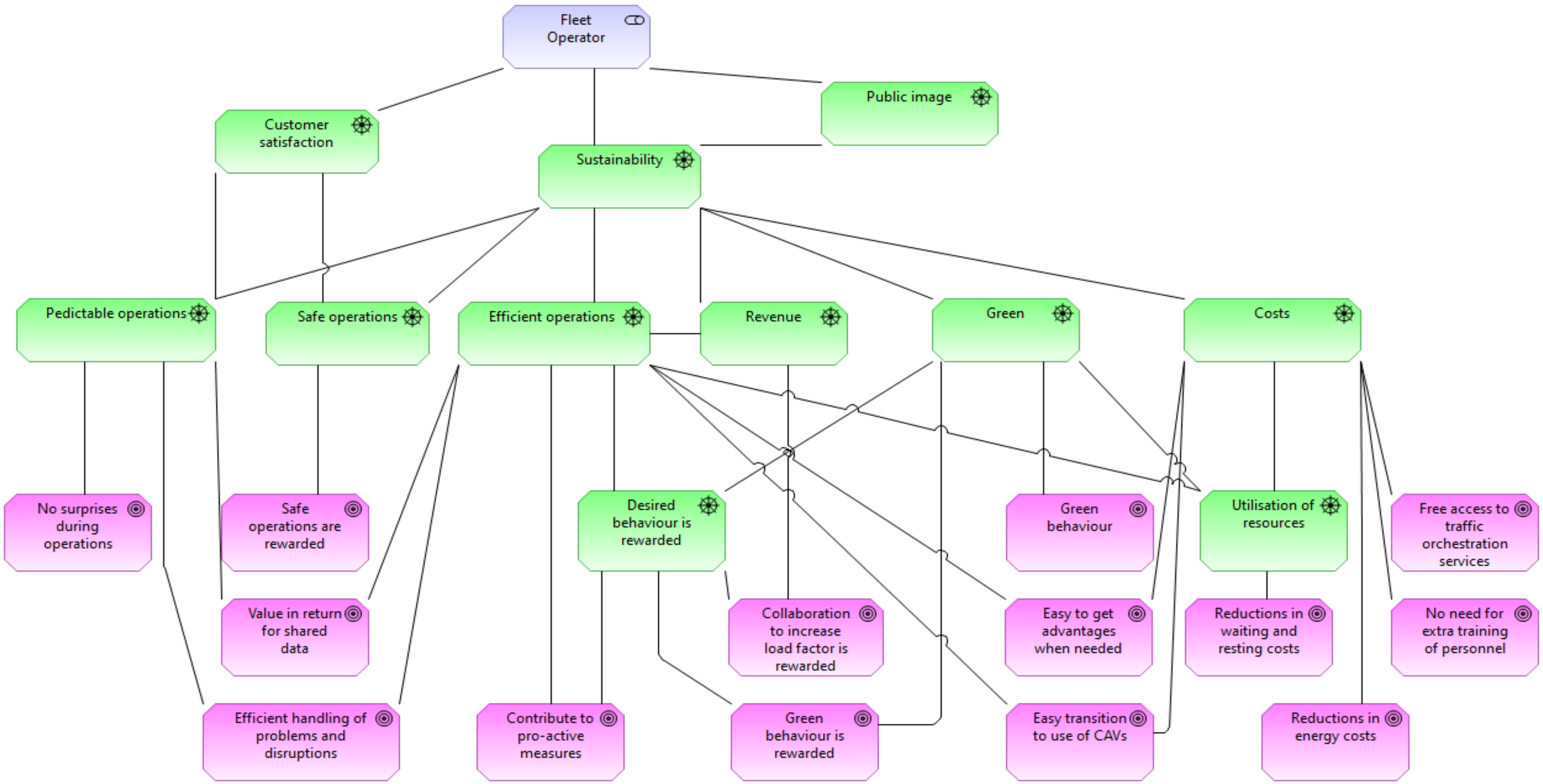

Figure 11 Fleet Operator Motivation Diagram: Drivers and Goals

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The Goals of the Fleet Operator are, as illustrated in Figure 11:

- **No surprises during operation:** In case of unforeseen situations, Fleet operators should get early notifications and warnings, preferably before situations occur, to have time to take mitigating actions. More time for re-planning should facilitate more optimal operations, cost reductions, and higher customer satisfaction.
- **Safe operations are rewarded:** Transport operations that are accomplished according to rules with transport means that fulfil all requirements should be rewarded.
- **Value in return for shared data:** When Fleet Operators provide data on planned and ongoing transport operations to the Traffic Orchestrator, they facilitate holistic and informed management of traffic flows. In return, Fleet Operator should get customised support during normal and abnormal traffic situation.
- **Efficient handling of problems and disruptions:** The Fleet Operators should be able to dynamically re-plan and adapt operation to current and upcoming situations to limit negative consequences. They need early notification and warnings about predicted situations, unforeseen situations (accidents, disruptions, etc.) that have occurred, and transport orchestration measures that may affect ongoing and planned operations. They should also get support for informed decisions on how to handle situations, e.g., information on the expected duration of the problem, advice on alternative routes, etc.
- **Contribute to pro-active measures:** Fleet Operator should be willing to contribute to efficient traffic flows. On request, they should also adapt their transport operations to requests from the traffic orchestrator as a pro-active measure. In return, they should get customised support.
- **Green behaviour is rewarded:** Transport operations should be handled according to their characteristics and their adaption to green behaviour. The use of green transport means and energy effective transport operations should be rewarded. The latter may for example be related to high load factors and eco-driving. Such transport operations should get advantages.
- **Collaboration to increase load factor should be rewarded:** Fleet operators that collaborates with other to increase load factors should be rewarded. New business models should arrange for collaborations.
- **Green behaviour:** The use of green Transport means should be the preferred alternative. They should be available and accessible and not more expensive than other alternatives. It must be easy and convenient to get access the energy needed, and the energy must be green.
- **Easy to get advantages when needed:** Critical transport operations should get advantages. The advantages may for example be provided based on the operation type (e.g., emergency operation). Other operations may however also be advantageous from a societal point of view. Transport operations that are legs in multimodal chains should for example get priority if the load factor of the next leg might be considerably reduced if the cargo/passengers cannot be delivered in time.
- **Easy transition to use of CAVs:** To reduce the burden of the Fleet Operators, the transition to use of CAVs should be supported by an easy, predictable, and seamless integration with the traffic orchestration.
- **Reductions in waiting and resting costs:** The traffic orchestration should facilitate more predictable operations with a minimum of waiting times. Resting times should be considered in the traffic orchestration. Delays that may cause additional resting times should if possible be avoided.
- **Reductions in energy costs:** The use of energy should be considered when traffic orchestration measures are taken. Suggested routes should for example be as energy efficient as possible.
- **No need for extra training of personnel:** The introduction of advanced traffic orchestration should reduce the possibility for human errors, increase the safety, and improve the efficiency of the transport operations without any additional requirements regarding the training of personnel.
- **Free access to traffic orchestration services:** The traffic orchestration interaction must be supported by all transport means after a certain production year. No extra investments should be required. The software in the transport means should update automatically, to facilitate integration with new transport orchestration services.

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5.3.3 Network User

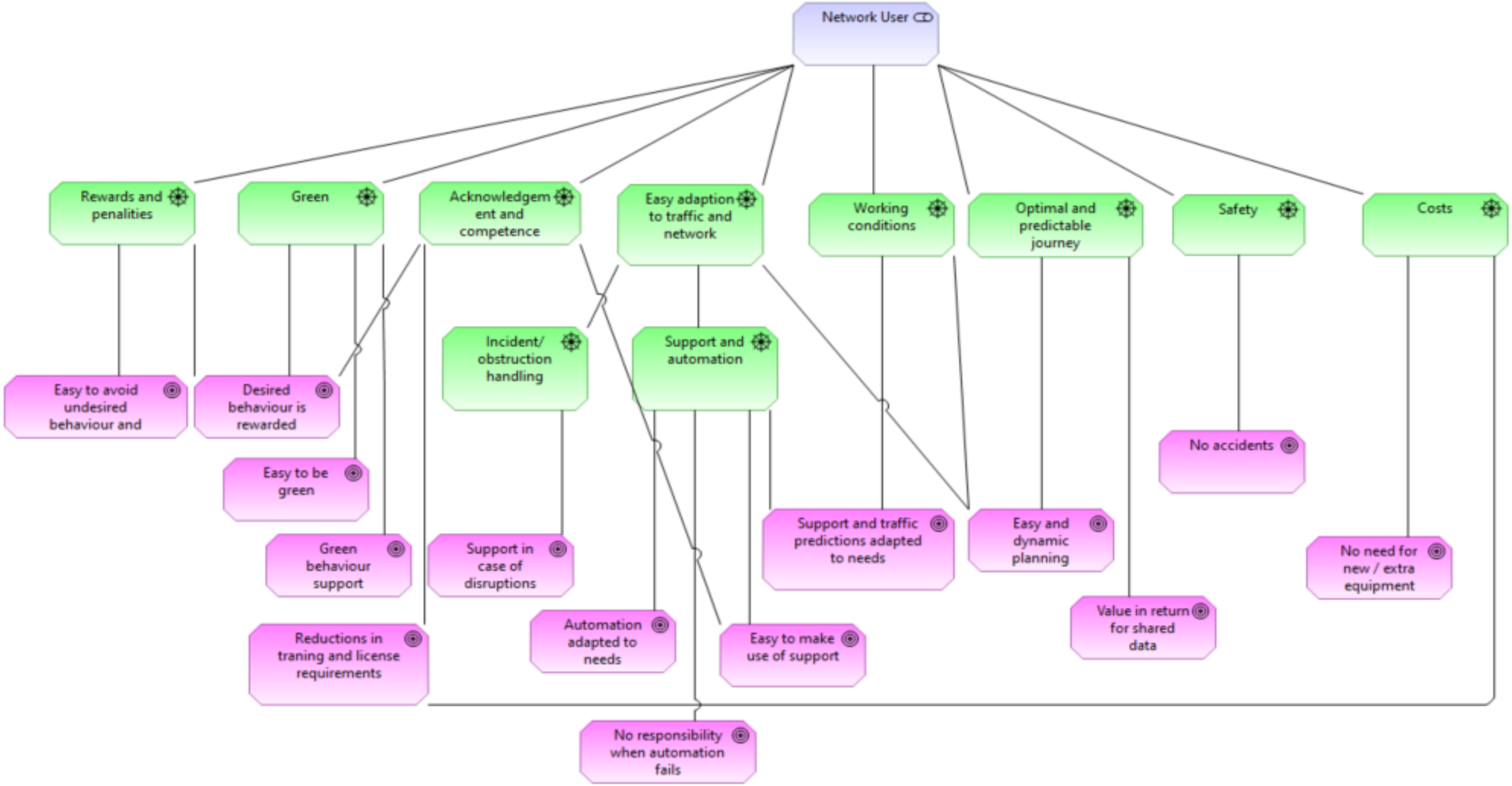

Figure 12: Network User Motivation Diagram: Drivers and Goals

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The Goals of the Network User are, as illustrated in Figure 12:

- **Easy to avoid undesired behaviour and penalties:** It must be easy for all types of Network Users to adapt to the desired behaviour. No ethical issues or discrimination should exclude any Network Users.
- **Desired behaviour is rewarded:** Network Users should be handled according to their characteristics and their adaption to the rules concerning the relevant network or the part of the network. Green transport means and those with a green behaviour should also get advantages compared with others.
- **Easy to be green:** Green modes and the use of green vehicles/vessels should be the easiest and preferred alternatives. They should be available and accessible and not more expensive than other alternatives. It must be easy and convenient to get access the energy needed, and the energy must be green.
- **Green behaviour support:** Network Users should be well informed about green alternatives and the advantages they represent – not only for the environment but also with respect to the traffic orchestration.
- **Reductions in training and license requirements:** The introduction of automation and advanced user support must not cause burdens on drivers and crew. The new solutions must be independent on the deriver/crew reduce the possibility for human errors, increase the safety, and improve the efficiency of the transport operations carried out.
- **Easy to make use of support:** The Network User should not be overloaded with information. They should as far as possible get just the information and support they need when they need it, via the equipment normally used by the Network User.
- **Support in case of disruptions:** Network Users shall get informed advices on how to handle disruptions. The advices should as far as possible be adapted to the planned transport operation.
- **Automation adapted to needs:** The degree of automation and the support provided to the Network User through automation must be adapted to the needs of the Network User and the situation.
- **No responsibility when automation fails:** The responsibilities must be well defined and regulated by laws so that they are clear to the Network User. If the automation fails or the collaboration between the automation and the Traffic Orchestrator fails, the Network User should have no responsibility.
- **Support and traffic predictions adapted to needs:** During the journey, the Network Users shall get informed advices and other information adapted to the situation and the transport operation. This includes advices on pro-active measures that can contribute to a better handling of foreseen situations in the transport network along the route.
- **Easy and dynamic planning:** At the start of a journey and during the transport, the Network User shall get planning/re-planning support adapted to current and foreseen situations in the transport network, disruptions included. Relevant information shall automatically be provided to the Fleet Operator to facilitate coordinated decisions.
- **Value in return for shared data:** When the Network User provides data on planned transport operations and real-time information during the execution of the transport operation to the Traffic Orchestrator, they facilitate holistic and informed management of traffic flows within and across networks and modes. In return the Network User should get customised support during normal and abnormal traffic situation.
- **No accidents:** The traffic management measures must arrange for safety for all types of Network Users, also soft modes like pedestrians and cyclist.
- **No need for new/extra equipment:** Support and information must be provided via the equipment normally used by the Transport Users, and it must be easy for the providers of such equipment to integrate the supporting services in a standardised way.

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5.3.4 Traffic Orchestrator

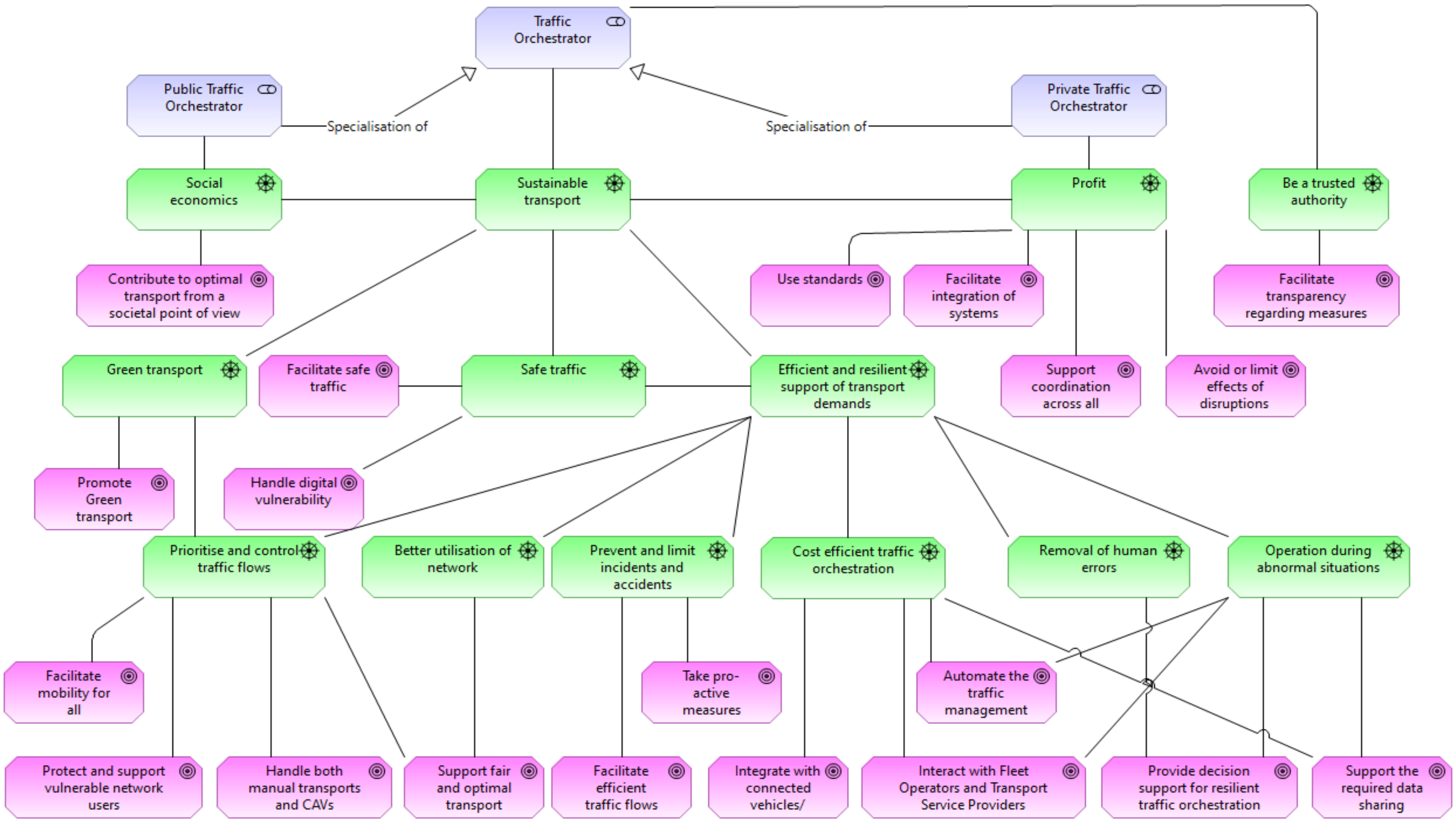

Figure 13: Traffic Orchestrator Motivation Diagram: Drivers and Goals

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The Goals of the Traffic Orchestrator are, as illustrated in Figure 13:

- **Contribute to optimal transport from a societal point of view:** The traffic should be coordinated and optimised across networks and modes.
- **Handle digital vulnerability:** The digitalisation of the traffic management should not cause a safety risk. Information security, cyber security, and backup solutions in the case of system failure must be emphasized.
- **Promote Green transport:** The traffic orchestration should arrange for use of green modes and also prioritize such modes according to the transport policy, strategy, and regulations of the network.
- **Facilitate mobility for all:** The traffic orchestration should not discriminate any network users. The traffic orchestration must be supported by standard on-board equipment, that according to international agreement should be installed in most transport means. Software updates must be automated and for free to facilitate broad deployment.
- **Protect and support vulnerable network users:** The traffic orchestration should take the needs of soft modes and vulnerable network users into account according to the transport policy, strategy, and regulations of the network.
- **Handle both manual transports and CAVs:** Traffic orchestration strategies must ensure that both manual vehicles/vessel and CAVs can be supported.
- **Provide fair and transparent traffic orchestration:** The traffic orchestration must be trusted to ensure acceptance and participation. The rules applied must be public and transparent, and based on open policies, strategies, and regulations.
- **Facilitate efficient traffic flows:** The traffic orchestration must optimise the traffic flows. Trade-off with other performance targets must however also be considered as defined by a strategy.
- **Take pro-active measures:** The evolvement of the traffic situation must be predicted, and pro-active measures must be taken to avoid undesired situations.
- **Integrate with connected Network Users:** The traffic orchestration must take future integration with a high number of CAVs into account.
- **Interact with Fleet Operators and Transport Service Providers:** Traffic Orchestrators must interact with Fleet Operators and Transport Service Providers to get input on and to influence planned and ongoing operations. This should give better predictions and more informed decisions regarding the operations.
- **Automate the traffic management when possible:** The traffic orchestration should be highly automated to ensure that the complexity can be handled, that measure conditions are followed, that efficiency is maintained, and that the quality is high. The involvement of human operator must however also be emphasized when this is suitable. Personnel must be trained, and human factors must be emphasized.
- **Provide decision support for resilient traffic orchestration:** The decisions taken must be supported by data analysis and artificial intelligence. Situations and events should if possible be detected in advance to arrange for pro-active and mitigating actions. In case of accidents and disruptions, the system should support mitigating actions and the restoration of the normal situation.
- **Support the required data sharing:** The traffic orchestration depends on access to a variety of data. The collection, management, and use of these data must be facilitated and manged.
- **Standardisation supporting the integration of systems**: Actors and systems must interact and support each other according to international standards to facilitate an economic sustainable establishment of the multimodal traffic management ecosystem.
- **Support coordination across all network types:** The mechanisms and rules regarding the coordination between modes and network must be standardised and supported by the networks.
- **Limit costs and effects of disruptions:** Disruptions must be avoided or limited through resilient traffic orchestration with advanced decision support.

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6 Context view

The context view addresses the context in which the System of Interest operates. This includes specifications of:

- *The functionality and abilities* of the System of Interest. The intention is to clarify the scope and to support the definition of the requirements to be fulfilled by the system.
- *Business objects* supporting the functionality. The notation used is described in Annex A.2.
- *Environmental model* describing the systems the System of Interest must interact with.
- *Mapping model* describing how the functionality described can be mapped to logical services.

ArchiMate Business Layer model elements are used to represent the functionality and the business objects (see notation in Annex A.2).

The overall concerns described in section 4.2 are met as follows:

- **Polycentricity**: The strategies for the perspectives identified are as follows:
  - *Stakeholder types*: The functionality described is linked to the stakeholder types needing the functionality.
  - *Transport modes, networks, governance levels, and transport types*: A high abstraction level is used to hide the differences. The functionality described is common to all modes, networks, governance levels, and transport types.
  - *Technology and digitalisation*: The technology to be used in the implementation is not addressed. The functionality described may be realised in several ways and may support both automation and manual activities.
- **Multimodality**: The functionality described is harmonized across modes. Solutions already implemented or tested in one model may be included as mode independent functionality to facilitate learning across modes. The approach will support a common understanding and communication across modes.
- **Resilience**: Functionality supporting resilience is included as decision support. See also section 6.5.

Note: The functionality described here *are not addressing one specific system* but rather a family of systems that fit into the multimodal traffic management ecosystem (MTME). Thus, the functionality does not address issues that are local to one single system such as for example how the user interface will work.

Note: The *aim* is to address overall functionality and abilities that systems should comply with if they should be a part of the MTME.

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6.1 Functionality for Traffic Orchestrator

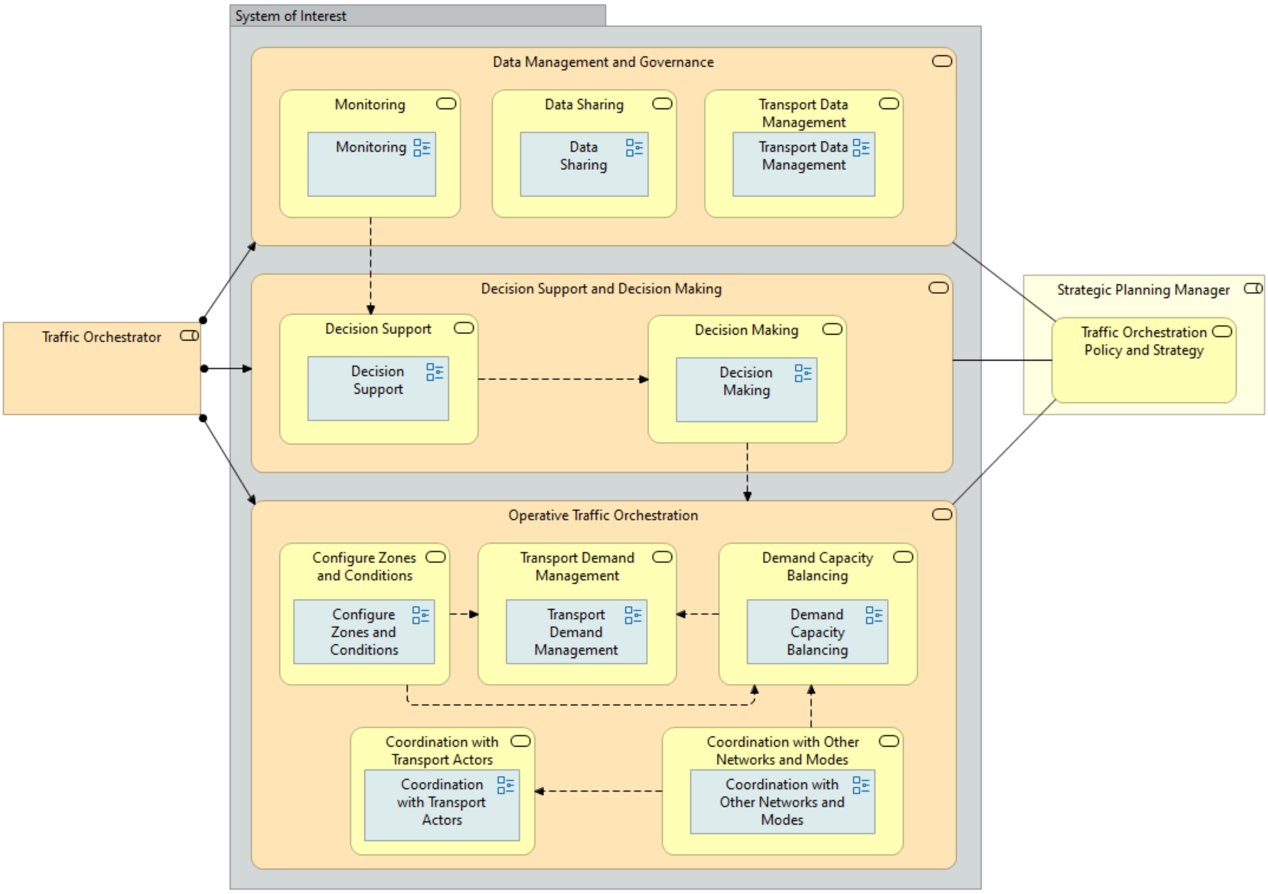

Figure 14: Overview of functionality needed by the Traffic Orchestrator

As illustrated in Figure 14, the functionality needed by the Traffic Orchestrator can be divided into three parts that together support the classic traffic management strategy where the situation is monitored through the collection of information and data (Data Management and Governance), decisions are taken based on the awareness established (Decision Support and Decision Making), and actions are taken according to the decisions (Traffic Orchestration).

All activities are in general carried out in parallel in a continuous process. The control flows in the diagram indicate the main dependencies: The monitoring provides input to the decision support, decision support provides inputs to decision-making, and decision-making guides all part of the traffic orchestration. Within traffic orchestration, the configuration of zones and conditions define how transport demand management and demand capacity balancing are to be accomplished, and demand capacity balancing may make use of transport demand management. Coordination with other modes and networks may make use of demand capacity balancing and may also initiate a coordination with transport actors.

Note: All parts must be adapted to the traffic orchestration policy and strategy for the area of governance, as defined by the Strategic Planning Manager.

In addition to the dependencies indicated by the control flows, all part of the diagram will use and update a common set of information sources (represented by business objects in the more details diagrams) to achieve the required coordination and synchronisation.

The overall functionalities are further decomposed and described in the sections below.

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6.1.1 Data Management and Governance: Monitoring

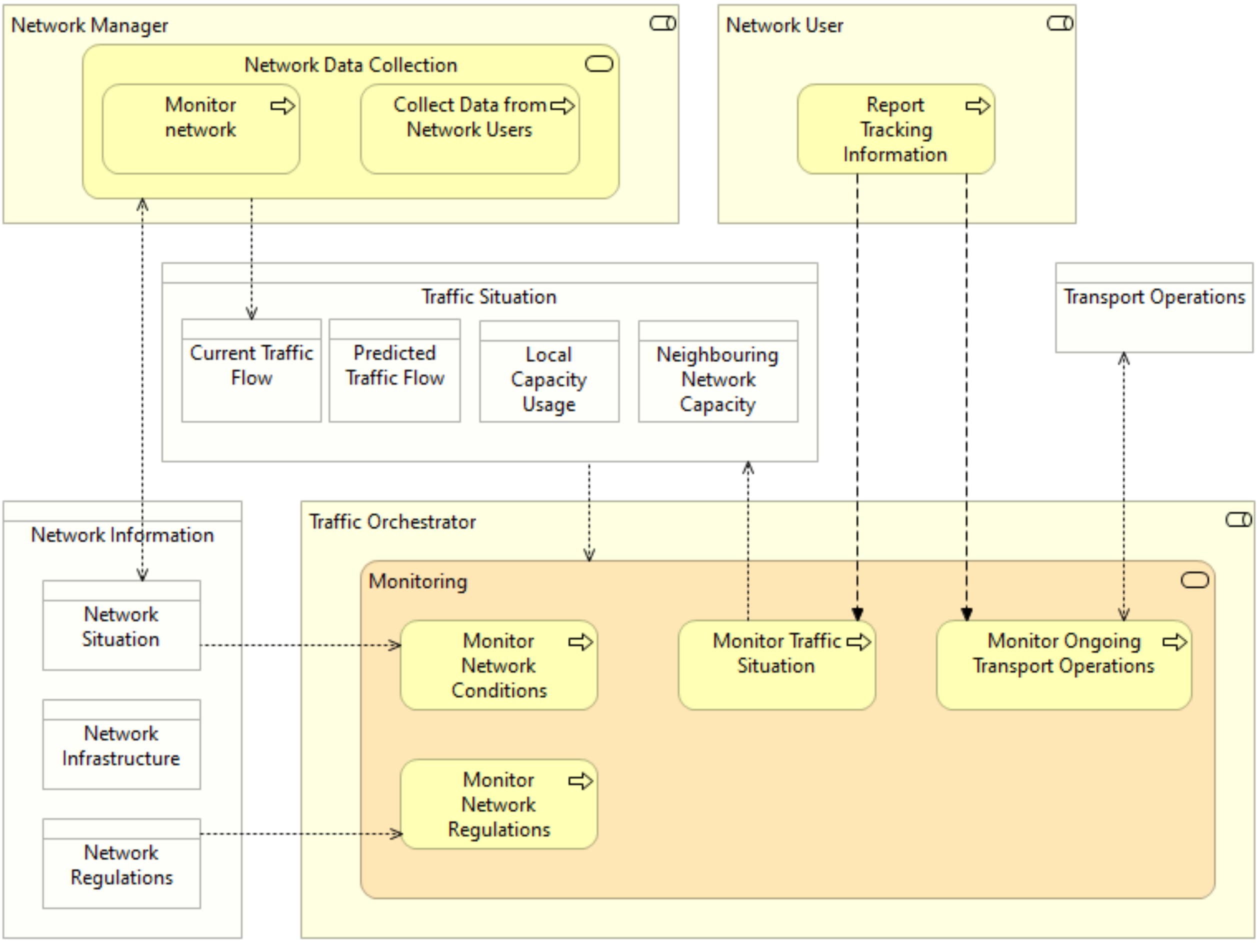

Figure 15: Business service: Monitoring

Several business processes monitor the network condition, the traffic situation, and the ongoing transport operations. The aim to establish awareness about current and predicted traffic situations to arrange for the best possible decision support and informed decisions.

The monitoring is a continuous activity. Depending on the complexity and the needs, the business processes may be fully or partly automated or they may support manual monitoring. The latter may for example be done through visualisations.

Monitor Network Conditions:

The monitoring will use network situation data collected and managed by the Network Manager (see the description of the Network Information business object for details on the information that is monitored).

Monitor Network Regulations:

The monitoring will also ensure the awareness about regulations that apply for the transport network, dynamic regulations that are adapted to current and foreseen traffic situations included. (see the description of the Network Information business object for details on the information that is monitored).

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Monitor Traffic Situation:

The monitoring will use traffic situation data. This is data about current and predicted traffic flows, current and predicted network capacity usage, and the capacity in neighbouring networks and modes. The Network Manager will provide data on the current traffic flows. The other parts of the traffic situation information are established and maintained by the traffic orchestrator (see details in the description of the Traffic Situation business object).

Monitor Ongoing Transport Operations:

The movements of the Network Users are monitored for two purposes: 1) to get an image of the current traffic situation – traffic density, speed, location of Network Users, etc.; 2) to get updated information on individual Transport operations. The latter is tracked in the Transport Operations business object.

6.1.2 Data Management and Governance: Data Sharing

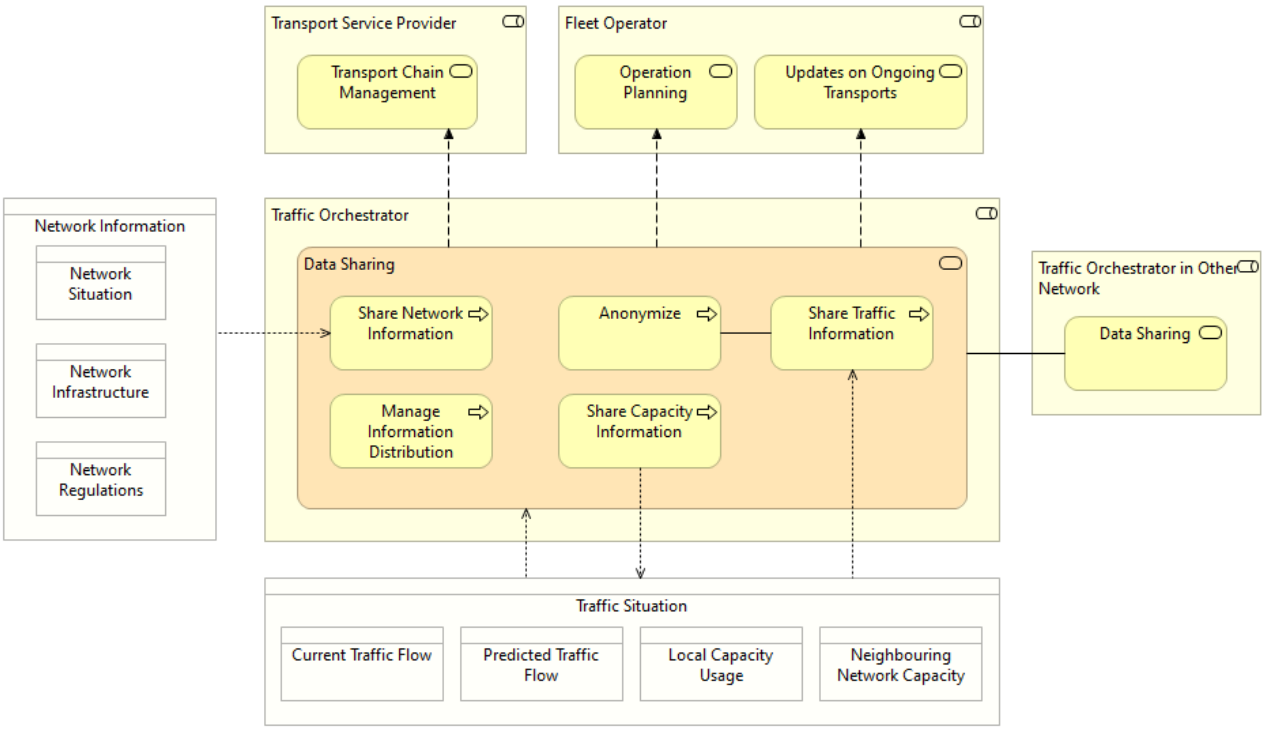

Figure 16: Business service: Data sharing

Data sharing is crucial in Multimodal Traffic Management. The aim is to provide information about current and upcoming traffic situation to transport service providers and fleet operator to support informed decisions on how to organise the transports. The aim is also to share information with neighbouring modes and network to support decisions regarding the transfer of transports between modes and networks. The data sharing and management must *consider safety and security concerns* like the protection of business secrets and privacy (GDPR), and information security. To ensure *acceptance and trust* in the traffic orchestration, the data sharing must also facilitate transparency regarding the rules and regulations that traffic orchestration decisions build upon.

The information shared in this business service can be adapted to individual stakeholder needs for a general information about network and traffic situations. Information related to the individual transport operations are however covered by the Coordination with Transport Actors business service (see section 6.1.11).

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Share Network Information

All types of network information may be shared. See the description of the Network Information business object for details.

Share Traffic Information

All types of traffic situation information may be shared. See the description of the Traffic Situation business object for details.

Anonymize

Information on the traffic situation will contain references to real transport operations that for some modes may qualify to be personal information (GDPR must be considered) or business sensitive information. Thus, the traffic situation information shared with externals must be anonymized before it is shared. The anonymisation strategies used must be adapted to the needs and may depend on among others the transport mode, the transport type, and the traffic density.

Share Capacity Information

The Transport Orchestrators of different governance areas and modes will exchange information about the capacities in their networks to support decisions regarding the demand capacity balancing. It may for example be relevant to transfer traffic to other modes and networks in case of capacity problems.

The Traffic Situation business object describes the current and predicted capacity situation in the different parts of the transport network managed by the Traffic Orchestrator as well as the capacity situations in neighbouring networks and modes. The information is frequently shared among Traffic Orchestrators and updated to arrange for informed decisions.

Manage Information Distribution

Traffic situation and network information will be shared through open channels. In additions, specialised information services may be provided to stakeholders like transport service providers and fleet operators. Such stakeholder may for example may subscribe to certain types of information, e.g., notifications or warnings in case of specific situations.

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6.1.3 Data Management and Governance: Transport Data Management

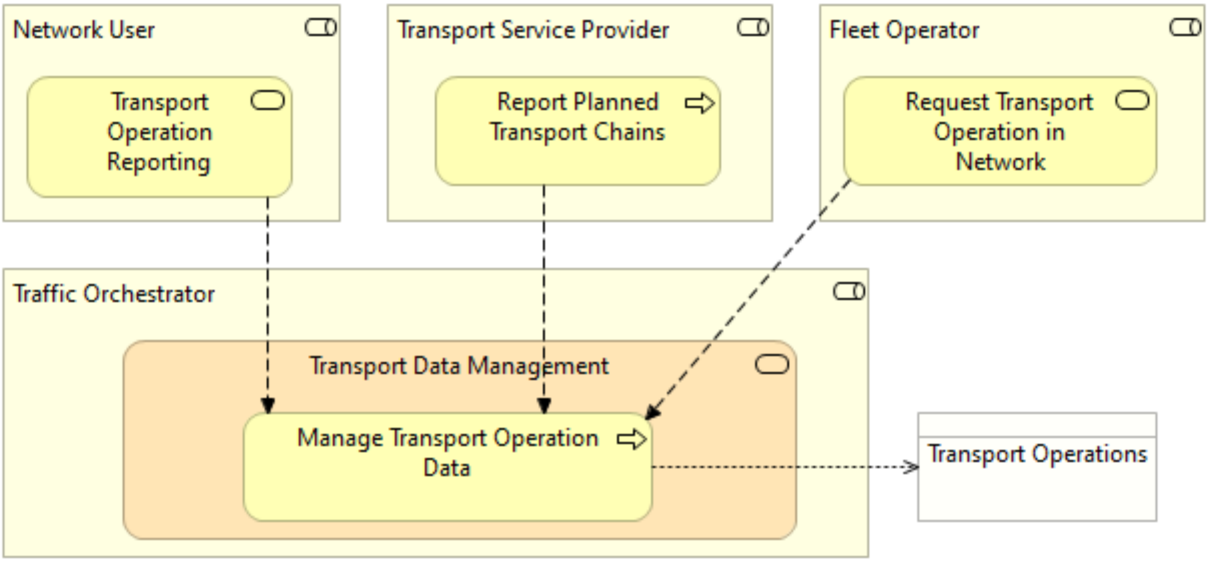

Figure 17: Business service: Transport Data Management

The Traffic Orchestrator will receive and manage information on planned and ongoing transport operations. The aim is to facilitate the use of such information in operative planning (e.g., when the future traffic situation is predicted and time slots are assigned), and in operative traffic management (e.g., when automated measures are taken depending on the characteristics of the individual transport operations).

Manage Transport Operation Data

Transport Service Providers and Fleet Operators report about planned operation. In some modes, this can be done a long time before the actual operations (months or years). The plans may be refined, updated or cancelled at any time. When a transport operation has started, Network Users may report about relevant aspects related to the operation (tracking information, stops, problems, etc.). See details in the description of the Transport Operations business object.

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6.1.4 Decision support and Decision Making: Decision Support

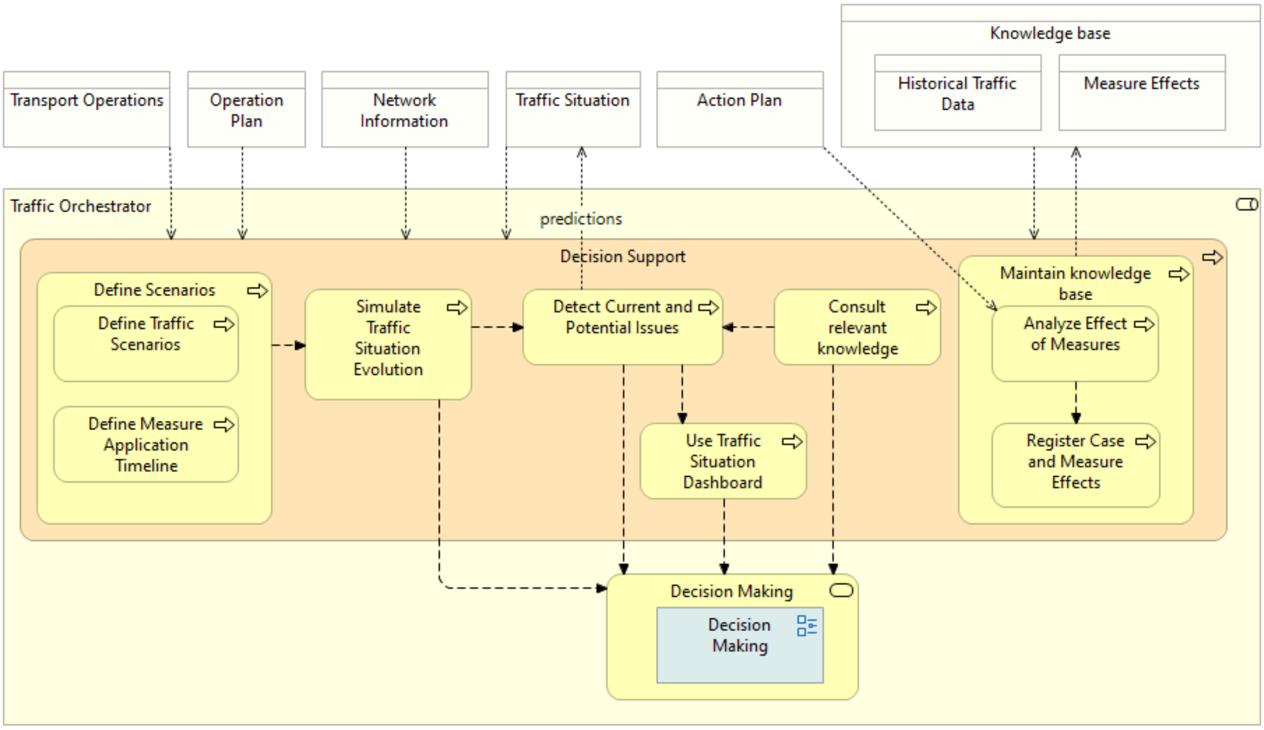

Figure 18: Business service: Decision Support

The aim of the decision support is to support the traffic orchestration decision making regarding the measures and action to be taken, and thereby to support resilience and the identification of the best possible measures or measure alternatives The decision support must be adapted to local and mode specific regulations and procedures and the complexity of the traffic to be managed. The decision support must also be adapted to the approach followed in the decision making (e.g., automated, semi-automated, or manual activities).

The decision support builds on the awareness established by the awareness established by the monitoring business service (real time data, predictions, and plans) as well as historical data. The use of historical data is facilitated through the maintenance of a knowledge base.

The decision support is a continuous activity, and depending on the traffic orchestration strategy and the traffic complexity of the traffic, several strategies may be used alone or in combinations:

- Provision of a traffic situation dashboard supporting manual decisions.
- Data analysis to detect current issues and to predict future traffic situations and upcoming issues.
- Simulations of scenarios where possible measures are taken. The simulation will provide information on the possible effects on of different measures.
- Use of knowledge base to learn from historical situations.

Define Scenarios: Define Traffic Scenarios

The scenarios to be simulated are defined. Data from the following business objects may be used: Traffic Situation, Network Information, Transport Operations, and Knowledge Base (see section on business objects for details).

Define Scenarios: Define Measure Application Timeline

The measures to be simulated are defined as a part of the simulation scenarios. It should be possible to put the measures into a timeline that is aligned with the predicted traffic situation and the operation plan.

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Simulate Traffic Situation Evolution

The simulator will use information from available business objects and simulate simulations scenarios where different measures are taken. The simulation results will show possible developments of the traffic situation provided that certain measures are taken.

The simulation results are input to the decision making and may also be used as input to the detection of potential issues (see below).

Consult Relevant Knowledge

Historical data and knowledge from the knowledge base are analysed to support decisions regarding the current and foreseen traffic situation. Artificial intelligence (AI) like machine learning techniques may be used for this purpose. The results may be provided to the business process on detection of current and potential issues (see below), or the results may be provided directly to the decision-making business service.

Detect Current and Potential Issues

Available data on the network and the traffic situation as well at data on current and planned transport operations and the operation plan are analysed (see details on the business objects). Simulation results and relevant knowledge derived from historical data may also be used. When appropriate, artificial intelligence (AI) like machine learning techniques may be used for this purpose. The result from the analyses may be:

- A detection of current issues that must be solved
- A prediction of the future traffic situation
- A prediction of future issues that may occur

The results may be provided to the traffic situation dashboard (see below) for manual decision support, or the results may be provided directly to the decision-making business service.

Use Traffic Situation Dashboard

A traffic situation dashboard for manual use will communicate relevant information to the traffic orchestrator and thereby support manual decisions.

Maintain Knowledge Base: Analyse Effect of Measures

A retrospective analysis of the effect of measures are carried out based on historical traffic data and historical data on the actions taken.

Maintain Knowledge Base: Register Case and Measure Effects

The knowledge gained from the retrospective analysis (see above) are registered in the knowledge base together with relevant historical data.

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6.1.5 Decision support and Decision Making: Decision Making

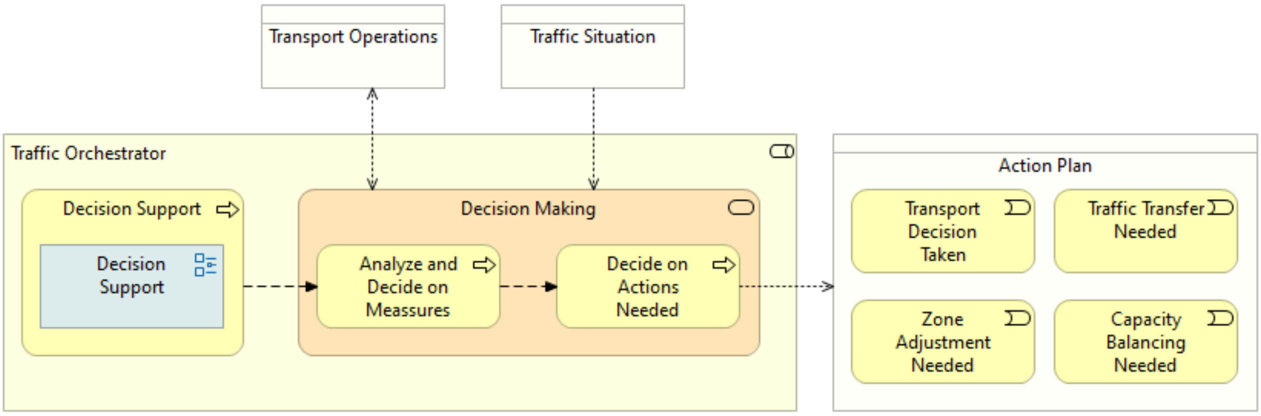

Figure 19: Business service: Decision Making

The decision making is based on input from the decision support. The reception and processing of the input may be automated, the input may be manually observed and handled, or a semi-automated process may be supported. In any case, the aim is to take decisions on the use of traffic orchestration measures and related coordination activities. The activity goes on continuously in parallel with the decision support.

Analyse and Decide on Measures

The decision support may suggest alternative approaches. In some cases, where there are clear rules on what to do, decisions can be automated. Manual decisions may however be needed in cases when the trade-offs between different performance targets cannot be automated.

Decide on Actions Needed

Based on the decisions, planned actions regarding planned and ongoing transport operations are entered into the Transport Operations business object. This may for example be decisions regarding responses to transport service providers and fleet operators (e.g., to confirm, to decline, to transfer, or to request a replanning).

In addition, actions and trigger events may also be registered in the Action plan together with definitions on the actions to be taken. The establishment of new zones may for example be decided to facilitate the handling of current or foreseen traffic situations.

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6.1.6 Operative Traffic Orchestration: Configure Zones and Conditions

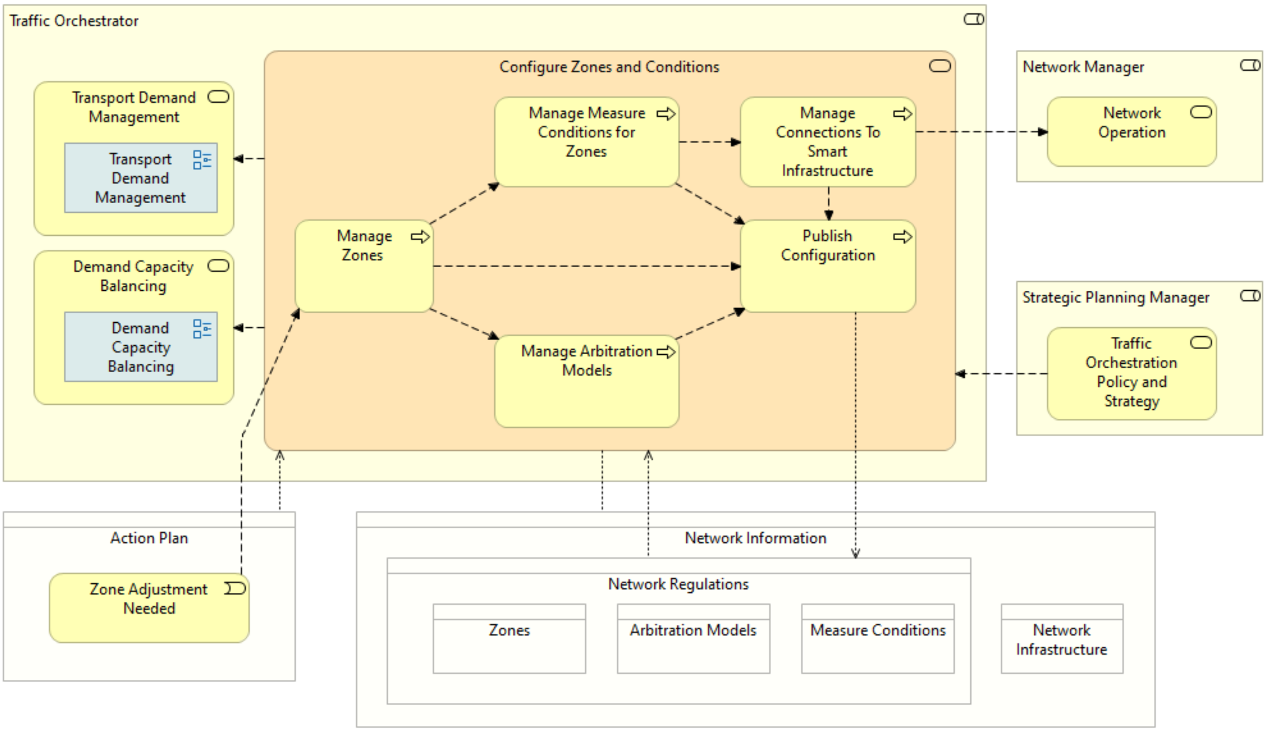

Figure 20: Business service: Configure Zones and Conditions

The governance area for the Traffic Orchestrator and the zones where the transport demand management and demand capacity balancing measures are taken are managed. The aim is to facilitate automated or semi-automated measures in accordance with to pre-defined rules and strategies.

The creation of zones may be triggered by the transport orchestration policy and strategy decisions taken by the Strategic Planning Measures. This may for example be more static zones for transport demand management, e.g., green areas with access control. In addition, decisions on the creation of new zones or adjustments of existing zones (e.g., updates in measure conditions) may originate from the decision-making business service.

The operational configuration of zones is registered in the network regulation business object, which is a part of the network information.

Manage Zones

The business process is triggered by "zone adjustment needed" event in the Action plan business object. This means that a decision has been taken regarding the creation of a new zone or the update of an existing zone. The Zone business object is updated accordingly (see details in the description of the Network Information business object).

Manage Measure Conditions for Zones

A decision has been taken regarding new and/or updated measures and/or measure conditions in a zone. The measure conditions are defined to support automated measures towards Network Users when the conditions are fulfilled. The measures and measure conditions are managed by the Measure Conditions business object (see details in the description of the Network Information business object).

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Manage Connections to Smart Infrastructures

Some measures can be automated or supported by smart infrastructures. In such cases, the smart infrastructure is configured to automate or support the measures.

Manage Arbitration Models

For some measures, trade-offs between different concerns and performance targets are required. The rules and strategies to be followed must be defined in arbitration models represented by the Arbitration Model business object (see details in the description of the Network Information business object).

Publish Configuration

When a zone and its related measures, related measure conditions, and arbitration models are defined, and the link towards the smart infrastructure services are established, the definitions can be published. This means that they become operative.

6.1.7 Operative Traffic Orchestration: Transport Demand Management

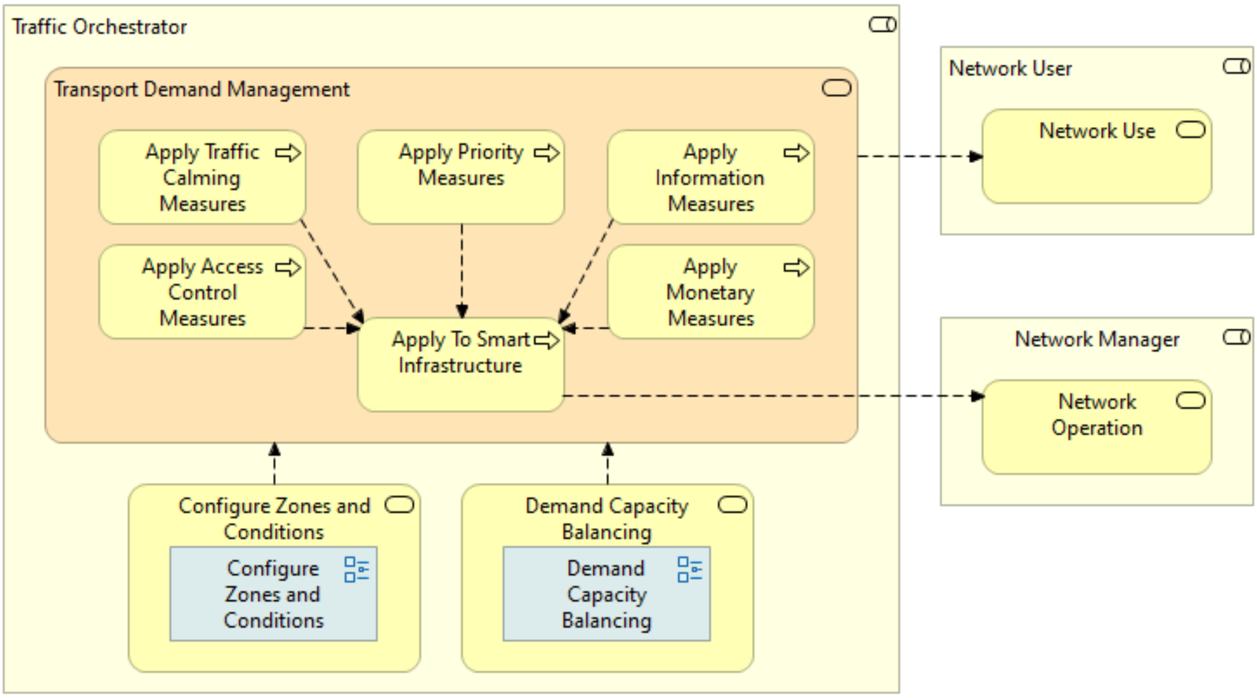

Figure 21: Business service: Transport Demand Management

The aim is to apply measures according to the configuration of the zones and according to the requests from the demand capacity balancing. The smart infrastructure operated by the Network Manager is used for this purpose.

The measures will be applied automatically according to the conditions defined for the zone. The communication with the Network User facilitates conditional measures. The Network User will pass over its characteristics, and the measures will be applied accordingly.

Apply Traffic Calming Measures

Control instructions are communicated to the Network User on how to operate within the zone. Measure conditions may support the use of different control instructions towards different Network Users depending on their characteristics.

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Apply Priority Measures

The Network Users are ranked according to their characteristics, as defined by the measure conditions., and priority is granted accordingly.

Apply Access Control Measures

Access to the zone will be assigned to the Network Users depending on its characteristics. The correct

Apply Traffic Monetary Measures

Whenever needed, information on the payment rules (e.g., price lists with related conditions) are communicated to the Network User.

Payment information is received or collected from the Network User to support decisions on or calculation of the price to pay. Several solutions may apply, for example:

- Payment information may include a price calculated by approved equipment residing in on-board equipment (calculated in accordance with the payment rules)
- Payment information may include or link to the characteristics of the Network User and/or the transport operation, and/or the duration of the network use. Such information may support decisions on or the calculations of the price to pay.

In any case, information on the price to pay is managed to be the bases for the billing and the payment.

Apply Traffic Information Measures

Information is passed to the Network Users. The content of the information may depend on the situation or on other measures taken. Priority measures and access control measures may for example be followed by information measures that explains the reason for not getting access or priority, and information may also be provided on required actions or recommended actions adapted to the characteristics of the Network User.

Apply to Smart Infrastructure

The measures are effectuated via the smart infrastructure.

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6.1.8 Operative Traffic Orchestration: Demand Capacity Balancing

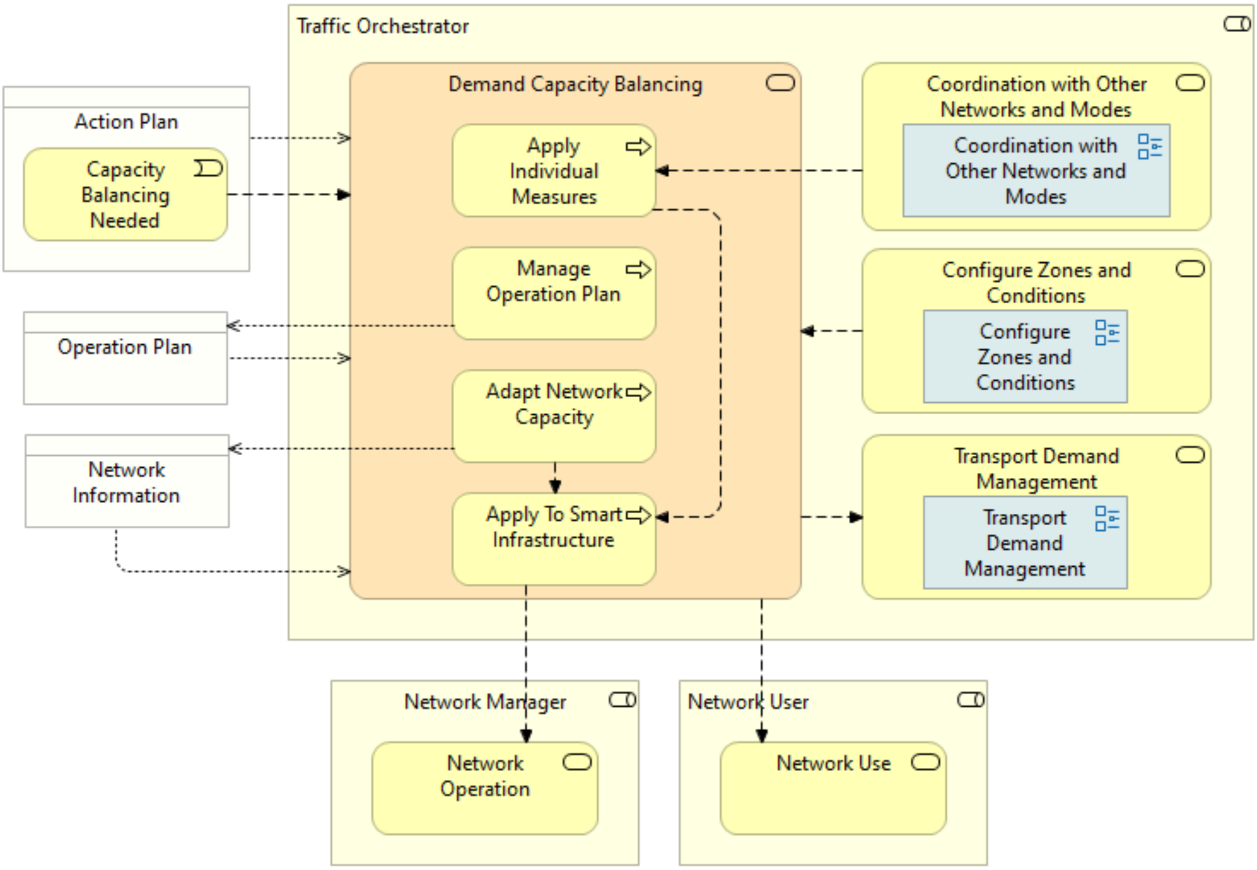

Figure 22: Business service: Demand Capacity Balancing

The business service is triggered by "capacity balancing needed" events and by requests from the coordination with other networks and modes business service. The latter applies when the coordination with other networks and modes requires individual measures towards Network Users.

The aim is to apply measures according to the decisions taken by the decision-making business service. The decisions are indicated in the Operation Plan and in the Action Plan (see business object description).

Parts of the Demand Capacity Balancing may be handled via Transport Demand Management. This is already organised via the decision-making business service, as the configurations of the related zones and measure conditions have been triggered from there.

Apply Individual Measures

The measures are defined in the Action Plan, and they may be automated or manual. The communication with the Network User facilitates conditional measures. The Network User will pass over its characteristics, and the measures will be applied accordingly.

Manage Operation Plan

The Operation Plan can be is followed up and managed in accordance with the action plan. This can be done automatically, manually of semi automatically.

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Adapt Network Capacity

The capacity of the transport network is adapted to the network conditions and the needs. Weather condition may for example reduce the capacity, or the capacity can be extended to better comply with the transport demand. The latter may for example de done by opening of additional network segments or to allow other transport types in parts of the network (e.g. lanes on a road). Such adjustments may require updates of the network information.

Apply to Smart Infrastructure

The measures are effectuated vis the smart infrastructure.

6.1.9 Operative Traffic Orchestration: Coordination with Other Networks and Modes

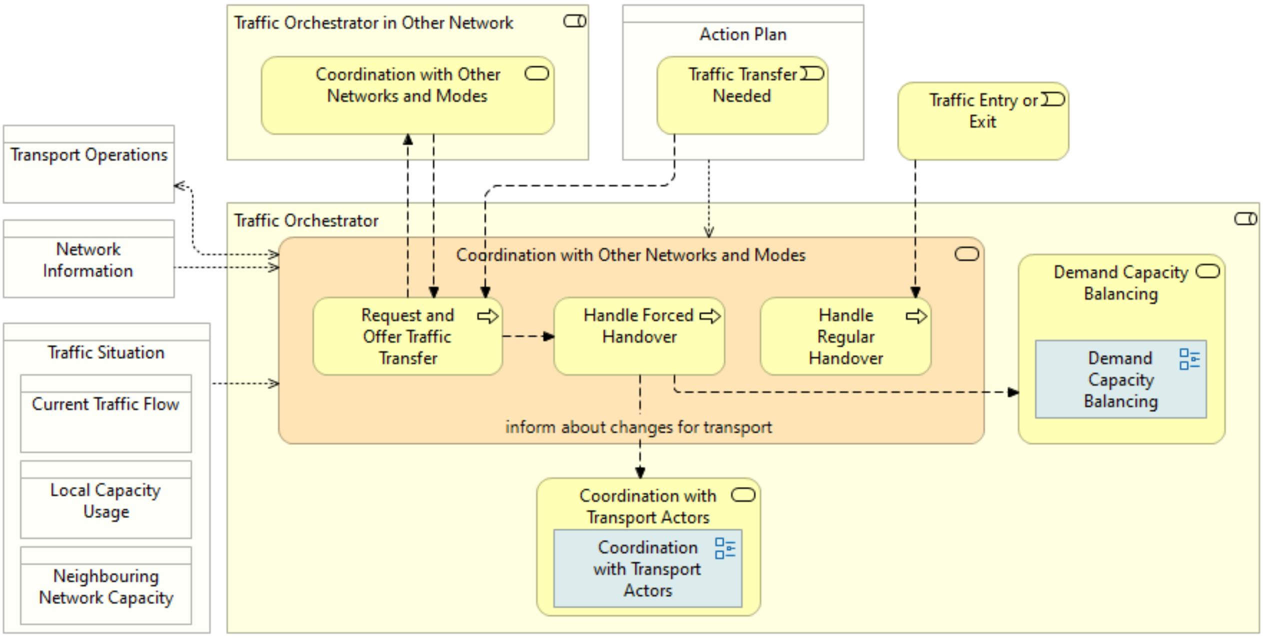

Figure 23: Business service: Coordination with Other Networks and Modes

Note that this business service deals with ongoing traffic. No coordination with other networks and modes is required for planned transports since the transport service providers and fleet operators are asked to replan their transports. Thus, the transports will be reported to other transports and modes in the normal way.

The aim is to handle the coordination with the traffic orchestration of other transports and modes. Such coordination is relevant both during regular situations and when the capacity in one network is too low compared with the transport demand. During normal situations, border crossings between the governance areas (exits and entries) must be handled. When the capacity is exceeded, a transfer of traffic from one network to another must be coordinated.

Note: This business service d*eals with ongoing traffic as coordination with other networks and modes is not required for planned transports.* In case of the latter, the transport service providers and fleet operators are asked to replan their transports, and the transports will be reported to other transports and modes in the normal way.

The *aim* is to handle the coordination with the traffic orchestration of other transports and modes. Such coordination is relevant both during regular situations and when the capacity in one network is too low compared with the transport demand. During normal situations, border crossings between the governance

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areas (exits and entries) must be handled. When the capacity is exceeded, a transfer of traffic from one network to another must be coordinated.

Request and Offer Traffic Transfer

A request to another network is triggered by a "traffic transfer needed" event. A transfer request is sent to a network with available capacity.

Transfer requests may also be received from other networks.

Handle Forced Handover

When transfer requests that are approved, transport operation information is passed to the new network, and the input is provided to the coordination with transport actors business service to informed about the transfer. Demand capacity balancing may be used to initiate the transfer measure towards individual Network Users.

Handle Regular Handover

Regular handovers are triggered by "traffic entry" or "Exit" events. Then port operation information is exchanged between the networks.

6.1.10 Operative Traffic Orchestration: Coordination with Transport Actors

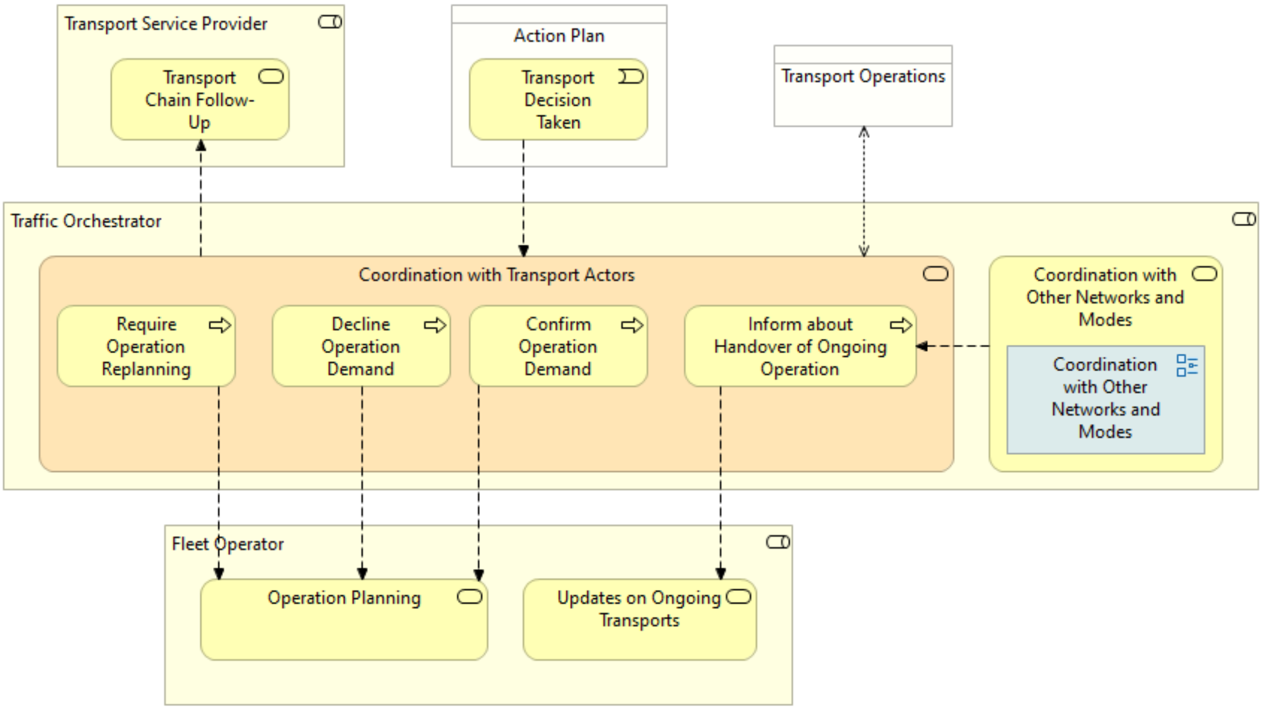

Figure 24: Business service: Coordination with Transport Actors

The business service provides feedback to the transport operation requests received from Fleet Operators and Transport Service Providers. The service may be triggered by a "transport decision taken" event in the Action Plan (this means that the request is processed) or by the coordination with other networks and modes business process. The latter is relevant in case of forced handovers to other networks and modes.

Require Operation replanning

When the "transport decisions taken" event in the action plan indicates this, a re-planning request is sent to the Fleet Operators or a Transport Service Providers of the associated planned transport operations. This may for

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example be the case if a transfer to another mode or network is suggested, or when a re-schedule is needed. The reason for the request should also be provided.

Decline Operation Demand

When the "transport decisions taken" event in the action plan indicates this, a decline is sent to the Fleet Operators of the associated planned transport operations. This may for example relevant if an obstruction makes the transport operation impossible, and if there are no alternative routes. The reason for the decline should also be provided.

Confirm Operation Demand

When the "transport decisions taken" event in the action plan indicates this, a confirm is sent to the Fleet Operators of the associated planned transport operations to confirm that the requested transport operations may go on as planned.

Inform about Handover of Ongoing Operation

If a forced handover of an ongoing operation to another network is accomplished, the associated Fleet Operator is notified. The reason for the transfer should also be provided.

6.1.11 Business objects

The business objects represent information assets that is needed to implement the functionality. The business objects may be shared or communicated between different stakeholders. One or more stakeholder types may read and/or update the information depending on responsibilities and access rights. The Traffic Orchestrator and the Network Manager may for example read and write the Network information.

> **Note:** Business objects are logical constructs. They may be implemented in different ways. One business object may be implemented by one or more physical systems, and several business objects may be combined into one physical system.

Traffic situation

This is the overall business object containing information about the dynamic traffic situation. The following business objects are included:

Current traffic flow: This is information about the current traffic flow (density, speed, etc.). The information is established by the Network Manager, e.g. by means of equipment and sensors in the network infrastructure and data collected directly from the Network Users (sensors in vehicles, etc.).

Predicted traffic flow: This is information about the predicted traffic flow (density, speed, etc.). The information is established by decision support mechanisms for predictions.

Local capacity usage: This is information about the current and foreseen use of the network capacity and will tell whether there is available capacity or a lack of capacity. The information is established by decision support mechanisms for data analysis and predictions.

Neighbouring network capacity: This is information about the current and foreseen use of the network capacity in neighbouring modes and networks. The information is established through communication with other traffic orchestrators, representing other networks and modes.

Network information

This is the overall business object containing information about the transport network. The information is strictly about the network and is not affected by the traffic situation. The transport network may be a road network, sea fairways, airways/airspaces, and railways. The following business objects are included in the overall Network information business object:

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Network infrastructure: This is spatial information about the transport network (e.g. coordinates, topography, extension, boarders, etc.). This is also information about network resources and smart infrastructures linked to the network (function, localisation, standards used for communication, etc.)

Network situation: This is the meteorological and/or hydrological condones in the transport network and related issues such as driving, sailing, and flight conditions (slippery road, snow, waves, swellings, wind, etc.).

Network regulation: This is information about the regulation of the transport network. The regulations are linked to the relevant network segments and may be static or temporal.
Regulations regarding the transport demand management and demand capacity balancing are expressed in:

- **Zones:** This is definitions of zones and includes their spatial location (the network segments, areas/space, point, line, etc.) and the type of zone (adapted to the measures needed).
- **Measure conditions:** This is information on the measures and the measure conditions related to the defined zones.
- **Arbitration models:** This is the arbitration models that regulates how trade off should be handled within defined zones.

Transport operations

This is the overall business object containing information about transport operations of relevance to the governance area. This is overall information on schedules, route, type of transport, total capacity, the capacity used (e.g. number of passengers and load factor), current location (when the operation has started), etc. The information may be updated at any time, and transport operations may also be cancelled.

The transport operations addressed are:

- **Planned transport operations:** This is information about transport operations planned by Transport Service Providers and/or Fleet operators but not yet started. Those from the Transport Service Provider have status planned. Those from the Fleet Operator may have status requested, approved, rejected, and completed.
- **Ongoing transport operations:** This is information about ongoing transport operations and may also include historical data on the routes taken (based on tracking).
- **Transport operations transferred or suggested transferred to other modes and networks:** This is information about ongoing transport operations that are transferred or planned operations that are asked to move to another network or mode due to capacity problems.

The overview of transport operations provided is used in the coordination towards Fleet operators and Transport Service Providers.

Knowledge base

This is a record of data on historical traffic situations, the measures that were taken, and the effect the measures had. The intention is to facilitate learning and to provide knowledge that be used in the decision support provided.

Operation plan

This is the plan addressing scheduled traffic events in the area of governance related to approved transport operations. This may for example be entries/exits of transport means to/from the area and other planned actions taken by the transport means (waiting and other stops, loading/unloading at waypoints, etc.).

The operation plan will link to transport operations business object where more details on the operations can be found.

Action plan

This is a plan showing scheduled actions to be taken by the Traffic Orchestrator and provides the details required to perform the actions.

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Related to the above, the action plan also includes the following trigger events:

- **Capacity balancing needed.** The event will trigger demand capacity balancing.
- **Traffic transfer needed.** The event will trigger coordination with other networks on the transfer of ongoing transport operations to another network or mode.
- **Transport decision taken:** The event will trigger coordination with Transport Service Providers and Fleet Operators. The event occurs if a transport operation cannot be fulfilled according to the demand. Details on the decision are provided the Transport Operations business object. The decision may for example be a decline, about re-scheduling, changes in route, transfer to other networks and modes, or a rejection.
- **Zone adjustment needed:** The event will trigger re-configurations of an existing zone (e.g. new access conditions) or the configuration of a new zone.

6.2 Functionality for Fleet Operator

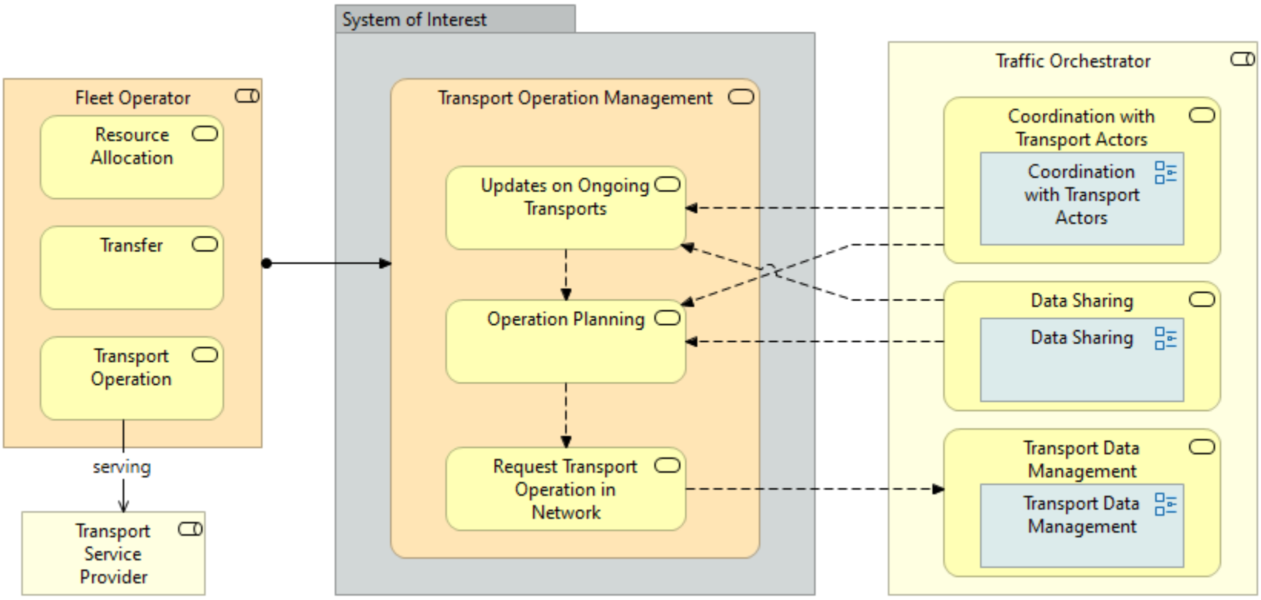

Figure 25: Overview of functionality needed by the Fleet Operator

The Fleet Operator provides transport operations to the Transport Service Providers and accomplish many actions that are outside the scope of the System of Interest (e.g., the service provision to the Transport Service Provider and the resource allocations to the transport operations).

The business processes of relevance to the System of Interest are depicted inside the Transport Operation Management business process within the grey frame in Figure 25. The processes interact with the Traffic Orchestrator to arrange for more optimal transports.

Operation Planning

Upcoming transport operations are planned. The Data Sharing business service of the Traffic Orchestrators provides input on current and foreseen network and traffic situations. Thus, the Fleet Operator can avoid mode, networks, and network segments where problems are foreseen or adapt the planned schedules to times when the traffic flow is assumed to be efficient. The plans can be dynamically updated at any time before the transport operations starts to adapt to foreseen situations. The Fleet Operator may subscribe to customised information services that may support the re-planning.

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The Coordination with Transport Actors business service of the Traffic Orchestrators may provide replies to transport operations requests (confirmations, declines, or re-planning requests) and information regarding handovers that should be taken into account in the plans.

Request Transport Operation in Network

When a transport operation is planned, a Fleet Operator will request the Transport Operator for approval regarding the use of the network in accordance with to the plan.

Updates on Ongoing Transports

The plans for ongoing transport operations may also be re-planned and adapted to current and foreseen situations when this is feasible. The Fleet Operator may subscribe to information services from the Data Sharing business services that are customised to individual needs to support the above.

6.3 Functionality for Network User

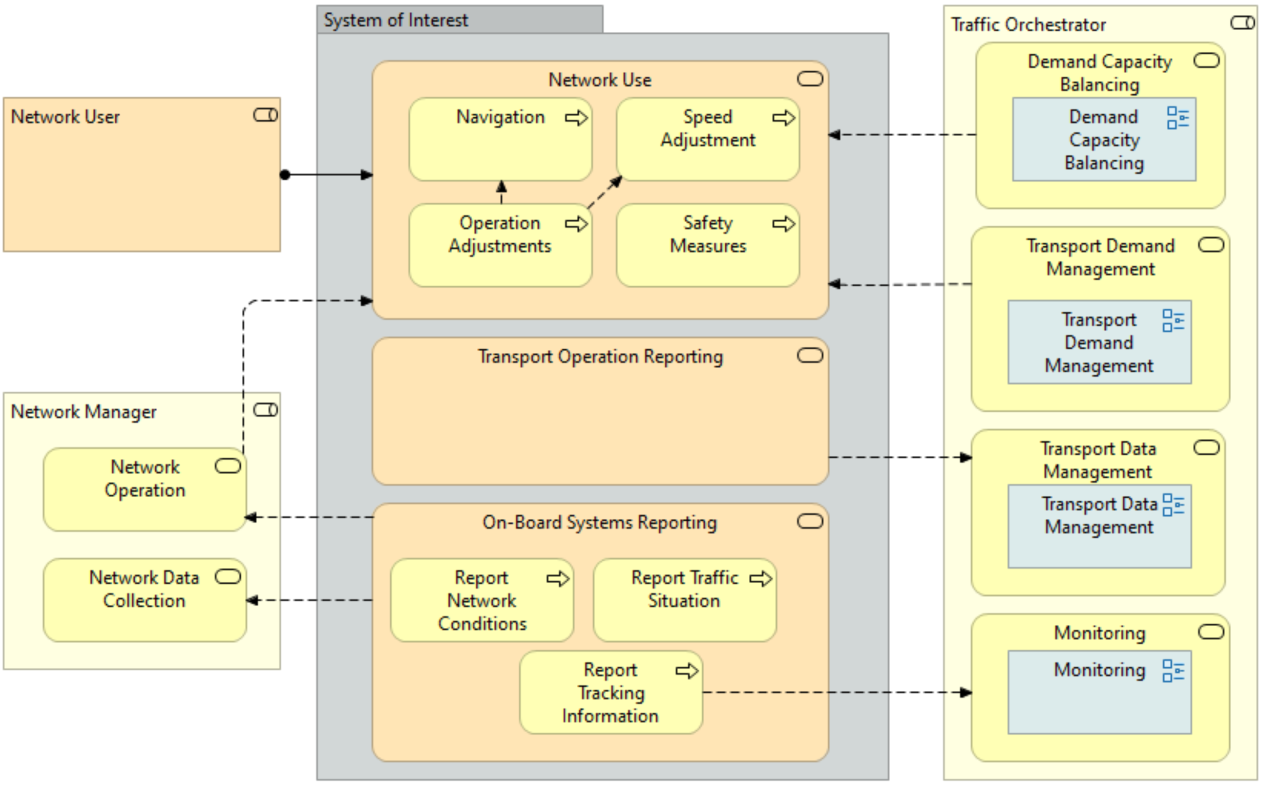

Figure 26: Overview of functionality needed by the Network User

The Network User may have two goals: To accomplish a transport operation according to directions received from the Fleet Operator, and to integrate in the traffic in a safe and efficient way according to directions received from the Traffic Orchestrator. The latter overrides the first in case of conflicts, and just this part is within the scope of the System of Interest.

The Network users will be the target for transport demand management and demand capacity balancing measures deployed in zones of the transport network (see the MTM concept model in section 4.3 for information on zones). The Network User will also report to the traffic orchestrator to contribute to the monitoring of the network and traffic situation and the ongoing transport operations.

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Network Use: Navigation

The navigation and manoeuvring of the transport means in the transport network may partly be controlled by the transport means itself and, if not a CAV, by its operator. In addition, directions may be received from the traffic orchestrator on among others the route/trajectory/course to be followed.

Transport demand management measures may influence the navigation. The navigation system will receive information on zones and regulations, and the navigation support will adapt to the regulations. The consequences may vary depending on the characteristics of the vehicle/vessel and the transport operation. Network Users that comply with the transport policy may for example get advantages.

Different types of transport demand management measures may influence the navigation and manoeuvring such as access control measures, priority measures, and information measures. Monetary measures may register the incurred cost to be paid for use of the network in monetary zones (use of gates, use of quay, payment for parking, road payment, toll road, etc.). The price to pay or data that supports decisions on the price to pay are automatically registered, and the price is adapted to the transport operation and the vehicle/vessel characteristics.

Network Use: Speed Adjustment

The speed may be partly controlled by the transport means itself and, if not a CAV, by its operator. In addition, directions may be received from the traffic orchestrator on for example acceleration/deceleration and the speed to used. The measures will to a high degree be automated.

Transport demand management measures may influence the speed control through regulations reported to the navigation system or through direct control of the transport means. This may for example be done in control zones, in traffic calming zones, and in critical zones.

Network Use: Safety measures

The traffic orchestrator may take individual measures to wards one or more individual transport means in case of emergency situations or situations that may develop to emergency situations or to avoid such situations. Emergency stop, invasive manoeuvring, or other measures may be requested to avoid or mitigate dangerous of potentially dangerous situations. The measures will to a high degree be automated.

Network Use: Operation Adjustment

This is about the execution of the transport operation. The operation is in general controlled by the Fleet Operator, but directions may also come from the traffic orchestrator on how to adapt the operation to the traffic situation.

Demand capacity balancing measures may for example tell the Network User to stop, wait/hold, or circulate. The Network User may also be rerouted to other parts of the network, to other networks, or to transhipment points for other modes. In such cases, other business services like Navigation and Speed Adjustment may be used to arrange for the best possible rerouting and transhipment.

Transport Operation Reporting

The Network User will report to the traffic orchestrator about the accomplishment of the transport operation. This may for example be information about the vessel/vehicle, next destination, earliest time of departure ETD) for next leg, latest time of departure (LTD) for next leg, latest time of arrival (LTA) at destination, load factor, changes in load factor (due to charging and discharging), vehicle weight, resting time status, etc.

The reporting should be accomplished automatically and should not interfere with the operation of the transport means.

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On-board System Reporting: Report Tracking information

Onboard sensors with related built-in systems will continuously provide data to both the Network Manager and the Traffic Orchestrator on the location of the Network user in the Transport Network via the smart infrastructure. For the reporting to the Traffic orchestrator, the position will be linked to the ongoing transport operation.

On-board System Reporting: Report Network Conditions

Onboard sensors with related built-in systems will continuously provide data on the network condition (temperature, friction, humidity, snow, slush, ice, waves, swelling, wind, obstructions, etc.) to the Network Manager via the smart infrastructure.

On-board System Reporting: Report Traffic Situation

Onboard sensors with related built-in systems will continuously provide data on the traffic situation (speed, traffic density, view, etc.) to the Network Manager via the smart infrastructure.

6.4 Functionality for Transport Service Provider

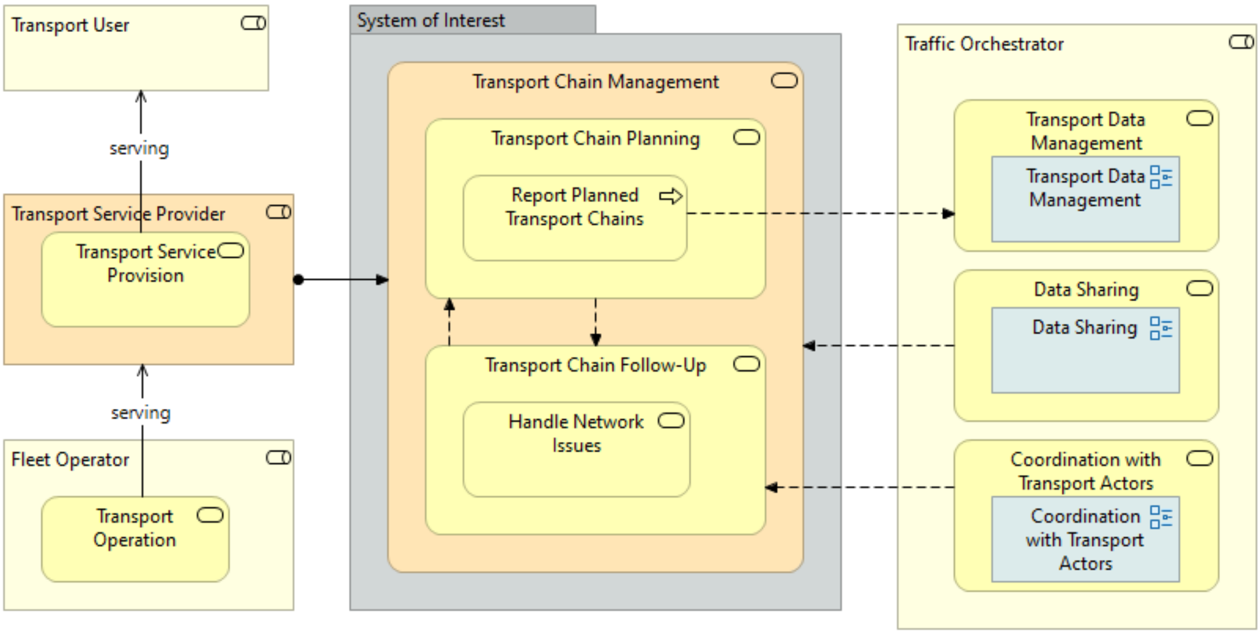

Figure 27: Overview of functionality needed by the Transport Service Provider

The Transport Service Provider provides transport services to Transport Users and accomplish many actions that are outside the scope of the System of Interest (e.g., the transport service management and service provision to the Transport User).

The business processes of relevance to the System of Interest are depicted inside the Transport Chain Management business process within the grey frame in Figure 27:. The processes interact with the Traffic Orchestrator to arrange for more optimal transports.

Report Planned Transport Chain

Upcoming transports are planned. The Data Sharing business service of the Traffic Orchestrators provides information on current and foreseen network and traffic situations. Thus, the planned transport chains and legs can avoid the use of modes, networks, and network segments where problems are foreseen. The plans can be dynamically updated at any time before the transport operations start.

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The planned chain is reported to the Transport Data Management business service al long time before the transport starts, and the Transport Service Provider can subscribe to information services that are customized to the follow up of the plans and the chains.

Handle Network Issues

The Coordination with Transport Actors business service of the Traffic Orchestrators may request a replanning of transport chains in case of current or foreseen network issues or capacity problems.

6.5 Resilience aspects

The Decision Support business service of the Traffic Orchestrator (see section 6.1.4) will support resilience. The diagram in Figure 28 provides another view upon how the resilience in the decision support is handled.

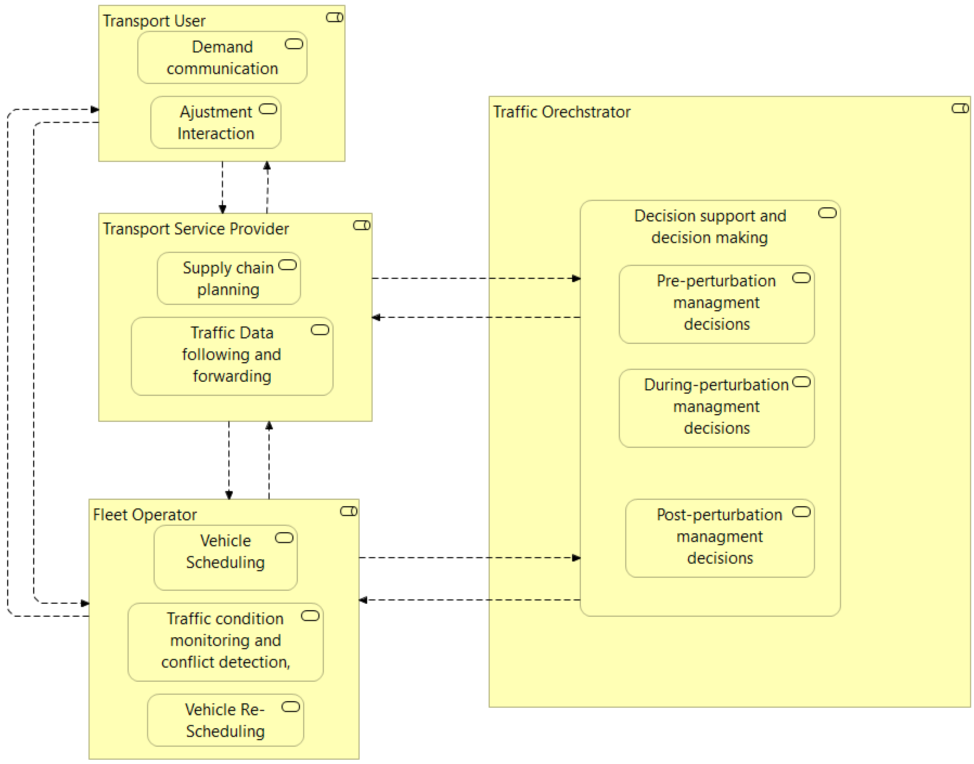

Figure 28: Resilience Management view upon Decision Support: pre-, during- and post-perturbations.

A **resilient** multimodal network can be planned in pre-, during- and post-perturbations stages. A well-organized coordination and traffic data exchange between stakeholders (including passengers, but this is outside the scope of the System of Interest) is crucial in all stages:

1) **Pre-perturbation stage**. In the transportation planning stage, the Transportation Service Providers and Fleet Operators are mainly responsible. The planning mainly considers the resource allocation to fulfil the demand of transport users. They should also be aware of the not-entirely-predictable future transport demand and other uncertainties when designing the service network topologies. *They are advised to communicate with the Traffic Orchestrator to learn more about possible perturbations and corresponding management approaches.* Among the commonly used resilience management approaches are anticipatory management and stochastic planning, which incorporate possible randomness in the pre-perturbation stage. Anticipatory management uses predictive knowledge, such as probabilistic insight into transportation demand, to plan for a horizon ahead. Stochastic planning prepares for potential randomness about the future with reserved capacity or reserved possible changes to reduce the risk of network capacity saturation.

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2) **During-perturbation stage**. Perturbations can inevitably happen and cause interruption to the planned transportation service. Timely adaptive actions during the perturbations are essential to diminish the caused negative effects and corresponding propagations in the multimodal network. The polycentric architecture is promising for controlling the operations of complex and interconnected systems. *It allows different forms of coordination via the traffic orchestrator, for example by negotiation or distributed planning, among different components of the network to resolve the perturbations locally and timely.* Timely and relevant data exchange is essential to assure communication among the traffic orchestrator, transportation service providers, carriers and ports. Besides, the transport users, for example, passengers or shippers, should also be well informed of the real-time status of their trips or deliveries as well as the adapted solutions to avoid possible confusion or lags.
3) **Post-perturbation stage**. The post-perturbation resilience management share a few similarities with during-perturbation resilience management, regarding the coordination and data sharing among different stakeholders. *One difference is the traffic orchestrator aims the post-perturbation management at recovering the multimodal network back to the normal stage efficiently* (bouncing back)*, and/or dynamically adapt to changed and new conditions* (bouncing forward) *because the state/situation is changed*. Commonly used measures directly after perturbations can be vehicle re-timing (changing the departure or arrival times of the vehicles), vehicle re-routing (changing the planned routes of vehicles), passenger rerouting (changing the planned passenger carriers or routes) and freight flow re-assignment (changing the planned freight carriers) or service cancellations. The traffic orchestrator can choose among the possible measures according to the situation for a flexible operation. In case of serious perturbations, such as disaster with heavy influences, the traffic orchestrator can also invoke escalated costs to construct temporary links, to hire extra carriers, and so on.

Why resilience is vital: The multimodal transportation network is becoming increasingly complex and interconnected, involving multiple carriers of modes, ports, users and other stakeholders. Thus, an adaptive capacity of a system to sustain critical functions and to adapt to changes to have a positive effect regarding e.g. safety and capacity/ efficiency, in addition to climate change and sustainability.

The multi-component network is exposed to more disturbances compared to a single-component network. According to Woods [3] resilience can be described as *network architectures* that can sustain the ability to adapt to future surprises as conditions evolve (sustained adaptability). However, resilience is more than robustness. While *robustness* refers to systems that are designed to effectively handle known failure modes, *resilience* describes how well the system can handle troubles that were not foreseeable by the designer. Thus, robustness refers to being able to deal well with *known unknowns*, while resilience also includes being able to deal well with *unknown unknowns*.

The network requests coordinated functions of composite players to achieve adequate and competent performances. Resilience involves both: (i) the inherent topology of the network and anticipation management to cope with perturbations *prior* to the perturbations, and (ii) potential actions that can be taken *during* and/or *after* the perturbations, vital to the multimodal network.

Evaluation of resilience management. There are diverse dimensions to evaluate the resilience of multimodal transportation networks. Here we briefly describe the evaluation from the qualitative and quantitative view of points.

For qualitative evaluation, *vulnerability* reflects the network's susceptibility to perturbations that could cause considerable reductions of network service or the ability to use a particular network route at a given time. If the network can serve deviated demands using the planned schedules unchanged, then the network is *Robust*. In normal situations, there are some modifications to the original schedule. *Flexibility* demonstrates the network's ability to adapt to changing circumstances and demands.

From the quantity side, *reliability* is used to evaluate the network's functions under perturbations. For example, connectivity reliability is to evaluate the probability that there exists at least one path without disruption or heavy delay to a given destination within a given period of time; travel-time reliability is to evaluate the

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probability that a trip can reach its destination with a given period. Besides, *efficiency* is another measurement, which is defined as the expected percentage of the total traffic that a network can manage.

7 Conclusions

This deliverable defines the initial version of the ORCHESTRA Polycentric Multimodal Architecture (PMA). It provides an overall model of the MTM ecosystem describing the main stakeholder roles, their concerns, and main functional needs. We think this is a good overview that provides insight into and understanding of the MTM area and clarifies the scope of MTM.

The PMA contributes to the fulfilment of the following ORCHESTRA objectives:

(O1) Establish a common understanding of multimodal traffic management (MTM) concepts and solutions, within and across modes, for various stakeholders, for various contexts, and addressing safety, resilience, accessibility, emission reduction, and business issues, considering:

- **a.** Drivers for change, needs, requirements and success criteria, barriers, and possibilities.
- **b.** What multimodal traffic management will do, how it will work, and what it will contribute to.
- **c.** Practices for optimisation and decision making.

(O2) Define MTME where traffic managements in different modes and areas (rural and urban) are coordinated to contribute to a more balanced and resilient transport system, bridging current barriers and silos. The MTME shall support:

- **a.** Real-time information sharing
- **b.** Orchestration of multimodal door-to-door transport services, adapted to traffic and network situations across modes.
- **c.** Integration of CAVs.
- **d.** Multi-actor and multi-governance settings where traffic orchestration and use of transport networks are coordinated and optimised across modes and governance areas to facilitate a better utilisation of resources as well as resilience towards disturbances.

Through a holistic and multimodal approach, the PMA envisions and prepare the ground for innovative solutions where technological and organisational opportunities are put together. So far, the innovations in the transport domain have mainly been individual solutions within single modes. With the PMA, the escalating technology developments (CAVs included) can be combined and used in a way that is beneficial to the society.

The intermediate and final versions of the PMA (D3.2 and D3.3) will refine and extend this deliverable. The main challenge is that MTM is a new concept that must emerge and be defined during the project. The functionality needed must be elaborated as well as the links to smart infrastructures. The further work towards the intermediate version (D3.2) will:

- Verify and refine the context view based on input from other parts of the project, such as the work on scenarios in D2.3, the work on the technical tools in D4.1, and the work on the simulation architecture in D5.1.
- Extend the context view based on further analyses of how the overall concerns (see section 4.2) and stakeholder goals (see section 5.3) should be addressed, and also analyses of the functionality needed in the smart infrastructure.
- Elaborate overall quality related concerns and adapt the PMA to these concerns.
- Use the above as a basis for the establishment of additional architectural views (see the ARCADE framework described in section 3.2.3) to specify a first version of the logical services, requirements, information models; and interfaces.

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8 References

[1] European Commission, Directorate-General for Research and Innovation, Horizon Europe: Strategic plan 2021-2024, Publications Office, 2021, https://data.europa.eu/doi/10.2777/083753

[2] Hollnagel, E. (2019). What is Resilience Engineering? https://www.resilience-engineering-association.org/blog/2019/11/09/what-is-resilience-engineering/

[3] Woods, D.D. (2015). Four concepts for resilience and the implications for the future of resilience engineering. *Reliability Engineering and System Safety* 141, 5-9.

[4] Lattanze, Anthony, 2005, The Architecture Centric Development Method, Carnegie Mellon University report CMU-ISRI-05-103. ATAM Tailoring Experience (cmu.edu)

[5] Blevins, Terry, Fatma Dandashi, and Mary Tolbert, 2010, *TOGAF ADM and DoDAF Models*, The Open Group White Paper. Case Study/White Paper Template (opengroup.org)

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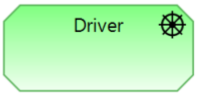
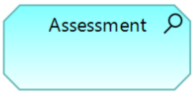
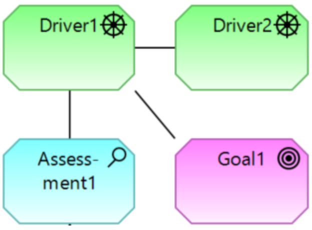
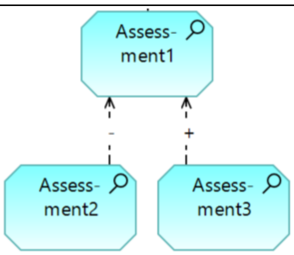
Annex A ArchiMate models

ArchiMate is a standardised of The Open Group and specifies the ArchiMate Enterprise Architecture modelling language (see https://pubs.opengroup.org/architecture/archimate3-doc/toc.html). The modelling of aspects of relevance to enterprise architectures is supported by a graphical modelling notation. Different types of model elements are provided. In ORCHESTRA we use a selection of the motivation elements to model motivation diagrams and a selection of the business layer elements to model the functionality needed.

A.1 Motivation diagram notation

The table below shows the notion used in the ArchiMate motivation diagrams. It consists of boxes with a symbol in the upper right corner, lines, and arrows. I addition to the symbol, we also use colours to better distinguish between the different model elements.

Notation used	Description
	The **stakeholder type** addressed by the diagram.
	A **driver** for the stakeholder type, i.e., what motivates the stakeholder type to an adaption to resilient and multimodal traffic orchestration.
	An **assessment** of the state of affairs with respect to some driver.
	A high-level statement of the **goal** of a stakeholder type, i.e., the intent, direction, or desired end state.
	The line is an **association relation. It is used to represent a dependency** between stakeholder types and drivers, between drivers, and between drivers and assessments and goals.
	The dotted arrow with a + or **-** is an **influence relation**. The + and – indicates how assessment2 and assessment3 influence assessment1. With a +, assessment1 is increased. With a –, assessment1 is decreased.

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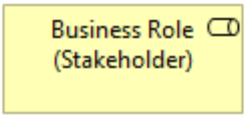
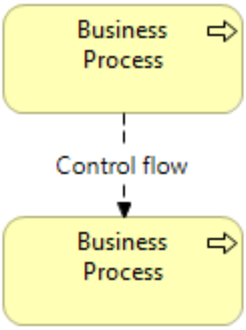
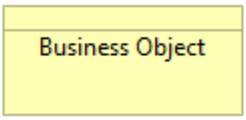
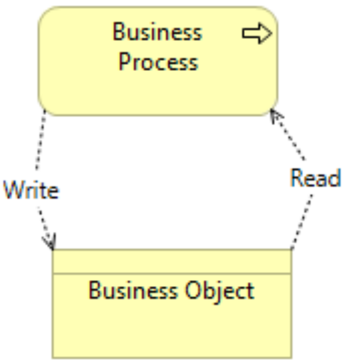
A.2 Functionality diagram notation

The table below shows the notion used in the ArchiMate functionality diagrams. It consists of boxes with a symbol in the upper right corner, lines, and arrows.

Notation used	Description
	The **business role** element represents the stakeholder type.
	The **business service** element represents functionality offered.
	The **business process** element represents behaviour or functions carried out by a business role (i.e. stakeholder type). A **control flow** between two business processes indicates that one business process is followed by another.
	The **business event** element represents something that happens that may trigger or influence a business process.
	The **business object** element represents a concept used in the business domain. In most cases this concept is an information asset.
	A business process may access a business object.

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