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ORCHESTRA Project Deliverable: D3.2

Intermediate PMA for multimodal traffic management

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Deliverable Identification

Deliverable ID:	D3.2	Deliverable title:	Intermediate PMA for multimodal traffic management
Release Number:	1.0		
Release Date:	2022-12-29		
Deliverable Description	The intermediate version of a Polycentric Multimodal Architecture (PMA) for a multimodal traffic management ecosystem (MTME). It describes of the System of Interest, stakeholders, and concern; intermediate use cases; intermediate description of logical services; intermediate requirements; intermediate information models; and identification of interfaces. The content of the deliverable will later be developed further to a final version of the PMA.		
Dissemination Level	PU=Public		
Deliverable Type	R = Report		
Due date (month number/date)	Month 20 / 2022-12-31		

Release History

Version	Date	Internal Review Milestone Reached (if relevant)	Summary of main changes introduced in this version
0.1	2022-03-18		Initial draft of outline
0.2	2022-04-07	PCOS proposed	
0.3	2022-06-13		Updated to new template and added content from D3.1
0.4	2022-11-01	Intermediate proposed	Added description of 2022 workshops, revised and refined motivation and context view, added initial drafts of requirement mapping view and component view.
0.5	2022-12-14	External proposed	Added environment model to context view, and more content to component view. Added description of the board game in an annex.
0.6	2022-12-20	External approved	Minor updates for comments from internal review.
1.0	2022-12-29	Released	

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About ORCHESTRA

The problem addressed by ORCHESTRA is that traffic caused by transport has many negative effects. There are congestions, delays, emissions and negative impacts on urban environments, and in case of disruptions, there may be huge consequences on the efficiency and timeliness. These challenges are hard to handle due to lack of coordination between the different transport modes.

The long-term vision of 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. The overall objective of ORCHESTRA is to provide European policy makers, public authorities, transport providers and citizens with new knowledge and technical and organisational solutions to enhance collaboration and synchronising of operations within and across transport modes.

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 the integration of 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

ORCHESTRA's main advancements beyond state-of-the-art are related to four focus areas:

- MTME facilitated by: 1) a Polycentric Multimodal Architecture (PMA) specifying how systems collaborate. 2) Flexible organizational and business models. 3) Simulation and training tools. 4) Policy and regulatory recommendations. 5) data governance and sharing framework
- Traffic orchestration supporting optimal traffic flows, adapted to current and foreseen situations and societal aspects. Data on ongoing and planned transports as well as other issues that may affect the traffic will be monitored and used in decision support and to facilitate resilience
- Coordination across modes and networks bridging current silos, ensuring best possible utilisation of transport system as a whole
- Traffic management supporting more optimal multimodal transport services and fleet operations, those carried out by CAVs included. Transport operations will be guided and controlled according to pre-defined rules and trade-offs between different optimisation targets.

The project will validate and evaluate the multimodal traffic management concept and related tools in its two Living Labs, both in Norway and Italy, covering freight and person transports across road, rail, water and air.

Legal disclaimer

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Executive Summary

The report covers the intermediate version of the ORCHESTRA Polycentric Multimodal 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, and this report aims to support the understanding of the MTM concept and the related functionality. Further, it aims to guide the creation of individual system architectures for a family of systems that fit into the ecosystem. The PMA is intended to specify a full-fledged implementation of the MTM concept.

The description of the PMA has been developed following the architectural description framework ARCADE, using the modelling languages ArchiMate and UML along with textual descriptions.

The intermediate version of the PMA is an extension of the initial version provided in deliverable D3.1. The intermediate version refines the views from D3.1 and adds new models and views, including an environment system model, requirement mapping view, and component view. The final versions of the PMA (in D3.3) will further refine the existing views and add new models to the component view.

Each view in the PMA express system concerns from a specific viewpoint. *The motivation view* focus on the drivers for change, i.e. what motivates significant stakeholders to adopt resilient and multimodal traffic orchestration. The content is established in collaboration with real stakeholders and experts in the transport domain. *The context view* models the functionality needed by the stakeholders, as well as the environment systems that the system of interest will interact with. The component view provides initial models for the information the system will handle and decomposition of the system into components.

MAIN OUTCOMES AND FINDINGS

(1) A definition of the System of Interest (SoI) is addressed by the PMA. The SoI comprises a family of systems doing MTM. The defined overall concerns of the SoI are sustainability, polycentricity, multimodality, resilience, and business neutrality.

(2) An overall concepts model defines the main concepts that together define the MTM. The concepts do among others address the transport network, transport demand management, and demand capacity balancing. A board game for multimodal traffic management has been developed to support understanding of the concepts and has been successfully tested at workshops.

(3) The motivation view: ArchiMate models describe the stakeholder archetypes of relevance to MTM and their related motivation models.

The main stakeholder archetypes are:

- *Traffic Orchestrator*: Responsible for the Multimodal Traffic Management.
- *Transport Service Provider*: Provides transport services to transport users. A service may integrate transport legs from several modes into a transport chain.
- *Fleet Operator*: Operates a fleet and manages the transport operations needed the transport chain legs composed by the transport service provider.
- *Network User*: A transport means and/or its operator. Carries out the transport operations managed by the Fleet Operator.
- *Network Manager*: Responsible for the management of the transport network, the connected infrastructure included.

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The motivation models identify for each main stakeholder archetype the drivers for a change towards MTM, assessments of the status with respect to the drivers, and the goals linked to the drivers. It also contains an analysis of how this covers the main architectural concerns that has been identified (resilience, polycentricity, multimodality, organisation flexibility, and automate driving).

Altogether, the motivation view provides insight into concrete motivations that as far as possible should be met in successful implementations of MTM. Identified drivers motivating stakeholders to adopt to resilient and multimodal traffic orchestration include among others:

- Environmental, economic, and social sustainability
- Resilience
- Public image and customer satisfaction
- Automation
- Data access

(4) The context view includes *models that describe the functionality of relevance to the SoI*, from the view of the main stakeholder archetypes. The functionality of the Traffic Orchestrator is emphasized since this is the core functionality supporting MTM. For the Transport Service Provider, Fleet Operator, Network User, and Network Manager, the focus in on the functionality addressing interactions with the Traffic Orchestrator. *An environment systems model* is included to identify which existing systems the system of interest will interface with, along with details on these interfaces such as formats and standards relevant for different modes. An analysis of the coverage of architectural concerns in the context view is also included.

(5) The component view includes initial versions of *the system information model* and *system decomposition model*. The system information model describes information elements needed in the Transport Operation and the Network Coordination interfaces of the system of interest. The decomposition model provides an initial draft of logical components that the system of interest can be decomposed into, based on the functionality described in context view and on tools identified in ORCHESTRA work package 4 (WP4).

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List of Abbreviations

Table 1: List of abbreviations

Abbreviation	Explanation
AIRM	ATM Information Reference Model
ATM	Air Traffic Management
CAV	Connected and Automated Vehicle/Vessel
CCAM	Connected, Cooperative and Automated Mobility
CEN	European Committee for Standardization
C-ITS	Cooperative Intelligent Transport Systems
CoP	Community of Practitioners
DATEX II	DATa EXchange between traffic and travel information centres
GA	Governance Area
GDF	Geographic Data Files
ICT	Information and Communication Technology
IEEE	Institute of Electrical and Electronic Engineers.
IHO	International Hydrographic Organization
ISO	International Organization for Standardization
ISAD	Infrastructure Support Levels for Automated Driving
MaaS	Mobility as a Service
METR	Management of Electronic Traffic Regulations
MTM	Multimodal Transport Management
MTME	Multimodal Transport Management Ecosystem
NGO	Non-governmental organization
OEM	Original Equipment Manufacturer
PMA	Polycentric Multimodal Architecture
SoI	System of Interest
SWIM	System Wide Information Management
TISA	Traveller Information Services Association
TN-ITS	Transport Network – Intelligent Transport Systems
TPEG	Transport Protocol Experts Group

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Abbreviation	**Explanation**
UBL	Universal Business Language
UML	Unified Modelling Language
UTM	Unmanned Aircraft System Traffic Management
UVAR	Urban Vehicle Access Regulation

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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*." [1]
Use case	The term "use case" is used in the description 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".*

Note: In addition to this brief list of some central definitions, see definitions for architectural concepts and viewpoints used in section 3.2, and the description of architectural concerns and domain concepts in chapter 4. Stakeholder definitions are provided in section 5.1

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1 About this Deliverable

This report describes the ORHESTRA Polycentric Management Architecture (PMA) in its intermediate version. 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. Further, it identifies requirements, defines a system information model, and describes how the System of Interest can be decomposed into a set of interacting logical components.

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 use of Automated and Connected Vehicles/Vessels (CAVs) in such a setting is also emphasized. The resilience is about an adaptable capability to handle future normal variations, expected and unexpected disruptions or abnormalities. On one hand, this process includes to detect foreseen changes, to response and to recover from disruptions in the traffic. On the other hand, resilience is proactive prepared for unexpected disruptions in advance, which reserves capacity in transportation network planning.

1.1 Why would I want to read this deliverable?

By reading this report, you will get an insight into what multimodal traffic orchestration is, and an overview of central concepts. Further, you will learn about what functionality different stakeholders in the ecosystem will need to reach their goals with respect to their participation in an orchestrated traffic system. You will also find initial thoughts for what information should be handled and which components a traffic orchestration system can be decomposed into. Altogether, the report will be useful and support the design, analysis, and deployment of future multimodal traffic systems.

1.2 Intended readership/users

This report is relevant to actors within the transport domain, researchers and others who want a conceptual understanding of the Multimodal Traffic Management Ecosystem (MTME) or who want to participate in the realisation of MTME. 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.

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 also be of interest to academia from diverse disciplines focusing on aspects of a socio-technical system.

In context of the ORCHESTRA project, the deliverable is relevant for all project partners, and especially for those involved in the conceptualisation and realisation. The report may also be of interest to the Community of Practitioners (CoP) members in ORCHESTRA, constituting relevant stakeholder types. The CoP has been engaged in workshops to ensure the relevance of elements of the ecosystem and validate the models and relationships. They have also provided input to the report.

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1.3 Other project deliverables that may be of interest

The deliverable has relations to other ORCHESTRA deliverables.

The main relation is to **D3.1 Initial use cases for multimodal traffic management**, which is direct predecessor of this document (**D3.2**). This document contains updated versions of the content of D3.1, and in addition adds new content such as architectural viewpoints that were not present in D3.1.

In more details, the following updates have been done compared to D3.1:

- Chapter 2 – no updates.
- Chapter 3 –section 3.1 has been updated with more activities and analysis, and a new subsection on input from related work. Section 3.2.3 has been updated to reflect the architectural viewpoints used this document. A short note on terminology have been added as section 3.3.
- Chapter 4 – in section 4.1, the task related to the society are defined. The architectural concerns defined in section 4.2 has been revised and in section 4.3 the description of the domain concepts has been revised.
- Chapter 5 – drivers (5.2) have been refined and aligned between stakeholders, and goals (5.3) have been refined. Assessments have been moved to Appendix B.3.
- Chapter 6 – added functionality model for Network Manager (6.2), minor refinements to functionality models for other stakeholders. Added section on environment systems (6.6). Section 6.7 now describes how architectural concerns are handled and includes resilience aspects that were a separate sub-section in D3.1.
- Chapter 7 – new chapter providing a requirement mappings view, with mapping between goals and functionality.
- Chapter 8 – new chapter on component view containing an initial draft of system information model with focus on identifying relevant standards, and an early draft on a decomposition model.
- Chapter 1 – updated conclusion chapter.
- Annex A – new annex showing full concept model figure.
- Annex B – ArchiMate models notation - same content as Annex A in D3.1.
- Annex C – new annex with description of the board game.
- Annex D – new annex on standardisation details.
- Annex E – new annex with examples from the living labs.

The following other deliverables are input to this document:

- D2.1 Initial target vision
- D2.2 Pre-Studies on environment analysis and drivers
- D2.3 Initial scenarios for multimodal traffic management
- D3.1 Initial use cases for multimodal traffic management
- D4.1 Initial version of technical tools
- D5.1 Simulation Architecture

This document is input to the following deliverables:

- D2.4 Final scenarios for multimodal traffic management
- D3.3 Final Polycentric Multimodal Architecture (PMA) for multimodal traffic management
- D4.2 Final version of technical tools for multimodal traffic management

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- D5.2 Simulator
- D5.4 Final Living Labs

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/v2.0.html

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 the leader of the work and the main author and provided most of the content in the deliverable. ITSN has provided input regarding the functionality needed by the Fleet Operator, on environment systems, and on relevant standards. TUDELFT has provided input on the functionality needed by the Transport Service Provider, and they have also provided content on architectural concerns related to resilience and automated driving. HES-SO has provided input on the functionality needed by the Network User, on the relation to tools, and on architectural concerns related to automated driving. NPRA has provided input on the functionality needed by the Traffic Orchestrator, on environment systems and on 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 description

Purpose of architectural descriptions in general: 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 have an interest in the system. To this end, the architecture description should describe the elements of the architecture, their relationships and properties, but also the stakeholders, motivations, 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 specifies 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 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

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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 [2] 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.
- Common Framework [3] 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.

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3 Approach

3.1 Methods for data collection and analysis

3.1.1 Workshops providing input on the Motivation view

Four workshops in 2021 gave input to the content of the motivation view in Chapter 5 “Motivation view”.

Workshop 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.

Workshop 2: Motivational models

Internal, online workshop with work package participants. Initial motivation diagrams for four stakeholder types (Traffic Orchestrator, Transport Service Provider, Fleet Operator, and Network User) were presented, discussed, and refined.

Workshop 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.

Workshop 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 Workshops providing input on the MTM Concept model including domain concepts

Workshops in 2022 have given input to the domain concepts in Chapter 4 “System and architectural overview” (especially to section 4.3 “Domain concepts”):

Workshop 5: Freight transport (Norwegian Living Lab)

Face-to-face workshop at Herøya in September 2022 with external participants (from the CoP and others). The first part was an *introduction* of the Multimodal Traffic Management (MTM) Concept model (see section 4.3), including:

- MTM Ecosystem (MTME), including key stakeholder archetypes
- Transport Demand Management (TDM) and Demand Capacity Balancing (DCB) concepts and measures to regulate traffic by means of TDM and DCB

- Data sharing and management
- Resilience
- Transport Network concepts, including "Zone" and "Governance Area"

The main part of the session was playing *a Board Game prototype (see Annex C).* The purpose was to create an understanding of traffic orchestration and to get input for improving the prototype. The board game constituted the main mean for information and feedback *on domain concepts and the concept model*, including:

- clarifications of the concepts "zones" and "Governance area" (GA)
- orchestration of a zone and GA
- coordination between traffic orchestrators of different zones/GA
- potentials measures enabling orchestration
- resilience
- the benefit and need of sharing information

The CoP workshop participants were split in groups and played the game. Five scenarios could be played: (1) Regular traffic with automated vehicles/vessels, (2) Concert in the city causing reduced traffic capacity, (3) Gas leakage in the industry park zone, (4) Accident at the ring road, (5) Airport train stops during rush hours.

The process was facilitated by a member of WP3 and taped.

Evaluation of the session was done by using the Mentimeter program.

Workshop 6: Passenger transport (Italian Living Lab)

Face-to-face workshop in Milan in October 2022 with external participants (from the CoP and others). The approach was mainly the same as for the workshop at the Norwegian Living Lab. Some adaptations were done based on the feedback received.

3.1.3 Data analysis regarding the Motivational view

The input from the two internal stakeholder workshops in 2021 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 workshops in 2021 (workshop 3 and 4), the results were analysed, and the generic stakeholder types and motivation diagrams were updated to cover all relevant aspects. Further, freight and passenger results were harmonised into one common set of diagrams.

3.1.4 Data analysis regarding the MTM Concept model including domain concepts

Data was collected from the two internal stakeholder workshops in 2022 (workshop 5 and 6) using voice recordings and a software service. Voice recordings were made during the board game sessions to capture discussions and feedback. The software service (Mentimeter) was used to get immediate feedback from the participants at the workshops on the board game session. This included reactions regarding: Purpose of playing the Board Game, Framework conditions/settings, Content, Player qualifications, Process, and Assessment of the game prototype.

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3.1.5 Input from related work

This deliverable is, as mentioned in section 1.3, based on input from other ORCHESTRA deliverables. In addition, other related work provide input to the several topics, as described below.

Related work on infrastructure support to automated and connected mobility:

- The Inframix project addressed the adaptation of the road network to automated driving, and they have published an infrastructure classification scheme for infrastructures with respect to automated driving.[1]

Related work on the digitalisation of the traffic regulation:

- Work is done on urban vehicle access regulations (UVAR). The UVAR Box and UVAR Exchange projects aims to help cities develop a user-friendly tool to provide UVAR data in a standardized format[2]. UVAR Box has suggested extensions to DATEX II that can represent regulations. UVAR Exchange project is working on the communication of information to Network Users in the vicinity of UVAR zones. The ReVeAL project[3] works on UVAR policies and technologies to make the traffic in European cities more sustainable.
- The CCAM (Connected, Cooperative and Automated Mobility) initiative[4] is working on the integration of technology and solutions for automated road transport from the perspectives of Network Users, policy makers, road operators, and industry.
- The work on future Air Traffic Management (ATM) in the Single European Sky ATM Research (SESAR) Programme.

Related work on data sharing:

- Regulation (EU) 2018/1724 on the Single Digital Gateway requires public authorities to provide information to road users through one access point.
- The revision of the Delegated Regulation on real time traffic information requires Member States to give access to a broad range of static and dynamic data to include new data sets, such as those pertaining to UVARs.
- The Data Governance Act and the proposed Data Act address the need for broader data sharing among all types of stakeholders.
- The Mobility Data Space initiative pave the way for a European ICT infrastructure for data sharing related to mobility.
- EUCARIS is a European initiative on cross border exchange of data from registration authorities on vehicle registrations, driving licences, vehicle owner/holder and insurance data, and traffic offenders. The registration authorities are decentralised hubs, and government institutions can request information from these hubs.
- Many standards of relevance are established, and relevant standardisation work is also ongoing. See section 6.6 and Annex D for details.

[1] Inframix Deliverable D5.4 Infrastructure Classification Scheme
[2] https://uvarbox.eu/
[3] https://revealproject.eu/
[4] https://www.ccam.eu/

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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 [4] 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 architectural assets that has structured, assisted, or otherwise guided the work. These assets are described in the following table.

Table 3: Architectural assets used

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.

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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.

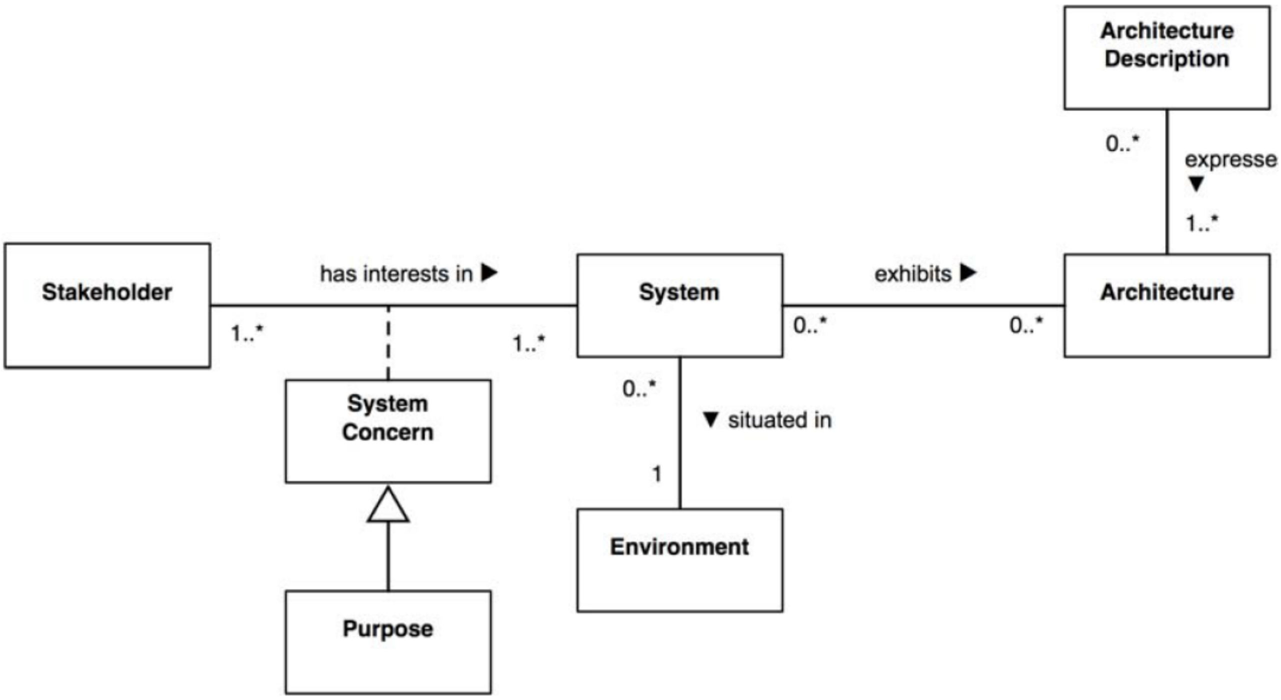

Figure 1: Context of architecture description [IEEE 42010-2011]

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

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management ecosystem (MTME). The stakeholders are archetypes – thus we talk about stakeholder types.

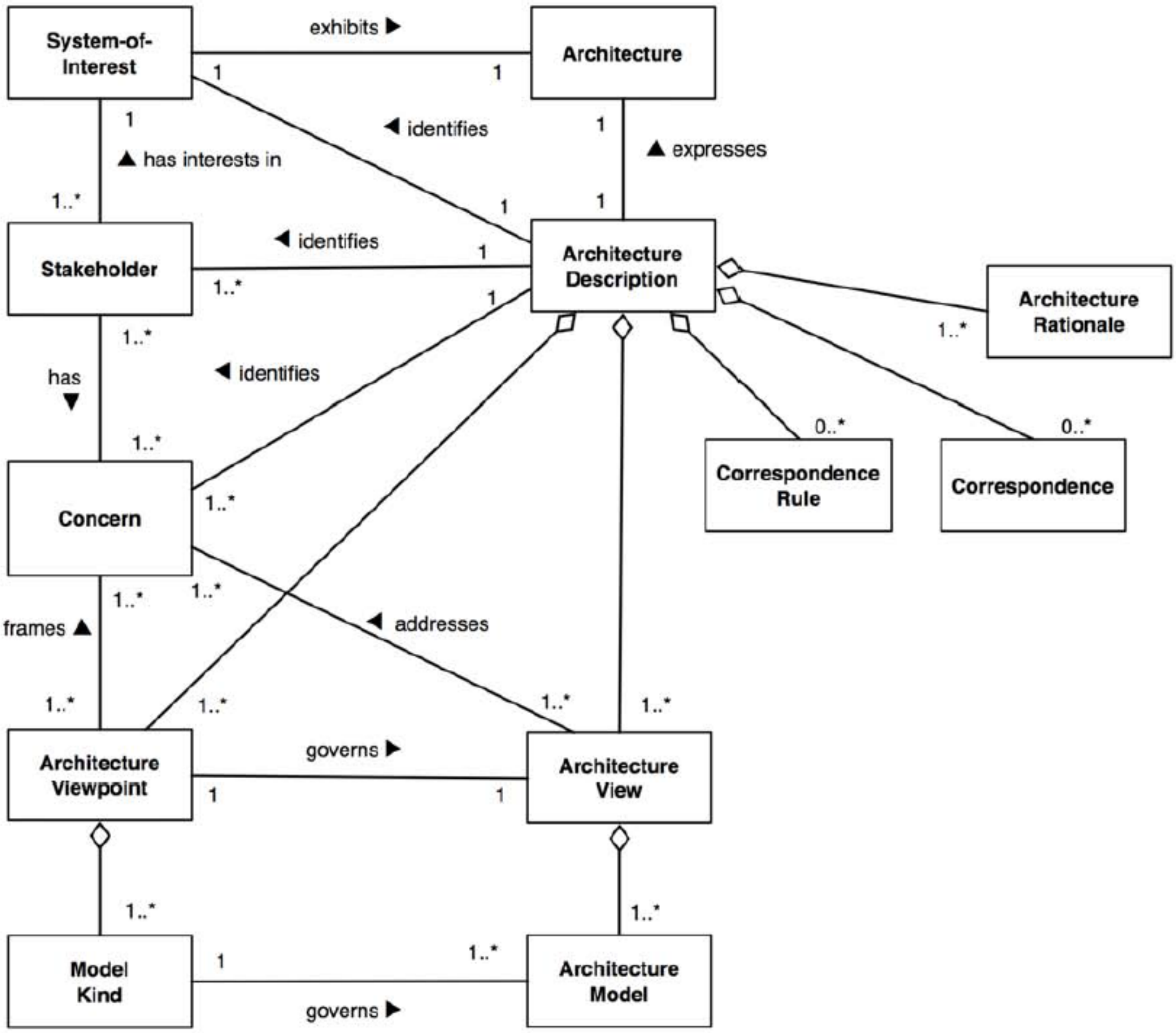

Figure 2: Architecture concepts [IEEE 42010-2011]

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].

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- 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.
- **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 architectural 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 [4] (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 described in this document:

- *Motivation*: The Motivation viewpoint 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 has previously not been part of ARCADE but is being added in an ongoing revision based on experiences from ORCHESTRA and other projects. In this document the Motivation viewpoint uses the motivational elements of ArchiMate for its description and corresponds to the Stakeholder viewpoint of ArchiMate. (See 3.2.1 for more details on ArchiMate).
- *Context*: The Context view defines the functionality for the main stakeholders that were identified in the Motivation view. ArchiMate Business Layer model elements have been used to define the functionality. The functionality models also identify which functionality

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is inside and outside the scope of the System of Interest. The Context view further defines an Environment Systems model that identified other systems that the System of Interest will or may interact with. This model is defined using UML component diagrams and textual descriptions. Interfaces towards these systems are identified and described, e.g. in terms of relevant standards.

- *Requirement mapping*: The goals defined in the motivation view define the overall requirements in this architectural description, while the functionality defined in the context model provides more detailed requirements. Instead of a separate requirement view, this document contains a mapping of the functionality to the goals, that verifies how the functionality supports the goals.
- *Component*: The component view in this document includes initial drafts for the System Information model and System Decomposition model. The System Information model has been divided into sub-models, and relevant standards are identified for each sub-model. The System Decomposition model identifies a set of tools and other components that can provide important parts of the functionality of the System of Interest. The model has been defined using UML component diagrams. The information model will be further elaborated as part of the ORCHESTRA D3.3 deliverable. The decomposition model will be further developed to a more consistent whole and to cover more of the functionality in D3.3. System Distribution and Interface Specification models will also be added in D3.3.

ARCADE is currently being updated and revised. Updates of the motivational view include revisions based on IEEE 42010-2011 in place of its predecessor IEEE 1471-2000. Further, it contains recommendations on use of ArchiMate as a supplement to UML. Experiences from developing the motivation view and context view in ORCHESTRA and other projects are used as input for the revision of ARCADE.

3.3 Terminology

Different transport modes use different terminologies. In this report we have however chosen to use a multimodal terminology to be able to provide specifications that are common to all modes and bridge the gap between the current silos. Thus, *the terminology used is new and multimodal and does not comply with the terminology used within each of the transport modes.*

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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*.

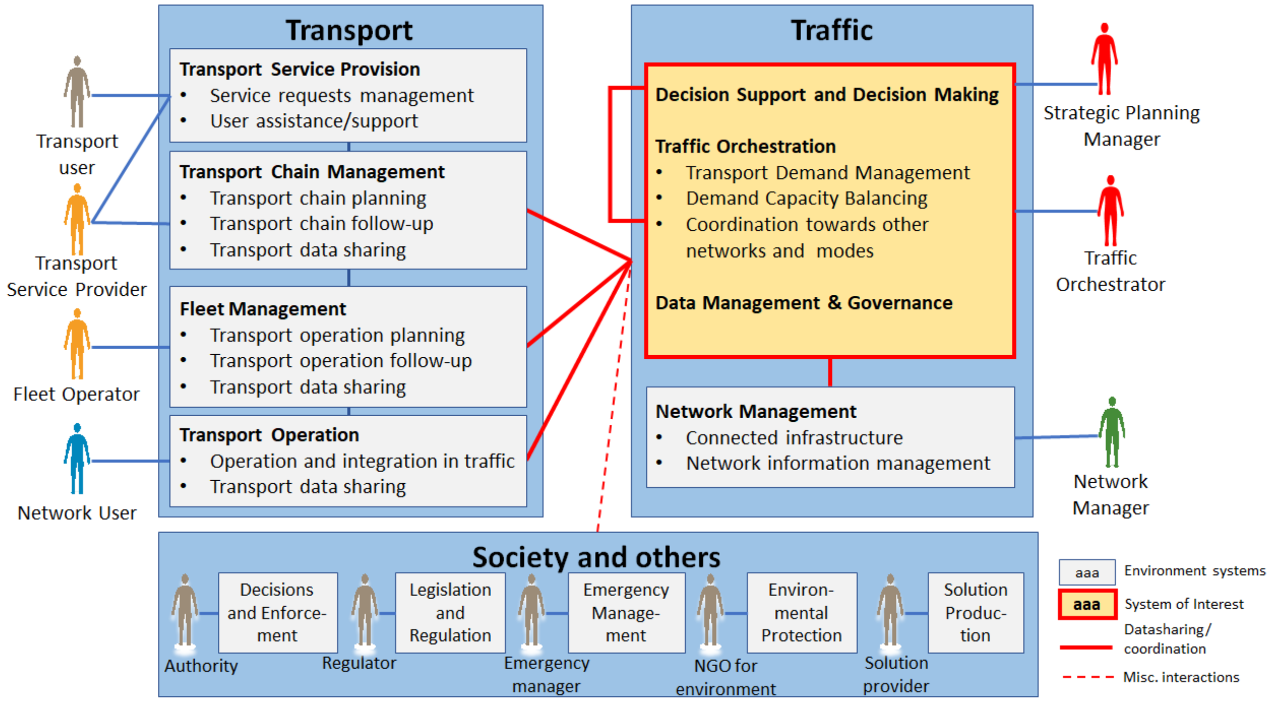

Figure 3: Multimodal Traffic Management Ecosystem (MTME) with System of Interest in its environment

Figure 3 provides an overview of the MTME. The System of Interest is the box with red boarders in the traffic part of the ecosystem, and the red links represent interactions towards the parts of the MTME that constitute the environment of the System of Interest. Examples of ecosystems are provided in Annex E.

As shown in Figure 3, the **ecosystem** is divided into three areas, described below: **Transport**, **Traffic**, and **Society and others**. There may be many system instances within each area. Many of the instances will have a defined governance area that for example will encompass a part of a network, 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 a real 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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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 Chain Management: The Transport Service Provider orchestrates the transports requested by Transport Users. The preferred transport options are selected and combined into a transport chain that can 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 or 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.

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:

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- *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 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 or holding area.

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 operations in addition to avoiding or limiting 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, connected infrastructures. Static data describing the infrastructure is managed as well as dynamic, real-time data collected by the connected 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, and the Traffic Orchestrator also interacts with the Network Users via the connected infrastructure.

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.

Decisions and Enforcement: Authorities have to define the transport policy and decide how it should be implemented. The compliance with laws and regulations must be ensured and enforced.

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Legislation and Regulation: Laws and regulations related to transport and digitalisation (e.g. data sharing and governance) must be defined. They set the premises for the multimodal traffic management.

Emergency Management: The emergency management is handled at many different levels (organisational, local, regional, national) and includes preparedness, emergency planning and emergency responses. Everything must be coordinated across levels and areas (e.g. areas such as search and rescue, health, and police).

Environmental Protection: Environmental protection is also done at has different levels (local, regional, national, public, private, sea, land, different types of emissions, etc.) and includes both preparedness/emergency planning and pollution response/combat operations.

Solution Production: Many solutions will support the transport and traffic parts of the ecosystem, e.g. solutions for connected infrastructures, technology and digital solutions for data collection, management and sharing and artificial intelligence for decision support.

4.2 Architectural concerns

By architectural concerns we mean main considerations to be taken into account when the architecture description for the System of Interest (SoI), as illustrated in section 4.1, is elaborated. The architectural concerns identified for this architecture description are: Polycentricity, multimodality and organisation flexibility.

Note that stakeholder concerns are covered under the identification of drivers in section 5.2.

4.2.1 Resilience

Resilience is one of the four strategic orientations for EU research and innovation for 2021-2024 [5], and the ORCHESTRA architecture must support:

- **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. This is the case for anticipated normal variations and expected disruptions. However, quick realization of the fact that one face an unexpected and completely surprising disruptions and potential catastrophes is crucial.
- **Adaptive actions during the perturbations**. The aim will be to diminish the caused negative effects and corresponding propagations in the multimodal network.
- **Efficient recovery**, either back to the normal stage **or adaption to new conditions**, will constitute the basis for developing 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 must support a resilient multimodal traffic management system. Handling of vulnerability and adaptability of the digital systems are central issues. The main concerns to be addressed 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.

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- **Safety issues.** Dynamically identify and handle risks to prevent accidents or hindering changes escalating to catastrophes.
- **Flexibility in governance and organisation**. It must be possible to implement the responsibilities and structures described in a flexible way, including the ability to hand over responsibilities when needed.

4.2.2 Polycentricity

The SoI operates, as illustrated in Figure 3 in section 4.1, 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 connected infrastructures and they may support different levels of automation and digitalisation.

4.2.3 Multimodality

The SoI addresses all transport modes, and the architecture description must use a terminology and specify solutions in a way that applies for all modes. The issues to be addressed are:

- **Legacy systems.** The SoI 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 SoI 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) for air transport. The overall concepts of traffic orchestration towards Network Users will however include many new concepts, for example concepts for adaption to resilient transport – monitored and controlled by the Traffic

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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 Flexible organisation and governance

The architecture description must not dictate a specific organisation of systems, system components and responsibility. It must be possible that different modes, networks and geographical areas organise the traffic orchestration in different ways. The architecture description must be flexible with respect to:

- **Centralised or distributed organisation of responsibilities.** The architecture description must be flexible with respect to how the responsibilities and tasks are assigned to actors.
- **Centralized or distributed systems.** The physical architecture of the technical systems may vary. The systems may be centralised of decentralised, and the functionality needed may be provided by in-house systems or by services provided by third parties.
- **Dynamic hand overs.** It must be possible to hand over responsibilities to others in case of technical problems or other disruptions, and also when assistance is needed due to the workload.
- **Fairness and accessibility.** Actors should not experience extensive barriers such as extensive capital requirements, difficulties with the 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.

4.2.5 Automated driving

The INFRAMIX project (https://www.inframix.eu/) has provided a classification of Infrastructure Support Levels for Automated Driving (ISAD) in the road network (see https://www.inframix.eu/infrastructure-categorization/).

Similar classifications do not exist for other modes. Many of the aspects mentioned are however of relevance to several modes, and the architecture description takes these aspects into account.

The architecture description must be related to this classification.

4.3 Domain concepts

This section describes the main concepts related to the MTM ecosystem by means of UML class models. The concepts are represented by classes, and the relations between them are also shown. Different concept categories are represented by classes stereotypes and colours:
- **Stakeholder** (yellow): These concepts refer to the stakeholder archetypes defined in section 5.1.
- **Spatial** (grey): These concepts are spatial objects and might be points, boarders, areas, or other spatial objects representing smaller or larger parts of physical transport network infrastructures or locations in the infrastructures.
- **Context** (light blue): These concepts constitute a context or an awareness that is a bases for the traffic orchestration.

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- **Measure** (pink): These concepts represent measure categories for traffic orchestration.
- **Rules** (beige): These concepts represent the rules to be followed in the traffic orchestration.
- **Orchestration** (blue): These concepts represent resilient traffic orchestration within a governance area, and cover anticipatory management, stochastic planning, deviation handling and efficient recovery back to normal situations.

A diagram showing the complete model is provided in Annex A. In this section we present sub-models that are smaller and easier to explain.

4.3.1 Transport Network concepts

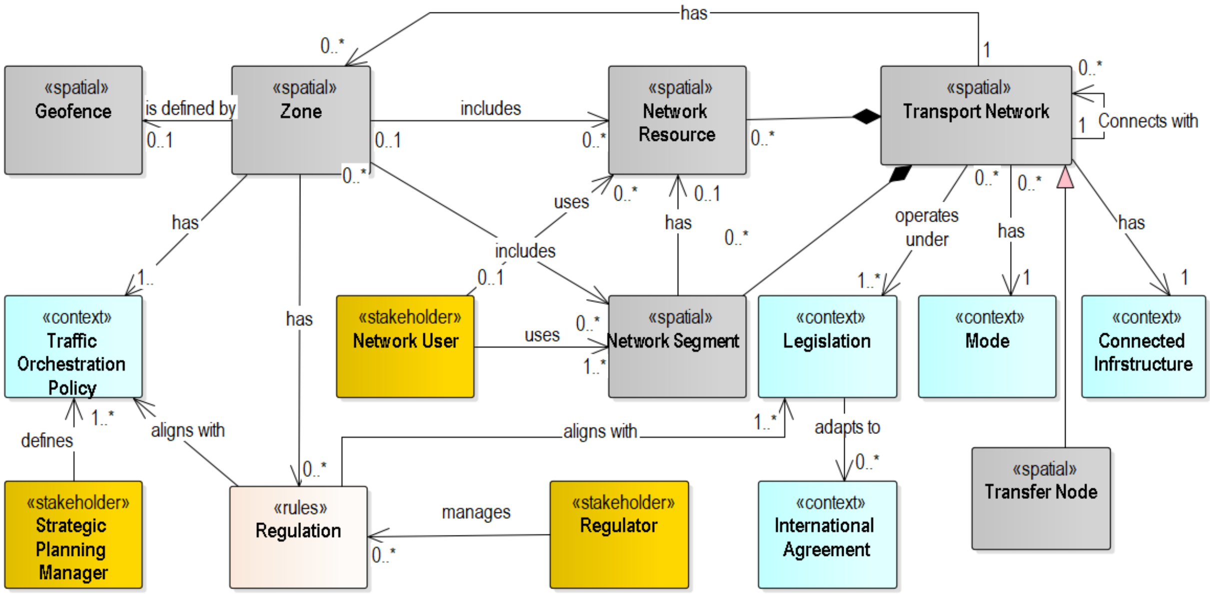

Figure 4: Main concepts related to the transport network

The MTME may consist of several transport networks, and there may also be several networks per mode. The main concepts related to a transport network is depicted in Figure 4. A Transport Network has a *Mode* (road, sea, rail or air) and it is operated under one or more *Legislations* (e.g. national and European) that may be adapted to *International Agreements* (e.g. those that apply for air or sea transport). A *Transport Network* may be connected with other Transport Networks. A road network may for example be connected to a railway network.

A *Transport Network* has a *Connected Infrastructure*, which is an ICT infrastructure. It collects data from sensor in the network and from the Network Users, and it may control network equipment via actuators. The Connected Infrastructure also facilitates communication with connected Network Users, both for data collection and as a channel for the traffic orchestration.

A *Transport Network* is composed of *Network Segments* and *Network Resources:*

- A *Network Segment* is a smaller or larger part of a transport network (e.g. a certain distance along a road, the roads within an area, a part of a fairway, railway segments or an air corridor). A network segment may at the same time be used by several *Network Users* (i.e. pedestrians, cyclists, cars, busses, trains, vessels or planes).
- A *Network Resource* is a part of the transport network that can be used by just one *Network User* at a time. A network resource may for example be a parking slot, a charge point, a quey in a seaport or a gateway in an airport.

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A *Transport Network* may have several *Zones:*

- A *Zone* may include *one* or more network segments and/or network resources.
- A *Zone* may be *defined* by a *geofence* (i.e. a dividing line or a geographical/spatial border defining an area or a space).

A *Zone* may have a *Traffic Orchestration Policy,* which is defined by a *Strategic Planning Manager*. Such a policy defines the overall traffic management objectives and strategies regarding the traffic management regulations and measures to use in the zone. The policy may for example define permanent measures for a zone (e.g. road pricing measures) and rules for priorities.

A Zone may have *Regulations* defining constraints and conditions regarding measures to be taken. The *Regulations* must be aligned with the *Legislation* and adapted to the *Traffic Orchestration Policy*. *Regulations* are managed by a *Regulator*. The *Regulator* may be the same actor as the Traffic Orchestrator, but may also be others, e.g. the police. The Regulator may dynamically adapt regulations to the situation. The Regulator may for example decide to close the road due to the weather conditions.

A *Transfer Node* is a geographical location where persons or cargo are transferred between transport means within one or different modes. Transfer nodes come in many sizes and complexity levels. Some covers just one transport mode (e.g. a bus stop), others are more complex (e.g. an airport). A Transfer Node is "a specialisation of" a Transport Network. This implies that a *Transfer Node* inherits all the properties of the Transport Network. Hence, a Transfer Node may be connected to several other networks, and it may have network resources, zones and network segments.

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4.3.2 Overall Transport Orchestration concepts

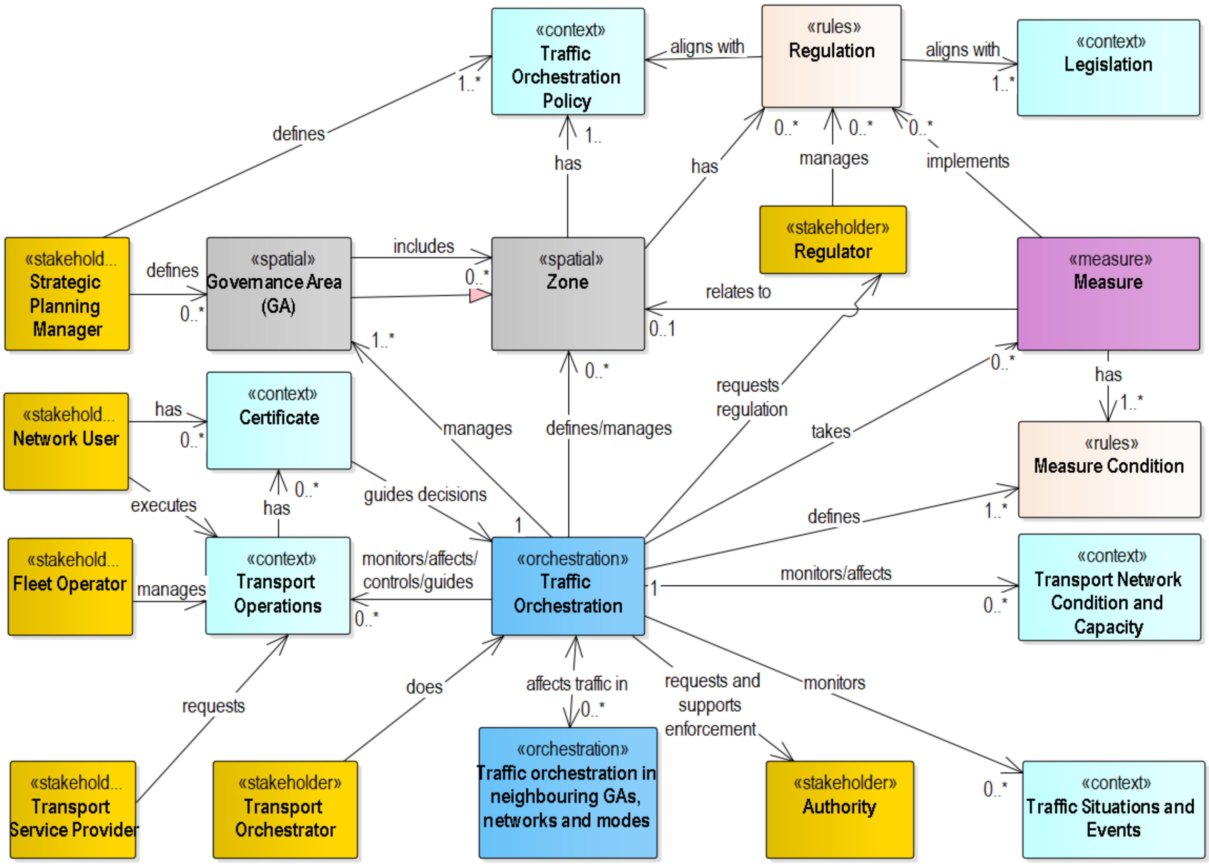

Figure 5: Traffic orchestration in Governance Area

Usually, a *Traffic Orchestrator* does *Traffic Orchestration* in one *Governance Area (GA)*. However, in some cases (e.g. if there are technical problems in one area), the *Traffic Orchestration* may cover several *GAs*. The spatial extension of a *GA* is defined by the *Strategic Planning Manager* and depends on strategic or mode-specific decisions with respect to how GAs should be organised, the complexity of the traffic in the area in need for monitoring and control, and also practical constraints.

- GAs may vary in size. For road networks, a GA may for example cover a bridge, a tunnel, a segment of road, or all roads within an area, e.g. a region or a municipality.
- GAs may be structured as non-overlapping areas. In sea transport, the coast of a national state may for example be divided into VTS areas.
- GAs may be structured in a hierarchy. In air transport, the GA of EuroControl covers the whole European air space. It is superior to regional GAs called Functional Airspace Blocks.
- Complex transfer nodes like airports, ports and industrial parks may also be defined as GAs where pedestrians and vehicles inside the transfer node are managed and supported.

A *GA* is a "specialisation of" a Zone and inherits the properties of the *Zone* (see 4.3.1). Thus,

- A *Transport Network* may have several *GAs*.
- A *GA* is related to a single *Transport Network* and thus also to a single *Mode*.
- A *GA* may cover several *Network Resources* and *Network Segments*.

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- A *GA* has a *Traffic Orchestration Policy* and *Regulations* that outlines the overall policy, strategy and regulations for the whole GA.
- A *GA* may have *Regulations* that are aligned with the *Legislation* and adapted to the *Traffic Orchestration Policy.*

The *Traffic Orchestration* monitors

- *Transport Operations* requested by the *Transport Service Providers*, managed (planned and controlled) by the *Fleet Operators* and executed by *Network Users.* The *Transport Operations* and the *Network Users* may have *Certificates* that confirms properties and abilities that may guide the traffic orchestrations, e.g. the type of operation, the greenness of the Network User, the right to access an area, etc.
- *Traffic Situations and Events.* The development of the traffic flows, as well as occurred situations and potential situations that might require measures.
- *Transport Network Conditions and Capacities*. Certain network conditions or traffic situations may affect the capacity of the network.

The *Certificates* are issued by a trusted *Certificate Authority* based on detailed information about the *Network User*/*Transport Operation*. The *Traffic Orchestrator* will not need all details and can take decisions based on *Certificates*. Thus, the *Certificates* contributes to privacy and may also protect sensitive business information.

As a part of the *Traffic Orchestration* within a *GA*

- *Zones* are defined and managed. A *GA* may have several *Zones* where the traffic is managed according to more local *Traffic Orchestration Policies*.
- *Regulations* of the *Zones* are requested, and related *Measure Conditions* are decided.
- *Measures* are taken within *Zones* to implement *Regulations.* Speed limits may for example be communicated to the Network Users. Some *Measures* are taken according to *Measure Condition*. Access control measures may for example have conditions for the access.
- *Transport Operations* are affected, controlled and guided to minimize the negative impacts of the operations, and to maximize efficiency of the traffic flow and the safety. *Certificates* may influence the decisions taken. Certain types of *Network Users*/*Transport Operations* may for example get privileges.
- *Traffic Orchestration in neighbouring GAs, networks and modes* may be affected. Avoidance of congestions in one GA may for example affect the traffic flow in adjacent GAs.
- In special situations, the *Traffic Orchestration* may request support and enforcement from different types of *Authorities*, e.g. the police.

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4.3.3 Transport Demand Management concepts

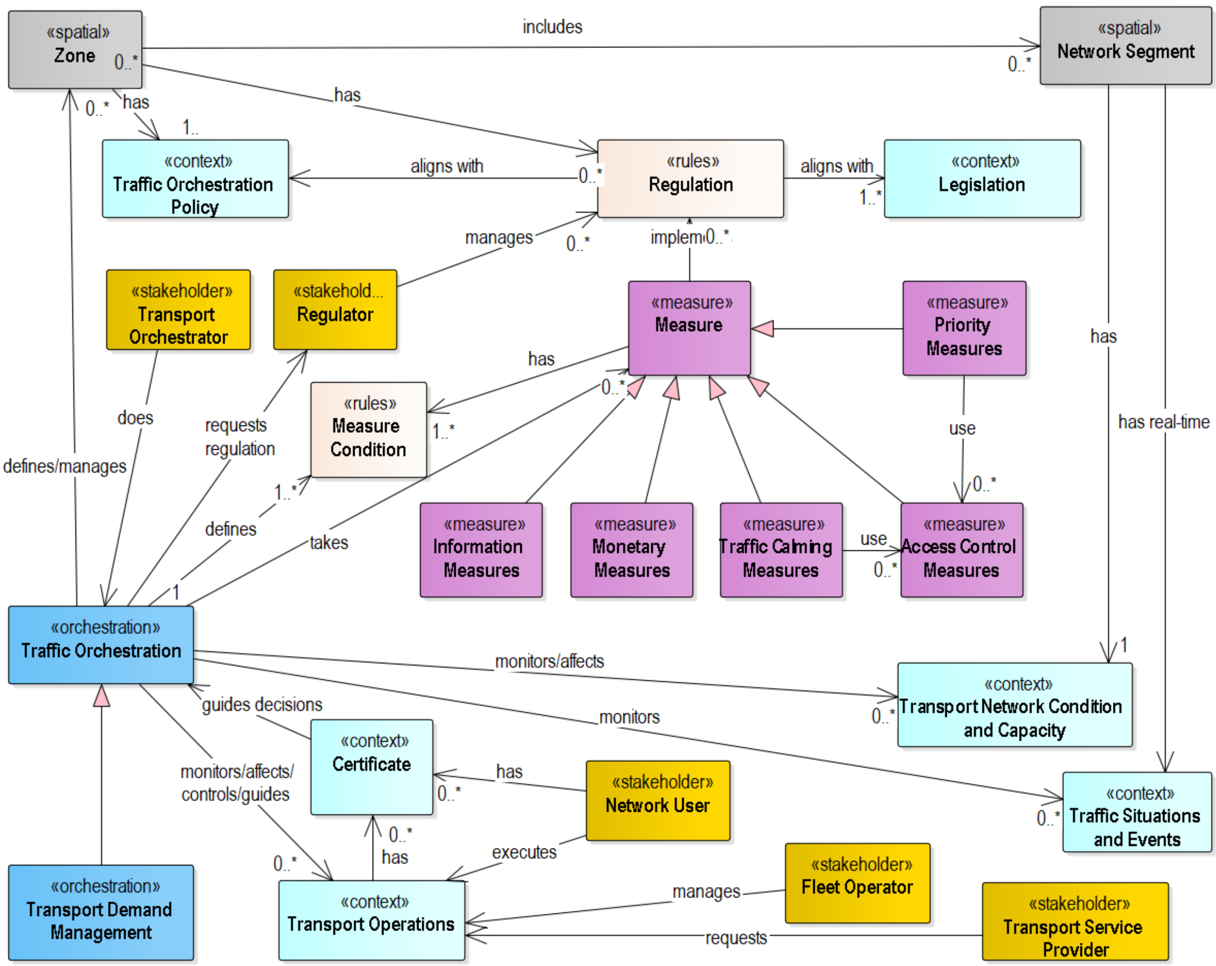

Figure 6: Transport Demand Management

Transport Demand Management (TDM) is a specialisation of *Traffic Orchestration* and inherits the properties of the *Traffic Orchestration*. Thus, the *Traffic Orchestrator* will do *TDM*, and *TDM* will align with the *Traffic Orchestration Policy* and define and manage Zones, request Regulations, define *Measure Conditions*, take *Measures*, and monitor, affect, control and guide the *Transport Operations*. *Measure Conditions* are defined in line with the *Traffic Orchestration Policy*.

TDM is about the management of the traffic volume and the type of transport in transport network zones. TDM may be used to shield against inconvenience from traffic (e.g. air pollution, noise, poor accessibility, barrier) and to channelize and prioritize road traffic in time and space. The *Measures* are to a large degree configured to be handled in an automated way. The *Measure Conditions* defines the rules regarding which measures to take depending on the characteristics and/or *Certificates* of the individual Network Users and Transport operation. The following TDM measures are relevant:

- *Information measures* provide information services targeting transport actors (Transport Service Providers, Fleet Operators, and Network Users) to influence both planned and ongoing Transport Operations. The aim is to affect the transport demand. In case of problems, information services may for example be used to

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    - Motivate the Transport Service Providers and Fleet Operators to use other modes or networks, to use other routes, or to change their plans and time schedules.
    - Communicate traffic information and regulations to the onboard systems providing navigation and driver support, and thereby affect how the Network Users use the transport network.
- *Monetary measures* facilitate billing and payment or other monetary transactions (earning of points, use of points, etc.) related to the Network Users' use of transport network segments and/or resources.
- *Traffic calming measures* target Network Users to reduce negative effects of the traffic. Speed limits may for example be reduced, or the number of Network Users within the zone may be managed.
- *Access control measures* supports access control towards Network Users to control the access to zones. The access may be linked to different characteristics of the vessels/vehicles and/or transport operations as well as other aspects like payment. In case of the latter, an access zone and a monetary zone may overlap to facilitate access for Network Users that have paid a fee and to stop other Network Users.
- *Priority measures* assigns priorities to Network Users to manage their use of the transport network segments and resources. Priorities may be assigned depending on different characteristics of the vessels/vehicles and/or transport operations as well as other aspects (e.g. payment).

Regulations, Measures and *Measure Conditions* for TDM may last for long periods, e.g. in a zone where road pricing is to be applied as a permanent measure. *Regulations, Measures* and *Measure Conditions* may however also be dynamically defined in case of immediate and temporary needs due to current or foreseen traffic situations.

Zones with different *Regulations, Measures* and *Measure Conditions* may partly or fully overlap to facilitate the TDM needed.

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4.3.4 Demand Capacity Balancing concepts

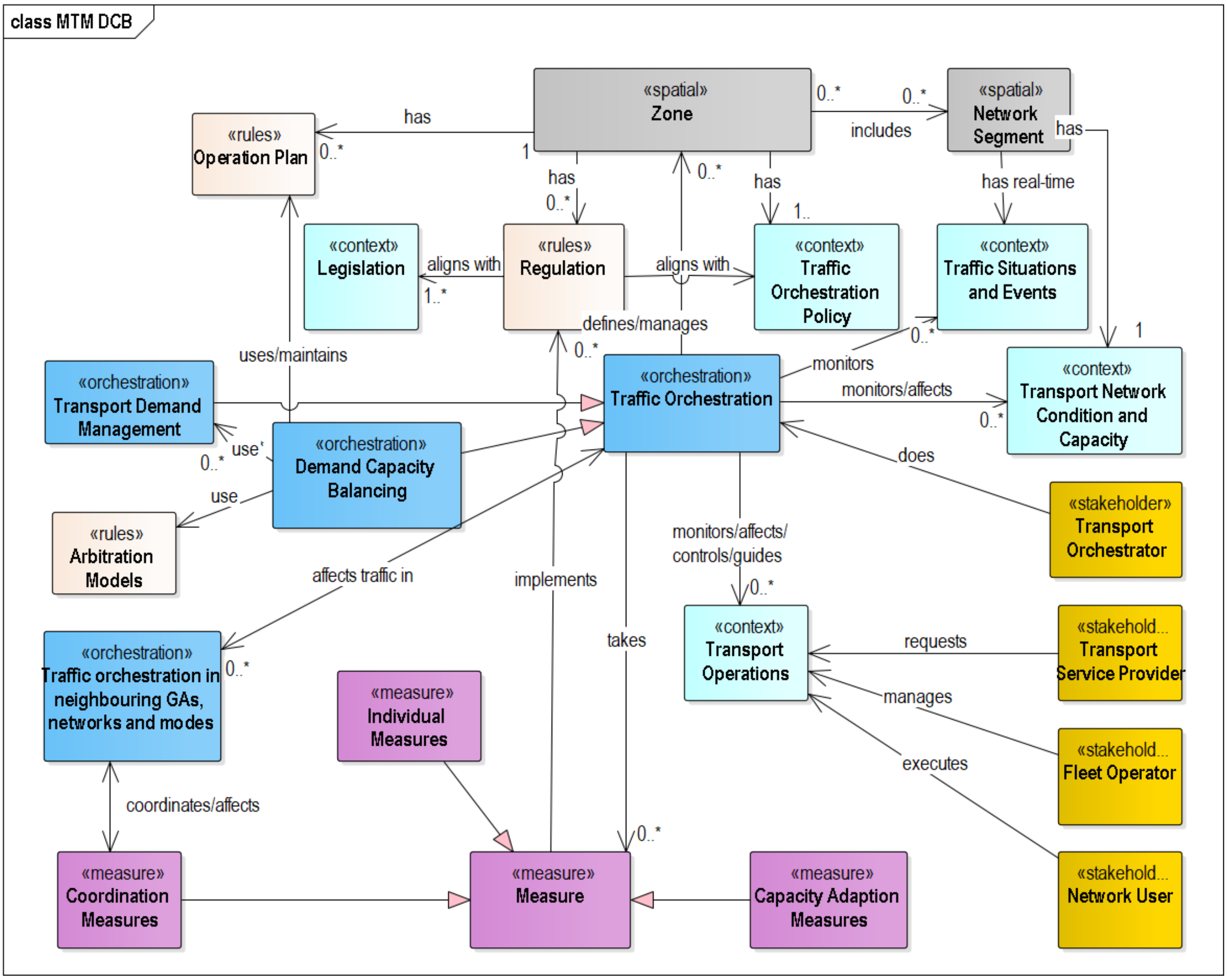

Figure 7: Demand Capacity Balancing

Demand Capacity Balancing (DCB) is a specialisation of *Traffic Orchestration* and inherits the properties of the *Traffic Orchestration*. Thus, the *Traffic Orchestrator* will do *DCB*, and *DCB* will align with the *Traffic Orchestration Policy* and define and manage *Zones*, take *Measures*, do monitoring, and affect, control and guide the *Transport Operations*.

DCB is about the handling of an imbalance or a potential or foreseen imbalance between the traffic and the transport network capacity. Depending on what is possible, the aim is to avoid unwanted situations, to reduce the extend of unwanted situations, to limit the negative effects, or to re-establish the normal situation as efficient as possible after an unwanted situation. Different types of DCB measures are taken to support this:

- *Individual Measures* towards individual *Network Users*. They are controlled or guided to contribute to an improvement of the situation.
- *Capacity Adaption Measures* to adapt the network capacity through use of relevant mechanisms (speed regulation, adaptation of the use of network segments, re-routing, etc.).
- *Coordination Measures* to coordinate the distribution of traffic with the *Traffic Orchestration in neighbouring networks and modes*.

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- Dynamic use of *Transport Demand Management* to balance the traffic volumes with the network capacity (see section 4.3.3).

The following support the actions to be taken:

- An *Operation Plan* providing an overview of upcoming events and situations (arrivals, departures, weather conditions, etc.) as well as the measures of different types to be taken and when they should be taken.
- *Arbitration Models* guiding the handling of conflicts and trade-offs between different needs.

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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 B.1 provides a description of the notation used.

5.1 Stakeholder overview

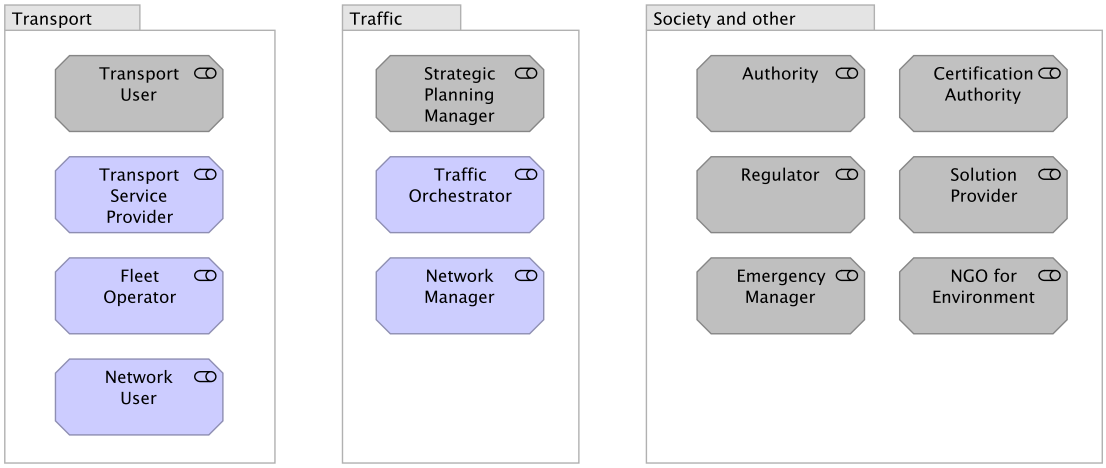

Figure 8: Generic stakeholder types.

Figure 8 provides an overview of the generic stakeholder types in the MTME. 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.

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- 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 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).

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5.1.2 Traffic

Strategic Planning Manager

The Strategic Planning Manager may operate at a local, regional, national or international level, and 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, arbitration rules, etc. The Strategic Planning Manager may also decide and authorize the use of more permanent zones and measures to fulfil political goals (e.g. low emission zones) and is also responsible for the overall strategies regarding the collaboration and coordination with other modes, networks and governance areas, as well as overall strategies for use of technologies.

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.
- 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 Network Manager plans and operates a transport network. This includes the physical infrastructure enabling the movement of transport means as well as equipment and the connected infrastructures linked to the network.

5.1.3 Society and others

Authority

The Authority is responsible for overall decisions on actions to be taken, monitoring and inspections of aspects of interest in the transport domain, and whenever this is required, for interventions and sanctions adapted to enforce envisioned situations.

Certification Authority

The Certification Authority is a trusted party that can issue certificates or appoint others that can issue certificates that prove the abilities and properties of Network Users and their transport operations.

- Transport Service Providers and Fleet Operators can send information about a transport operation to the Certification Authority and get a certificate in return.
- The Network User can send information about the vehicle/vessel to the Certification Authority and get a certificate in return.

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Certificates can be used in the communication with the Traffic Orchestrator to prove abilities and proprietaries that affect traffic orchestration measures. Certificates can be used instead of extensive data sharing on Network User and transport operation details, and certificates may thus protect privacy and/or business sensitive information.

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.

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.

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 may be provided according to many different business models.

5.2 Drivers

Drivers that are associated with a stakeholder are often called “concerns” and represent interests in the system relevant to one or more of the stakeholders (see section 3.2.2 "Architecture concepts"). This is linked to the purpose the stakeholder ascribes to the system**.**

A **driver** motivates the stakeholder to a change towards the adaption to the multimodal traffic orchestration ecosystem. Figure 9 provides an overview of the main drivers/concerns for the stakeholder archetypes.

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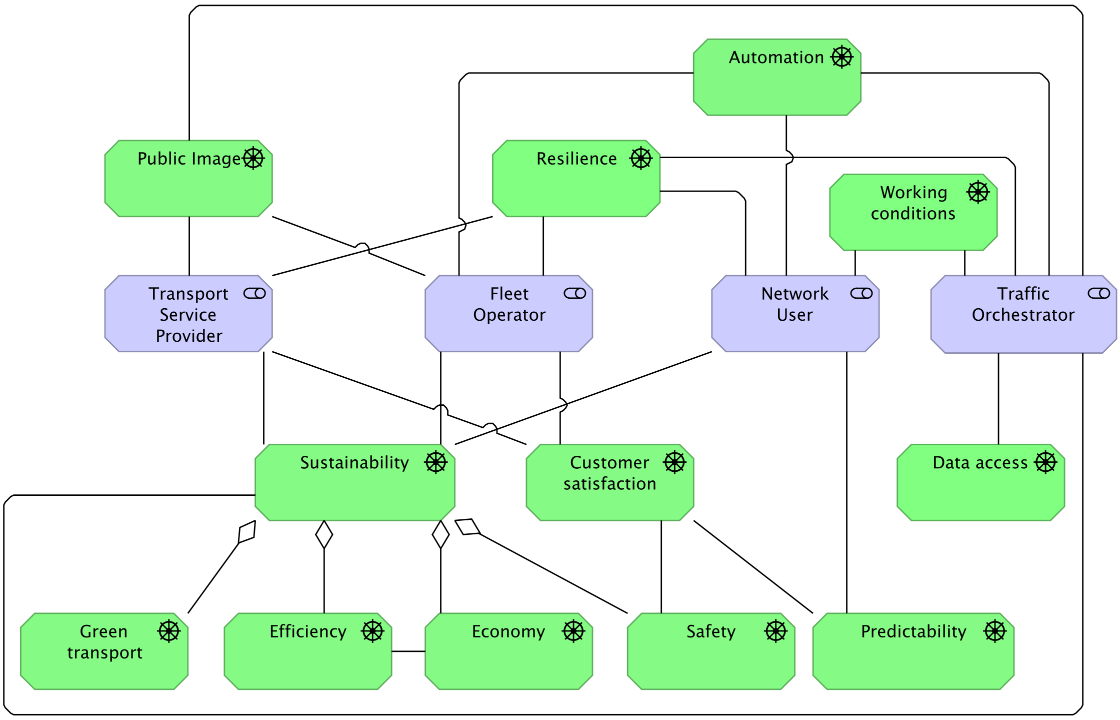

Figure 9: Drivers per stakeholder archetype

Table 4 provides a description of the details linked to the drivers of relevance to the stakeholder archetypes.

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Table 4: Drivers and aspects of relevance for the stakeholder archetypes

Drivers	Transport Service Provider (TSP)	Fleet Operator (FO)	Network User (NU)	Traffic Orchestrator (TO)
Resilience	• Ability to detect relevant (both expected and unexpected) traffic issues early through information and notifications from TOs • Ability to take timely, informed and correct decisions and actions • Ability to mitigates or avoids unwanted situations • Ability to deliver services and maintain the level of service in case of unwanted situations	• Ability to detect relevant (both expected and unexpected) traffic issues early through information and notifications from TOs • Ability to take timely, informed and correct decisions and actions • Ability to mitigate or avoid unwanted situations, and to get support from TOs regarding how to handle situations • Ability to carry out transports, and bring down the extra cost also in case of unwanted situations	• Ability to detect upcoming and occurred (both expected and unexpected) traffic situations early • Ability to get support from onboard systems interacting with TOs • Ability to take good decisions, adapt to situations and to handle unwanted situations • Ability to use transport networks with different levels of support for automation	• Ability to detect and understand of upcoming and occurred (both expected and unexpected) situations early and rapidly • Ability to detect and avoid human errors • Ability to take informed decisions on how to avoid/mitigate unwanted situations, to apply strategies and rules, and to minimise negative effects through measures and regulations • Ability to find capacity in the transport system and to support TSPs, FOs and NUs in the use of available capacities
Sustainability	• See *Green Transport*, *Economy*, *Efficiency* and *Safety* below	• See *Green Transport*, *Economy*, *Efficiency* and *Safety* below	• See *Green Transport*, *Economy*, *Efficiency* and *Safety* below	• See *Green Transport*, *Economy*, *Efficiency* and *Safety* below • Facilitate decision and measures according to policies e.g. transport demand management, reduced emissions, and improved air quality • Ability to maintain social aspects related to transport • Good life in cities
Customer satisfaction	• Provide competitive services fulfilling customer expectations • Ability to handle deviations in a good way	• To be a preferred transport provider • Carry out transport operations fulfilling the expectations of customers (TSPs) • Ability to handle deviations in a good way		
Predictability	• Awareness of issues that may affect the transport chains • Ability to take mitigating measures and to handle deviations at an early stage	• Awareness of occurred/upcoming situations to arrange for better (re-) planning of transport operations. • Adaption to traffic orchestration strategies, policies and measures • Ability to take pro-active measures	• Predictability with respect to departures, arrivals, durations, routes, transport orchestration measures, etc. • Predictability reducing stress and supporting the adaptation	

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Drivers	Transport Service Provider (TSP)	Fleet Operator (FO)	Network User (NU)	Traffic Orchestrator (TO)
		to avoid or reduce deviations.	of the transport operations	
Green transport[5]	• Reach customers through green transport chains offerings • Benefit from use of green FOs • Benefit from use of green modes	• Get competitive advantage through green transport operation offerings • Benefit from adaptations to rules and regulations and societal norms on green behaviour	• Low emissions • Minimal use of energy • Benefit from desired green behaviour	• Fulfil green policies • Provide benefits to and support green transport operations
Economy	• Get return of investment and cost coverage • Provide attractive and cost-effective services to customers • Get new business opportunities based on new technology and green services	• Get return of investment and cost coverage • Ability to get optimal transport operations (routes, schedules, etc.) • Ability to use resources like onboard capacity and personnel better • Effectiveness (time is money) • Standardised integration into MTM via onboard systems and equipment	• Get cost reductions through eco-driving • Get cost reductions through routes that minimize the energy and time use (adapted to the transport operation)	• Public TOs: Fulfil social economics policies • Private TOs: Ability to generate profit • Contribute to the data economy – collected traffic data can be used in new services and smart solutions
Efficiency	• Ability to detect situations at an early stage • Ability to efficiently adapt transport chains to occurred and upcoming situations • Benefit from efficient transport operations.	• Ability to detect situations at an early stage • Ability to efficiently plan and adapt plans and ongoing operations to occurred and upcoming situations. • Benefit from opportunities generated by transport orchestration strategies, policies and measures	• Efficient trips (best route, fey/small deviations) • Ability to find good alternatives in case of deviations	• Ability to cope with complexity and CAVs in a cost-effective way • Ability to rapidly understand situations and possible consequences • Ability to rapidly make correct decisions • Ability to communicate efficiently with Network Users and other transport actors • Ability to utilise the transport network capacity in an optimal way
Safety	• Ability to provide services that that are recognised as safe	• To be recognised as a safe operator with safe operations • Ability to minimize injuries and damages and related costs.	• Ability to avoid accidents and close to accident situations • Minimised safety risks and threats	• Maintain traffic safety • Ability to detect potentially dangerous situations in time to take mitigating actions

[5] Green transport has many aspects. The focus here is on reduction on emissions.

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Drivers	Transport Service Provider (TSP)	Fleet Operator (FO)	Network User (NU)	Traffic Orchestrator (TO)
				• Ability to prevent or limit consequences of accidents
Data access				• Ability to access and use relevant data of sufficient amount, type and quality, suitable for decision support • Willingness to share data on planned and ongoing transport operations
Public image	• Ability to maintain an image that generate more customers • Willingness to pay for the services provided.	• Ability to maintain an image that generate more business • Willingness to pay for the transports.		• Support TSPs, FOs and NUs in a good way • Orchestrate traffic in a fair and neutral way, according to policies and strategies • To be trustworthy through transparency and openness about rules and strategies • Ability to measure and show effects of traffic orchestration
Working conditions			• Predictability for professional NU • Positive appreciations due to skills and competence	• Ability to get decision support in complex situations • Less stress and reduced workload during unwanted situations • Less fear for human errors
Automation		• Ability to use CAVs	• CAVs or semi-automated vehicles/vessels • Traffic orchestration and infrastructure supports automated/cooperative driving and microscopic traffic situations can be perceived • All relevant information (static and dynamic) is available on a digital form (maps, etc.)	• Support for automated decisions • Support for automated actions and real-time communication with Network Users for optimised traffic flows

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5.3 Goals

An assessment of the current state with respect to the drivers identified in section 5.2 is provided in Annex B.3. This section provides goals regarding how to fill gaps and meet the drivers of each stakeholder archetype. A goal can represent anything a stakeholder may desire and describe results that are essential for the MTME as seen from the perspective of the stakeholder archetype. Goals can be used to measure the success of the System of Interest, and the functionality described in the Context view must address these goals.

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5.3.1 Traffic Orchestrator

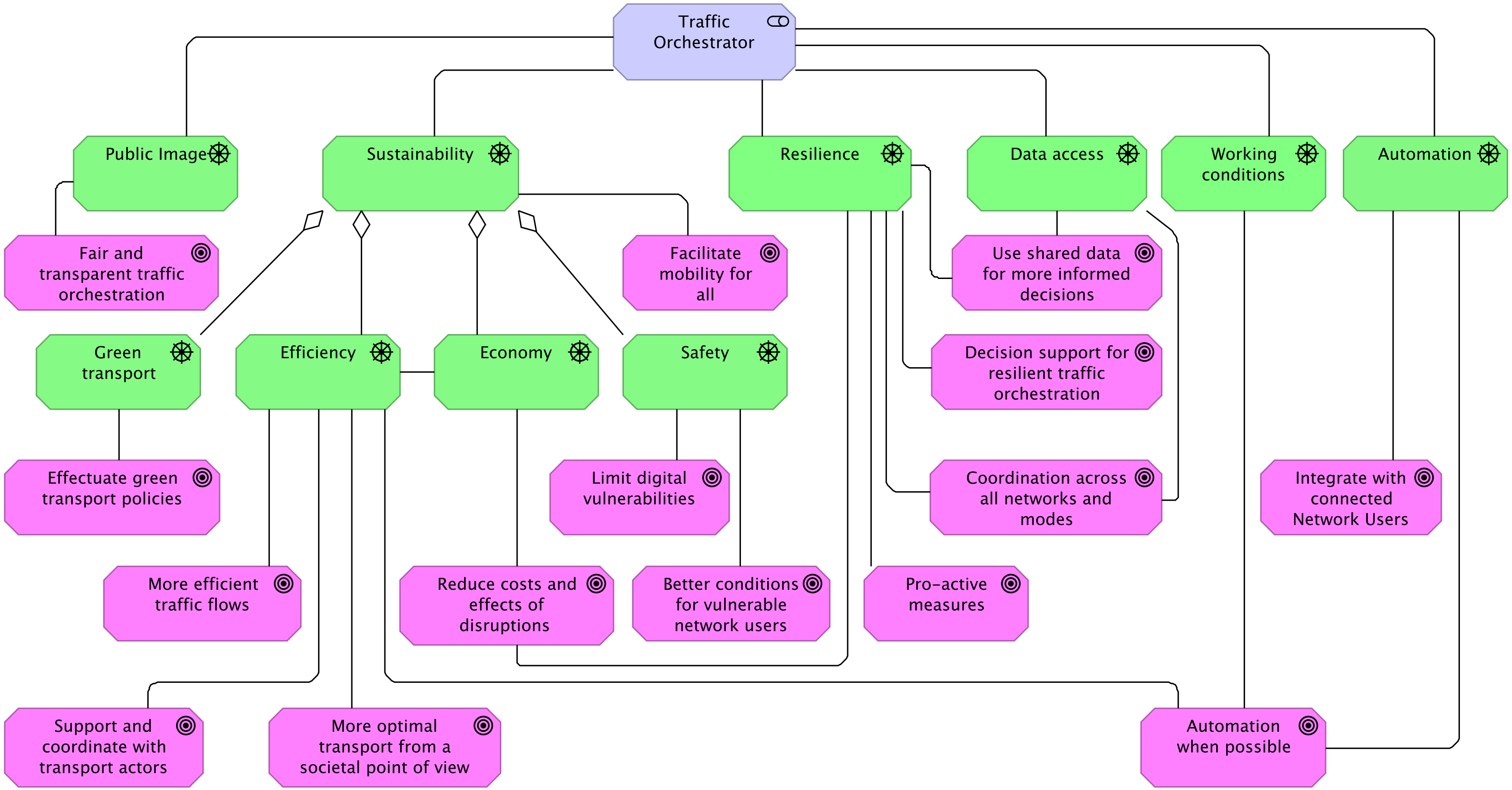

Figure 10: Traffic Orchestrator drivers and goals

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The Goals of the Traffic Orchestrator are, as illustrated in Figure 10:

- **TO1: Fair and transparent traffic orchestration:** The traffic orchestration is trusted to ensure acceptance and participation. The rules applied are public and transparent, and based on open policies, strategies and regulations.
- **TO2: Effectuate green transport policies:** The traffic orchestration is implemented according to approved strategies and policies to arrange for use of green modes and benefits for those with green behaviour.
- **TO3: More efficient traffic flows:** The traffic orchestration optimises the traffic flows. Trade-off with other performance targets must however also be considered as defined by overall policies and strategies.
- **TO4: Integrate with connected Network Users:** The traffic orchestration can handle a high number of connected vehicles/vessels and CAVs. Real-time information on their movements is received, and they can be guided one by one, or as a group to optimise the traffic flow.
- **TO5: Support and coordinate with transport actors:** Traffic Orchestrators interact with Fleet Operators and Transport Service Providers to get information about and to influence planned and ongoing transport operations to facilitates predictions and more informed decisions. The communication is performed according to international standards to facilitate an economic sustainable establishment of the multimodal traffic management ecosystem.
- **TO6: More optimal transport from a societal point of view:** The traffic should be coordinated and optimised across networks and modes (as defined by public policies, strategies and rules).
- **TO7: Facilitate mobility for all:** Traffic orchestration strategies ensure that both manual vehicles/vessel and CAVs can be supported. The traffic orchestration does not discriminate any network user and is supported by standard onboard equipment, that according to international agreement is installed in most transport means. Software updates are automated and for free to facilitate broad deployment.
- **TO8: Reduce costs and effects of disruptions:** Disruptions are avoided or limited through resilient traffic orchestration with decision support.
- **TO9: Limit digital vulnerability:** The digitalisation of the traffic management may increase the safety risk. Information security, cyber security and backup solutions are accounted for.
- **TO10: Better conditions for vulnerable network users:** The traffic orchestration takes the needs of soft modes and vulnerable network users into account according to the transport policy, strategy and regulations of the network.
- **TO11: Take pro-active measures:** The evolvement of the traffic situation is predicted, and pro-active measures are taken to avoid undesired situations.
- **TO12: Automation when possible:** The traffic orchestration is highly automated to ensure that the complexity is handled, that measures 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.
- **TO13: Use shared data for more informed decisions:** The traffic orchestration depends on access to a variety of data. The collection, management and use of these data are facilitated and manged.
- **TO14: Decision support for resilient traffic orchestration:** The decisions taken are supported by data analysis and artificial intelligence. Situations and events are, if possible, detected in advance to arrange for pro-active mitigating actions. In case of accidents and disruptions, the system supports mitigating actions and the restoration of the normal situation.
- **TO15: Coordination across networks and modes:** Coordination between modes and network is supported by the networks and performed according to international standards.

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5.3.2 Transport Service Provider

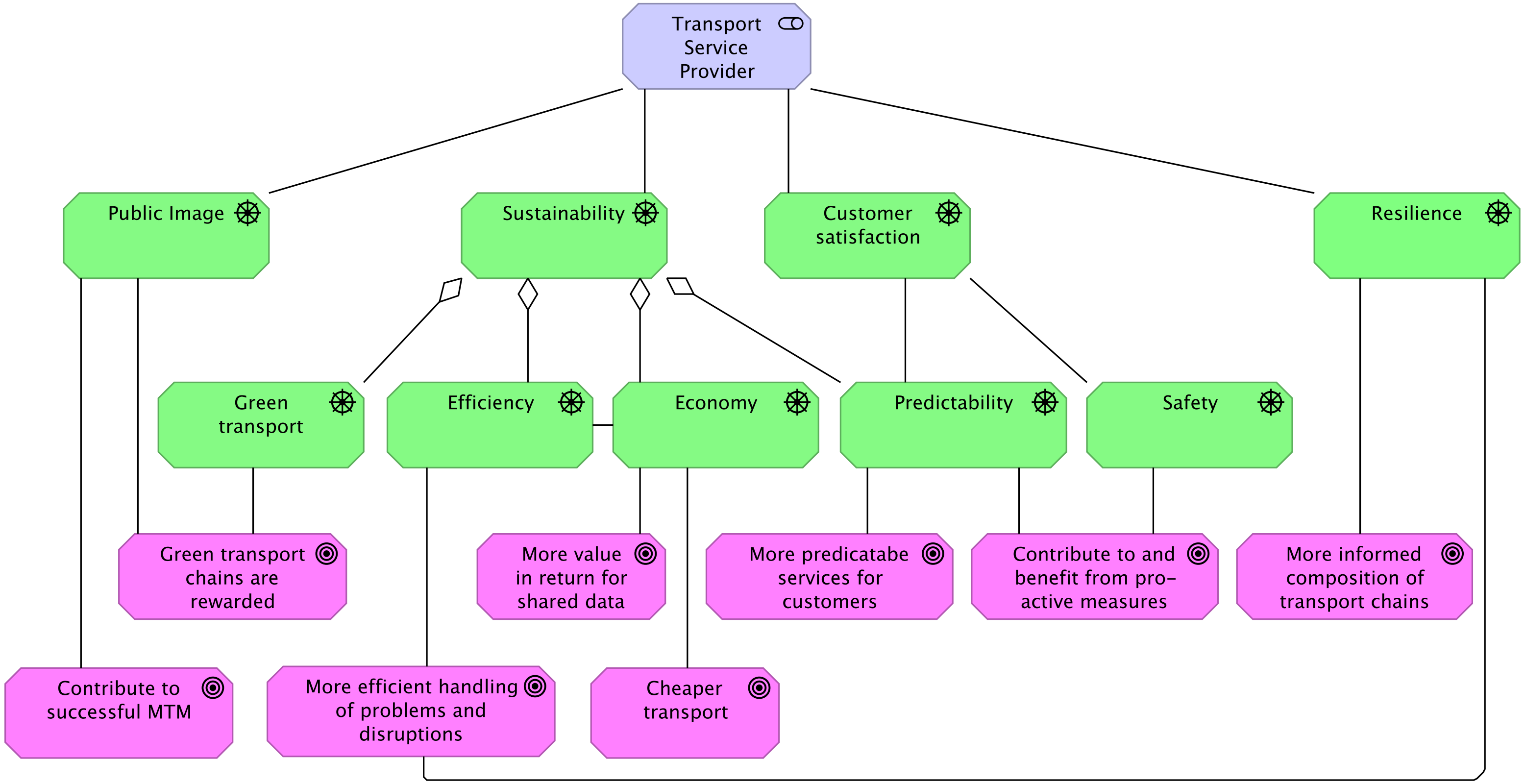

Figure 11: Transport Service Provider drivers and goals

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The Goals of the Transport Service Provider are, as illustrated in Figure 11:

- **TSP1: Green transport chains are rewarded:** The provision of green transport services is good for the public image, and Transport Service Providers prefer to use green modes when customers request green services and when the green modes are available and accessible, and not more expensive than other alternatives. The use of green modes and services is rewarded. Transport operations for cargo or passengers to/from such green modes (first/last mile) may for example get benefits.
- **TSP2: Contribute to successful MTM:** Transport Service Providers want to appear as contributors to sustainable transport. Thus, they are willing to contribute to multimodal traffic management (MTM) to the best of the society. This implies that they share data with the Traffic Orchestrator and adapt their decisions to information and guidelines received from the Traffic Orchestrator.
- **TSP3: More efficient handling of problems and disruptions:** Transport Service Providers get early notification and warnings about predicted and occurred situations (foreseen problems due to weather conditions, reduced capacities in networks, accidents, disruptions, etc.), and they also receive information on transport orchestration policies, strategies and measures. Thus, Transport Service Providers can take informed decisions and be more resilient, and dynamically plan, re-plan and adapt the transport chains to current and upcoming situations.
- **TSP4: Contribute to and benefit from pro-active measures:** As a consequence of the above, and providing that this is likely to give more optimal, predictable and safe transports, Transport Service Providers share data with the Traffic Orchestrator and adapt the transport chains to requests from the Traffic Orchestrator. In this way, they contribute to pro-active measures (e.g. when congestions are predicted) and to the handling of unwanted situations.
- **TSP5: More predictable services for customer:** The customers of Transport Service Providers are affected by traffic problems, and they may get even more affected as transports more often are affected by the climate change. In the case of deviations, predictability is important. Due to information and support from the Traffic Orchestrator, Transport Service Providers can provide more predictable services. They can inform their customers at an early stage in case of foreseen deviations or deviations.
- **TSP6: More informed composition of transport chains:** Transport Service Providers can compose the transport chains based on knowledge about current and predicted network and traffic situations. When transport chains are composed in a more dynamic and resilient way, the next leg is planned when the previous leg is ongoing or finalised. Customised real-time information, predictions, early notifications and warnings give Transport Service Providers time to look for the best possible transport opportunities for the next leg.
- **TSP8: More value in return for shared data:** Transport Service Providers trust the Traffic Orchestrator and share data due to their societal responsibility and the benefits the sharing of the data may give. Metadata on planned and ongoing transport chains are shared to facilitate holistic and informed management of traffic flows. In return, the Transport Service Providers get customised support during normal and abnormal traffic situation.
- **TSP9: Cheaper transport:** Transport Service Providers buy transports from Fleet Operators. The traffic orchestration services make the transport operations more reliable, predictable and cost efficient. This directly and indirectly also reduce the costs for the Transport Service Providers.

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5.3.3 Fleet Operator

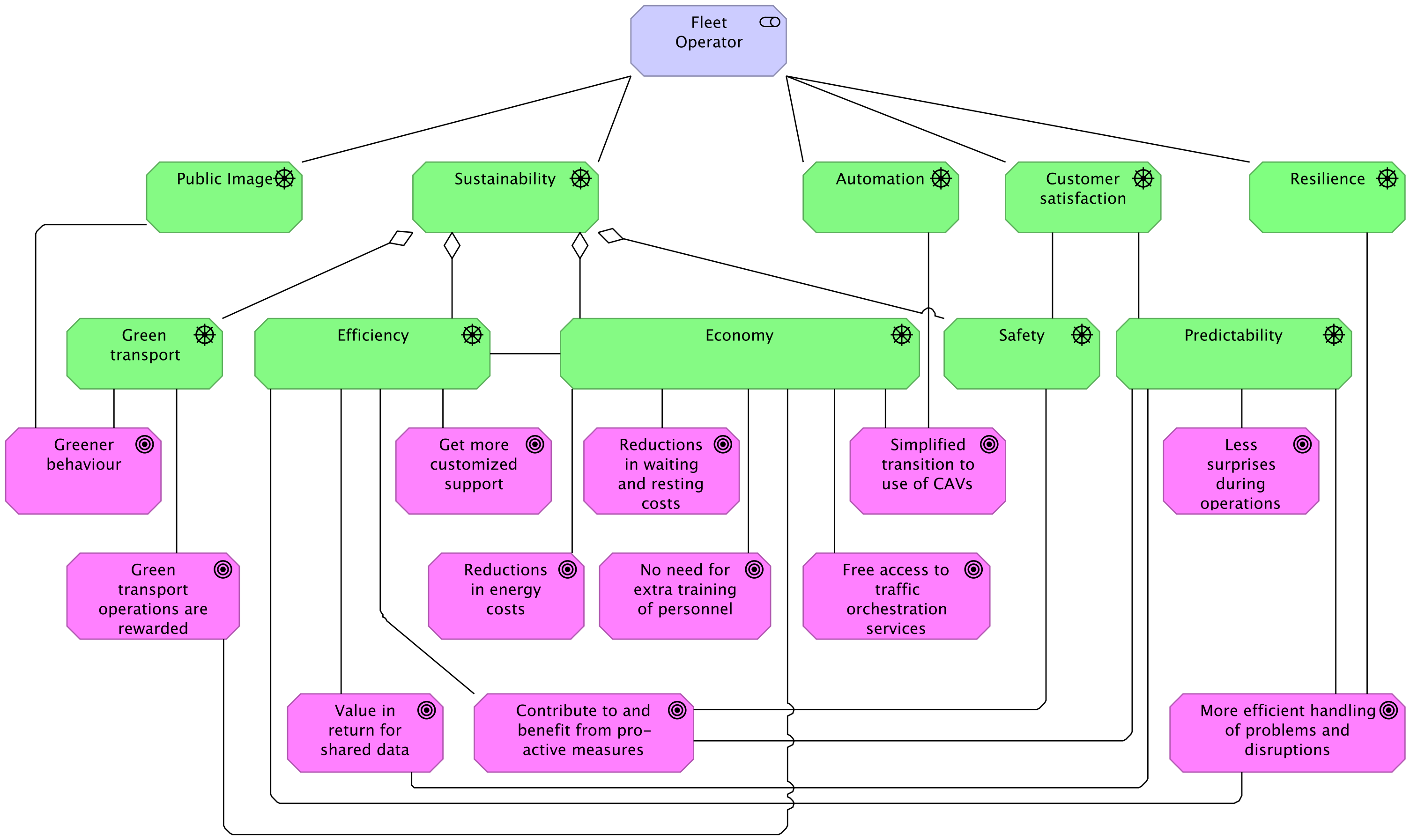

Figure 12: Fleet Operator drivers and goals

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The Goals of the Fleet Operator are, as illustrated in Figure 12:

- **FO1: Green transport operations are rewarded:** Transport operations are handled according to their characteristics and their adaption to green behaviour. Thus, the use of green transport means and energy effective transport operations are rewarded. Fleet operators that collaborate with other to increase load factors may for example be rewarded. New business models must arrange for such collaborations.
- **FO2: Green behaviour:** The use of green transport means is the preferred alternative. Such means are available and accessible and not more expensive than other alternatives. It is easy and convenient to get access to green energy.
- **FO3: Get more customized support:** When fleet operators share data on planned and ongoing transport operations, they get customized support. Information of relevance the operations is received, and informed decisions can be taken, for example regarding the need for a re-planning. Fleet Operators also get information on polices and measures of relevance to their operations. Thus, the operations are better adapted to rules and requirements, and they are rewarded. Critical transport operations (e.g. emergency operation) may get priorities, green operations may get access to low emission zones, and transport operations that are the first or last legs in green, multimodal chains may get a priority. Under certain conditions, it may also be possible to request or pay for privileges.
- **FO4: Contribute to and benefit from pro-active measures:** FOs share data with the Traffic Orchestrator and adapt their transport operations to requests from the Traffic Orchestrator. In this way, FOs contribute to, and benefit from, pro-active measures and resilience (e.g. when congestions are predicted). FOs can better handle unwanted situations, carry out safe operations and get more efficient traffic flows.
- **FO5: Less surprises during operation:** In case of unforeseen situations, Fleet Operators get early notifications and warnings, preferably before the situations occur, and the Fleet Operators have time to take mitigating actions and to do re-planning at an early stage. The latter facilitate more optimal operations, cost reductions, and higher customer satisfaction.
- **FO6: 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 Operators get customised support during normal and abnormal traffic situation and the operations can be more predictable and more cost-efficient.
- **FO7: More efficient handling of problems and disruptions:** Fleet Operators get early notifications and warnings from the Traffic Orchestrator about predicted situations, situations that have occurred (accidents, disruptions, etc.), and planed and effectuated transport orchestration measures that may affect ongoing and planned operations. They also get advice on how to handle situations (e.g. re-routing). Due to the support from the Traffic Orchestrator, Fleet Operators are able to dynamically re-plan and adapt operation to current and upcoming situations, and to limit the negative consequences. They have more predictable operations and can inform their customers at an early stage in case of foreseen deviations.
- **FO8: Simplified transition to use of CAVs:** To reduce the burden of the Fleet Operators, the transition to use of CAVs is supported by an easy, predictable and seamless integration with the traffic orchestration. All CAVs are equipped and prepared for such integrations.
- **FO9: Reductions in waiting and resting costs:** The traffic orchestration facilitates more predictable operations with a minimum of waiting times. Resting times are considered in the traffic orchestration. Delays that may cause additional resting times are if possible be avoided.

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- **FO10: Reductions in energy costs:** The use of energy is considered when traffic orchestration measures are taken. Suggested routes are for example be as energy efficient as possible.
- **FO11: No need for extra training of personnel:** The introduction of advanced traffic orchestration reduces 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.
- **FO12: Free access to traffic orchestration services:** The integration with the traffic orchestration is supported by all transport means after a certain production year. No extra investments are required. The software in the transport means is updated automatically, to facilitate integration with new transport orchestration services.

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5.3.4 Network User

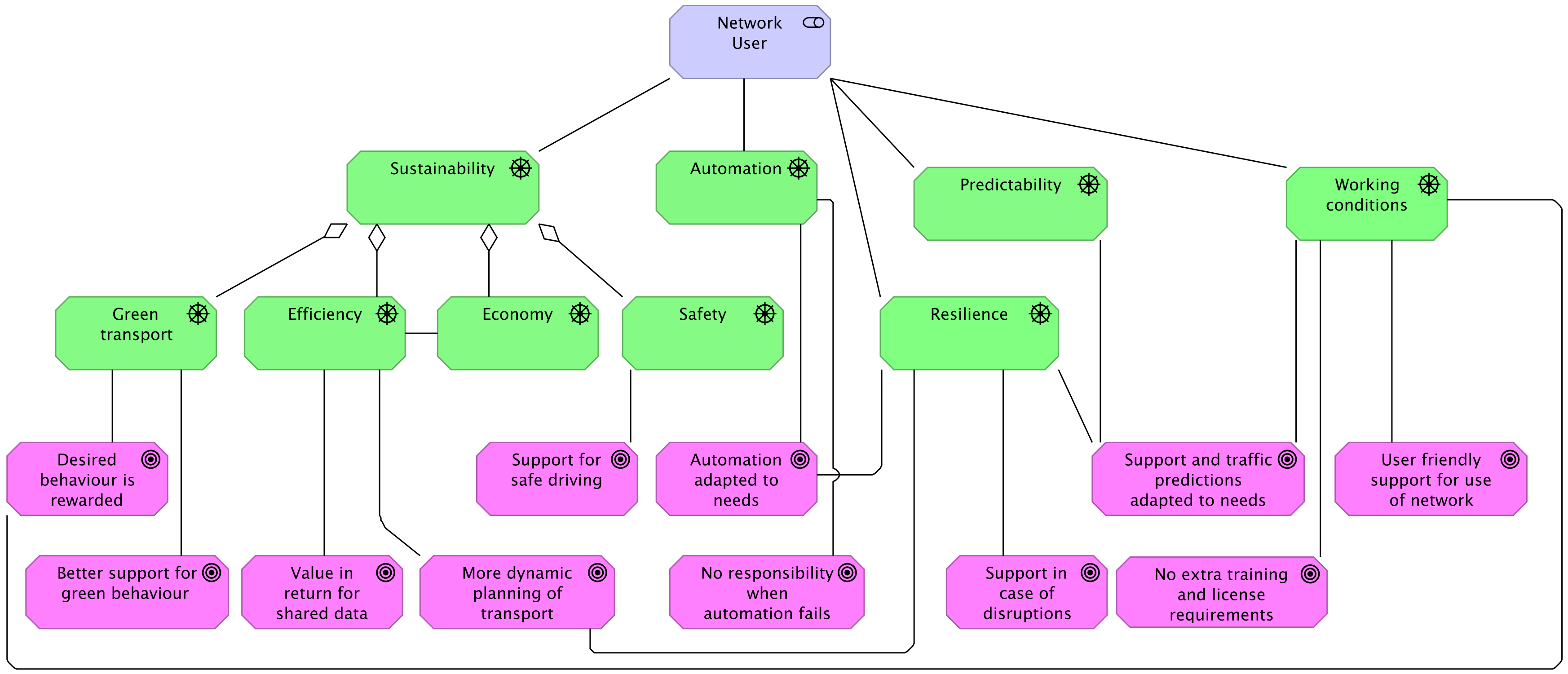

Figure 13: Network User drivers and goals

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The Goals of the Network User are, as illustrated in Figure 13:

- **NU1: Desired behaviour is rewarded:** Network Users are handled according to their characteristics and their adaption to the policies concerning the relevant network (or the part of the network). Ethical issues or discrimination should exclude any Network Users. Green transport means, and those with a green behaviour get advantages compared with others.
- **NU2: Better support for green behaviour:** It is easy for all types of Network Users to adapt to green behaviour. Green modes and the use of green vehicles/vessels are the easiest and preferred alternatives, and green modes are available and accessible and not more expensive than other alternatives. It is easy and convenient to get access to the energy needed, and the energy is green. Network Users are well informed about the advantages the green alternatives represent – not only for the environment but also with respect to the traffic orchestration.
- **NU3: Value in return for shared data:** When Network Users provide data on planned transport operations and real-time information during the execution of the transport operations to the Traffic Orchestrator. In return, Network User get customised support during normal and abnormal traffic situation.
- **NU4: More dynamic planning of transport:** At the start of a journey, and during the journey, Network Users will get planning/re-planning support adapted to current and foreseen situations in the transport network, disruptions included. Relevant information is automatically provided to the Fleet Operators to facilitate coordinated decisions.
- **NU5: Support for safe driving:** The traffic management measures arrange for safety for all types of Network Users, also soft modes like pedestrians and cyclist.
- **NU6: Automation adapted to needs:** The degree of automation and support provided to Network Users is adapted to the needs of the Network Users, to the situation, and to the infrastructure. All relevant static and dynamic information can be received, and the use of the information is supported to facilitate automated or semi-automation operation.
- **NU7: Support in case of disruptions:** Network Users get informed advice on how to handle disruptions. The advice is adapted to the individual transport operations.
- **NU8: Support and traffic predictions adapted to needs:** During the journey, Network Users get informed advice and other information adapted to the situation and the individual transport operations. This includes advice on pro-active measures that can contribute to a better handling of foreseen situations in the transport network along the route.
- **NU9: No extra training and license requirements:** The introduction of automation and advanced user support do not cause extra training and license requirement. The new solutions reduce the possibility for human errors, increase the safety, and improve the efficiency of the transport operations carried out.
- **NU10: User friendly support for network use:** The Network User is not overloaded with information, and do not need new/extra equipment. The Network Users get the information and support they need via the equipment installed in the vehicles/vessels. The providers of such equipment integrate the supporting services with the MTM in a standardised way.
- **NU11: No responsibility when automation fails:** The responsibilities are well defined and regulated by laws. If the automation fails or the collaboration between the automation and the Traffic Orchestrator fails, the Network User should have no responsibility.

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5.4 Architectural concerns

This section describes how the motivation view meet the architectural concerns described in section 4.2. The architectural concerns are resilience, polycentricity, multimodality, organisation flexibility and automated driving.

5.4.1 Resilience

Resilience is a main driver for all stakeholder types, and aspects of relevance to resilience, or issues that may be solved through resilience are addressed in assessments, goals and requirements. The adaptation of the architecture towards resilience is however not done here.

5.4.2 Polycentricity

Polycentricity is covered with respect to:

- *Stakeholder types:* All stakeholder types of relevance are identified and described, and drivers, assessments, goals and requirements are defined for the stakeholder types that are users of the SoI.
- *Transport modes, networks, governance levels and transport types*: Unless nothing is said about particular issues, all specifications 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 view.

5.4.3 Multimodality

The motivation view is as far as possible harmonized across modes. Assessments of the current situation with respect to the drivers may however include references to specific modes to support learning. The mode-independent descriptions support a common understanding and communication across modes.

5.4.4 Organisation flexibility

The use of generic stakeholder types arranges for flexible organisations. The stakeholder types can be covered by different actors, and one actor may cover one or more stakeholder types, and several actors may also have the same stakeholder type.

5.4.5 Automated driving

Automation is a main driver for Fleet Operators, Network Users and Traffic Orchestrators, and aspects of relevance to automation are addressed in the associated goals and requirements. The aspects addressed by the ISAD levels addressed in 4.2.5 are included.

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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. ArchiMate Business Layer model elements are used to represent the functionality and the business objects (see notation in Annex B.2).
- *Environmental model* describing the external systems the System of Interest must interact with.
- *Mapping model* describing how the functionality described can be mapped to logical services.

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

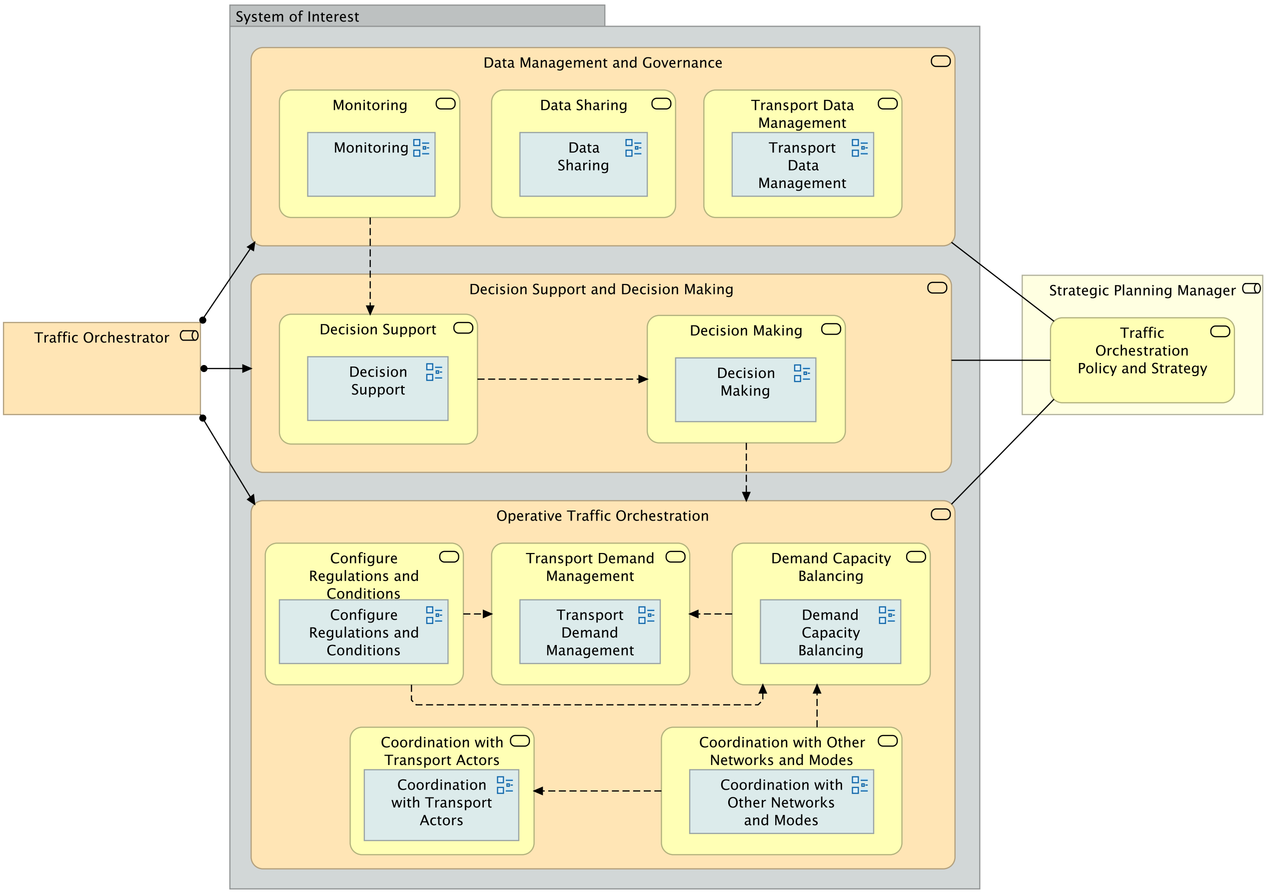

Figure 14: Overview of functionality needed by the Traffic Orchestrator

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.

Also note that the business processes and services described may be realised in several systems that might be local or centralised. The logical components are described in the decomposition model in section 8.2.

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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.

6.1.1 Data Management and Governance: Monitoring

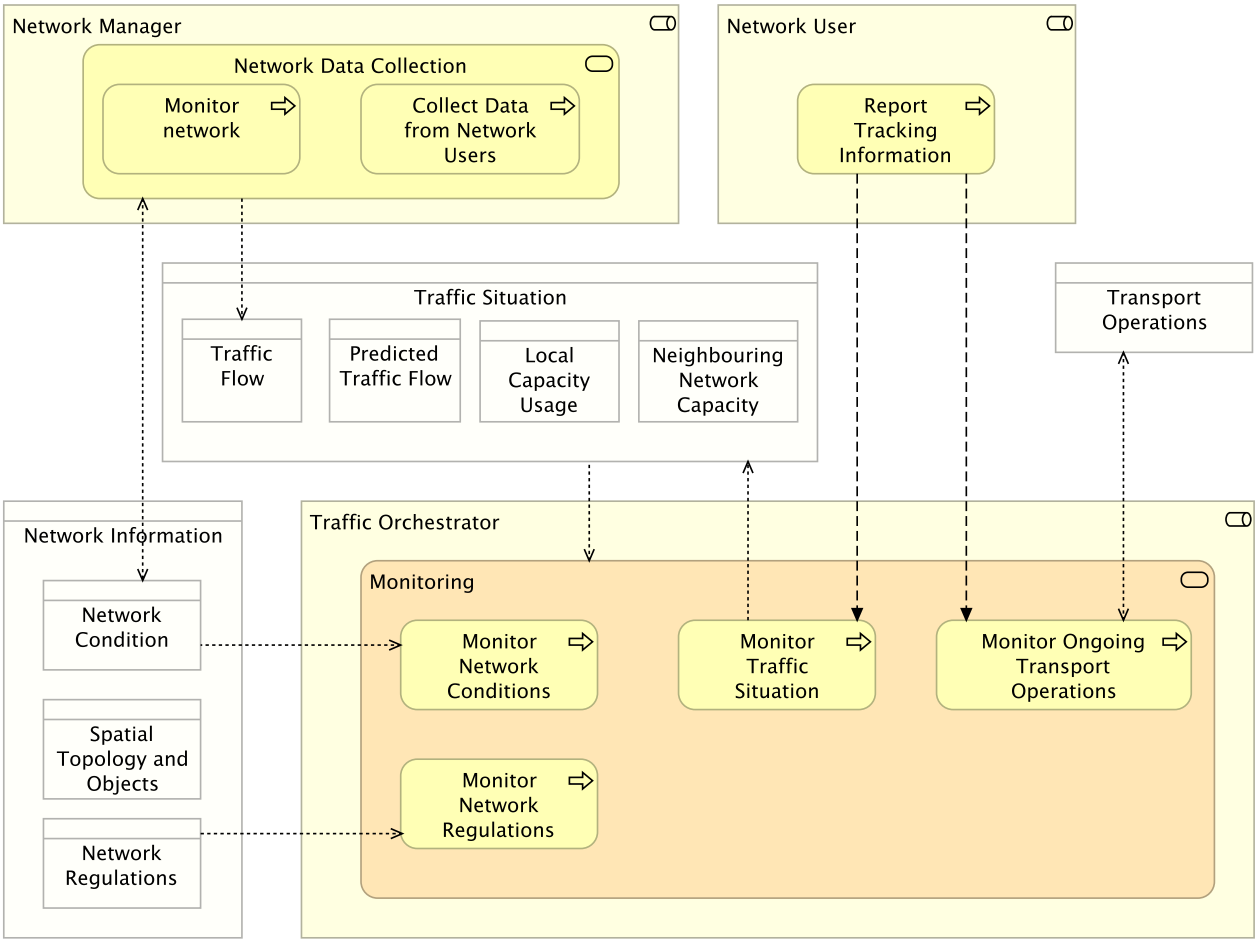

Figure 15: Business service: Monitoring

Several business processes monitor the network condition, the traffic situation and the ongoing transport operations. The aim is to establish awareness about current and predicted traffic situations and 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).

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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).

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 – density, speed, location of Network Users, etc.; 2) to get updated information on individual Network Users and related Transport Operations. The latter is tracked in the Transport Operations business object.

6.1.2 Data Management and Governance: Data Sharing

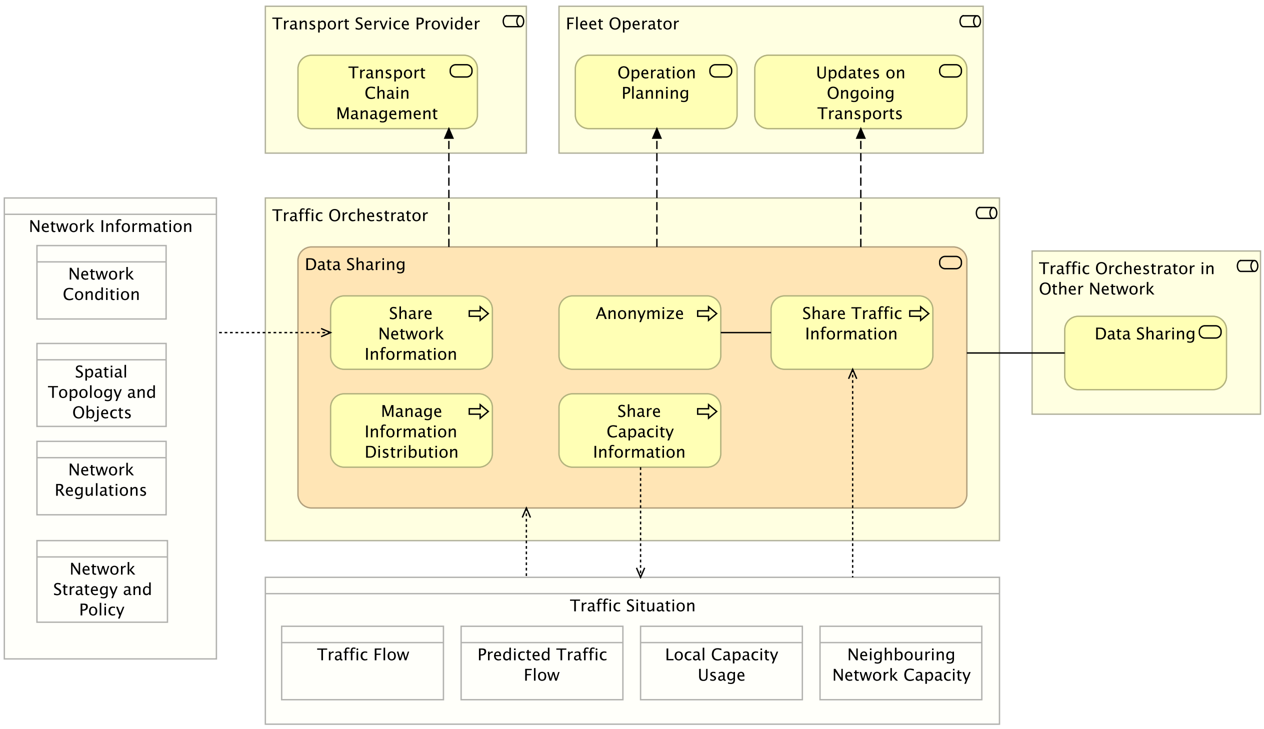

Figure 16: Business service: Data sharing

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

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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).

Share Network Information

All types of network information may be shared, information about network strategies and policies and regulations included to arrange for transparency. 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

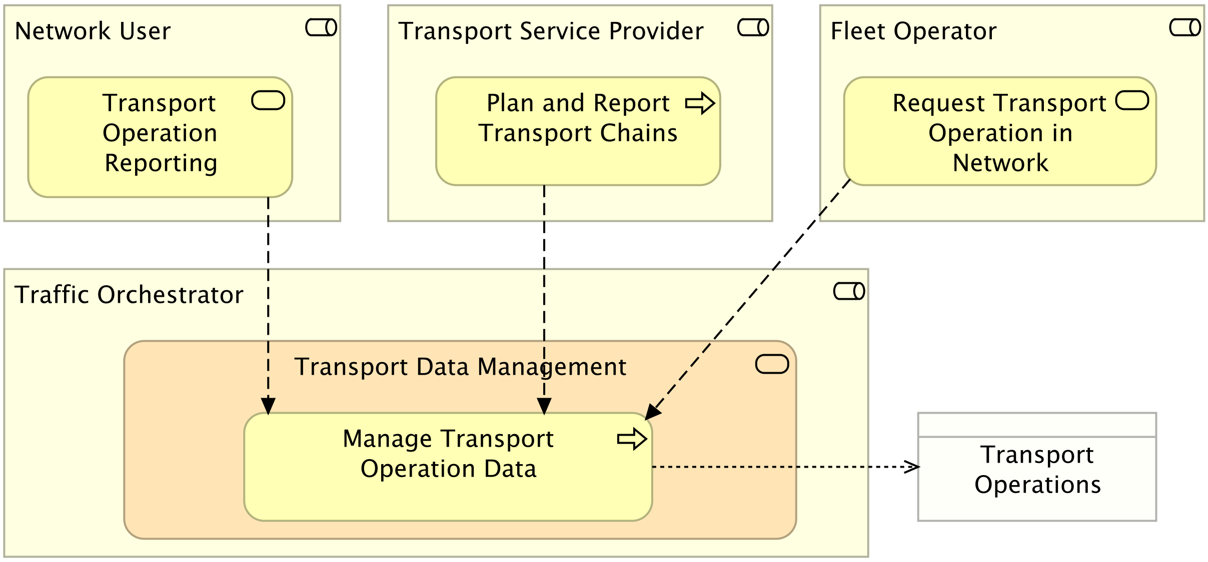

Figure 17: Business service: Transport Data Management

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 (entries to/exits from the governance area, 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

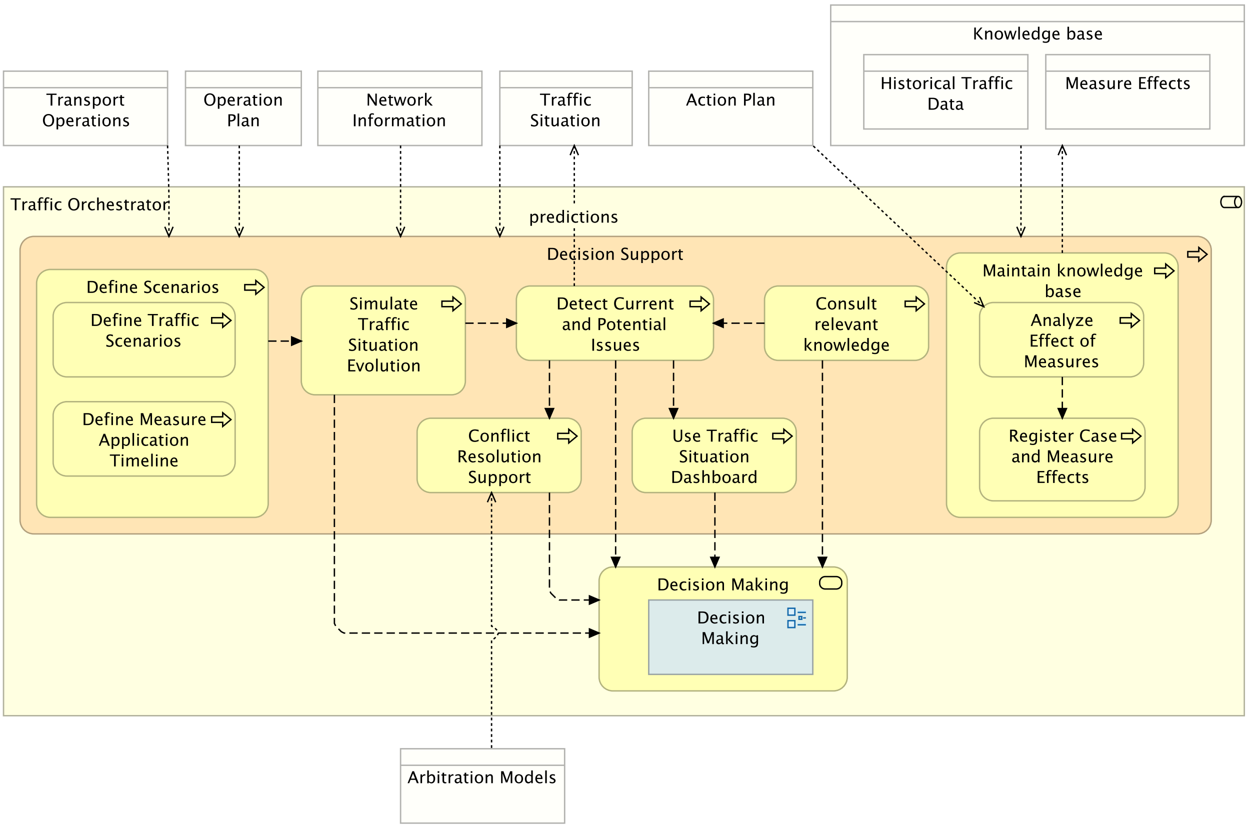

Figure 18: Business service: Decision Support

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 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 decision support 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 of different measures.
- Use of knowledge base to learn from historical situations.

For some predefined situations, decisions many be automated.

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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. The measures must be aligned with the overall policy and strategy (see details on the Network Information business object). It should be possible to put the measures into a timeline that is aligned with the predicted traffic situation and the operation plan.

Simulate Traffic Situation Evolution

The simulator will use information from available business objects and simulate 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 in section 6.1.11). Simulation results and relevant knowledge derived from historical data may also be used. When appropriate, AI 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
- That a conflict will or has occurred that has to be solved through dedicated mechanisms

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

Conflict Resolution Support

Different mechanisms may be used to solve conflicts. The mechanisms may be automated or semi-automated and may for example cover:

- Use of arbitration models defining rules for priorities in case of conflicts

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- Auction mechanisms where actors may offer payments or other offerings (e.g. use of greener vehicles and higher load factors) to get a priority
- Negotiation support
- Random ("lottery")

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.

6.1.5 Decision Support and Decision Making: Decision Making

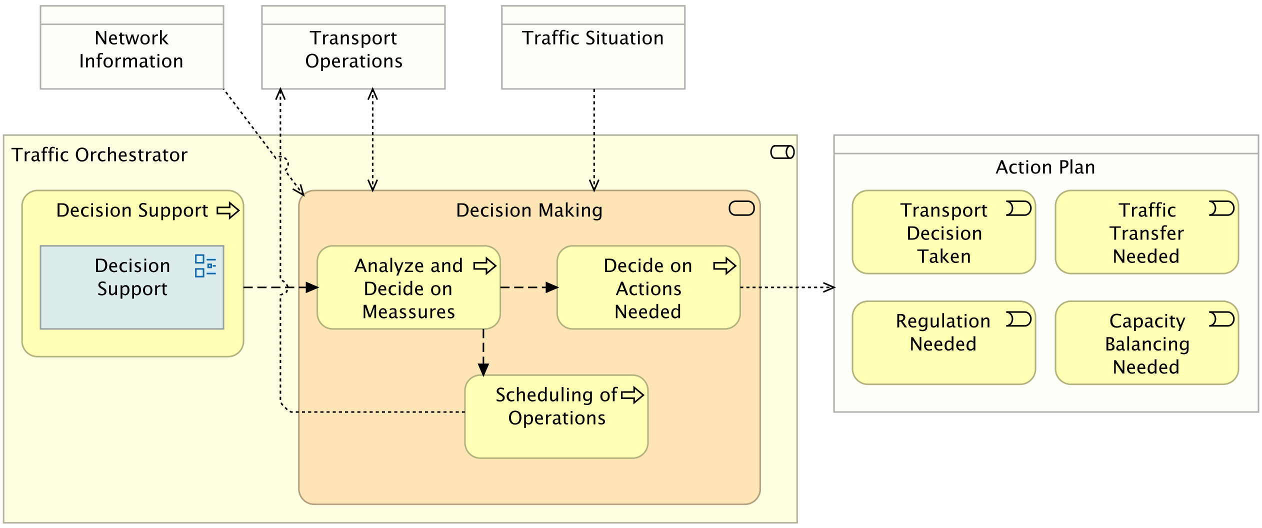

Figure 19: Business service: Decision Making

The decision making is based on input from the decision support. The reception and processing of the input may be automated, or 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. The rules defined by the network strategies and policies (in the Network Information business object) is consulted. In some cases,

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when 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.

Scheduling of Operations

Even though the sequence of transport operations may be decided by the sequence they arrive in, by assigned priorities, or by other decisions regarding priorities, etc. (see 6.1.5), the actual scheduling and assignments of time slots must be done. Individual Network Users or blocks of Network Users will be scheduled and get time slots. In some cases, the Network User may also be assigned access to a supporting service (e.g. handlers, tugboat and follow me car). The time slots will be registered in the Operation Plan of the Traffic Orchestrator and communicated to the Network User.

Decide on Actions Needed

Decisions on different types of actions are taken:

- **Transport Demand Management measures.** The traffic situations can be handled through regulations, measures and measure condition. Decisions on new or updated regulations are taken. Trigger event in Action Plan: "Regulation needed".
- **Demand capacity balancing.** Foreseen or occurred situations causing imbalance between traffic volumes and network capacity must be handled. Capacity balancing must be done, and if relevant, combined with transport demand management. Trigger event in Action Plan: "Capacity balancing needed".
- **Actions towards planned and ongoing transport operations.** 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). The effect of decisions on individual transport operations should also be considered. Decisions that may cause the need for extra waiting and resting times for Network Users or use of extra energy (e.g. in case of rerouting) should if possible be avoided. When there is a clear connection between measures and actions, decisions on actions may be automated. The actions are entered into the Transport Operations business object. Trigger event in Action Plan: "Transport decision taken".
- **Transfer to other networks and modes:** Other networks or modes have the capacity to take over transport. Trigger event in Action Plan: "Traffic transfer needed".

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 Regulations and Conditions

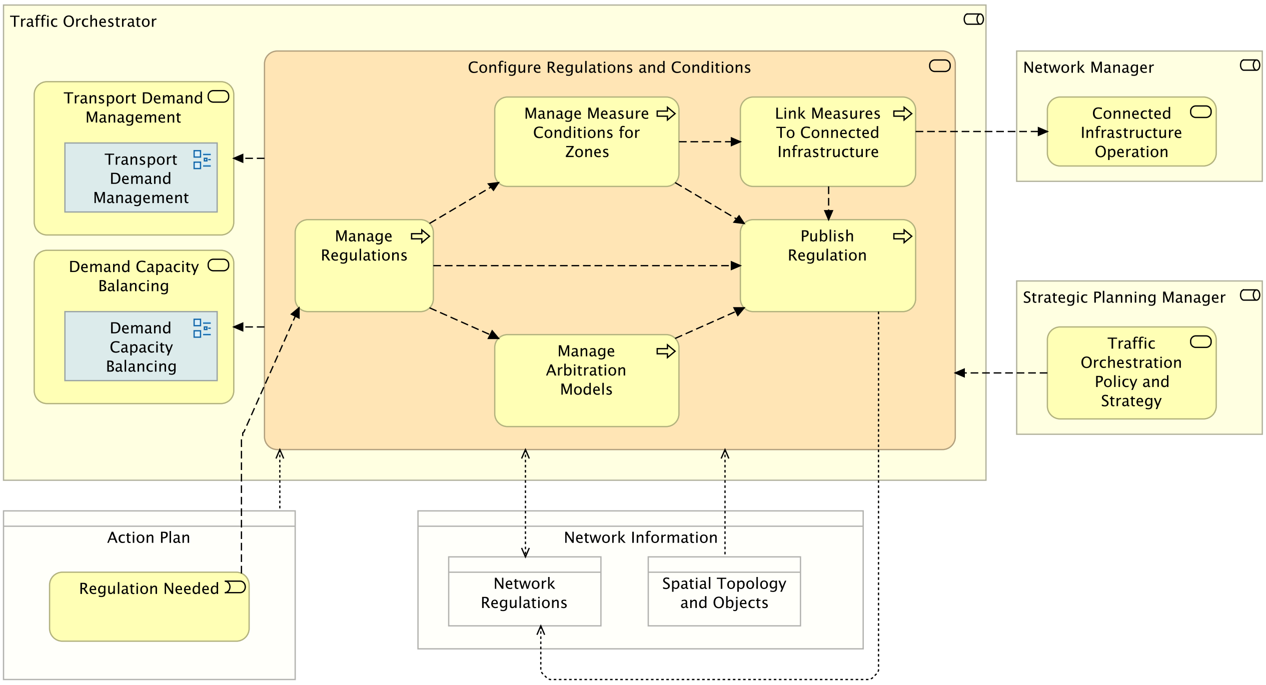

Figure 20: Business service: Configure Regulations and Conditions

The regulations for the governance area of 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 conditions, policies and strategies.

The regulations may be triggered by the transport orchestration policy and strategy decisions taken by the Strategic Planning Measures. This may for example be more static regulations and 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 part of the Network Information business object.

Manage Regulation

The business process is triggered by "Regulation Needed" event in the Action Plan business object. This means that a decision has been taken regarding a regulation. Existing regulations that are terminated or changes must be marked as expired, and new regulations must be defined. The regulations are managed in the Network Regulation part of the Network Information business object.

Manage Measure Conditions for Zones

A decision has been taken regarding new regulation within a zone, and information in the Network Regulation part of the Network Information business object must be established. This includes information about the zone, the measure to be taken and the measure conditions. The measure

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conditions may support automated measures towards Network Users when the conditions are fulfilled.

Link Measures to Connected infrastructures

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

Manage Arbitration Models

For some regulations, priorities and/or trade-offs between different concerns and performance targets are required. This can be done manually but may also to some extend be automated by means of generic rules and strategies defined in arbitration models represented in the Network Regulation part of the Network Information business object.

Publish Regulation

Regulations are continuously published to ensure that they are available to Network Users and others. The latter may for example be providers of electronic maps used in navigation systems and providers of onboard systems managing road pricing and other ITS applications.

It might be relevant to publish all regulations in a governance area or zone, detailed and machine-readable conditions included, to facilitate that onboard systems (like for example navigation systems) can assist in the adaptation to the regulations.

Links towards the connected infrastructure services are established if this is relevant, e.g. to control the content of variable signs and the operation of transport network equipment in accordance with regulations.

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6.1.7 Operative Traffic Orchestration: Transport Demand Management

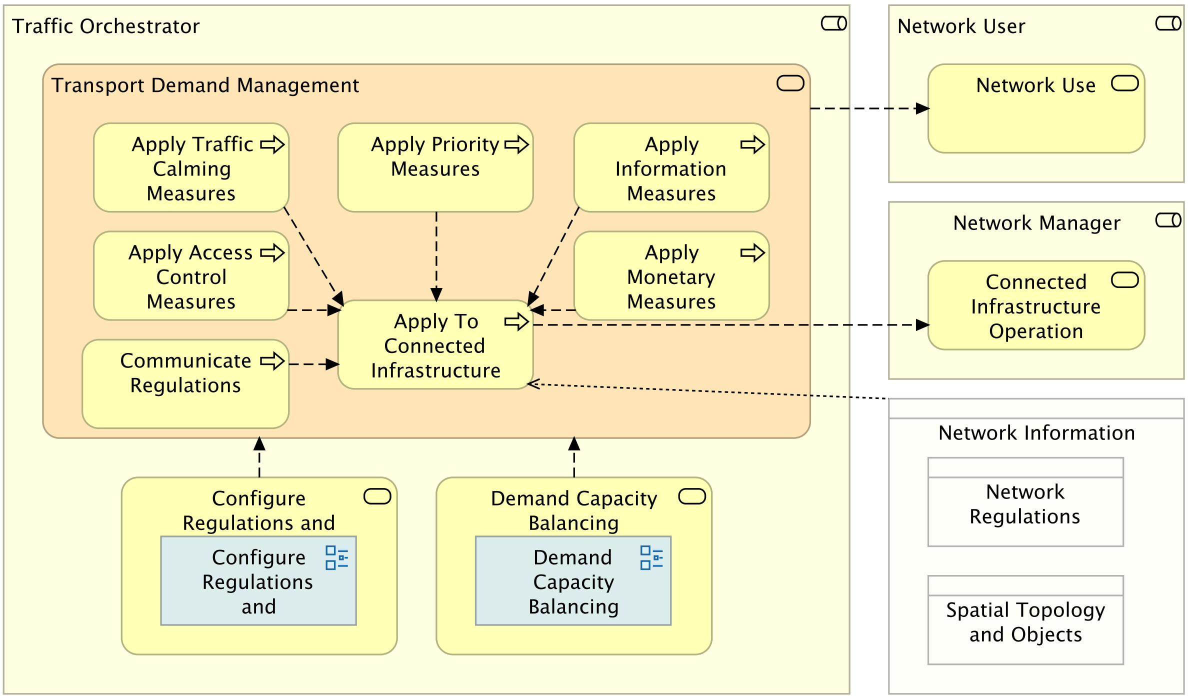

Figure 21: Business service: Transport Demand Management

The aim is to apply measures to control the traffic according to regulations within zones, including measures requested from the demand capacity balancing. The connected infrastructure operated by the Network Manager is used for this purpose.

The regulations are defined in the Network Regulation part of the Network Information business objects. The measures will be applied automatically according to the measure conditions defined for the zone. This arranges for conditional measures. The Network User will pass over its characteristics, and the measures will be applied accordingly.

Communicate Regulation

The regulations defined in the Network Regulation part of the Network Information business model are communicated to the Network Users in the relevant Governance Area zone (via the connected infrastructure) to arrange for automated adaptation to the regulations.

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.

Apply Priority Measures

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

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Apply Access Control Measures

Access to zone is assigned to the Network Users depending on their characteristics.

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 onboard 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 information content depends on the situation or the 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 Connected infrastructure

The infrastructure is used for different purposes:

- To communicate electronic regulations to the Network users.
- To facilitate the measures. This may include the collection and registration of data needed in decisions, and the communication with the Network Users to implement the measures.

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6.1.8 Operative Traffic Orchestration: Demand Capacity Balancing

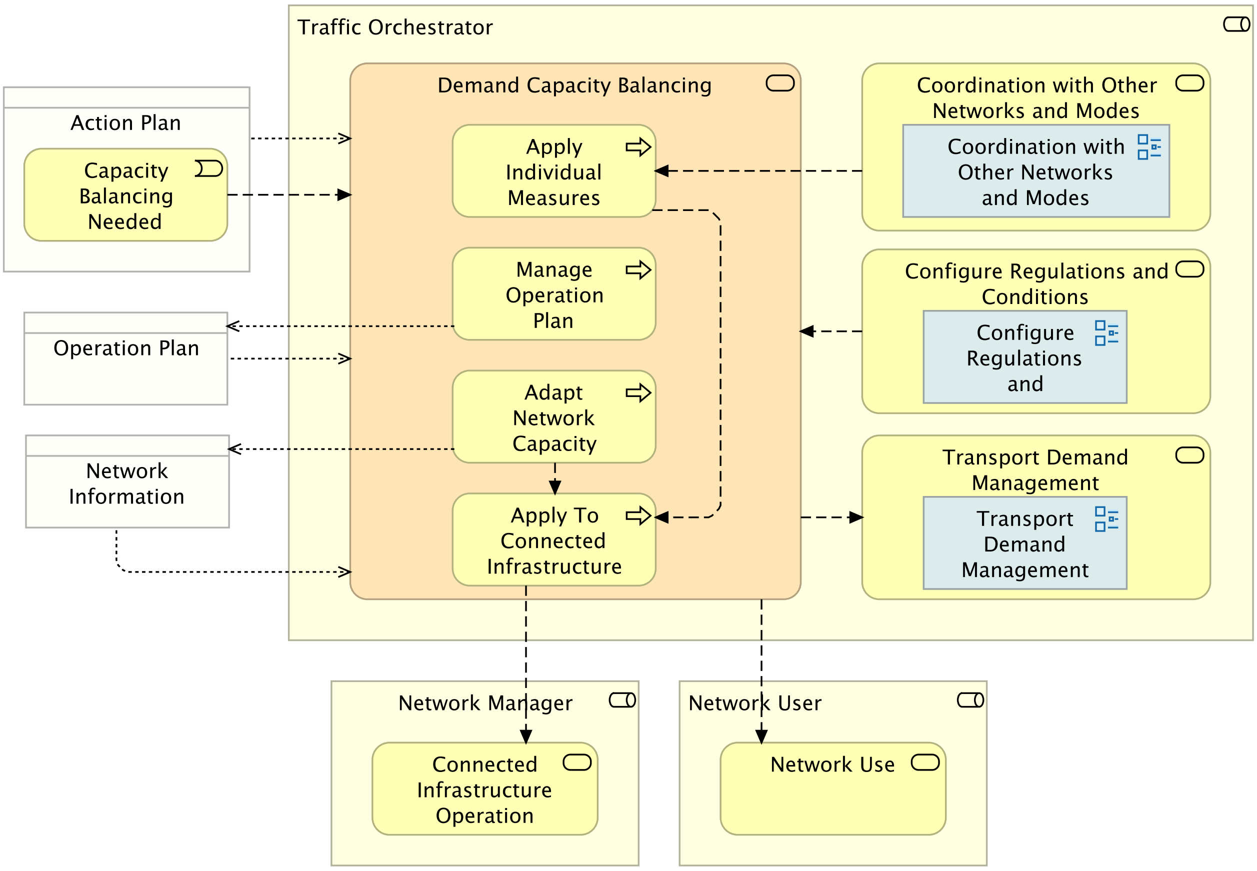

Figure 22: Business service: Demand Capacity Balancing

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 the Action Plan business objects. Some well-defined actions may be automated.

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 or 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 be 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 Connected infrastructure

The measures are effectuated via the connected infrastructure.

6.1.9 Operative Traffic Orchestration: Coordination with Other Networks and Modes

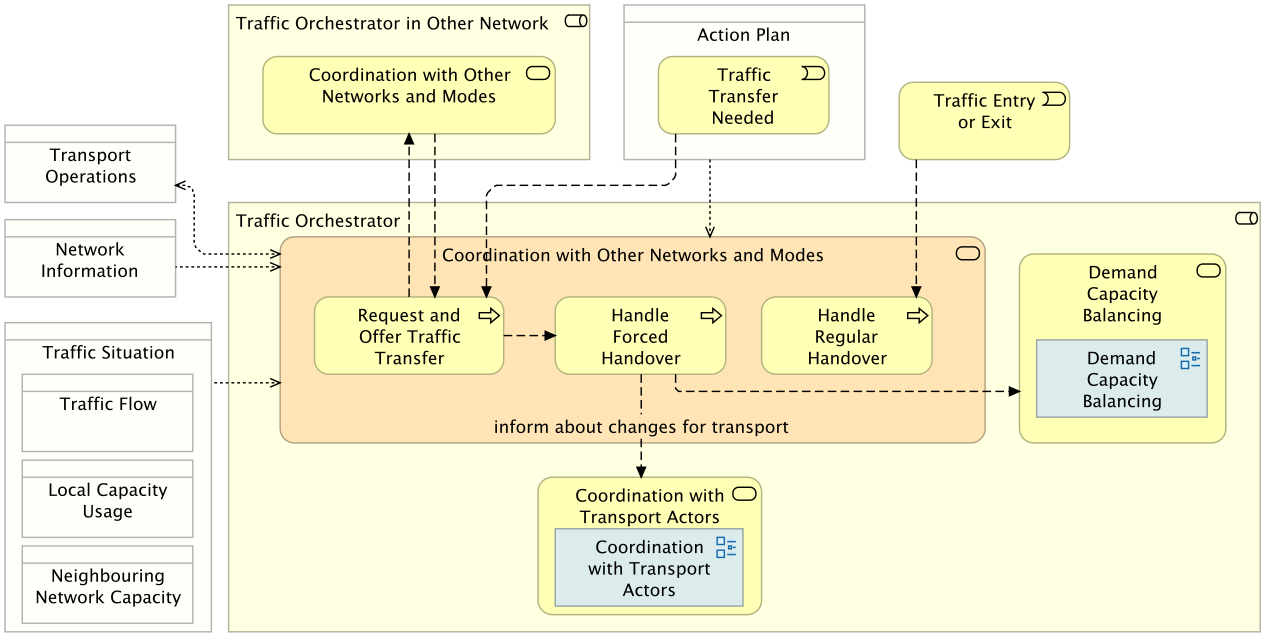

Figure 23: Business service: Coordination with Other Networks and Modes

> **Note:** This business service *deals 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 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.

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Handle Forced Handover

When transfer requests 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 inform about the transfer. Demand capacity balancing may be used to initiate the transfer measure towards individual Network Users.

Handle Regular Handover

The overview of entries and exits to/from the governance area are listed in the Transport Operations business object. Such entries/exits will trigger "entry" or "exit" events in the action plan, and these events will also trigger the exchange of transport operation information between the governance areas and networks.

6.1.10 Operative Traffic Orchestration: Coordination with Transport Actors

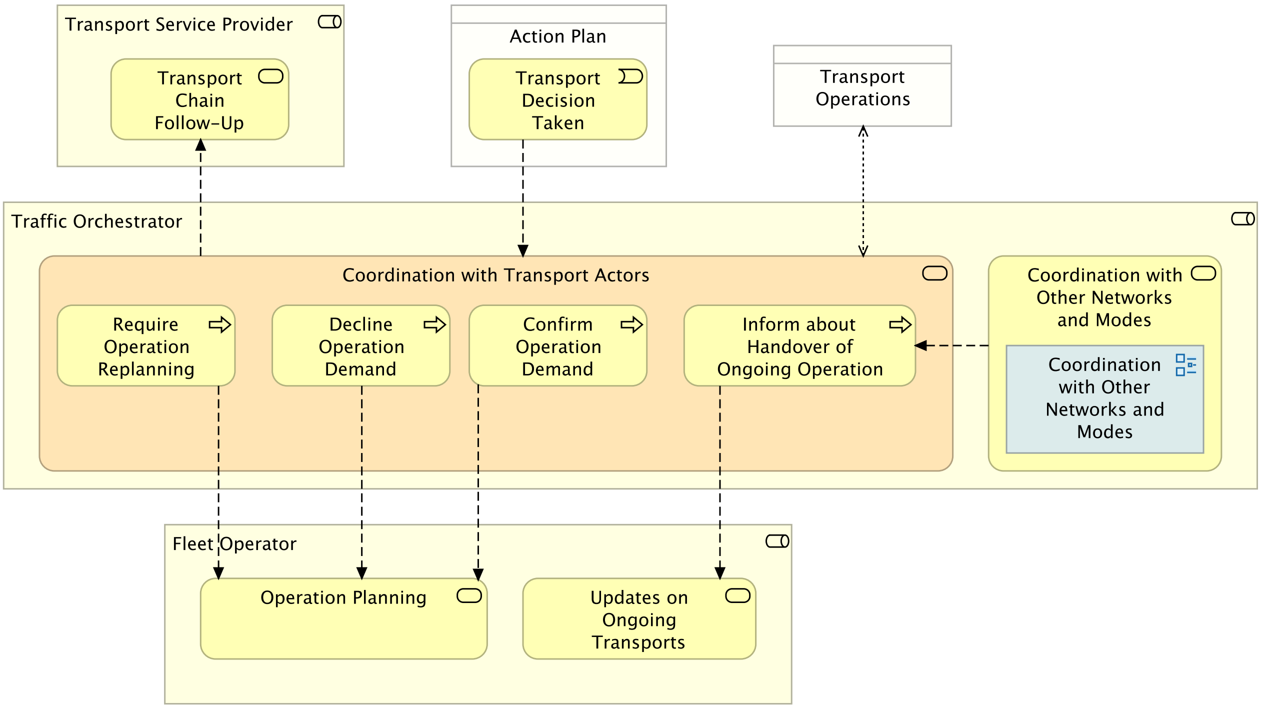

Figure 24: Business service: Coordination with Transport Actors

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 Transport Service Providers of the associated planned transport operations. This may for 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.

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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 confirmation 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 are 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.

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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:

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 connected infrastructures linked to the network (function, localisation, standards used for communication, etc.)

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

Network strategy and policy: This is information about the overall strategies and policies for the Governance Area. The following is defined:

- **Governance Area (GA):** This is the spatial location managed by the Traffic Orchestration
- **GA zones.** These are zones in the GA with a traffic orchestration strategy and policy. The strategy and policy may vary between GA zones. The policy for a city centre may for example be different from the policy for the areas outside the city centre.
- **Overall rules:** These are defined for each GA zone and defined rules to be applied when measure conditions are defined and measures are taken.

Network regulation: This is information about actual regulations within zones of the transport network. The regulations may be static or temporal, and they are expressed by:

- **Policy basis:** The regulation is linked to overall rules applied for the relevant GA zone (see network strategy and policy above).
- **Legal basis:** The regulation is linked to national laws and regulations.
- **Zone:** The spatial location of the zone in which the regulation is applied (network segments, areas/space, point, line, etc.).
- **Measure conditions:** The measures and the conditions for measures are defined.
- **Arbitration models:** Models that define how trade off should be handled.

Transport operations

This is the overall business object containing information about transport operations of relevance to the governance area. This is overall information on the Network User executing the operation (vehicle/vessel), schedules and routes, 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.

Certain type of information might be confirmed by Certificates issued by trusted Certification Authority. In such cases, the detailed information will not have to be provided. Certificates may for example confirm the greenness of the Network User, the type of Network User/Transport Operation (e.g. emergency vehicle, utility vehicle, public transport, taxi, etc.), the right to access an area (e.g. due to being a resident), special rights due to disabilities, etc.

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The transport operations addressed are:

- **Entries to/exits from** the governance area: The planned entries and the planned exits are listed.
- **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.

Related to the above, the Action Plan also includes the following trigger events:

- **Capacity balancing needed.** The event will trigger demand capacity balancing and, if needed, dynamic transport demand management measures.
- **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 in the Transport Operations business object. The decision may for example be re-scheduling, change of route, transfer to other networks and modes, or a rejection.
- **Regulation needed:** The event will trigger the implementation of a new regulation with related measures and measure conditions (e.g. new access conditions) in a zone.

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- **Traffic entry or exit:** The event will (if necessary) trigger focus on and handling of expected entries and exits to/from the governance area. This is crucial for some modes, e.g. air and sea.

6.2 Functionality for Network Manager

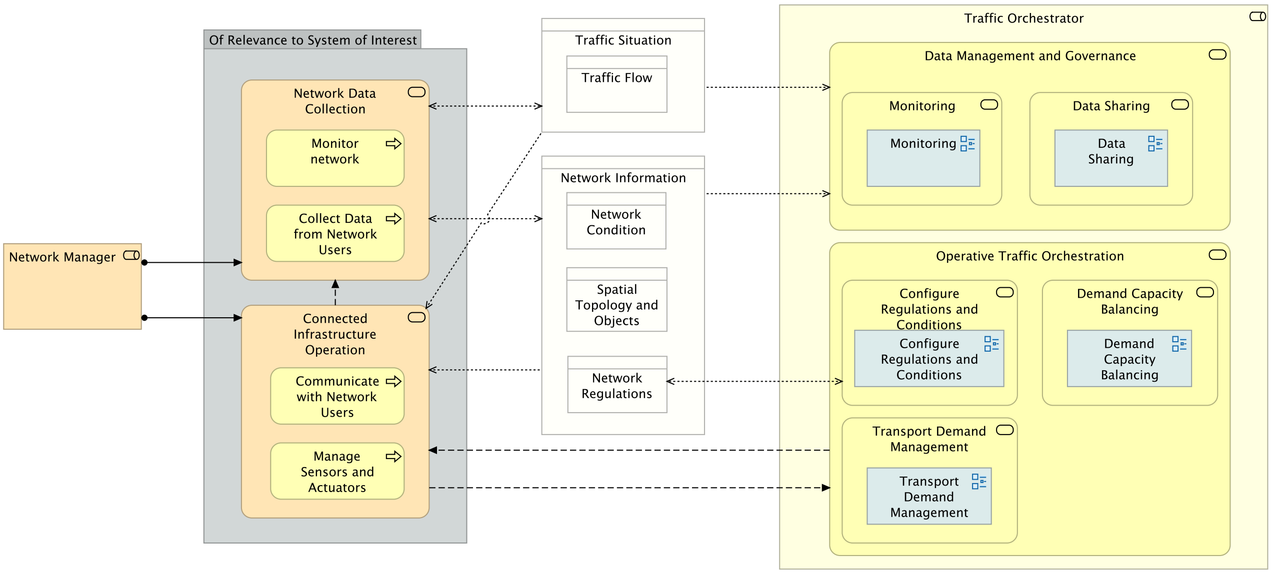

Figure 25: Overview of functionality needed by the Network Manager

The Network Manager manages the transport network infrastructure. This includes many actions that are outside the scope of relevance to the System of Interest (e.g. maintenance of the physical infrastructure).

The business processes of relevance to the System of Interest are depicted inside the Network Data Collection and Connected Infrastructure Operation business services within the grey frame in Figure 25. The connected infrastructure is a digital infrastructure facilitating data collection from sensors, control of actuators and communication with connected Network Users (i.e. connected vehicles/vessels).

Monitor Network

Data on network conditions and traffic situations is collected from sensors in the transport network. Many types of sensors may be used (temperature, humidity, camaras, loops, air quality, etc.), and the data collected may provide information on network conditions and traffic situations (traffic density, speed, type of transport, etc.).

The collected data is transformed to the desired format and stored in the Traffic Situation and Network Information business objects, that are shared with the Traffic Orchestrator (see descriptions in 6.1.11).

Collect Data from Network Users

Network Users may also have sensors, and the data registered by the sensors and relevant data registered in other ways, may be communicated to the connected infrastructure (see business process *Communicate with Network Users* below). The Network Manager will register the data in

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the Traffic Situation and Network Information business objects, that are shared with the Traffic Orchestrator (see descriptions in 6.1.11).

Communicate with Network Users

The connected infrastructure will communicate with connected Network Users both to provide and receive information.

- Received data on the transport network condition and the traffic will be forwarded to the *Collect Data from Network Users* business process (see above).
- Network information and information on the traffic situation may be sent to the Network Users (both push and pull).
- Information from the Traffic Orchestrator (notifications, directions, guidelines, priorities, access rights, etc.) will be communicated to individual Network Users or to blocks of Network Users.

Manage Sensors and Actuators

The data collection from sensors will be manged and actuators for different types of network equipment (signalling systems, variable signs, etc.) will be controlled. The latter will be done based on directions from the Traffic Orchestrator or according to pre-defined plans. The sensor data will be forwarded to the *Monitor Network* business process (see above).

6.3 Functionality for Transport Service Provider

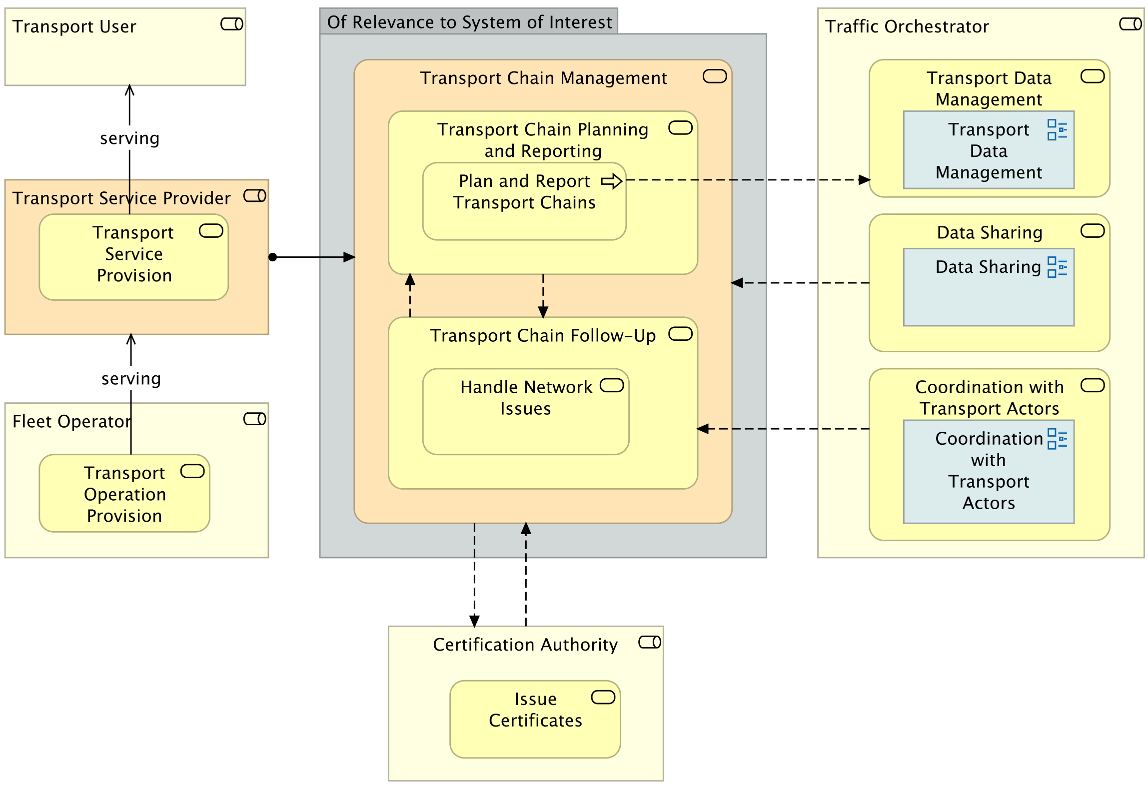

Figure 26: Overview of functionality needed by the Transport Service Provider

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The Transport Service Provider provides transport services to Transport Users and combine operations delivered by different fleet operators, port service providers and warehouses owners to deliver the services. This includes many actions that are outside the scope of relevance to 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 26. The processes interact with the Traffic Orchestrator to arrange for more optimal transports.

Plan and Report Transport Chains

The Transport Service Provider receives information on strategies, policies, regulations, measures, current situations and upcoming/predicted situations (e.g. possible perturbations) from the *Data Sharing* business process of the Traffic Orchestrator. The information can help the Transport Service Provider to plan more robust transport chains and legs. They may for example 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.

The planned transports are reported to the relevant Traffic Orchestrators. This may for some modes, for example the rail service, long-distance waterborne services and airplane services, be done a long time before the transport starts. When the plans are refined with more details or the transports are re-planned (e.g. when deviations in one leg affects other legs), the updates are also sent to the Traffic Orchestrators.

Handle Network Issues

The Transport Service Provider receives information on strategies, policies, regulations, measures, current situations and upcoming/predicted situation from the Data Sharing business service of the Traffic Orchestrators. Transport Service Provider may also subscribe to information that is customized to needs, e.g. information that is of relevance to planned and ongoing transports, for example when problems or potential problems are detected, and chain or the legs must be replanned (in the *Plan and Report Transport Chain* business process).

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. Such requests should cause replanning (in the *Plan and Report Transport Chain* business process).

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6.4 Functionality for Fleet Operator

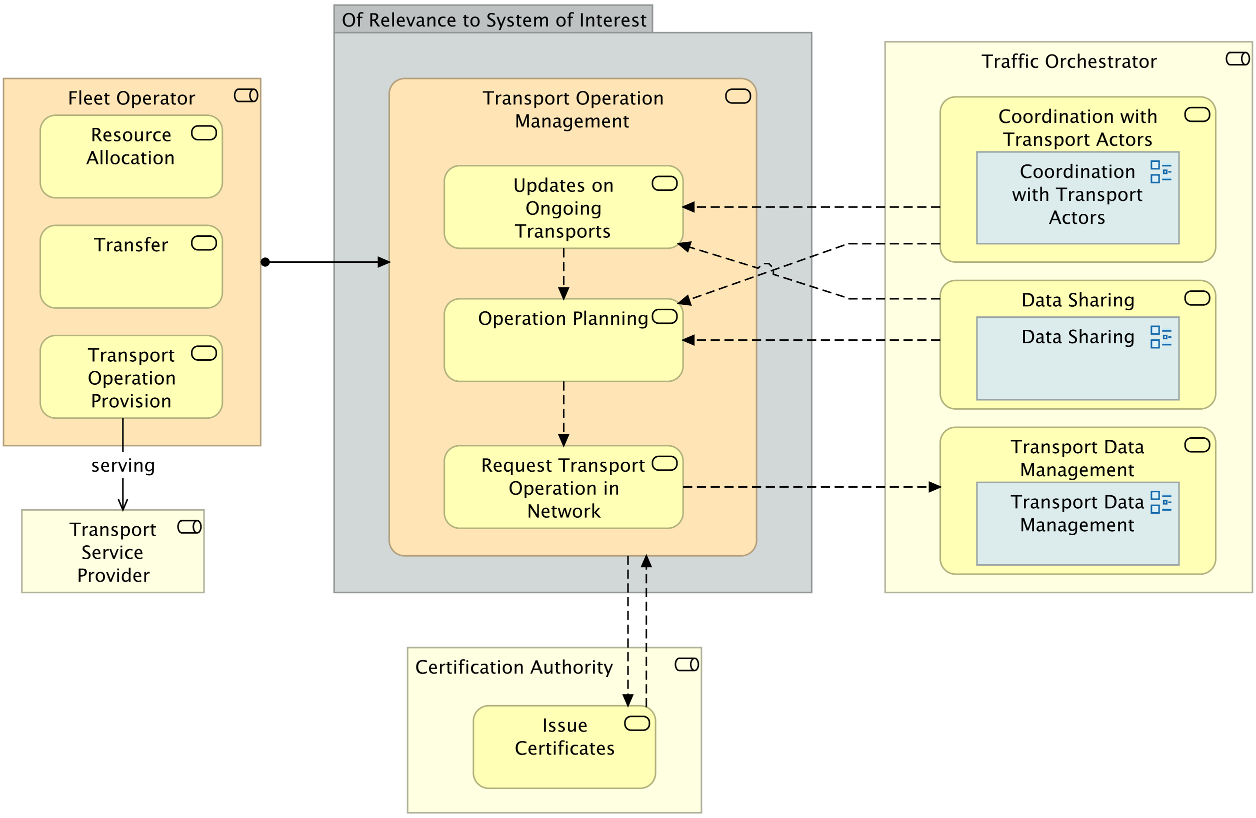

Figure 27: Overview of functionality needed by the Fleet Operator

Fleet Operators provide the transport operations for the legs of the transport chains managed by the Transport Service Providers. As a part of this, the Fleet Operators accomplish many actions that are outside the scope of relevance to 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 27. 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 as well as regulations and measures. Thus, the Fleet Operator can adapt to regulations and measures (e.g. ensure that the operations are as green as possible), avoid networks and network segments where problems are foreseen, and adapt schedules to times when the traffic flow is assumed to be efficient. Plans can be dynamically updated at any time before the transport operations starts to adapt to changes. The Fleet Operator may also subscribe to customised information services that may support the re-planning.

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.

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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, and the Fleet Operators may also get information from the Traffic Orchestrator on necessary adaptation.

If the plans are changed, the fleet operator must inform the relevant Network Users directly using its own communication facility.

6.5 Functionality for Network User

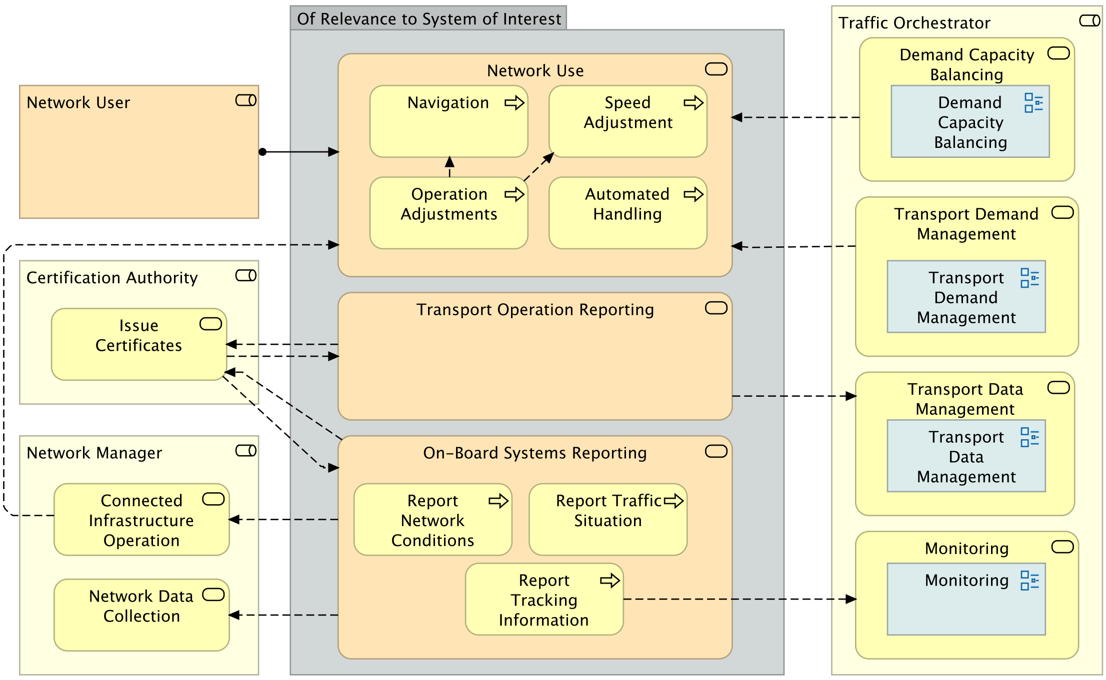

Figure 28: Overview of functionality needed by the Network User

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 relevance to 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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Connected vessels and vehicles will have onboard systems and equipment for network use that facilitate the use of the information and support provided by the Traffic Orchestrator. The built-in equipment will integrate the new functionality in a seamless way to ensure no extra burden on or distraction of human operators, and the systems will make the transition to CAVs easier.

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. The navigation systems supporting the operator and the onboard systems operating CAVs will receive directions from the Traffic Orchestrator on possible, upcoming and occurred situations and directions regarding how to handle the situations, e.g. 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. Information measures may also arrange for more predictability. 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.

In case of traffic abnormality, new regulations and information sent to the navigation system may automatically change the transport operation and inform the person operating the vessel/vehicle (if not a CAV). This enables the network users to immediate response to the operating environment, such as speed adjustment, route adjustments, waiting, etc.

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.

Network Use: Automated handling

The Traffic Orchestrator may take individual measures towards one or more Network Users in case of emergency situations or other unwanted situations where a rapid response is required and in case of situations that may develop to such situations. Emergency stop, invasive manoeuvring or other measures may be requested to avoid or mitigate dangerous or potentially dangerous situations and other unwanted situations. The responses to 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 The Network User may also to some extend decide how to carry out the

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operations, and 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.

Onboard 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 connected infrastructure. For the reporting to the Traffic Orchestrator, the position will be linked to the ongoing transport operation.

Onboard 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 connected infrastructure.

Onboard 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 connected infrastructure.

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6.6 Environment systems

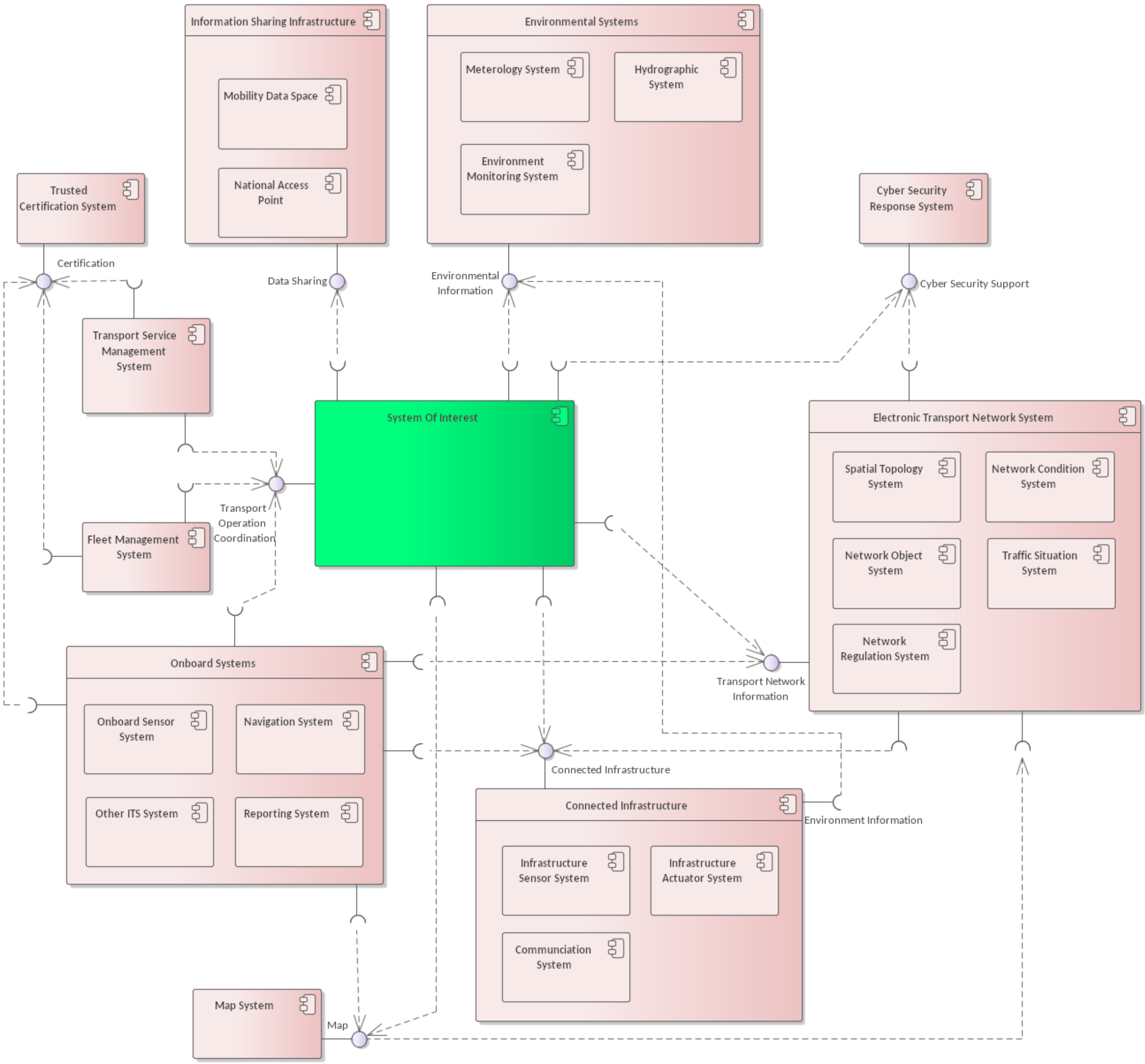

Figure 29: Environment systems and interfaces

This section describes the environment systems for the System of Interest, i.e. systems that the System of Interest will interact with through open interfaces. As this is a reference architecture, the environment systems are generic and not concrete implementations. The environment systems and the interfaces are depicted in Figure 29.

The System of Interest provides the Transport Operation Coordination interface for coordination and communication directly with Transport Service Providers, Fleet Operators and Network Users. The interface is further described in section 8.1.

The System of Interest uses interfaces provided by the environment systems, as depicted in the figure. These systems and their interfaces are described in the sections below.

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6.6.1 Electronic Transport Network System

The Electronic Transport Network System is managed by a Network Manager and provides the **Transport Network Information interface**. It facilitates communication for exchange of information from the following sub-systems:

- **Spatial Topology System** manages core information about the topology of the transport network infrastructure as nodes and edges.
- **Network Object System** manages information about objects in the network, e.g. related equipment and properties.
- **Network Condition System** manages dynamic information about the network conditions
- **Traffic Situation System** manages dynamic information about the traffic situation
- **Network Regulation System** manages information about static and dynamic regulations applicable to the different parts of the transport network.

The Spatial Topology information provides navigation and location information used in Network Objects, Network Conditions, Traffic Situations and Network Regulations.

The interface facilitates communication (both push and pull) with the System of Interest and Onboard Systems (e.g. Navigation Systems and other ITS Systems to support the Network User). The interface also facilitates communication with Map Systems and Connected Infrastructures for indirect communication with the Onboard Systems of connected vehicles/vessels. Table 5 provides an overview of how the interface can be realised.

Table 5: Transport Network Information interface realisation

Mode	Formats/Standards used
Road	• Spatial Topology information: Geographic Data Files (GDF) (derived from national mapping and road authorities and capture topologies collected by cars driving with map sensors) and ISO 19100-series. • Traffic Situation and Network Condition information: DATEX II (traffic flow), TPEG and TISA (information on events). • Network Regulation information: TN-ITS (used today), extensions to DATEX II (proposed by the UVAR Box project), and new standards suggested by the ISO/NP 24315 METR (Management of Electronic Traffic Regulations) initiative (work in progress, scheduled for 2024).
Sea	• Information about the ocean space/water ways/fairways and related information on network conditions, traffic situations and regulations are communicated according to the upcoming "IHO Universal Hydrographic Data Model", known as S-100. S-100 is a framework geospatial standard for hydrographic-related digital data. S-100 is aligned with the ISO 19100 series of geographic standards, thereby making the use of hydrographic and other geographic data more interoperable than the present IHO S57 data transfer standard.
Air	• Information about the air space and traffic and air space conditions will communicated by means of information objects defined in SWIM/AIRM which is a comprehensive and openly available information model with information elements describing among others the airspace.
Rail	• To be investigated and described in Deliverable D3.3.

6.6.2 Connected Infrastructure

The Connected Infrastructure is managed by a Network Manager and is linked to the physical transport network. The infrastructure includes:

- **Infrastructure Sensor Systems.** They collect and mediate different types of sensor data from the network infrastructure

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- **Infrastructure Actuator System.** They support the control of physical equipment in the infrastructure, e.g. signalling systems and variable signs
- **Communication Systems.** They facilitate communication between the Network Users and the Traffic Orchestrator

The Connected Infrastructure provides the **Connected Infrastructure interface**. The interface serves several purposes:

- Collection of information from Onboard Systems (tracking and collection of network/traffic information)
- Communication of information to Onboard Systems (push/pull). The information is received from the System of Interest/Electronic Transport Network System and may be directions/guidelines, access rights/priorities, safety alerts, regulations, network/traffic information, etc.
- Communication of control directions from System of Interest/Electronic Transport Network System. The directions will be used in the control of actuators.
- Communication of network and traffic information (received from Onboard Systems and infrastructure Sensor Systems) to the Electronic Transport Network System.

The communication with the System of Interest and Electronic Transport Network System is not further addressed as the interactions may be proprietary as the systems might be tightly integrated.

The communication with the Onboard systems (bullet point one and two above) must however be standardised. Table 6 provides an overview of how the communication with the Onboard Systems can be realised.

Table 6: Connected Infrastructure interface realisation – the communication with Onboard Systems

Mode	Formats/Standards used
Road	For the communication with Onboard Systems, different types of information for Cooperative, Connected and Automated Mobility (CCAM) will be communicated through C-ITS messages: • Tracking information from Onboard Systems: New C-ITS message are needed • Information on network conditions/traffic situation to/from Onboard Systems: New C-ITS messages are needed • Information on regulations to/from Onboard Systems: New ITS message is needed. • Information on directions/guidelines, access rights/priorities, etc.: New C-ITS message are needed • Information on safety issues: Existing safety related C-ITS messages Elements from existing standards such as DATEX II, TPEG, TN-ITS and GDF can be used as a starting point for the new C-ITS messages. The message on regulations may also build on the results from the METR (Management of Electronic Traffic Regulations) initiative.
Sea	For the communication with Onboard Systems, the following standards will be used • Tracking information from Onboard Systems: AIS • Information on network conditions/traffic situation to/from Onboard Systems: • Information on regulations to/from Onboard Systems: S100 and/or S200 objects • Information on directions/guidelines, access rights/priorities, safety issues, etc: S100 and/or S200 objects Electronic Navigation Charts (ENC) compatible with S-100 and the IALA defined S-200 series of standards, which will be compliant with the IHO S-100 standard, including Aids to Navigation (AtoN), Vessel Traffic Services (VTS), positioning systems and communication system will be used.
Air	• To be investigated and described in Deliverable D3.3.
Rail	For the communication with Onboard Systems, the European Rail Traffic Management System (ERTMS) is a single interoperable train control and command system, supporting cross-border interoperability and a seamless, EU-wide railway system.

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6.6.3 Map System

The system is managed by a Solution Provider. Data from the Electronic Transport Network Information interface will be used to generate maps with spatial topology of the transport networks enriched with static objects and situational awareness from dynamic objects. The dynamic objects may for example represent dynamic traffic regulations and traffic situations.

The Map System provides the **Map interface**, and this interface supports the exchange of information to among others the System of Interest and Onboard Systems like Navigation Systems. Table 7 provides an overview of how the interface can be realised.

Table 7: Map interface realisation

Mode	Formats/Standards used
Road	• Maps for proprietary Navigation Systems (e.g. TomTom, Here, Zendrin and Waze) will in general build on GDF for ITS defined by ISO/TC 204/WG 3 as well as the other types of information (DATEX II, TN-ITS, TISA, TPEG and new formats for regulations).
Sea	• Information about the ocean/water ways/fairways and related information on network and traffic conditions is communicated as Electronic Navigation Charts (ENC) objects according to the upcoming "IHO Universal Hydrographic Data Model", known as S-100[6]. The ENCs are aligned with Onboard Electronic Chart Display and Information Systems (ECDIS). ENCs cover the content of paper charts as well as supplementary information.
Air	• To be investigated and described in Deliverable D3.3.
Rail	• To be investigated and described in Deliverable D3.3.

6.6.4 Onboard System

The system supports the Network User in the execution of the transport operation and in adaptation to the traffic situation through the following sub-systems:

- **Navigation System** offers route planning and navigation support adapted to the directions and guidelines provided by the Traffic Orchestrator
- **Other ITS System** offers different types of functionalities adapted to the directions and guidelines provided by the Traffic Orchestrator, and they may also report to the Traffic Orchestrator
- **Onboard Sensor System** collects and mediates different types of sensor data from the vehicle/vessel and its surroundings, positioning data included
- **Reporting System** reports information to among others the Traffic Orchestrator. This may be real-time tracking information and updated information about the transport operation

The Onboard Systems will not provide an interface but will exchange information (push and pull) via interfaces provided by other systems. The Map interface and the Transport Network Information interface will provide access to maps and network information. Connected vehicles/vessels (CAVs included) will also receive information via the Connected Infrastructure interface and certificates via the Certification interface.

6.6.5 Environmental System

The system may be managed by an Authority, by a NGO for Environment or by a Solution Provider, and it addresses environmental issues through the following sub-systems:

[6] https://iho.int/uploads/user/pubs/standards/s-100/S-100_Version_1.0.0.pdf

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- **Meteorology Service** provide meteorological information
- **Hydrographic Service** provide hydrographical information
- **Environment Monitoring Service** provide information on emissions, air quality, etc.

The Environmental System provides the **Environmental Information interface**. It facilitates reception of

- Environmental data from for example the Connected Infrastructure System

The interface is multimodal (common to all modes) and provides access to/pushes the following information

- Meteorological information
- Hydrographic information
- Environmental information

6.6.6 Information Sharing Infrastructure

The infrastructure is offered by a Solution Provider and supports access to available data through the following infrastructures:

- **Mobility Data Space,** an emerging European infrastructure for the sharing of mobility data not yet available
- **Data Access Point**, access point for the sharing of open data. This may be the European Data Portal[7] or National Access Point (NAPs)

The Information Sharing Infrastructure provides the **Data Sharing interface**. It facilitates access to

- Mechanisms for data discovery
- Metadata about available data
- Links to data repositories where the data can be accessed

A common interface must be defined, and the interface must be multimodal (common to all modes). So far, the European Data Portal and NAPs in general provide support for manual data discovery and manual access to metadata.

6.6.7 Trusted Certification System

The system is managed by a Certification Authority and issues certificates proving properties and abilities of actors and transport operations.

The system provides a **Certification interface.** It facilitates access to:

- Certificates for Network Users, i.e. the vessel/vehicle or the operator of the vessel/vehicle.
- Certificates for the transport operation.

The certificates must be standardised. The certificates for the Transport operations should preferably be multimodal. So far, some work is done on customs declarations in the EU Customs Data Mode[8], but other certificates may also be needed to support the traffic orchestration (e.g.

[7] https://data.europa.eu/en

[8] https://taxation-customs.ec.europa.eu/system/files/2021-01/eucdm_guidance_document_en.pdf

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certificates proving the load factor, the use of green modes in a chain where the first/last mile is by road, type of transport operation, etc.).

The certificates for the Network User must be specific for the different modes.

Table 8: Certificate interface realisation. Transport User certificates

Mode	Formats/Standards used
Road	• The EUCARIS initiative defines how data on vehicle registrations, driving licences, vehicle owner/holder and insurance data, and traffic offenders should be exchanged. • Other standards may be needed to prove other properties, e.g. disabilities, type of vehicle (emergency vehicle, utility vehicle, public transport vehicle, etc.), and residence in area.
Sea	• To be investigated and described in Deliverable D3.3.
Air	• To be investigated and described in Deliverable D3.3.
Rail	• To be investigated and described in Deliverable D3.3.

6.6.8 Cyber Security Response System

The system is managed by an Authority, and it aims to monitor digital infrastructures to detect cyber security threats and to provide support in case threats or possible threats are discovered.

The system provides a **Cyber Security Support interface** for monitoring and support. The mechanisms used for the monitoring are not openly available, and so far, there is no well-defined digital interface for the support. The interface may for example provide warnings and support to the traffic orchestrator in case of cyber-attacks.

6.7 Architectural concerns

This section describes how the context view meet the architectural concerns described in section 4.2. The architectural concerns are resilience, polycentricity, multimodality, organisation flexibility and automated driving.

6.7.1 Resilience

The functionalities of Traffic Orchestrators play crucial role in the different stages of the resilience management:

- **Prior abnormality** (perturbations, disruption or even disasters): The Traffic Orchestrator might be aware of abnormities that can happen, and the related probability and possible impact.
- **Adaptive abnormality:** Data is a resource and describes where the abnormity is from, what type it is, the number of affected Network Users, etc. At the same time, the Traffic Orchestrator should have real time status about the capacity of unaffected areas, which can be rescue resource. Decisions can include but are not restricted to cancelling or adding extra capacity, retiming, rerouting, re-assigning, and a combination of any of the mentioned methods. During this process, the adaptive actions to deal with the abnormities should be distributed to related transport actors to get them informed and coordinated. In case of a disaster or severe disruptions, the Traffic Orchestrator can coordination with other networks and modes to ensures a smooth and efficient communications and coordination across modes and Governance Zones.
- **During abnormality:** Information sharing about abnormalities to the Network Users to avoid possible further harm, and to the Transportation Service Providers and Fleet Operators

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to achieve a coordination among them to better support the finding of alternative solutions and the business continuity. This must be done in short time.

- **Post abnormality:** Data management will document of the abnormity type and taken actions, to be analysed and future studied for the resilience management.

The following table summarizes resilience management for each stakeholder, regarding functionality, resilience related measures within the corresponding function, and in which stage these measures take place.

Table 9: Resilience aspects related to each stakeholder: Functionality, measures and action stage

Stakeholders	Functionality	Resilience-related measures	Action stage
Traffic Orchestrator	Monitoring	Data collection and monitoring facilitating early detection of abnormal situations.	Prior abnormality
	Data sharing	Forward the information about what and where is the abnormality to all involved partners. This will prevent not-informed Service Providers/Fleet Operators from making non-optimal decisions, and the Network Users further affected by the abnormality	During abnormality
	Monitoring transport data management	Receive and distribute real time information about the abnormality and corresponding adjustments. Document the above information after wards, to be used for the future planning.	Prior, adaptive and post abnormality
	Decision support	Provide information to the decision making. Useful information can be affected services, possible alternative services from other subnetworks, the predictions of delay propagations.	Adaptive abnormality
	Decision making	Make decisions about traffic assignment, vehicle operating route, departure time, etc. against the abnormality and to continue with transportation tasks.	Adaptive abnormality
	Configure regulations and conditions	Set regulations and measures about how to deal with possible abnormalities that can rise in the governance zone	Prior abnormality
	Demand capacity balancing	Adapt transport capacity, within the governance zone or across zones if needed, to meet the real time transport demand, for a temporary solution.	Adaptive abnormality
	Coordination with other network and Modes	Apply another mode, or utilize transport capacity across zones to meet the transport demand, re-arrange the extra capacity according to demand.	Adaptive abnormality
	Coordination with transport actors	Collect and deliver information from/to the transport actors in real time, support the resilience management decisions and implementations.	Adaptive abnormality
Transport	Plan and report	Be aware of possible abnormality when planning the transport chains. Reserve capacity, design	Prior abnormality

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Stakeholders	Functionality	Resilience-related measures	Action stage
Service Provider	transport chains	corresponding stochasticity or robustness to be prepared in advance.	
	Handle network issues	Reorganize the transport chains: change the affected service-leg(s); follow the decision support and decision made by Traffic Orchestrators; communicate with the Network Users about the abnormality and caused changes;	Prior/Adaptive abnormality
Fleet Operator	Operation planning	Plan buffer time or slack time in the timetable, reserve some redundancy vehicles per zone or per trip.	Prior abnormality
	Updates on Ongoing transports	Exchange data with Traffic Orchestrator and Transport Service Provider. Get necessary support such as extra infrastructure or extended usage time to the assigned infrastructure.	Adaptive abnormality
Network User	Navigation	Detect abnormality if there is. Support for the handling of abnormalities.	Prior/Adaptive abnormality
	Speed adjustment	Change speed if needed (not relevant to all Network Users).	Immediately adaptive abnormality
	Automated handling	Automated handling if needed.	Immediately adaptive abnormality
	Transport operation reporting	Report the abnormality to the Traffic Orchestrator, the Transport Service Provider and Fleet Operator about the abnormality	Immediately adaptive abnormality
	Onboard system reporting: report tracking information, network conditions, and traffic situation	Communicate with the Traffic Orchestrator, the Transport Service Provider and Fleet Operator to get more information about the network traffic situation, support and decisions.	Adaptive abnormality

6.7.2 Polycentric

Polycentricity is covered with respect to:

- *Stakeholder types:* The functionality described is linked to all stakeholder types that are users of the SoI as identified and described.
- *Transport modes, networks, governance levels, and transport types*: A high abstraction level is used to hide the differences. Unless nothing is said about particular issues, all functionality described and the environment systems are common to all modes, networks, governance levels and transport types.
- *Technology and digitalisation*: The technology to be used in the implementation is not addressed, and it may be realised in several ways and may support both automation and

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manual activities. The interfaces may also be realised by means of different standards for different modes, and when such standards are known, they are identified.

6.7.3 Multimodality

The functionality described in the context view is harmonized across modes. Functionality already implemented or tested in one mode may be included as mode independent functionality to facilitate learning across modes. The environment systems and interfaces are also described in a mode independent way. The realisation of the interfaces may however vary depending on the mode as different standards and conventions are used, and in such cases the existing standards are identified. The mode-independent descriptions support a common understanding and communication across modes.

6.7.4 Organisation flexibility

The mode independent description of the functionality needed by the generic stakeholder types arranges for a flexible organisation of responsibilities. The stakeholder types can be covered by different actors, and one actor may cover one or more stakeholder types, and several actors may also have the same stakeholder type.

The mapping of functionality to systems aims to arrange for flexibility. The system components may be further combined into systems, and the cardinalities arrange for flexibility. The systems for data management and sharing may for example be used by one or more systems doing traffic orchestration.

6.7.5 Automated driving

System of Interest and the MTM ecosystem, as defined in section 6.6, will provide and use interfaces that arrange for functionality needed related to Network Users that are CAVs:

- The status of Network Users will be monitored to create awareness about traffic situations
- Messages containing regulations, guidance, etc., will be communicated to the Network Users via connected infrastructures
- Traffic situations will be microscopically managed by providing driving instructions (speed, lane, etc.) to the Network Users

The infrastructure classification chosen is based on the European project *Inframix* (https://www.inframix.eu/), which aims to classify and harmonize the capabilities of a road infrastructure to support and guide automated vehicles. To achieve this, *Inframix* proposes a classification scheme called Infrastructure Support Levels for Automated Driving (ISAD), which is similar to the SAE levels classifying the capabilities of CAVs.

This classification scheme has five levels (A to E) and every part of a given transportation network can be assigned with one of these levels (see Figure 30 from https://www.inframix.eu/infrastructure-categorization/).

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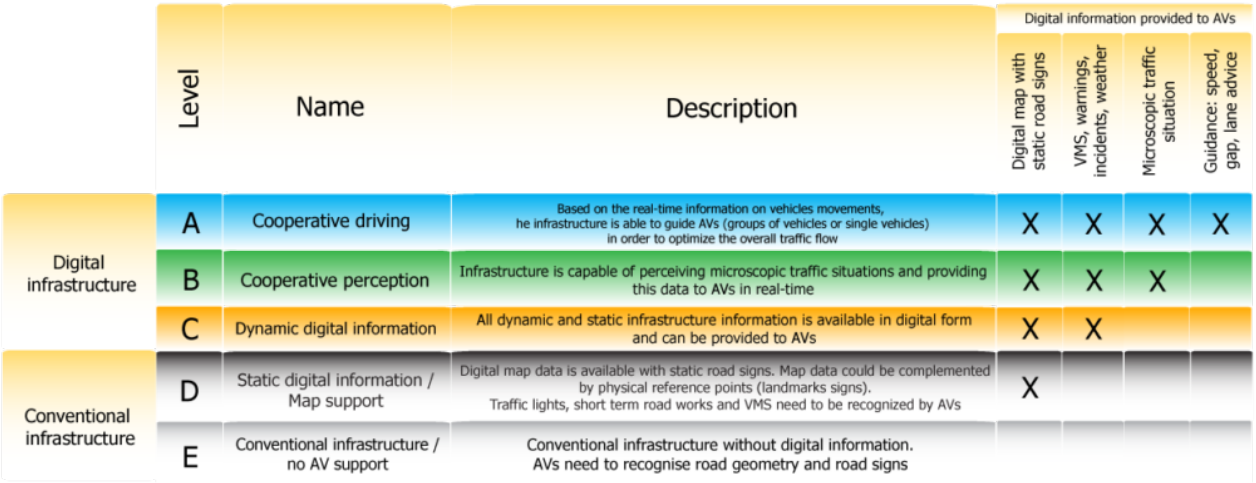

	Level	Name	Description	Digital information provided to AVs: Digital map with static road signs	VMS, warnings, incidents, weather	Microscopic traffic situation	Guidance: speed, gap, lane advice
Digital infrastructure	A	Cooperative driving	Based on the real-time information on vehicles movements, he infrastructure is able to guide AVs (groups of vehicles or single vehicles) in order to optimize the overall traffic flow	X	X	X	X
	B	Cooperative perception	Infrastructure is capable of perceiving microscopic traffic situations and providing this data to AVs in real-time	X	X	X	
	C	Dynamic digital information	All dynamic and static infrastructure information is available in digital form and can be provided to AVs	X	X		
Conventional infrastructure	D	Static digital information / Map support	Digital map data is available with static road signs. Map data could be complemented by physical reference points (landmarks signs). Traffic lights, short term road works and VMS need to be recognized by AVs	X			
	E	Conventional infrastructure / no AV support	Conventional infrastructure without digital information. AVs need to recognise road geometry and road signs				

Figure 30: Automated driving classification scheme from Inframix

The first two levels are designated to conventional infrastructure, beginning at ISAD level E, corresponding to conventional infrastructure without any support for automation. Going up one level (Level D), requires the availability of a static digital map with some regulatory information (e.g. speed limits).

The three upper levels specify digital infrastructure, starting at level C, where all relevant information has to be digitally available, for example variable-message sign (VMS), and traffic light information. The second highest level (Level B) requires infrastructure that is capable to recognise and transmit traffic situations on a microscopic level. This can be achieved by combining the data of fixed road-side sensors and the data of the vehicles in the network.

At the highest level (Level A), the microscopic traffic perception of the infrastructure is used for microscopic traffic management, which goes further than simple dynamic speed limits, providing optimised speed, lane usage, and inter-vehicle distance recommendations.

Table 10 assigns a minimum required ISAD level to all the relevant functionalities of the ORCHESTRA stakeholders.

Table 10: ISAD level related to each stakeholder: functionality and rational explanations

Stakeholders	Functionality	Min. ISAD level	Explanation
Traffic Orchestrator	Monitoring	C	This functionality monitors the real time network conditions, regulations, traffic situations and ongoing transport operations. This therefore requires at least an ISAD level C infrastructure. ISAD level B would be needed to monitor microscopic traffic situations.
	Data sharing	C	The monitored real time information is shared between (automated) vehicles/trains/vessels and the infrastructure. A level C infrastructure is needed to handle this dynamic digital information.
	Transport data	C	Traffic Orchestrator receives and manages data on planned

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Stakeholders	Functionality	Min. ISAD level	Explanation
	management		and ongoing transport demand. Therefore, it requires at least an ISAD level C infrastructure.
	Decision support	C	The decision support functionality depends on real time traffic conditions (dynamic) and historical data (local and mode specific regulations and procedures), meaning ISAD level C is required at a minimum.
	Decision making	C	The decision making involves macroscopic decisions such as traffic flow re-assignment and re-routing. But does not always support microscopic decisions such as real time speed adjustment according to the real time traffic conditions, which would require a level B infrastructure.
	Configure regulations and conditions	D	This functionality is the establishment of regulations in advance, which rely mainly on static information.
	Transport demand management	D	This functionality is the establishment of transportation measures in advance, which relies mainly on static information.
	Demand capacity balancing	C	This functionality applies the transport demand management dynamically to meet the real time transport capacity. This means that ISAD level C is required at a minimum.
	Coordination with other network and modes	C	The coordination with other networks or modes is real time and dynamic (level C), but the handling of microscopic traffic situations requires level B.
	Coordination with transport actors	C	The coordination with fleet managers, traffic service providers, and network users is real time and dynamic (level C), but as already mentioned above, understanding microscopic traffic situations requires a level B infrastructure.
Transport Service Provider	Plan and report transport chains	D	This functionality plans the transport chains in advance, mainly based on static information or prediction of the transport demand in the next planning period.
	Handle network issues	C	This functionality is a dynamic adjustment of the pre-planned transport chains according to the real time information of changes.
Fleet Operator	Operation planning	D	This functionality plans the vehicle fleet route, frequencies, and schedules in advance, mainly based on static information of currently available capacity and predictions of the transport capacity in the next planning period.
	Updates on Ongoing transports	C	This functionality is a dynamic adjustment of the established operation plans, taking into account the real time information

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Stakeholders	Functionality	Min. ISAD level	Explanation
			of changes.
Network User	Navigation	E	This depends entirely on the level of automation of the vehicle, but in principle this functionality does not need any additional intelligence, and a human driver can perform this action without assistance (although CAVs cannot). Navigation assistance, and to make it possible for CAVs to navigate, requires a digital map. Therefore, the ISAD level needs to be at least D. Higher levels could then be used to add more precision and intelligence to the navigation.
	Speed adjustment	E	As above, this can be done by a human without additional assistance. Even CAVs can theoretically follow road signs to adjust their speed. However, a better solution would be to make use of Vehicle-to-Infrastructure (V2I) and Vehicle-to-Vehicle (V2V) communication, but this requires at least an ISAD level C infrastructure.
	Operation adjustments	E	This functionality describes the general operation of a vehicle, and as above, this does not need any additional intelligence at the basic level. And CAVs, using onboard sensors and computer vision, could also do this. Again, V2I and V2V would greatly improve this functionality, but requires at the minimum a level C infrastructure.
	Automated handling	B	The automated handling functionality describes the possibility of traffic orchestrators taking individual measures towards one or several Network Users when a rapid response is required. This clearly indicates that an understanding of microscopic traffic situations is required, therefore a level B infrastructure is necessary.
	Transport operation reporting	C	In the most basic case, the transport operation reporting can be done without any additional connected infrastructure (level E), as the operation information can only be communicated at the start and end of the journey. This is not very useful however, as a continuous updating of the transport operation is desired, meaning that a level C infrastructure is required.
	Onboard system reporting: tracking information, network conditions, and traffic situation	C	A continuous exchange of data between the network user, network manager, and traffic orchestrator. Such a dynamic data exchange can only be accomplished with an infrastructure of at least level C.

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Out of the twenty considered functionalities, thirteen require a digitalised infrastructure (level C or higher) corresponding to the connect infrastructure managed by the Network Manager. This means that a great majority of the current transport networks is probably not yet equipped to properly enable these functionalities.

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7 Requirement mapping view

The goals defined in section 5.3 express the overall requirements to the System of Interest. More detailed requirements are defined by the functionality description in Chapter 6. This chapter:

- Verifies that the goals are met in the specifications of the functionality descriptions in Chapter 6
- Identifies extra-functionality requirements related to the goals

7.1 Functionality related requirements

Table 11, Table 12, Table 13, and Table 14 in the sections below verify that the goals are met in the functionality described for each stakeholder archetype in Chapter 6. Thanks to this mapping, gaps in the functionality are identified and accounted for.

7.1.1 Traffic Orchestrator

Table 11: Mapping from Traffic Orchestrator goals to functionality

Goal in section 5.3	How Traffic Orchestrator functionality supports the goals
TO1: Fair and transparent traffic orchestration	Data Sharing (6.1.2): Information on network strategies and policies and regulations (measure conditions included) is shared. Regulations links to policies and strategies.
TO2: Effectuate green transport policies TO6: More optimal transport from a societal point of view TO10: Better conditions for vulnerable network users	Network Information business object (6.1.11): Green and social strategies and policies can be defined, and regulations must link to policies. Decision Making (6.1.5): Strategies and policies are used when regulations are decided.
TO3: More efficient traffic flows	Decision Support (6.1.4): Decision support is used to find the optimal ways to manage the transport.
TO4: Integrate with connected Network Users	Transport Demand Management (6.1.7) and Demand Capacity Balancing (6.1.8): Regulations, measures and information are communicated, and connected infrastructures are used.
TO5: Support and coordinate with transport actors	Data Sharing (6.1.2): Information is shared Coordinate with Transport Actors (6.1.10): Information on changes and decisions is communicated and support is provided.
TO7: Facilitate mobility for all	Data Sharing (6.1.2), Transport Demand Management (6.1.7) and Demand Capacity Balancing (6.1.8): Regulations, measures and information are communicated via different channels, connected infrastructures included.
TO8: Reduce costs and effects of disruptions TO11: Take pro-active measures	Decision Support (6.1.4): Decision support is used investigate scenarios, to detect current and potential issues, and to find the optimal ways to manage disruptions and foreseen situations.
TO12: Automate the traffic management when possible	Decision Support (6.1.4) and Decision Making (6.1.5): For some situations, decisions about the actions to be taken may be automated. Transport Demand Management (6.1.7): Some measures will be taken automatically according to well defined conditions. Coordination with Others Networks and Modes (6.1.9) and Coordination with

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Goal in section 5.3	**How Traffic Orchestrator functionality supports the goals**
	Transport Actors (6.1.10), and Demand Capacity Balancing (6.1.8): The measures can be taken automatically when they are well defined.
TO13: Use shared data for more informed decisions	Monitoring (6.1.1): Data needed in decision support is collected and managed. Decision Support (6.1.4): A lot of data support decisions, data shared by other actors included, e.g. data on transport operations and data about the traffic situation in other networks and modes.
TO14: Decision support for resilient traffic orchestration	Decision Support (6.1.4): A variety of strategies is used based on many different types of data. Current situations are detected at an early stage, further developments are predicted, historical data is consulted, different scenarios are considered, and mitigating measures and measures to handle situations are suggested.
TO15: Coordination across networks and modes	Data Sharing (6.1.2): Traffic situation information is exchanged Coordination with other Networks and Modes (6.1.9): Handover of traffic is managed.

7.1.2 Transport Service Provider

Table 12: Mapping of Transport Service Provider goals to functionality

Goal in section 5.3	**How supported by functionality**
TSP1: Green transport chains are rewarded	**Traffic Orchestrator functionality:** Network Information business object (6.1.11): Green and social strategies and policies can be defined, and regulations link to policies. Decision Making (6.1.5): Strategies and policies are used when regulations are decided. If expressed in the policy, green transport chains are rewarded. **Transport Service Provider functionality:** Plan and Report Transport Chains (6.2): The TSP will adapt to regulations and measures targeting green transport.
TSP2: Contribute to successful MTM	**Traffic Orchestrator functionality:** Transport Data Management (6.1.3): Data from Transport Service Providers is received and managed. The data facilitates awareness, better decisions, and better support. Data Sharing (6.1.2): Regulations, measures and information are communicated to TSP to facilitate adaptation of plans to policies, strategies and situations. Customised information may be provided to individual TSPs. Coordination with Transport Actors (6.1.10): Request for changes and decisions are communicated to Transport Service Providers. **Transport Service Provider functionality:** Plan and Report Transport Chains (6.2): TSPs will adapt their chains to the relevant strategies, policies and regulations, and planned transports are reported to TOs to facilitate awareness and better decisions. Handle Network issues (6.2): TSPs re-planned chains when this is requested by TOs.
TSP3: More efficient handling of problems and disruptions	**Traffic Orchestrator functionality:** Monitoring (6.1.1): Data from Transport Service Providers are collected and managed for facilitate awareness. Data Sharing (6.1.2): Information on policies, regulations, traffic situation
TSP4: Contribute to and benefit from pro-active measures	

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Goal in section 5.3	How supported by functionality
TSP9: Cheaper transport TSP5: More predictable services for customer TSP6: More informed composition of transport chains TSP8: More value in return for shared data	(predictions included), and measures is communicated to TSPs to support their planning and management of transport chains. Transport Data Management (6.1.3), Decision Support (6.1.4) and Decision Making (6.1.5): Due to data sharing, current and upcoming situations can be detected at an early stage, and mitigating actions and actions to handle situations can be taken. Decision support is used to find the optimal measures, pro-active measures included, and thus arrange for efficient traffic flows and low transport costs. Coordination with Transport Actors (6.1.10): TSPs get support and directions on how problems related to transports can be handled. **Transport Service Provider functionality:** Plan and Report Transport Chains (6.2): TSPs receive information on regulations, measures, current situations and upcoming situations, and use this information to (re-)plan and manage more optimal transport chains. Handle Network issues (6.2): TPSs can subscribe to customised information from TOs, e.g. information about issues that may affect planned transports. TPSs also get support and directions on how problems related to transports can be handled.

7.1.3 Fleet Operator

Table 13: Mapping of Fleet Operator goals to functionality

Goal in section 5.3	How supported by functionality in section 6.1
FO1: Green transport operations are rewarded FO2: Green behaviour	**Traffic Orchestrator functionality:** Data Sharing (6.1.2): Regulations, measures and information showing the benefits of green transport are communicated to FOs. Network Information business object (6.1.11): Green and social strategies and policies can be defined, and regulations link to policies. Decision Making (6.1.5): Strategies and policies are used when regulations are decided. If expressed in the policy, green transport operations are rewarded. **Fleet Operator functionality:** Operation Planning (6.4): The FO will adapt to regulations and measures targeting green transport.
FO3: Get more customized support FO4: Contribute to and benefit from pro-active measures FO5: Less surprises during operation FO6: Value in return for shared data FO7: More efficient handling of problems and disruptions	**Traffic Orchestrator functionality:** Monitoring (6.1.1): Data from FOs are collected and managed. Awareness about the operations facilitates better support. Data Sharing (6.1.2): Regulations, measures and information are communicated to Fleet Operators to support the planning and the management of the operations. Decision Support (6.1.4) and Decision Making (6.1.5): Current situations are detected at an early stage, and the further developments are predicted. Based on this, mitigating measures and measures to handle situations can be taken. The needs of the Fleet Operators can be considered when this is appropriate. Coordination with Transport Actors (6.1.10): Request for changes and decisions are communicated to FOs. In case of unwanted situation, FOs are supported. **Fleet Operator functionality:** Operation Planning (6.4) and Updates on Ongoing Transports (6.4): FOs can subscribe to customised information from TOs, and the planning and re-planning of

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Goal in section 5.3	How supported by functionality in section 6.1
	operations can be adapted to information on regulations and measures and current and foreseen traffic situations. Request Transport Operation in Network (6.4): Information on planned and ongoing operations is sent to TOs. Such information facilitates awareness and better support.
FO8: Simplified transition to use of CAVs.	**Traffic Orchestrator functionality:** Transport Demand Management (6.1.7) and Demand Capacity Balancing (6.1.8): Regulations, measures and information are communicated to NUs via connected infrastructures **Network User functionality:** Network use – navigation, speed adjustment, operation adjustments, safety measures (6.5): Connected vessels and vehicles have onboard systems and equipment that utilise information and support from the Traffic Orchestrator in a seamless way. No extra training of personnel should be required. Such systems will also make the transition to the CAVs easier for FOs.
FO11: No need for extra training of personnel	
FO9: Reductions in waiting and resting costs	**Traffic Orchestrator functionality:** Decision Making (6.1.5): Decisions that may cause the need for extra waiting and resting times and extra energy use are if possible avoided. **Fleet Operator functionality:** Updates on Ongoing Transports (6.4): FOs can subscribe to customised information from TOs, and the planning and re-planning of operations can be adapted to information on regulations and measures and current and foreseen traffic situations.
FO10: Reductions in energy costs	

7.1.4 Network User

Table 14: Mapping of Network User goals to functionality

Goal in section 5.3	How supported by functionality
NU1: Desired behaviour is rewarded	**Traffic Orchestrator functionality:** Decision Making (6.1.5): Strategies and policies are used when regulations are decided. If expressed in the policy, green transport chains are rewarded. Decision Making (6.1.5): Strategies and policies are used when regulations are decided. If expressed in the policy, green transport operations are rewarded. Transport Demand Management (6.1.7) and Demand Capacity Balancing (6.1.8): Regulations and measures arrange for benefits for green behaviour. **Network User functionality:** Transport Operation reporting (6.5) and Onboard System Reporting (6.5): NUs provide information on their greenness and their operation in the network. Network Use – navigation, speed adjustment, operation adjustments, automated handling measures (6.5): Connected vessels and vehicles have onboard systems that ensure rewarding and provide guidance.
NU2: Better support for green behaviour	
NU3: Value in return for shared data	**Traffic Orchestrator functionality:** Monitoring (6.1.1): Data from NUs are collected and managed. Data Sharing (6.1.2): Regulations, measures and information are communicated to the onboard systems of the NUs to support the operation in the transport network and to arrange for more predictable operations.
NU4: More dynamic planning of transport	
NU7: Support in case of	

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Goal in section 5.3	How supported by functionality
disruptions NU8: Support and traffic predictions adapted to needs	Decision Support (6.1.4) and Decision Making (6.1.5): Awareness about the NUs and the operations facilitates better decisions and support, e.g. in the case of disruptions. Situations are detected at an early stage, and the further developments are predicted. Based on this, mitigating measures and measures to handle situations can be taken. The needs of the NUs are considered when this is appropriate. Transport Demand Management (6.1.7) and Demand Capacity Balancing (6.1.8): Regulations and measures arrange better handling of unwanted situations. **Network User functionality:** Transport Operation Reporting (6.5) and Onboard System Reporting (6.5): NUs provide information on their transport operations and their operation in the network. Network Use – navigation, speed adjustment, operation adjustments, automated handling (6.5): Connected vessels and vehicles get the input on regulations and measures as well as other directions that contributes to a better handling of unwanted situations, and the NUs should operate accordingly. They may also get more individual support regarding how to handle situations.
NU5: Support for safe driving NU6: Automation adapted to needs	**Network User functionality:** Network Use – automated handling (6.5): Connected vessels and vehicles have onboard systems and equipment that automatically respond on directions from TOs. In certain situations, TOs may give directions regarding how to handle situation, e.g. safety threat, that trigger automated actions.
NU9: No extra training and license requirements NU10: User friendly support for network use	**Traffic Orchestrator functionality:** Transport Demand Management (6.1.7) and Demand Capacity Balancing (6.1.8): Regulations, measures and information are communicated t NUs. **Network User functionality:** Network use – navigation, speed adjustment, operation adjustments, safety measures (6.5): Connected vessels and vehicles have onboard systems and equipment that utilise information and support from the Traffic Orchestrator in a seamless way. No extra training/licensing should be required.

7.2 Extra-functional (non-functional) requirements

Table 15 provides an overview of extra-functional requirements derived from the goals in section 5.3. Many of these requirements cannot be fulfilled by ORCHESTRA as they depend on external issues like standardisation and regulation. The requirements are however listed to address such dependencies.

Table 15: Mapping from Goals to extra-functional requirements

Goal in section 5.3	Requirements
TO1: Fair and transparent traffic orchestration TO13: Use shared data for more informed decisions TSP6: More informed composition of transport chains TSP2: Contribute to successful MTM TSP8: More value in return for shared data FO4: Contribute to and benefit from pro-active measures FO6: Value in return for shared data	Standardisation is needed for data/information sharing. Regulation is needed to ensure data sharing and access to data European Data Space for mobility is needed for data discovery and access.

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Goal in section 5.3	Requirements
NU3: Value in return for shared data	
TO1: Fair and transparent traffic orchestration TO2: Effectuate green transport policies TO6: More optimal transport from a societal point of view TO10: Better conditions for vulnerable network users TSP1: Green transport chains are rewarded FO1: Green transport operations are rewarded NU1: Desired behaviour is rewarded NU2: Better support for green behaviour	Strategies and policies are needed. Overall rules must be defined in a standardised way.
TO5: Support and coordinate with transport actors TSP5: More predictable services for customer FO3: Get more customized support FO5: Less surprises during operation FO7: More efficient handling of problems and disruptions	Standardisation is needed for communication with the TSPs and FOs.
TO6: More optimal transport from a societal point of view	New business models for more collaboration are needed.
TO3: More efficient traffic flows TO4: Integrate with connected Network Users TO7: Facilitate mobility for all TO12: Automate the traffic management when possible TSP3: More efficient handling of problems and disruptions FO8: Simplified transition to use of CAVs. FO11: No need for extra training of personnel FO12: Free access to traffic orchestration services NU1: Desired behaviour is rewarded NU2: Better support for green behaviour NU5: Support for safe driving NU6: Automation adapted to needs NU7: Support in case of disruptions NU8: Support and traffic predictions adapted to needs NU9: No extra training and license requirements NU10: User friendly support for network useNU4: More dynamic planning of transport	Standardisation of communication with Network Users. Onboard equipment and systems must support standardised interactions with traffic orchestrators. Mechanisms for automated software updates must be supported.
TO5: Support and coordinate with transport actors TSP5: More predictable services for customer	Regulation is needed to define obligations and ensure collaboration and data sharing.
TO9: Limit digital vulnerability NU5: Support for safe driving	Standardisation is needed for software updates and security issues.

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Goal in section 5.3	Requirements
	Software updates must be standardised and automated. Information security, cyber security, and backup solutions must be manged.
TO15: Coordination across networks and modes	Standardisation is needed for communication with other traffic orchestrators Regulation is needed to ensure collaboration. European Data Space for mobility is needed for data discovery and access
FO8: Simplified transition to use of CAVs. NU11: No responsibility when automation fails	The distribution of responsibilities must be regulated.

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8 Component view

The PMA specified in this report is, as described in section 2.1, a Reference Architecture that aims to arrange for integrations of several systems (from several system providers) into the system of systems that constitute a MTM ecosystem. Thus, the specification of interfaces and interactions between the systems is important.

Section 6.6 provides an overview of the environment system and interfaces, i.e. the systems that the System of Interest interacts with, and their interfaces. The interfaces provided by the environment systems are addressed in section 6.6, and they are not further addressed here. The interfaces provided by the System of Interest are however further explored in the component view:

- A system information model identifies and specifies information elements to be exchanges via the interfaces offered by the System of Interest.
- A system decomposition model describes how the System of Interest is decomposed into components and/or logical application services. The interfaces towards the systems are identified at a high level with references to the relevant parts of the information model.

8.1 System Information Model

The System of Interest will communicate with other systems via

- **External interfaces**, i.e. interfaces provided by other systems, as described in the section on Environment systems (see section 6.6). The realisation of these interfaces is not further addressed in this report.
- **Transport Operation interface**, which supports the communication between the Traffic Orchestrator and the transport actors (Transport Service Providers, Fleet Operators and Network Users). This interface is also mentioned in section 6.6, but since this is an interface provided by the System of Interest the interface is specified in this section.
- **Network Coordination interface,** which supports the communication between the Transport Orchestrators in different network and modes. This interface is also specified in this section.

The MTM information model aims to define the information elements needed in the Transport Operation and the Network Coordination interfaces. Many issues must be considered, for example:

- Legal level – consents/agreements between actors with different jurisdictions and frameworks.
- Organisational level – alignments of goals, responsibilities and processes for controlled data sharing (onboarding, certification, service level agreements, operations, etc.).
- Semantic level – common understanding of the information/data to be collected and shared.
- Technical level – formats and protocols.

A preliminary specification of the technical level of the sub-information models is provided in the sections below. The remaining issues will be addressed in Deliverable D3.3.

8.1.1 Transport Operation interface and sub-information model

The Transport Operation interface must support the communication of:

- **Subscriptions** to network and traffic information. Transport Service Providers and Fleet Operators may subscribe to information of relevance to planned and/or ongoing operations.

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- **Network status** with foreseen/occurred network conditions and traffic situations that may support the planning or follow up of transport operations.
- **Transport operation plans** from Transport Service Providers
- **Transport operation requests** from Fleet Operators and related responses (confirm, decline, replanning request)
- **Transport operation reporting** from Network Users
- **Handover information** – to inform about a forced handover to another network

Information models on transport operations and the network status exist, partly as multimodal models, and partly as mode specific models. The Transport Operation interface should be mode independent since Transport Service Providers and Fleet Operators may cover several modes.

Table 16 provides an overview of content in the information to be exchanged, and when available, existing standards and models that may support the definition of information elements. Their relevance with respect to the above communication needs are also provided. The transport operation information model must in addition include certificates that can verify the properties and abilities of Network Users and transport operations.

As seen from the table, the Subscriptions and Handover information is so far not covered. It might however be possible to build the information elements needed from the existing standards/models.

Table 16: Overview of relevant content with existing models and standards and their relevance

Mode/ Topic	Content - Models/Standards when available	Relevance
Freight transport	**ISO 19845** - Information technology — Universal business language version 2.1 (UBL v2.1) Standardised, multimodal information model defining freight transport chains and transport operations, description of load units and cargo included.	Transport operation plans Transport operation requests Transport operation reporting
Person transport	**Transmodel v6.0 – CEN EN 12896** Reference Data Model for Public Transport. The following standards are based on Transmodel: • **IFOPT** – Fixed Objects in Public Transport, e.g. stops and points of interest • **CEN TS 17413** – Transmodel extensions for new modes • **SIRI - CEN/TS 15531** Standard Interface for Real-Time Information • **NeTEx - CEN/TS 16614** Network Timetable Exchange	Transport operation plans Transport operation requests Transport operation reporting
Network User information	• Network User information • Certificates proving properties and abilities • Status (energy status, operation status, next destination, …)	Transport operation reporting
Transport operation	• Certificates proving properties and abilities • Timestamp and action (loaded, unloaded, …) • Information (type of operation, …) • Status (load factor, first/last mile, …)	Transport operation reporting
Sea	**SeaSWIM** – Information model for the sea transport sector. Service interfaces are specified and available. • Routes • Port calls **SafeSeaNet**	Transport operation plans Transport operation requests Transport operation reporting

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Mode/ Topic	Content - Models/Standards when available	Relevance
	• Reporting voyage and port calls	
Air	**SWIM/AIRM**[9] – Comprehensive and openly available information model for the air transport sector containing "everything" • Flights • Air traffic operations	Transport operation plans Transport operation requests Transport operation reporting
Rail	**TSIs** (Technical Specifications for Interoperability) for standardised information exchange regarding, among others • **TSI TAF** (Telematics Applications for Freight) • **TSI Rolling Stock** (train)	Transport operation plans Transport operation requests Transport operation reporting
Road	• Traffic Situation and Network Condition information: **DATEX II (traffic flow), TPEG and TISA (information on events)**. • Network Regulation information: **TN-ITS** (used today), **extensions to DATEX II** (proposed by the UVAR Box project), and **new standards suggested by the ISO/NP 24315 METR** (Management of Electronic Traffic Regulations) initiative (work in progress, scheduled for 2024).	Network status
Sea	• Information about the ocean space/water ways/fairways and related information on network conditions, traffic situations and regulations is communicated according to the upcoming **"IHO Universal Hydrographic Data Model", known as S-100**.	Network status
Air	• Information about the air space and traffic and air space conditions will communicated by means of information objects defined in **SWIM/AIRM**.	Network status
Rail	• To be investigated and described in Deliverable D3.3.	Network status

8.1.2 Network Coordination interface and sub-information model

The Network Coordination interface must support the communication of:

- **Multimodal network status** covering network condition and traffic situation.
- **Network capacity.** This is time series several hours ahead with information about the estimated share of a defined max capacity reached.
- **Traffic transfer.** This is a request for transfer of a traffic volume provided as a time series several hours ahead, and a related response that confirms or rejects the request.

The information models for the network coordination must be mode independent since the coordination may be between networks belonging to different modes.

Table 17 provides an overview of existing standards and models that may be input to a multimodal network status format. The Network capacity and the Traffic transfer information elements will be defined in deliverable D3.2.

Table 17: Overview of relevant, existing models and standards and their relevance

Mode/ Topic	Models/Standards	Relevance

[9] https://airm.aero/

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Mode/ Topic	Models/Standards	Relevance
Road	• Traffic Situation and Network Condition information: **DATEX II** (traffic flow), **TPEG** and **TISA** (information on events). • Network Regulation information: **TN-ITS** (used today), **extensions to DATEX II** (proposed by the UVAR Box project), and **new standards suggested by the ISO/NP 24315 METR** (Management of Electronic Traffic Regulations) initiative (work in progress, scheduled for 2024).	Input to a definitions of multimodal network status information
Sea	• Information about the ocean space/water ways/fairways and related information on network conditions, traffic situations and regulations are communicated according to the upcoming **"IHO Universal Hydrographic Data Model", known as S-100**.	
Air	• Information about the air space and traffic and air space conditions will communicated by means of information objects defined in **SWIM/AIRM**.	
Rail	• To be investigated and described in Deliverable D3.3.	

8.2 System Decomposition Model

The System Decomposition Model in Figure 31 describes how the System of interest is decomposed into logical components, independent on deployment and realisation technology. The current model is an early draft that identifies some generic components, some more concrete components and some relations based on the functionality models from Chapter 6 and tools from ORCHESTRA WP4. In the current model, the components are not yet put together into a more complete structure that identifies connections between the components, nor how they handle the required and provided interfaces of the System of Interest. The model will be reworked, expanded and further elaborated in final version of the ORCHESTRA PMA.

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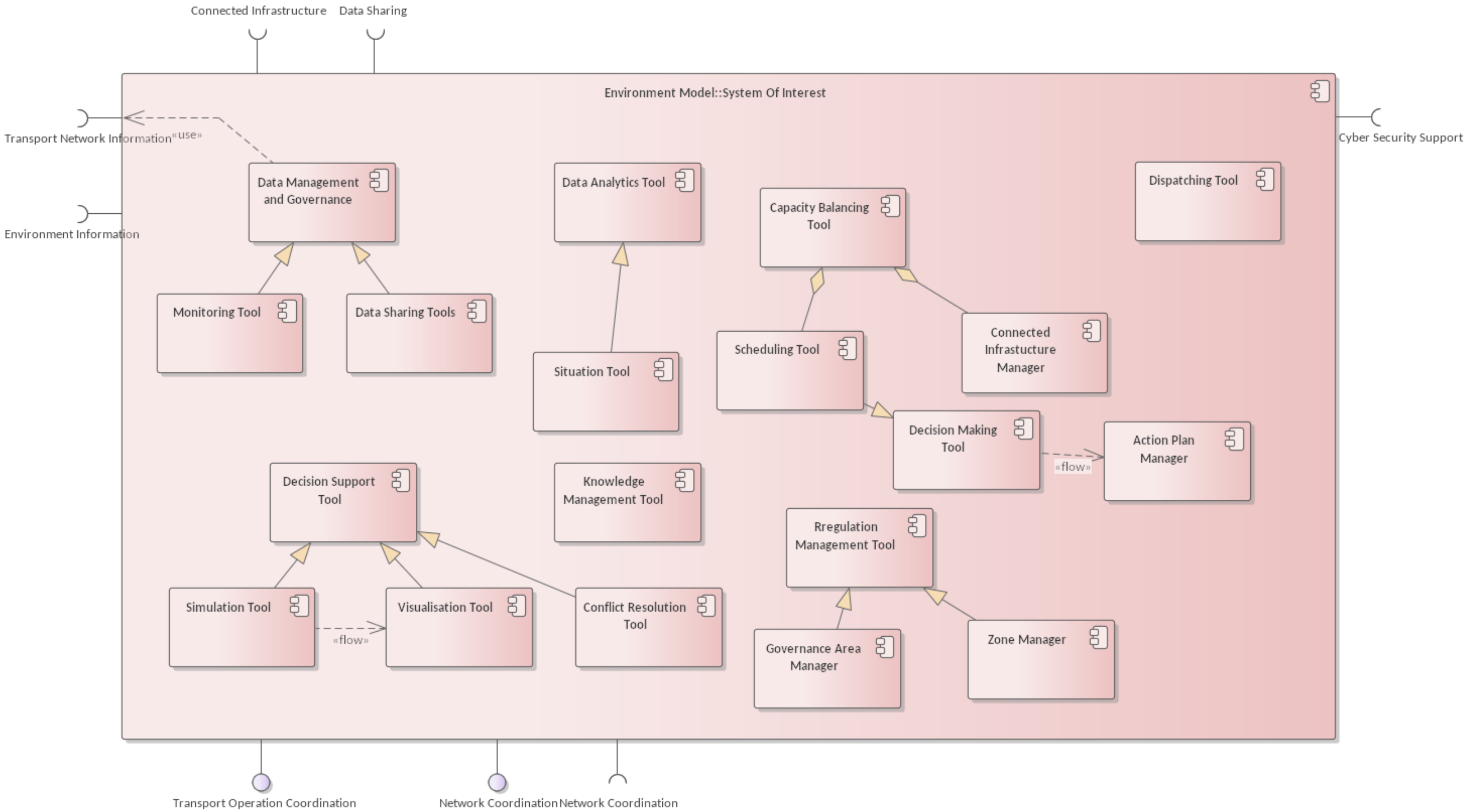

Figure 31: System Decomposition Model

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9 Conclusions

This deliverable defines the intermediate version of the ORCHESTRA Polycentric Multimodal Architecture (PMA). It provides an overall model of the MTM ecosystem describing the main stakeholder roles, their motivations for multimodal traffic management, and their main functional needs and requirement. The PMA also describes the environment of the traffic orchestration system, an initial version of a common information model, and a system decomposition model. We think The PMA 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 aspects play 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 final version of the PMA (D3.3) will refine and extend this deliverable to cover the additional architectural views as described by the ARCADE framework (see section 3.2.3). The MTM is a new concept that must emerge and be defined and refined during the project. Thus, the final version (D3.3) will capture knowledge gained and lessons learned during the last part of the project, especially from the work on the scenarios in WP2, the tools, organisation models and business models in WP4, and the Living Labs in WP5. Thus, the Motivation and Context views may still be refined. The environment model will for example be better balanced across all modes. The Component view will be elaborated further and extended:

- The system information model will be further specified, and the details on the interfaces provided by the traffic orchestration will be defined.

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- The system decomposition model will be further elaborated to reflect a realistic decomposition into logical system component, verified by means of the tools from WP4 and the Living Labs in WP5.
- A system collaboration model will be added that describes the interaction between the components and how they together realise the functionality defined in the context view.
- A component and interface specification model may be added to further specify the interfaces of components and the external interfaces to the system of interest.

So far, most examples and references are made to initiatives and standards from the road transport domain, since the road sector is the most mature sector when it comes to ITS and works as a good starting point. This will in D3.3. be extended to cover the other modes in a more details.

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10 References

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[3] Vennesland, A, Natvig, M., Stav, E., Daniele, L. iCargo Deliverable D1.7 - iCargo Common Framework Specification, 2014.

[4] Erlend Stav, Ståle Walderhaug, and Ulrik Johansen. ARCADE: An Open Architectural Description Framework. Version 1.02, December 2013. http://arcade-framework.org/

[5] 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

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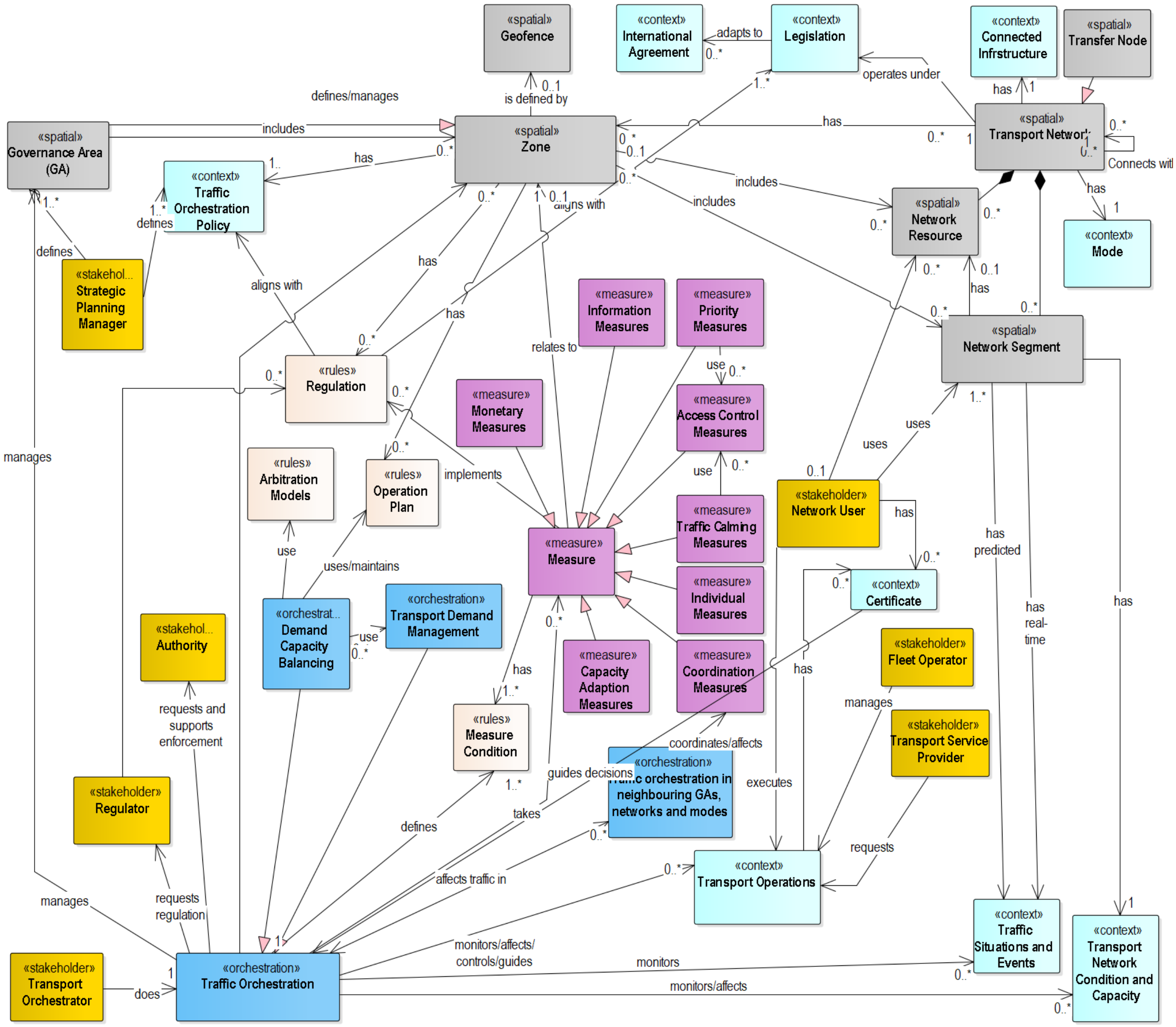
Annex A Complete concept model



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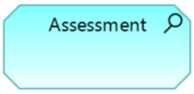
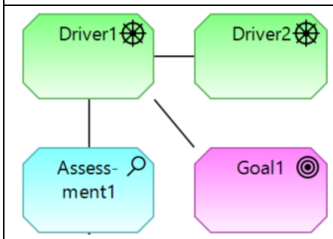
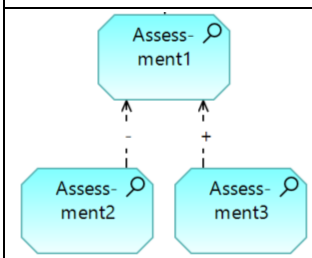
Annex B ArchiMate models

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.

B.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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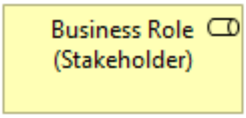
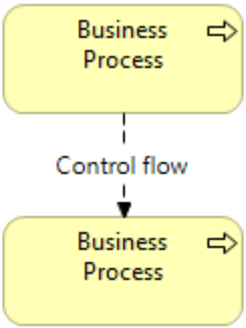
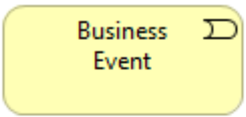
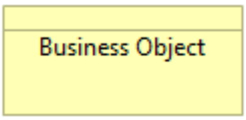
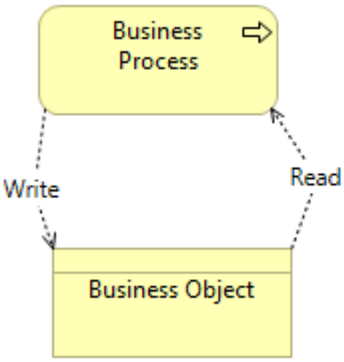
B.2 Functionality diagram notation

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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B.3 Assessment diagrams

This chapter provides supplementary diagrams and descriptions for the motivation view, giving a more detailed analysis of assessment of the drivers of the main stakeholders. This content is provided as part of this Annex as we consider it to be reference material providing more detailed descriptions for interested readers, and not a core content of the motivation view.

For each stakeholder a sub-section first provides a diagram showing the stakeholder, its drivers and the assessments. The assessments are further described in a table, organized by the main driver that it associated with. Each assessment is an analysis of the current situation with respect to one or more drivers. For assessments that are related to multiple drivers, their full description is provided only under the main driver, and brief references to where the full description is found is given under other the other drivers.

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B.3.1 Assessments for Traffic Orchestrator

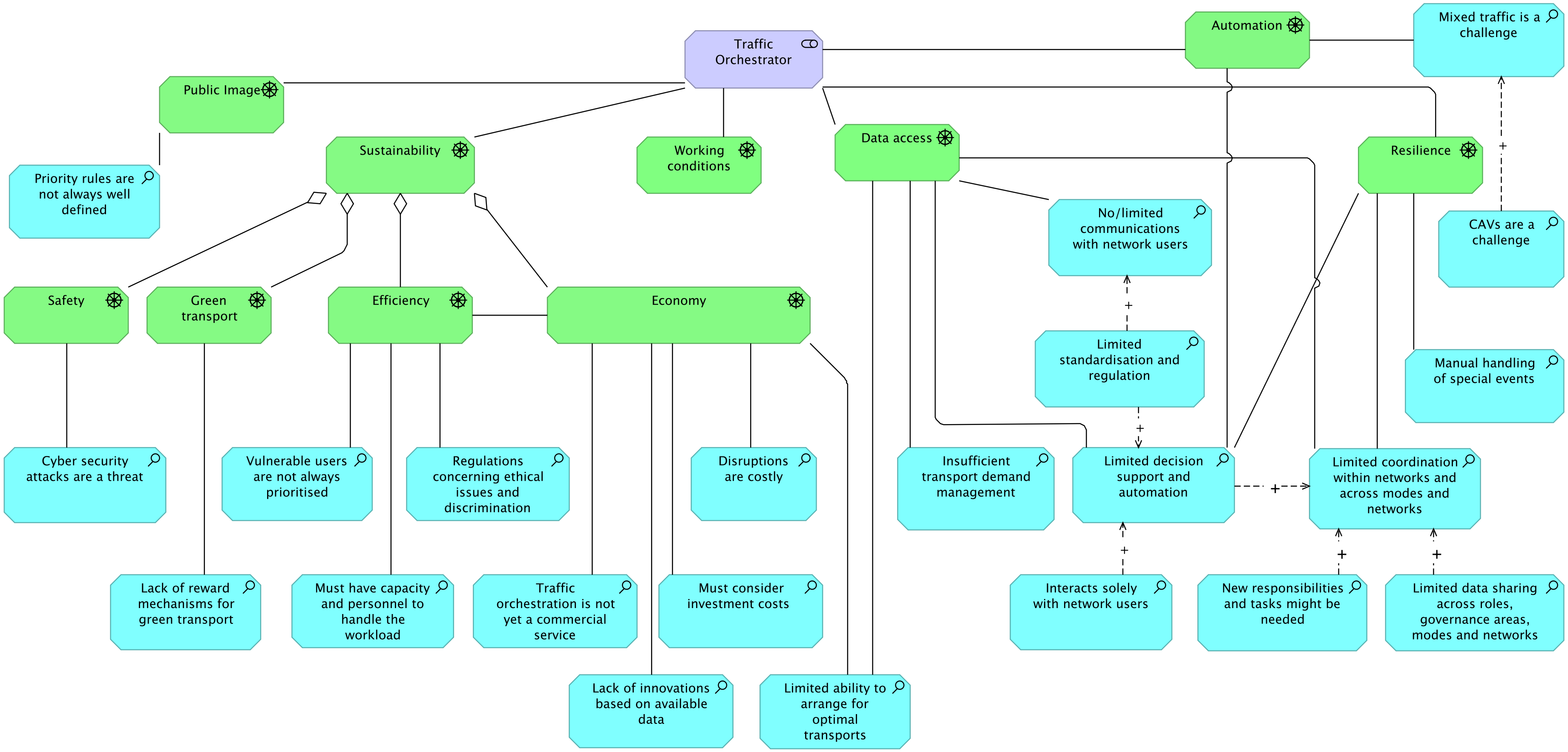

Figure 32: Traffic Orchestrator Motivation Diagram: Drivers and Assessments.

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Table 18 provides descriptions of the Drivers and Assessments from Figure 32.

Table 18: Traffic Orchestrator drivers and assessments

Drivers	Assessments
Resilience	**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. **Limited decision support and automation:** See under Automation.
Economy	**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. **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.

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Drivers	Assessments
	Disruptions are costly: In private transport network, the cost of disruptions will influence the willingness to invest.
Green transport	**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.
Safety	**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.
Data access	**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. **Limited ability to arrange for optimal transports:** See under Economy. **Limited decision support and automation:** See under Resilience. **Limited coordination within networks and across modes and networks:** See under Resilience.

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Drivers	Assessments
Automation	**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. **CAVs are a challenge:** The emerge of CAVs raise new questions regarding responsibilities. The regulations are unclear, or regulations are also missing. **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. **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.
Efficiency	**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. **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.
Public Image	**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

Drivers	Assessments
	which measures that can be taken to get the advantages. Clarity in rules create trust in the Traffic Orchestrator and thus also increase the willingness to share data.
Sustainability	Covered by the following drivers: **Green transport, Efficiency, Economy,** and **Safety.**

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B.3.2 Assessments for Transport Service Provider

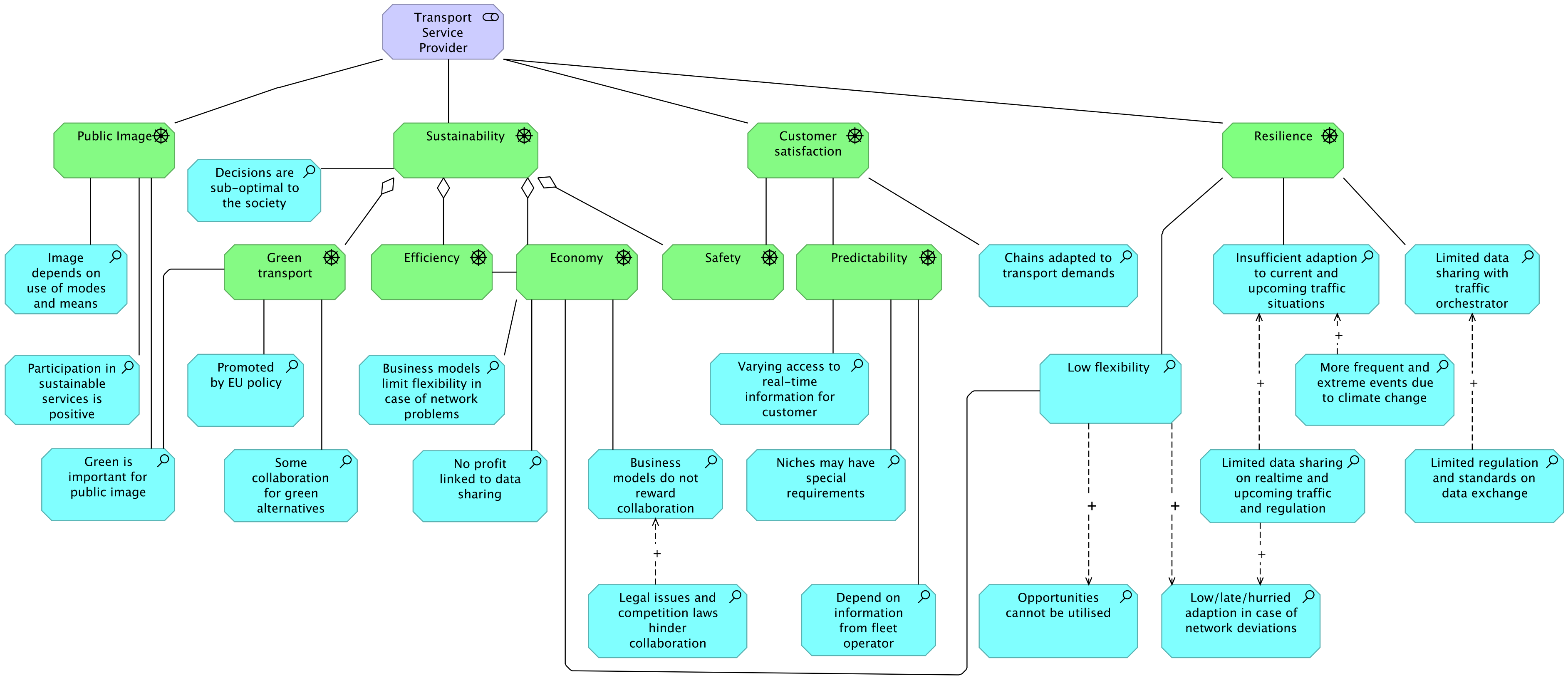

Figure 33: Transport Service Provider Motivation Diagram: Drivers and Assessments

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The table below provides descriptions of the Drivers and Assessments in the motivation diagram in Figure 33.

Table 19: Drivers and assessments for Transport Service Provider

Drivers	Assessments
Customer satisfaction	**Chains adapted to transport demands:** Transport services fulfil different types of demands, e.g. the shortest or cheapest travel time.
Predictability	**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.
Resilience	**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. 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

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Drivers	Assessments
	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. **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 is also a lack of services that support the utilisation of such opportunities.
Sustainability	**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. **See also:** Assessments for the drivers **Green transport** and **Economy**.
Economy	**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.

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Drivers	Assessments
	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. **Low flexibility:** See under resilience.
Green transport	**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.
Public image	**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. **Green behaviour is important for public image:** See under Green transport.
Safety	No relevant assessments identified.
Efficiency	Similar assessments as for the **Resilience** driver.

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B.3.3 Assessments for Fleet Operator

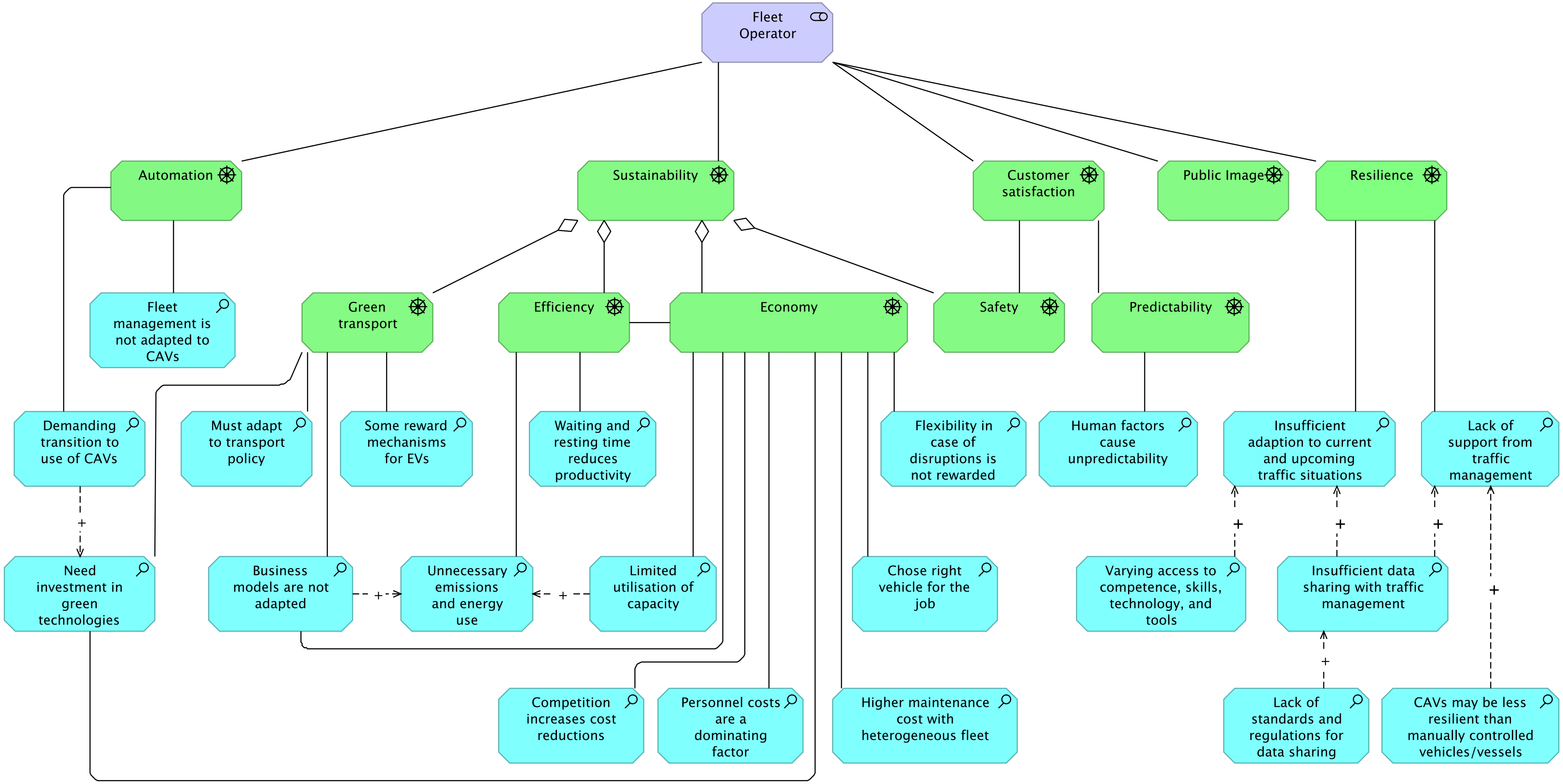

Figure 34: Fleet Operator Motivation Diagram: Drivers and Assessments

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The table below provides descriptions of the Drivers and Assessments in the motivation diagram in Figure 34.

Drivers	Assessments
Resilience	**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. 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. **CAVs may be less resilient than manually controlled vehicles/vessels:** The technology is currently immature, and there are restrictions on where it is

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	possible to drive, speed, etc. The technology may also not yet be able to handle unexpected situations in a flexible way.
Predictability	**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.
Efficiency	**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. **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.
Green transport	**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.). **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.

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	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. **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. **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.
Automation	**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. **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.
Economy	**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 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

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	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. **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. **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 is to a little degree affected by the traffic management. However, use of electric vehicles may in some countries get privileges. **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. **Business models are not adapted:** See under Green transport. **Need investment in green technologies:** See under Green transport.
Customer satisfaction	Covered by the following drivers: **Predictability** and **Safe operations**
Sustainability	Covered by the following drivers: **Green transport, Efficiency, Economy,** and **Safety.**

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B.3.4 Assessments for Network User

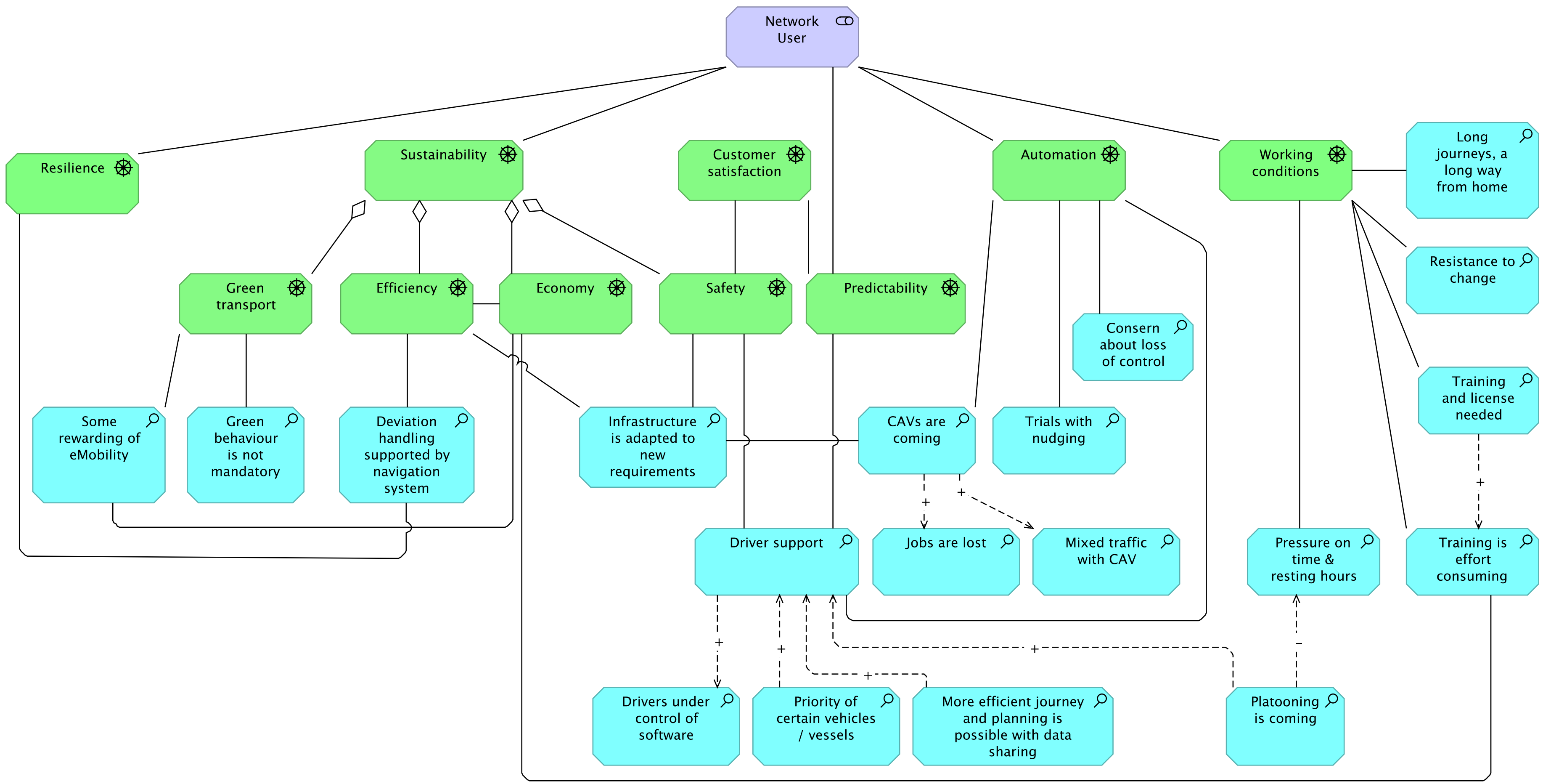

Figure 35: Network User Motivation Diagram: Drivers and Assessments

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The table below provides descriptions of the Drivers and Assessments in the motivation diagram in Figure 35.

Drivers	Assessments
Resilience	**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.
Green transport	**Some rewarding of eMobility:** 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 behaviour is not mandatory:** Today, Network Users are not obliged to a green behaviour. It is voluntary to take green decisions.
Automation	**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. **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. **Concerns about loss of control:** For some, automation means loss of control. Users may not like that they have to share data. **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. **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

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	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.
Working 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. **Long journeys, a long way from home:** Drivers must live in the car for days during long journeys. **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. **Platooning is coming:** See under Automation.
Efficiency	**Deviation handling supported by navigation systems:** See under Resilience. **Infrastructure is adapted to new requirements:** See under Automation.
Safety	**Infrastructure is adapted to new requirements:** See under Automation. **Driver support:** See under Automation.
Predictability	**Driver support:** See under Automation.
Economy	**Training is effort consuming:** See under Working conditions. **Some rewarding of eMobility**: See under Green transport.
Customer satisfaction	Covered by the following drivers: **Predictability** and **Safe operations**
Sustainability	Covered by the following drivers: **Green transport, Efficiency, Economy,** and **Safety.**

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Annex C The ORCHESTRA Board Game

Concept models and reference architectures are useful tools for describing advanced systems. Such models are, however, quite abstract by nature, and it can be challenging to communicate them to stakeholders in the domain. To address this issue, we are developing a traffic orchestration board game. The game is a board game in the genre of serious games. Serious games are games that has a purpose beyond pure entertainment, and additional goals can include learning, team building, etc. for all participants.

The goal when developing the board game is that it should become a tool for learning about the ORCHESTRA concept model and reference architecture, and for engaging stakeholders such as the CoP and others to provide their input and feedback to the model. The primary target audience of the game are actors within the transport and traffic domains. In addition to learning about the concept, it is intended that the game should trigger discussions which can be used as feedback to the reference architecture topics, including overall idea, concepts that are unclear, relevance of concepts and features, as well as missing concepts and features. The players should be given strategical choices, and the level of randomness should be low.

This game introduces the new concept of traffic orchestration based on the concept model and reference architecture. In the game, the players are trying to handle transport and traffic challenges both in ordinary and extraordinary situations. The board shows the transport networks available with destinations for picking up and/or delivering passengers and goods. The game is asymmetric, in that different player roles have different things to accomplish. Transport service providers/fleet operators try to carry out transports as efficient as possible, while one or more traffic orchestrator(s) attempts to manage the traffic to the best of society. The game is driven forward by a set of situation cards which determine situations in the game, such as changes in transport needs, regulations, high traffic volume, incidents, accidents, etc. Concepts covered include traffic orchestration, transport network, network segments, zones, and different types of measures (including traffic calming, access control, priority and monetary measures).

During early testing of the game, we have decided that it would be useful with two variants of the game: one targeted at use in workshops which can be completed within an hour, and a more in-depth version that allows introduction of more advanced concepts and details with less time restriction. Of these two, the workshop version is most complete at the time of writing. The two versions are described in the following sub-chapters.

C.1 Workshop edition of the Board Game

The initial version of the Board Game is targeted for use in workshops, and with the purpose of communicating the content of the concept model and getting a good discussion within a one-hour session. To this end, the game has been kept simple, and instead of a competition it is more a collective puzzle exercise.

In the game, one player takes the role as the orchestrator, while the other players (up to 6) take roles of transport service provide/fleet operator. The game is played in a set of rounds, and at the start of each round a situation card is drawn which explains the current situation. The situation can be a regular situation or an extraordinary one, such as an event that causes heavy traffic in a zone, or an

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accident or incident. The situation also defines how dense the current traffic is each of the zones, and the orchestrator updates the board by placing markers on each zone for this.

Each of the transport service provider/fleet operator players are then dealt a card with a transport assignment that they should try to complete within the round. In the workshop version the players play with open cards and add markers on the board for where their vehicle starts, where they have a pickup and where they have a delivery.

The orchestrator then decides on a set of measures to apply to the zone to handle the current situation and facilitate the current transport assignments. The measures selected by the orchestrator affect where and how far the other players can drive in the round, and ultimately whether they can complete their assignment. In the workshop version this can trigger discussions in the player group on how the measures affect them and how it could be done differently to better facilitate the transports. The experience can in this way be a kind of shared puzzle-solving.

When the measures have been applied, each player will in turn try to complete their assignment by moving their cards, taking the measures and traffic situation in the zones into account. The overall experience can in this way be a shared puzzle-solving

More details about the setup of the game and the flow of each round can be found in the instructions for to the players, that is provided in section C.3.4.

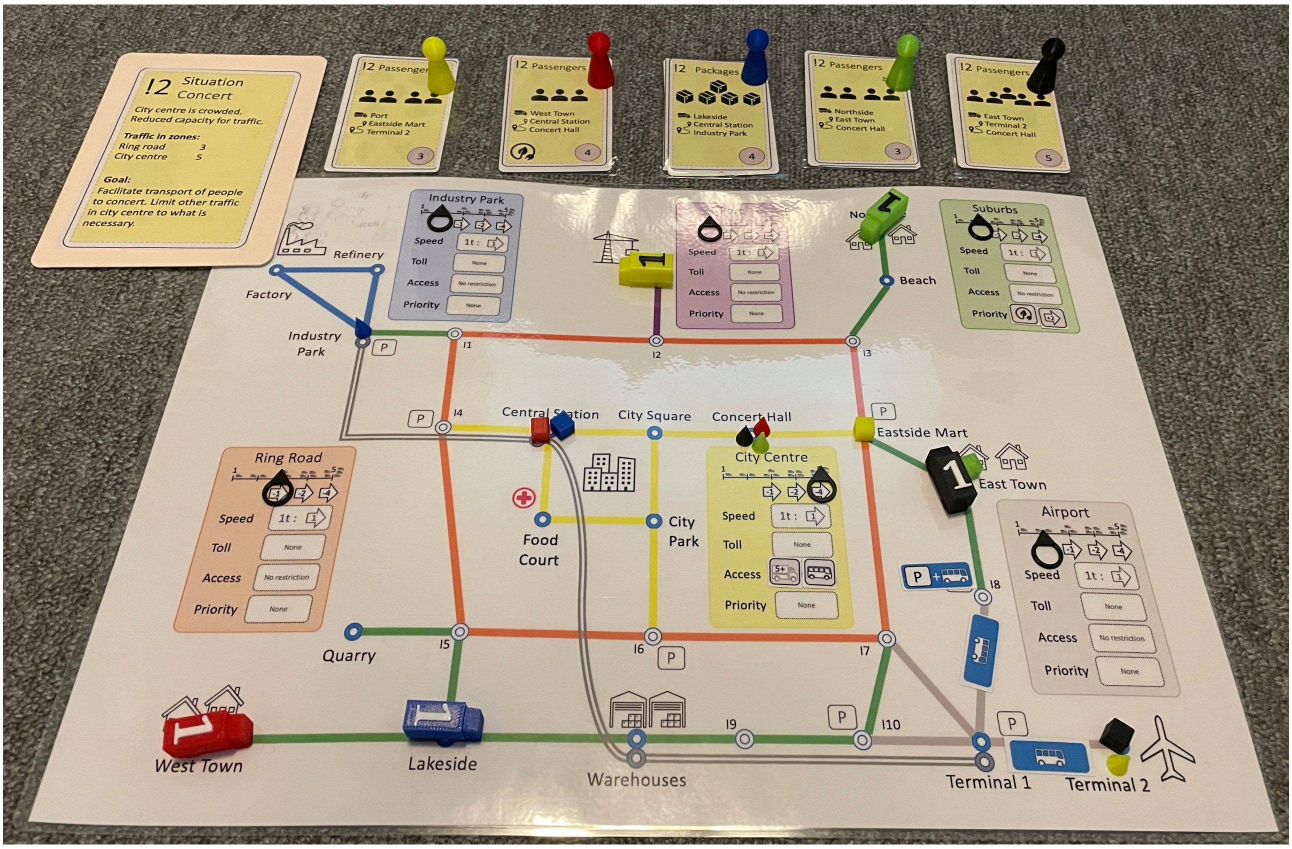

Figure 36: The workshop version of the board game set up ready to play

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C.2 Full edition of the Board Game

The full edition of the Board Game is planned to cover further aspects of traffic orchestration under regular as well as special situations. This version of the game will facilitate more in-depth learning and discussions about the concept model. This edition will contain more game elements that also cover some competition elements between the transport actors, use of multi-modal transport chains. The game be planned to be suitable for a 2–3-hour session.

Some additional game elements that are currently considered:

- Each transport actor has a fleet of 1 to 3 cars.
- The transport actors will get more regular transport assignments to choose from in addition to the ones specific to the situation.
- Each car can be assigned multiple transport assignments that can be combined to give a good load factor.
- There will a money / reward system for completing assignments, which gives the game a competition element
- The players may buy "upgrades" to their cars or systems that allow them to better interact with the orchestration or perform transport assignments with special requirements. This will gradually introduce more game elements and rules during the game, allowing us to include further elements of traffic orchestration as well as competitive elements that can increase player engagement.

C.3 Board game components

This chapter shows examples of the game components for the version of the board game that was used in the workshops in the autumn of 2022. The components are not explained in further detail here, but the player instructions which is provided in section C.3.4 provide some overview of the setup of the game, the steps in each round, as well as brief explanation of the measures that can be applied.

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C.3.1 Board

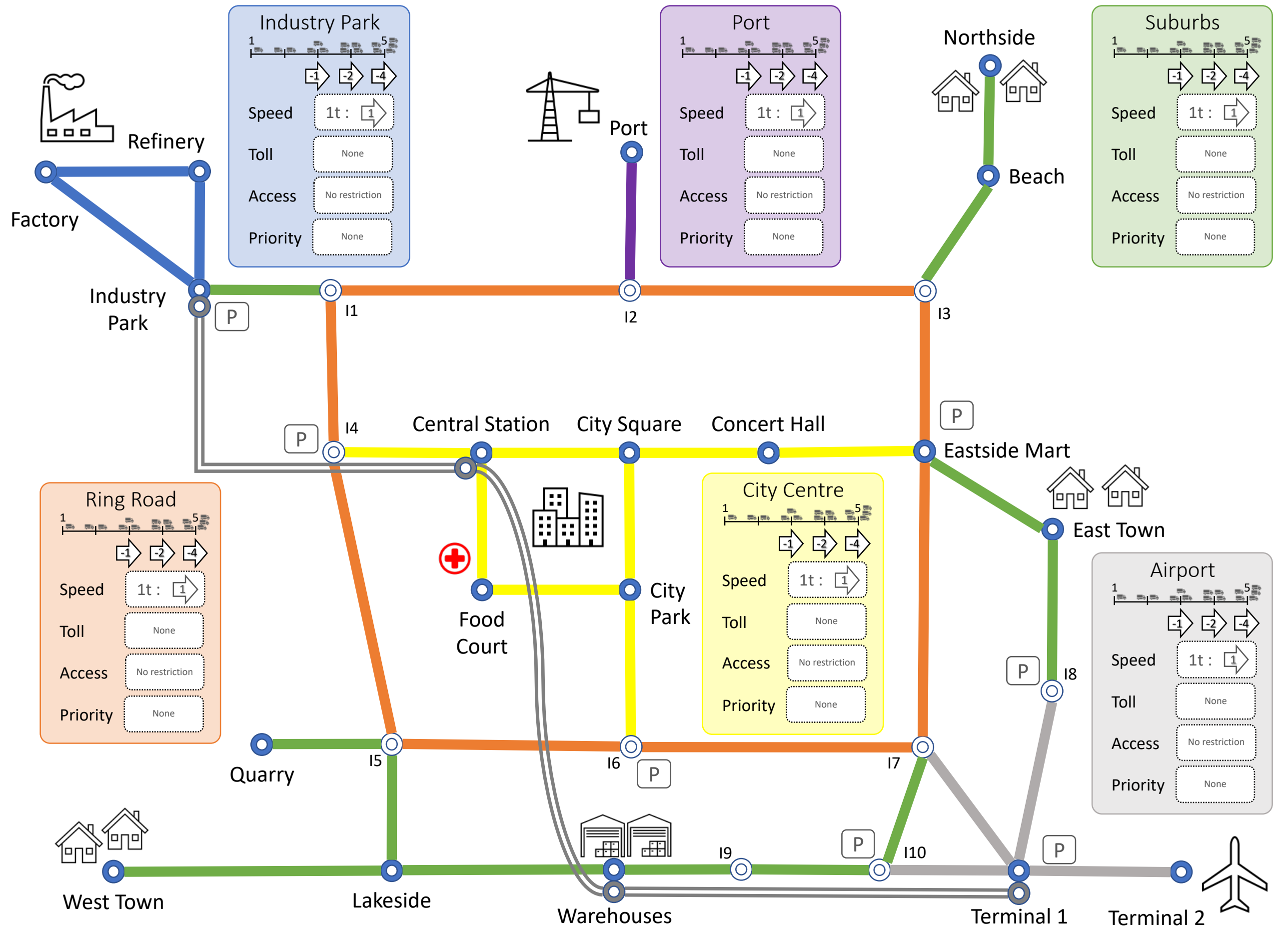

Figure 37: The board of the board game

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C.3.2 Situation Cards

!1 Situation
Regular traffic

Regular traffic in all zones.

Traffic in zones:

All	2

Goal:
Facilitate transport operations.
Reward green behaviour.

!2 Situation
Concert

City centre is crowded.
Reduced capacity for traffic.

Traffic in zones:

Ring road	3
City centre	5

Goal:
Facilitate transport of people to concert. Limit other traffic in city centre to what is necessary.

!3 Situation
Gas Leakage

Gas leakage in Industry Park zone. Health and explosion risk.

Traffic in zones:

Industry Park	1
Ring Road	3

Goal:
Evacuate people and dangerous goods from the area. Safety comes first.

!4 Situation
Accident

Accident in ring road section I6 - I7. Traffic blocked in east-bound lanes.

Traffic in zones:

Ring Road	5
City Centre	3
Suburbs	3

Goal:
Support emergency services.
Coordinate with other zones.

!5 Situation
Airport train stops

No train from City Centre to Airport during rush hours. Delays for passengers.

Traffic in zones:

Airport	4
Ring road	4
Suburbs	2

Goal:
Passengers reach airport in time.

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!1 Situation
Regular traffic

Regular traffic in all zones.

Traffic in zones:

All	2

Goal:
Facilitate transport operations.
Reward green behaviour.

!2 Situation
Concert

City centre is crowded.
Reduced capacity for traffic.

Traffic in zones:

Ring road	3
City centre	5

Goal:
Facilitate transport of people to concert. Limit other traffic in city centre to what is necessary.

!3 Situation
Gas Leakage

Gas leakage in Industry Park zone. Health and explosion risk.

Traffic in zones:

Industry Park	1
Ring Road	3

Goal:
Evacuate people and dangerous goods from the area. Safety comes first.

!4 Situation
Accident

Accident in ring road section I6 - I7. Traffic blocked in east-bound lanes.

Traffic in zones:

Ring Road	5
City Centre	3
Suburbs	3

Goal:
Support emergency services.
Coordinate with other zones.

!5 Situation
Airport train stops

No train from City Centre to Airport during rush hours.
Delays for passengers.

Traffic in zones:

Airport	4
Ring road	4
Suburbs	2

Goal:
Passengers reach airport in time.

Figure 38: The situation cards in the workshop version of the board game

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C.3.3 Transport Assignment Cards

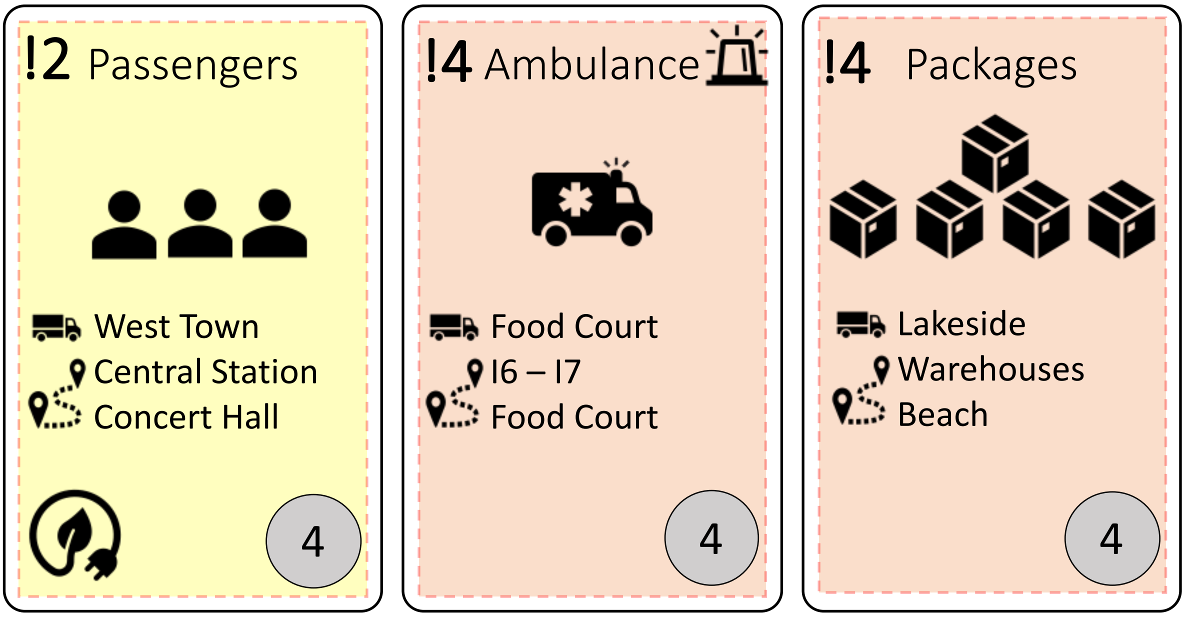

Figure 39: Examples of transport assignment cards in the board game

C.3.4 Player Instructions

Setup:

1. Select who will be the orchestrator (the others are referred to as players here)
2. Orchestrator should have this instruction card and lead the setup
3. Place board on table
4. Put traffic markers on default value (2) in all zones
5. Each player gets a set of pieces in a single colour:
   - Player token (to remember their colour)
   - One car
   - One package marker (cube) and one destination marker (cone). There are one extra of each of these, in case they get lost.
6. The orchestrator keeps all measure tokens easily accessible
7. Select which player will be first player in the first round. (After the first round, rotate each round who is first player)
8. Flip this page for instructions for the rounds

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Each round:

1. Draw situation card (we suggest to play them in order from 1 to 5)
2. Deal the situation assignment card, one for each player. The assignment cards should have the same number and colour as the situation card.
3. Update the board based on information on the situation card
4. Ask the players to put their car, pick-up location and destination on map.
   NB! In **situation 1**, only put car on map to illustrate that transport information is not yet shared.
   In **situation 2**, mention the visualisation effect of the shared information on the map
5. Coordinate and apply measures
    - Select measures to put on zones or map segments
    - Communicate with the players about the decisions
    - Tell how you coordinate with other orchestrators, e.g. to transfer traffic to other zones
    - Adjust traffic markers to take measures into account
6. Tell each player to takes their turn, i.e. to move and perform their assignments.
    - Each player has 8 time units to move. With regular traffic and no measures, this allows the player to move up to 8 spaces / network segments. Modify by traffic effects, speed limit, and priorities.
    - In case of problems for one or more players, take time to discuss how other measure choices would affect the outcome.
7. Clean-up – only traffic markers remain on board, reset to their default value (2)

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Measures for use in zones (or network segments on map)

Access control. Used for a zone or a network segment to restrict access to one or more types of vehicles / transports.

Effect: the traffic in the Zone or segment is redused to 2.

- Electrical / green vehicle.
- Bus and shuttle bus
- Dangerous / explosive goods
- Vehicle with high load factor (5+ passenger / packages)
- Emergency services
- Pick-up or delivery of passengers or packages

Priority. Use the above (as for access control) together with one of the following to specify who has priority and degree of priority:

+1 +2 ***Effect***: move 1 or 2 extra segments in zone.

Speed. Use for a zone to set a speed limit (traffic calming).

2t : 1
3t : 1 3t : 2

Effect: Use 2t of your 8t (time units) to move 1 space/network segment, use 3t to move 1, use 3t to move 2. (speed is 1/2, 1/3, 2/3 of normal)

Payment. Used for a zone to require payment for driving there.

: €1 : €2

Effect: Pay 1 or 2 coins to enter zone. Reduces traffic in zone by 1 or 2.

Measures for use on map and network segments

P + Park & Ride. Place on a parking spot on map. **Effect**: Make deliveries here, use bus to destination.

Place on segments from P&R and limit access to bus. **Effect**: traffic is 2 in segments (no penalty).

X-X Block network segment

One-way drive. **Effect**: redirect traffic.

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Annex D Standardisation details

There are a lot of standards in place (and some are being developed) that will support directly or indirectly the ORCHESTRA's main ideas. Even if most standards are developed to full fill specific domain-related goals for either the industry or the public sector – they often have an open-ended architecture that makes them generic.

In this Annex, a selection of ISO standards (from TC204 ITS and TC211 GIS) is listed. These standards are, for a large part, mirrored in CEN and form the basis for both manual and automated messaging between actors, roadside sensors and traffic management in the road sector. Many of them have connotations to standards in other domains – at least on the conceptual level.

The road sector is the most mature sector when it comes to ITS. This is due to the sheer number of actors and vehicles in Europe. While there are hundreds of millions of cars in Europe that need coordination - there are less than 100 000 vessels and planes operating in Europe. Thus, starting with an open list of standards for roads gives a good overview of the ecosystem in the cross-domain sector.

- ISO/TS 4398:2022: Intelligent transport systems — Guided transportation service planning data exchange
- ISO 13111-1:2017: Intelligent transport systems (ITS) — The use of personal ITS station to support ITS service provision for travellers — Part 1: General information and use case definitions
- ISO 13183:2012: Intelligent transport systems — Communications access for land mobiles (CALM) — Using broadcast communications
- ISO/TR 13185-1:2012: Intelligent transport systems — Vehicle interface for provisioning and support of ITS service
- ISO 14814:2006: Road transport and traffic telematics — Automatic vehicle and equipment identification
- ISO 14819-2:2021: Intelligent transport systems — Traffic and travel information messages via traffic message coding
- ISO 14827-1:2005: Transport information and control systems — Data interfaces between centres for transport information and control systems
- ISO 15638-5:2013: Intelligent transport systems — Framework for collaborative Telematics Applications for Regulated commercial freight Vehicle
- ISO 17185-1:2014: Intelligent transport systems — Public transport user information
- ISO/TS 17187:2019: Intelligent transport systems — Electronic information exchange to facilitate the movement of freight and its intermodal transfer — Governance rules to sustain electronic information exchange methods
- ISO 17419:2018: Intelligent transport systems — Cooperative systems
- ISO 17427-1:2018: Intelligent transport systems — Cooperative ITS
- ISO 17687:2007: Transport Information and Control Systems (TICS) — General fleet management and commercial freight operations — Data dictionary and message sets for electronic identification and monitoring of hazardous materials/dangerous goods transportation
- ISO/TS 18234-1:2013: Intelligent transport systems — Traffic and travel information via transport protocol experts group, generation 1 (TPEG1) binary data format
- ISO 20524-1:2020: Intelligent transport systems — Geographic Data Files (GDF) GDF5.1

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- ISO/TS 21219-1:2016: Intelligent transport systems — Traffic and travel information (TTI) via transport protocol experts group, generation 2 (TPEG2)
- ISO 19147:2015: Geographic information — Transfer Nodes
- ISO 19148:2021: Geographic information — Linear referencing

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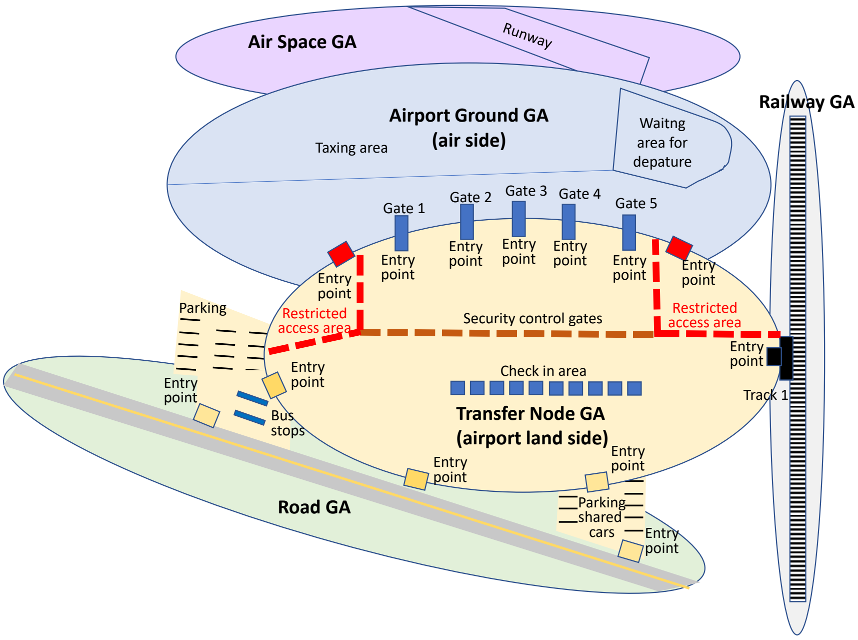
Annex E Examples from Living Labs

The Living Labs (LLs) are the Malpensa Airport in Milan, Italy and the Herøya Industrial Park in Norway. The LLs and the areas around them are divided into Governance Areas (GAs) with Traffic Orchestrators.

E.1 Malpensa Living Lab, Italy



The GAs are depicted in the picture above (from deliverable D5.3) and the stakeholders covering the roles are listed in the table below.

GA	Role	Real actor
Transfer Node GA (airport land side)	• Traffic Orchestrator	• SE
	• Network Manager	• SEA (check in desks, security gates, parking areas, bus stops, entries, area in general)
	• Network Users	• Travellers - People moving in the network • Vehicles used in the airport area
	• Transport Service Providers	• Airlines
	• Fleet Operators	• Airlines/Handlers (fleet of persons handling travellers) • Bus operators serving airport • Car sharing companies serving airport • …
Road GA	• Traffic Orchestrator	• ANAS
	• Network Manager	• ANAS
	• Network Users	• Buses • Shared cars • Private cars • …
	• Transport Service Providers	• NA
	• Fleet Operators	• Trenord (operator of buses replacing buses) • Other bus operators • Shared car operators • Owners of Private cars
Railway GA (Malpensa Express)	• Traffic Orchestrator	• Trenord
	• Network Manager	• Ferrovienord
	• Network Users	• Trains

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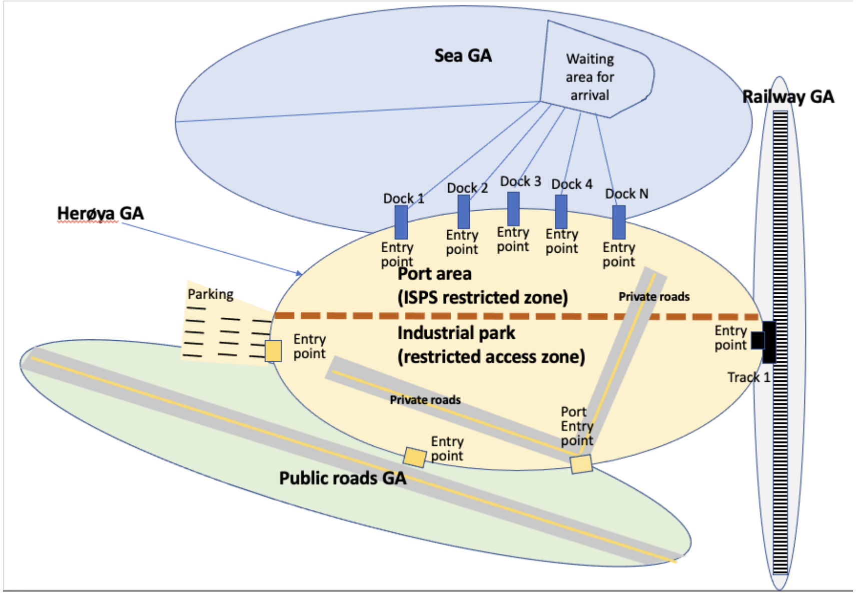
	• Transport Service Providers	• Trenord
	• Fleet Operators	• Trenord
Air space GA Airport Ground GA	• Traffic Orchestrator	• ENAV
	• Network Manager	• Not defined
	• Network Users	• Planes
	• Transport Service Providers	• Airlines
	• Fleet Operators	• Airlines

E.2 Herøya Living Lab, Norway



The GAs are depicted in the picture above (from deliverable D5.3) and the stakeholders covering the roles are listed in the table below.

GA	Role	Real actor
Industrial Park	• Traffic Orchestrator	• Herøya Industrial Park
	• Network Manager	• Herøya Industrial Park
	• Network Users	• Trucks • CAV
	• Transport Service Providers	• Bilfinger • Applied Autonomy (CAV)
	• Fleet Operators	• Truck operators • Applied Autonomy (CAV)
Road	• Traffic Orchestrator	• Norwegian Public Road Administrator (NPRA)
	• Network Manager	• Norwegian Public Road Administrator (NPRA)
	• Network Users	• Trucks • Private cars • …
	• Transport Service Providers	• NA
	• Fleet Operators	• Truck operators • Owners of Private cars
Train	• Traffic Orchestrator	• Bane Nor
	• Network Manager	• Bane Nor
	• Network Users	• Trains
	• Transport Service Providers	• Train operators
	• Fleet Operators	• Train operators
Sea	• Traffic Orchestrator	• Norwegian Coastal Administration (NCA)

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	• Network Manager	• Norwegian Coastal Administration (NCA)
	• Network Users	• Vessels • Self-driving vessel
	• Transport Service Providers	• Misc. Forwarders
	• Fleet Operators	• Vessel operators • Yara (self-driving vessel)

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 953618. This document reflects only the author's view and the Agency is not responsible for any use that may be made of the information it contains.

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