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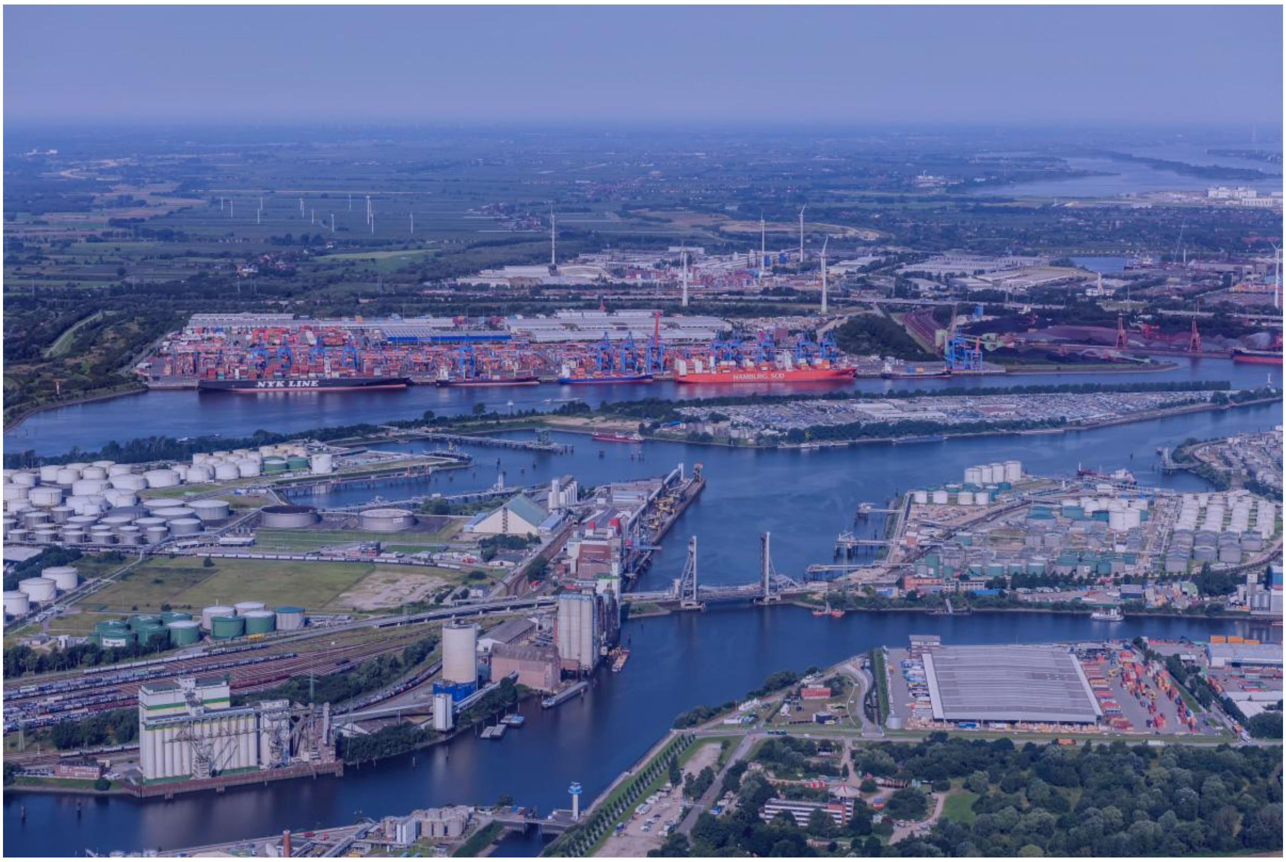
A LEAP TOWARDS SAE L4 AUTOMATED DRIVING FEATURES

A leap towards SAE L4 automated driving features

D4.4 Collaborative CCAM Fleet- and Traffic Management

31st March 2025



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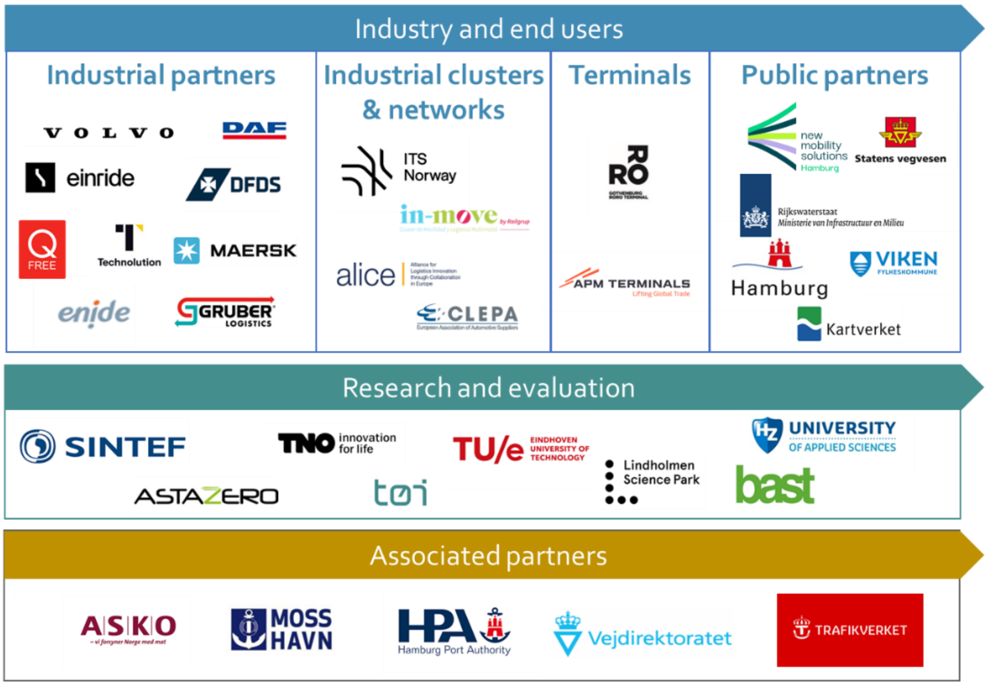

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Terms and abbreviations

B2B	Business to Business
CAV	Connected and Automated Vehicle
CCAM	Connected, Cooperative and Automated Mobility
C-ITS	Cooperative Intelligent Transport Systems
DATEXII	DATEXII traffic information protocol
DVM-Exchange	DVM-Exchange traffic information protocol
ETA	Estimated Time of Arrival
FCD	Floating Car Data
ITS	Intelligent Transport Systems
KPI	Key Performance Indicator
L4	SAE level 4
MTM	Multimodal Traffic Management
MTME	Multimodal Traffic Management Ecosystem
NAPCORE	National Access Point Coordination Organisation for Europe
OCIT	OCIT traffic information protocol
OEM	Original Equipment Manufacturer
PDI	Physical Digital Infrastructure
PMA	Polycentric Multimodal Architecture
ROI	Return on Investment
RSMP	RSMP traffic information protocol
RTTI	Real-Time Traffic Information
SRTI	Safety-Related Traffic Information
TLC	Traffic Light Controller
TM1.0	Traffic Management 1.0
TM2.0	Traffic Management 2.0
TMC	Traffic Management Center
TMS	Transport Management System
UVAR	Urban Vehicle Access Regulation
VMS	Variable Message Sign

Executive Summary

Over recent years the increase in connectivity capabilities in the domain of traffic management has shifted from a mainly public and top-down form of traffic management (TM1.0) to new forms of public-private collaboration between public road operators and private service providers, known as Traffic Management 2.0 (TM2.0). This concept of public-private interactive traffic management has developed towards a framework allowing these road operators and service providers to exchange data as well as deploying coordinated mobility management strategies. For road operators this brought improved means of sharing information to road users, and for service providers this brought enriched data to improve their commercial navigation services for their clients. This concept of TM2.0 shows clear potential in enabling improved collaboration between public road operators and logistics stakeholders in the MODI context of deploying CCAM L4 Freight vehicles on public roads, however it also requires an extension for use in this different context. This report explores that extension by understanding which stakeholders should be involved in these new forms of win-win collaboration, what potential benefits are there to be gained, and how these benefits could be achieved in practice. The focus here lies on public road traffic management, although the confined area is addressed for optimising last-mile logistics and mobility surrounding private confined areas. These findings are aggregated into a functional architecture for such public-private interactive traffic management collaborations, as well as a related high-level technical architecture to implement such collaborations. In doing so, this report complements the work of MODI on the optimal design of physical digital infrastructure for CCAM vehicle deployment is defined.

Three main roles are seen as relevant for TM2.0 collaboration schemes:

- **Traffic Orchestration.** This role refers to public road authorities responsible for safety and optimisation of the public road network infrastructure.
- **Transport Management.** This role refers to private logistics stakeholders responsible for optimising transport operations of one or more freight vehicles on public roads and within confined areas.
- **Confined Area Management.** This role is a sub-set of Traffic Orchestration with the main difference that this refers to private entities responsible for traffic orchestration upon private (logistics) terrain such as terminals and warehouses.

Involvement of stakeholders within and beyond the MODI consortium that fit one of these roles identified several potential benefits that these collaboration forms could enable. In total 13 potential benefits are identified. Whilst many of them had to do with the additional competencies that vehicle automation will bring, several of them already could be achieved in an earlier stage where vehicle and logistics digitalisation would be improved without full automation being a requirement. In many cases the full automation of vehicles could be seen as extending the benefits that digitisation brought.

In order to understand how these potential benefits could be achieved in practice, four use cases are described that would bring those benefits to the stakeholders involved:

1) *Day ahead exchange of road infrastructure information and anticipated freight movement*
2) *Same day exchange of road infrastructure information and anticipated freight movement*
3) *Last-mile interaction between traffic orchestrator and confined area management*
4) *Target-group based and diversified traffic management.*

The functional interrelations of the roles described in these use cases have been aggregated into one comprehensive **functional architecture** showing which roles should exchange which information in order to achieve these potential mutual benefits. In order to provide the first steppingstones in implementing such collaborative schemes a **high-level technical architecture** is provided showing how first deployment steps could be taken.

Conclusions from the work performed on collaborative public-private traffic management on public roads are that in exploring these collaborative frameworks, three main roles are seen as most relevant in making this work: the Traffic Orchestrator, the Transport Manager and the Confined Area Operator as a subset of Traffic Orchestration. Moreover, the win-win benefits of these collaborative schemes will become apparent far before actual widely deployed L4 automated freight vehicles are in operations as these are mostly established by further digitalisation in logistics operations and improving the ability to automatically interpret and process available logistics operations data. It also became apparent that most traffic orchestrators have only limited interest in receiving data from logistics stakeholders as traffic orchestrators foresee a lack of ability to act upon this information. The traffic orchestrator places emphasis on expanding its own capabilities in sharing data to logistics stakeholders so that planning and operations can be effectively aligned with public road conditions.

Recommendations from the findings in this deliverable are to perform further research on how traffic orchestrators and logistics stakeholders should further improve their strategy effectiveness by use of data sharing. Moreover, research should focus on exploring how innovative forms of public-private data exchange can be fitted into existing legislative frameworks or what is required for these collaborations to work for public entities. Finally, it is recommended to explore further how internationally acknowledged data standards (e.g. DATEX II) could serve as mutual bases for public and private stakeholders throughout the European Union to share traffic and transport data for both international and local collaboration forms.

The findings from this report constitute first steps in bringing traffic road network optimisation considerations into the final route command for a CCAM freight vehicle, and vice versa bring understanding to logistics stakeholders in how their strategic goals could be achieved through increased collaboration with road authorities.

1 Introduction

1.1 Project summary

MODI Ambitions: A leap towards SAE L4 automated driving features

The MODI project aims to accelerate the introduction of highly automated freight vehicles through demonstrations and by overcoming barriers to the rollout of automated transport systems and solutions in logistics. The logistics corridor from the Netherlands to Norway has been chosen for demonstration activities as the Netherlands, Germany, Denmark, Sweden, and Norway are expected to be among the first movers to implement fully automated vehicles in Europe.

MODI comprises five use cases, each describing a part of the logistics chain in confined areas and on public roads. It identifies what is already possible on an automated driving level without human interaction and what is yet to be developed. The MODI objectives are to:

- Implement new technology within the CCAM spectrum.
- Define recommendations for the design of physical and digital infrastructure.
- Demonstrate viable business models for connected and automated logistics.
- Perform technical and socio-economic impact assessments.

Major challenges include regulatory aspects and standardisation, border crossings, access control, charging, coordination with automated guided vehicles, loading/unloading and handover from the public to confined areas.

MODI test sites include a CCAM test corridor from Rotterdam to Oslo with specific use cases at Rotterdam (The Netherlands), Hamburg (Germany), Gothenburg (Sweden), and Moss (Norway).

The ambition of MODI is to take automated driving in Europe to the next level by demonstrating complex real-life CCAM use cases while:

- Showing the local, national, and international context of freight transport with CCAM vehicles, both in confined areas and on public roads.
- Cooperating and co-creating with logistics companies, road operators, vehicle OEMs, providers of physical and digital infrastructure and other stakeholders to bridge the gap between R&D and market readiness.
- L4 solutions for long-distance operational design domains.
- Creating innovative business models and improved business models across the logistics chain.
- Proving that the technology can soon deliver on promised benefits at relatively high speeds and medium traffic complexity, including a coordinated CCAM system to support smart traffic management.
- Paving the way to enable highly automatic transport on important corridors, connecting main ports across Europe.
- Accelerating CCAM in Europe by setting examples of business-wise CCAM integration in logistics.

1.2 Aim of the deliverable

The aim of this deliverable named *D4.4 Collaborative CCAM Fleet- and Traffic Management* is to present a comprehensive report on why and how the concept of interactive public-private traffic management known as Traffic Management 2.0 (TM2.0) could be extended for usability in the context of higher penetration of L4+ CCAM freight vehicles on European road infrastructure. This deliverable reflects on the current understanding of TM2.0, its limitations in the context of CCAM vehicle fleets, and proposes the extension of the concept in a functional architecture and related high-level technical architecture.

1.3 Relation to MODI output

The deliverable complements the work within the MODI project on defining a Coordinated CCAM interface and optimal physical, digital infrastructure (PDI). With a focus on public road use, this deliverable particularly builds upon findings within MODI on PDI for public road (D4.2) and PDI for confined areas (D4.3), extending the gained knowledge on the functional/technical architectures required for operating (groups of) individual L4 CCAM freight vehicles on public roads with the higher level functional/technical architectures on aligning the operations of large fleets of CCAM (freight) vehicles with the goals and means for road operators in traffic management and road network optimisation. The alignment of the proposed functional and high-level technical architecture with findings from MODI work on sub system development (workpackage 3) and the Coordinated CCAM interface (workpackage 4) is further described in chapter 4.

1.4 Structure of the report

This report starts with exploring the concept of Traffic Management 2.0, the potential of this concept for large-scale deployment of L4 CCAM freight vehicles in Europe, as well as the need for extending this concept for use in the context of automated freight operations. These topics are addressed in chapter 2 and 3. The report continues by describing how the work in this report contributes and builds upon other work, concepts and architectures within the MODI project in chapter 4. Chapter 5 addresses the identification of relevant roles and stakeholders in these collaborative schemes, and how these relate to the roles within MODI and the MODI use cases. In Chapter 6 the potential benefits of extended TM2.0 collaboration are identified, and several collaborative schemes are designed in which these benefits can be achieved. Eventually these schemes are aggregated into the overarching functional architecture in chapter 7, and the related high-level technical architecture in chapter 8. The main conclusions are described in chapter 9, as well as the discussion and recommendations.

2 Traffic Management 2.0

This chapter describes the relevance and development of interactive public private traffic management (Traffic management 2.0) in Europe, how it is reflected in national and European legislations, and its limitations and opportunities in the light of increased penetration of CCAM freight vehicles on public roads.

2.1 The development towards interactive public-private traffic management

For decades the increasing number of vehicles on public roads have brought a strong need for managing this traffic across our road infrastructure. At individual crossings and intersections, road operators have managed traffic through use of traffic priority policies, and communicated with drivers through means such as, traffic wardens, traffic lights and road signs. As soon as the amount of vehicles on public roads started to lead to congestion issues, road operators extended this traffic management strategies focused on individual intersections to managing and optimising groups of intersections, initially as corridors, and eventually towards managing and optimising road networks. Especially in urban areas road authorities have over the years shaped local, regional and national traffic management strategies dictating static hierarchies in road types (e.g. highways, main roads, urban roads), modalities (e.g. busses, cars, pedestrians) and vehicles (e.g. emergency vehicles, busses). These strategies are focused on traffic safety as well as 'collective' traffic management: aligning traffic flows with road capacities, thereby preventing and reducing congestion issues. The real-time traffic state is monitored and acted upon by the road authorities and incidents/congestion information is shared. The related traffic management strategies communicate directly from several road authority information means such as static and dynamic signs, Variable Message Signs (VMS's), radio, and traffic lights towards vehicle drivers. These drivers interpret this information and make a decision if and how to follow the advice. This direct, mainly public and mainly top-down form in traffic management as shown in figure 1, could be called *Traffic Management 1.0*.

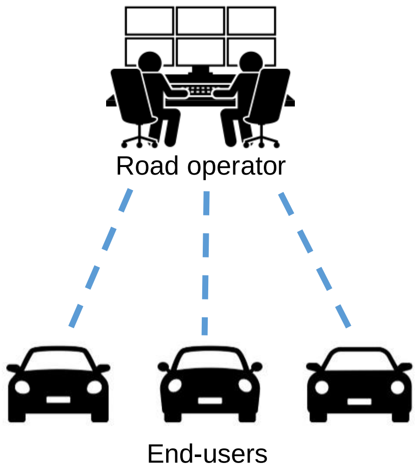

Figure 1: Traffic Management 1.0

With increased communication technologies, new ways of communicating with these drivers have emerged, as well as new business models that have led to new (private) stakeholders becoming involved in collective traffic management. Drivers are still receiving direct communication from road authorities, but also use in-car navigation services either integrated in vehicles or through use of smartphones. This leads to fundamental changes in traffic management operations, some of which (Two emerging risks, and two emerging opportunities) are listed below.

1) Next to road authority traffic management information, **drivers receive traffic information from a new source,** from either a private navigation service provider or their vehicle manufacturer on-board navigation service. These navigation advices are primarily based on providing the fastest route for the individual driver from A to B, and incorporate real-time mobility information derived from other service users ('floating-car data'). This 'individual optimal' route information sometimes differs from information received from the responsible

road authorities, leading to an emerging risk of conflicting information, unpredictable driver behaviour and decreasing follow-up rates for road authority traffic advice.

2) The difference between an individual navigation optimum and the collective mobility network optimum leads to the emerging risk of an **ongoing clash between effective strategies from navigation providers and road authorities**. For example, if an incident occurs on a highway in an urban area, the road authorities started rerouting traffic across other highways to avoid an urban gridlock, whilst navigation service algorithms start looking for alternative routes through the city to accommodate individual users in the area.
3) **Navigation services are able to differentiate their navigation advice for each individual user**, whilst the 'public' communication means of road authorities are only able to communicate a one-size-fits-all message for all drivers. This means an emerging opportunity in the ability to provide different mobility strategies to different kinds of users, in a fit-for-purpose manner, and largely based upon data models and -algorithms.
4) Due to increased numbers of navigation service users, and the technical ability for these services to aggregate vast amounts of real-time mobility data from their users, **road authorities have gained the emerging opportunity of a new source of real-time traffic information,** further enriching their own sensing information. Now road authorities have a wider view on the mobility network then merely the locations where traffic sensors were installed, enabling real-time traffic monitoring in more regional/remote roads as well. Vice versa, **through sharing information, navigation providers could receive fast and reliable information** on active traffic measures and their duration, as well as incident information, active traffic circulation plans, roadworks, etc, further improving their private services.

Several public and private European mobility stakeholders started to understand the fact that collaboration and continuous alignment of strategic, tactical and operational decisions between (largely public) road authorities and private navigation providers could have the potential to solve the challenges of conflicting traffic management strategies and conflicting information for end-users, whilst enabling the potential of more reliable, effective and tailor-made navigation services as well as collective traffic management strategies. This public-private collaboration scheme (Figure 2) in which mobility stakeholders collaborate to provide end-users with reliable and effective mobility measures became known as *Traffic Management 2.0*.

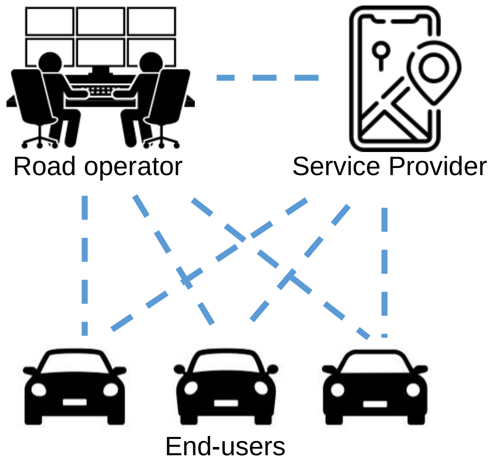

Figure 2: Traffic Management 2.0

The concept of Traffic Management 2.0 has since been researched, tested and implemented in several ways and scopes. For example, the ERTICO partnership established the TM2.0 innovation platform [1], consisting of public and private stakeholders discussing, researching and validating several key enablers of effective TM2.0 collaboration such as governance structures [2], collaborative business models [3], required data standards [4], etc. Several innovation projects incorporated the concept in its deployments such as the CEF Socrates 2.0 project [5], implementing several TM2.0 schemes in Amsterdam, Antwerp, Copenhagen and München, as well as the Austrian EVIS project [6], the several Scandinavian Nordicway projects [7], the Dutch Amsterdam Practical Trials [8], and more.

These developments and findings led to establishing different 'collaboration levels' ranging from relatively simple collaboration forms such as merely exchanging information, to more complex forms of hands-on joint traffic management with clear expectations and mutual dependencies. A lower-level collaboration form is easier to shape as it does not involve much governance and/or contractual agreements, however it also brings the lowest level of additional potential. The higher-level collaboration forms are more complex in terms of required architecture, governance, contractual agreements and active collaboration, however it also brings the highest potential in collaborative traffic management. These collaboration models are summarised in figure 3, and shortly described below.

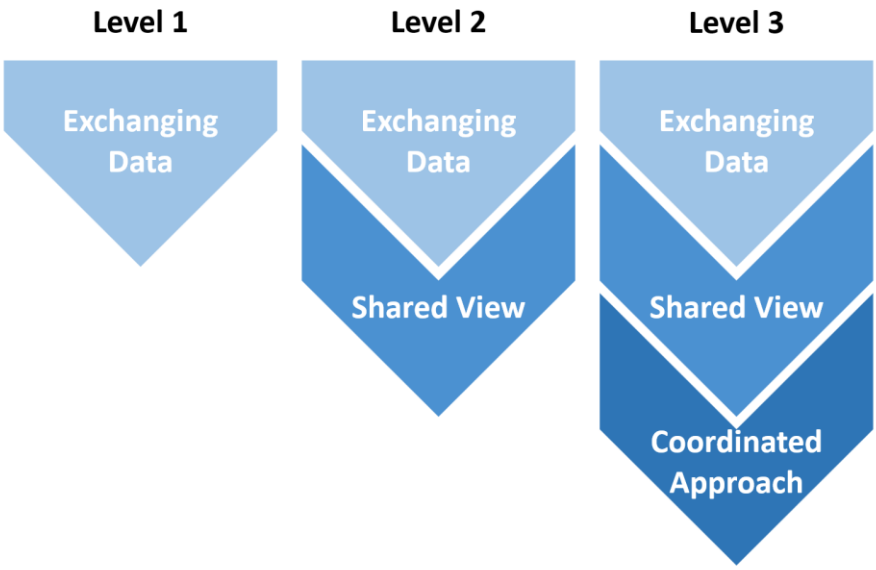

Figure 3: TM2.0 collaboration levels

Collaboration Level 1: In this collaboration level, only information is exchanged between the partners. What to do with that information is totally up to the decision of these stakeholders. They are likely to have more information than before and they can use that to optimise their service. There are no agreements on how other parties are to act upon shared information, and thus the potential in this collaboration level is merely being 'aware' of what other stakeholders are seeing and possibly doing, and not particularly in requesting or expecting certain behaviour by other stakeholders in return.

Collaboration Level 2: In this collaboration level information is shared, and from that information a common picture of the current or expected situation is derived. Partners have the same „picture" in front of them, however what they do with this information is for each partner to decide for itself. The additional potential on top of collaboration level 1 lies in the merging of information, and all acting upon the same joint truth. This implies not only technical data merging, but also agreements on problem definitions and KPI's (e.g. at what traffic speed/duration/volume do we see congestion as problematic and worth acting upon?) This collaboration level 2 also entails validating your own information by referencing it against information from others. For example, if the road authorities have activated a road closure, but service providers still see moving traffic across the assumed road closure, this might mean system failures, information errors or at least unsafe local situations.

Collaboration Level 3: In this level information is shared, and from that information a common picture of the current situation is developed. Partners have the same "picture" in front of them, and in this case, they actually coordinate what actions are taken on both public and private side. For example, if road authorities send out a reroute advice for users due to a traffic incident, there is a request (and incentive) towards navigation service providers to also start rerouting (shares of) service users across the same alternative route. The idea is that stakeholders can strengthen and complement each other instead of sending contradictory messages. And they can have positive impact on each other's' (and/or common) goals and KPIs in a coordinated manner. Also, in this case the cooperation can be translated into an impact driven business model. The use of the term 'coordinated approach' is not to be confused with 'coordinated' CCAM as main aim for the whole MODI project. In this context the 'coordinated' aspect refers to public road operators and private entities jointly taking action when operational issues occur at either side, and having contractual agreements on how to act in case these issues arise.

These collaboration levels and related implementations across Europe are designed to find suitable balance between collaboration complexity and expected outcome for solving traffic management challenges. The work on reducing the main risks (conflicting information to the driver and conflicting traffic management strategies) and exploiting the main potential (Enriched data and Differentiate traffic measures to (groups of) individual drivers.

3 Extending the TM2.0 concept for use in the context of L4 freight vehicle operations.

The research work performed in the context of TM2.0 have shown its use especially in the context of manually driven private vehicles. However, especially in the MODI context of automated freight vehicles, the TM2.0 concept shows several clear limitations that require further work. Work on TM 2.0 has so far primarily revolved around (1) sharing of insights and data, (2) aligning information that drivers and mobility users receive from multiple public and private stakeholders, and (3) aligning mobility and traffic management strategies. Both the emphasis on freight and logistics instead of passenger cars, as well as the focus on higher levels of CCAM instead of merely human-driven vehicles will show challenges. The real-time machine-to-machine communication character of a new ecosystem such as scaled automated freight vehicles however requires rethinking of these subjects, as well as increased requirements.

For example, where TM2.0 data sharing and alignment previously roughly revolved around road authorities, navigation service providers and end users, *new stakeholders will become involved* for the operation of automated freight vehicles such as fleet managers, traffic management software providers, vehicle manufacturers, vehicle owners, cargo owners, etc. Work has been performed in exploring TM2.0 potential in the field of logistics by the FENIX [9] and ORCHESTRA [10] projects which can be used as basis within this MODI task. These new, and yet partly unknown character of stakeholders changes the business cases and contexts of stakeholders involved in traffic management. In line with findings on user requirements as described in MODI deliverable D1.1, the complex interactions between existing and emerging stakeholder groups in the context of automated freight are not understood yet to a sufficient level, and should be further explored in order to align strategies in further CCAM vehicle deployment [11].

Moreover, where TM2.0 information alignment previously revolved around a driver receiving comparable advice from its navigation service and the road authorities, all this *alignment will now have to be fitted into one route* that is requested/commanded to these freight vehicles as there is no driver in the loop anymore to 'interpret' possible discrepancies. This brings the question: how does this route-command come into existence, who is involved in designing and updating the route, and how are individual and 'collective' traffic management goals incorporated into the many different routes that these automated vehicles drive.

And finally, the alignment of mobility and traffic management strategies will become more complex as the number and character of stakeholders (and thus corresponding strategies) will increase and widen, and the public-private interaction will increasingly reach *a highly competitive commercial domain* when it comes to freight and logistics.

In the light of L4 Freight vehicles, level one collaboration between Traffic Management Centres (TMCs) and L4 freight vehicle logistics stakeholders will be a basic requirement, as for continuous and reliable operations on highways the vehicle will have to be fed with beyond the line of sight information (e.g. the 'awareness driving' deployment phase as defined in the Car 2 Car consortium) [12]. This provides the vehicle with awareness of what to expect and therefore the capability to anticipate certain traffic situations, an essential capability for a heavy dury freight vehicle driving at higher speeds. However, collaboration levels 2 and 3 are yet unexplored in their usability for both traffic management and logistics fleet management, although showing a conceptual resemblance to the Car 2 Car consortium defined 'Sensing driving' and 'cooperative driving' deployment phases, as shown in figure 4. In these phases, automated vehicles cooperate closer with each other as the deployment level grows. This also brings the need for multi-stakeholder collaboration, balancing objectives, etc. Exploring the need and potential of these two phases, and shaping the functional architecture of that collaboration is strongly needed.

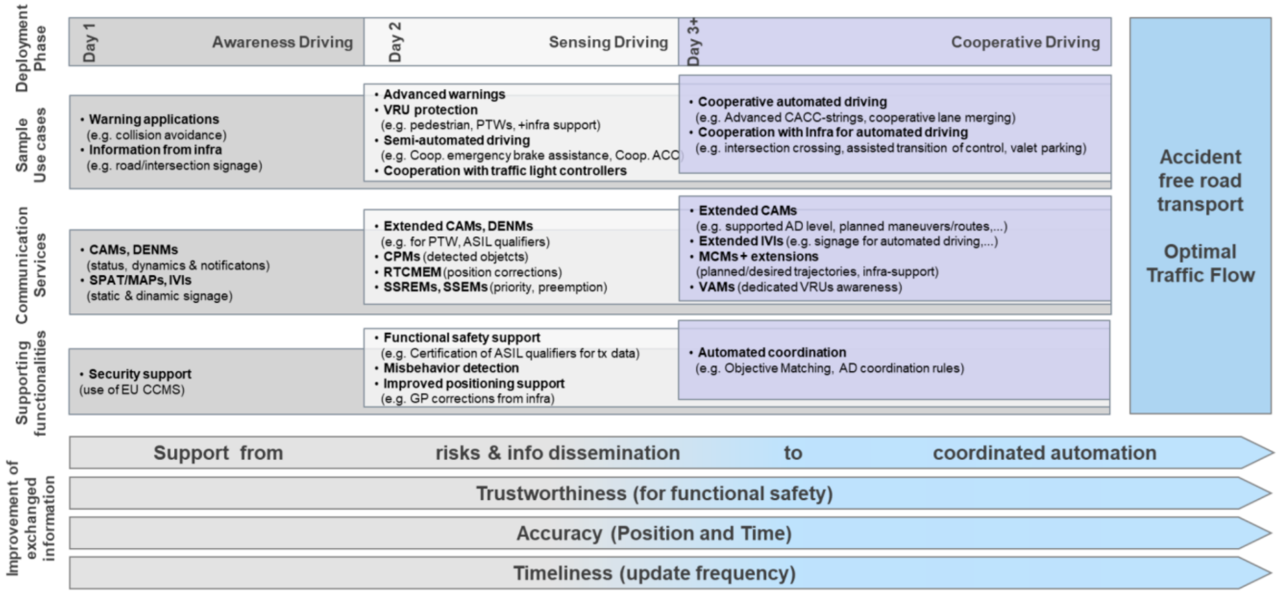

Figure 4: CCAM deployment phases as defined in the Car 2 Car consortium

The MODI project will demonstrate CCAM deployment of Freight vehicles especially in the Awareness Driving and Sensing Driving context, having individual vehicles integrated into several operational environments. Adequate deployment of TM2.0 for automated freight vehicles will enhance the mutual understanding that stakeholders need in the context of day 3+ Cooperative Driving, and enable taking coordinated and mutually beneficial actions across the stakeholder chain surrounding these CCAM freight vehicles.

4 Alignment within the MODI project

By extending the TM2.0 framework for use in the context of L4 CCAM freight vehicle operations this complements the other work performed within the MODI project on designing Physical and Digital Infrastructure. Examples are the MODI user requirements, MODI Physical and Digital infrastructure and CCAM validated interface, the understanding of relevant users and their projected responsibilities and strategies in the context of CCAM deployment. Within the MODI D3.2 report on automation requirements [13] the need for understanding the role of collaboration between several stakeholders involved in guiding and managing automated freight vehicles is shown in the figure 5, representing the CCAM vehicle and its logistics' context.

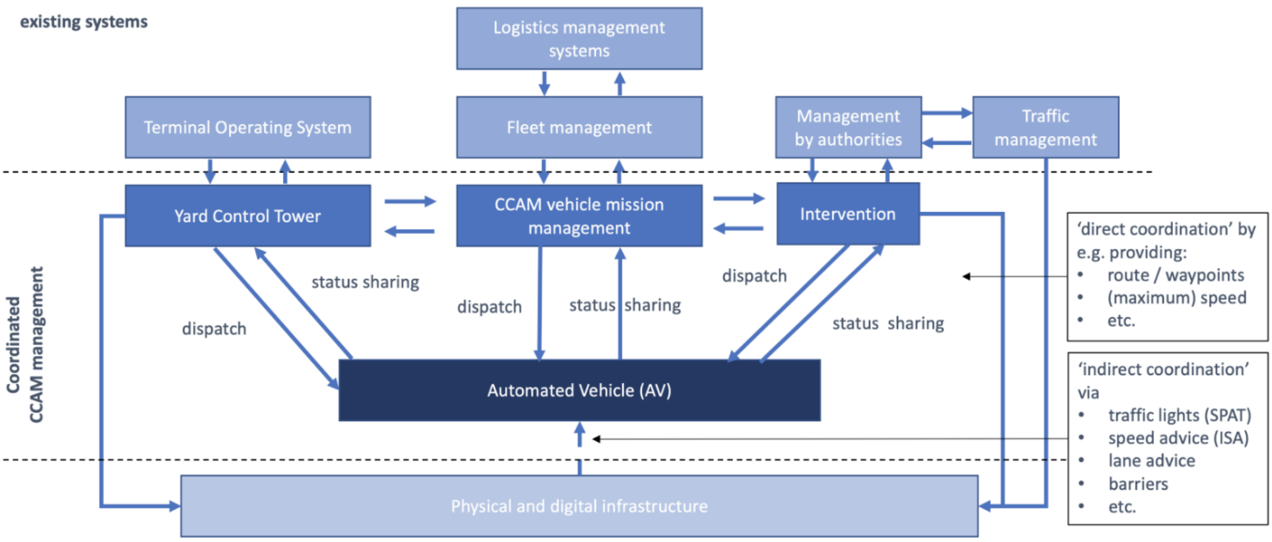

Figure 5: CCAM vehicle and its context from MODI report on automation requirements (D3.2)

On the upper level of the picture, the several relevant stakeholders are shown representing how different organisations with different responsibilities are all involved in how an automated vehicle can eventually be enabled to drive automatically for logistic purposes. A *terminal operator system*, using a so-called Yard control tower, is responsible for optimising confined area operations in which this automated vehicle is one of many actors. A *logistics operator*, using a logistics management system, is responsible for optimising its own transport planning and operations on both public and private terrain for one or more vehicles under its operational scope. And *traffic management authorities* are responsible for safety and efficiency of the public road network, in which these automated vehicles represent one of many road users. These different entities should somehow collaborate to at least avoid conflicting management strategies, and hopefully mutually optimise its own operations. These forms of communication are represented in this figure in two ways. First, the operational exchange of data is shown in the data streams between yard control towers, CCAM vehicle mission management, and authorities' interventions. Second, any tactical or strategic collaboration or data exchange between these entities can be seen of the wider Physical and Digital infrastructure as shown in the box at the bottom of the picture.

MODI Deliverable 4.1 on the Validated interface for Coordinated CCAM [14] describes on a generic level an architecture through which CCAM vehicles communicate with surrounding infrastructure. In this architecture, shown in figure 6, interfaces are defined through which these several stakeholders can communicate with the CCAM vehicle.

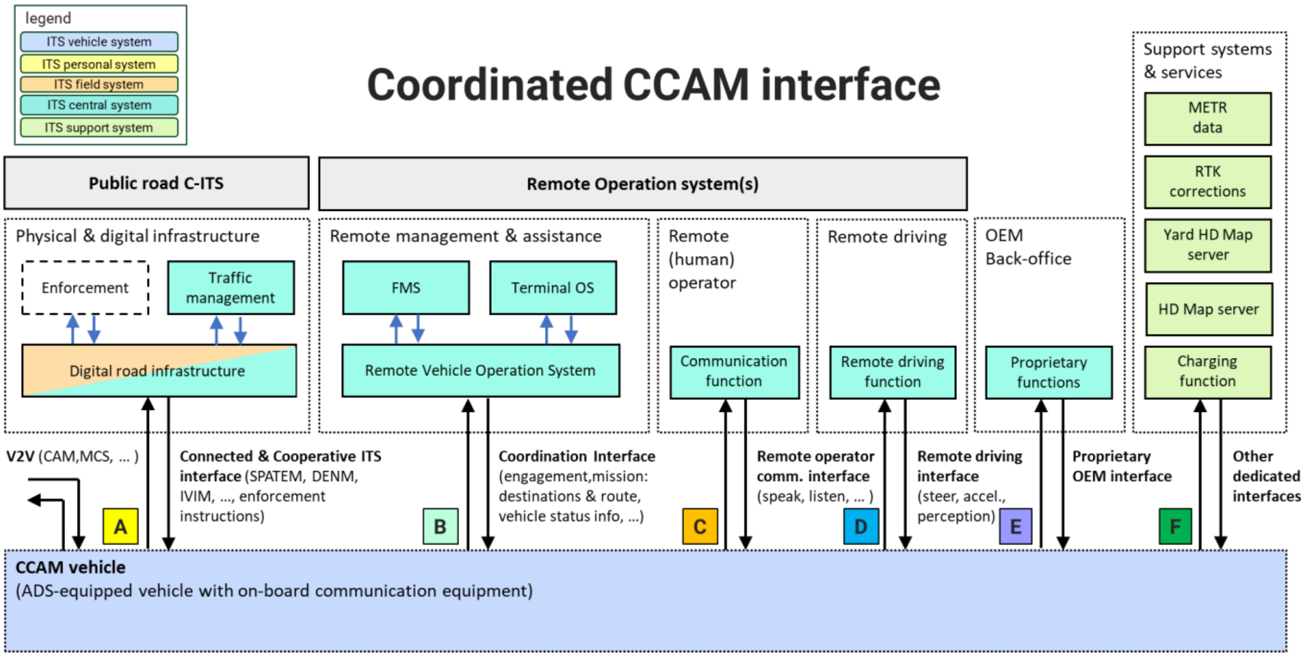

Figure 6: MODI high-level generic system architecture for defining the coordinated CCAM interface as shown MODI report on validated interface for coordinated CCAM (D4.1)

In this system architecture for the coordinated CCAM interface again these entities of a terminal operator (by use of a terminal operation system), a logistics operator (by use of a Fleet Management System, FMS) and a traffic management authority (by use of public road C-ITS and traffic management) are depicted in their individual means of communicating with the CCAM vehicle through interfaces A and B.

This report on collaborative public private traffic management in the context of CCAM freight vehicles extends on the work described in MODI report D4.1 on the optimal design for physical and digital infrastructure by exploring what these entities represent in terms of responsibilities, missions and strategies, and how these collaborations between these entities will on the one hand avoid conflicting management strategies and on the other hand enable mutually beneficial collaboration schemes in the context of operational CCAM freight vehicles.

5 Collaborative traffic management framework

5.1 Identification of roles and actors in collaborative CCAM Fleet- and traffic-management

In order to understand the stakeholders involved in the collaborative traffic management framework in both the traffic management and logistics fleet management domains, their roles and responsibilities are identified. These are roles that often are present in different collaborative schemes, but might be performed by different actors in accordance with the local context. Within the Orchestra project [15], several roles in traffic management orchestration were identified, which are described below.

The Polycentric Multimodal Architecture (PMA) is to be considered as a reference architecture for Multimodal Traffic Management (MTM) [10]. Efficient traffic management across modes and networks require the involvement and collaboration of many actors and systems that interact as part of an ecosystem (Multimodal Traffic Management Ecosystem – MTME). This is outlined in Figure 7.

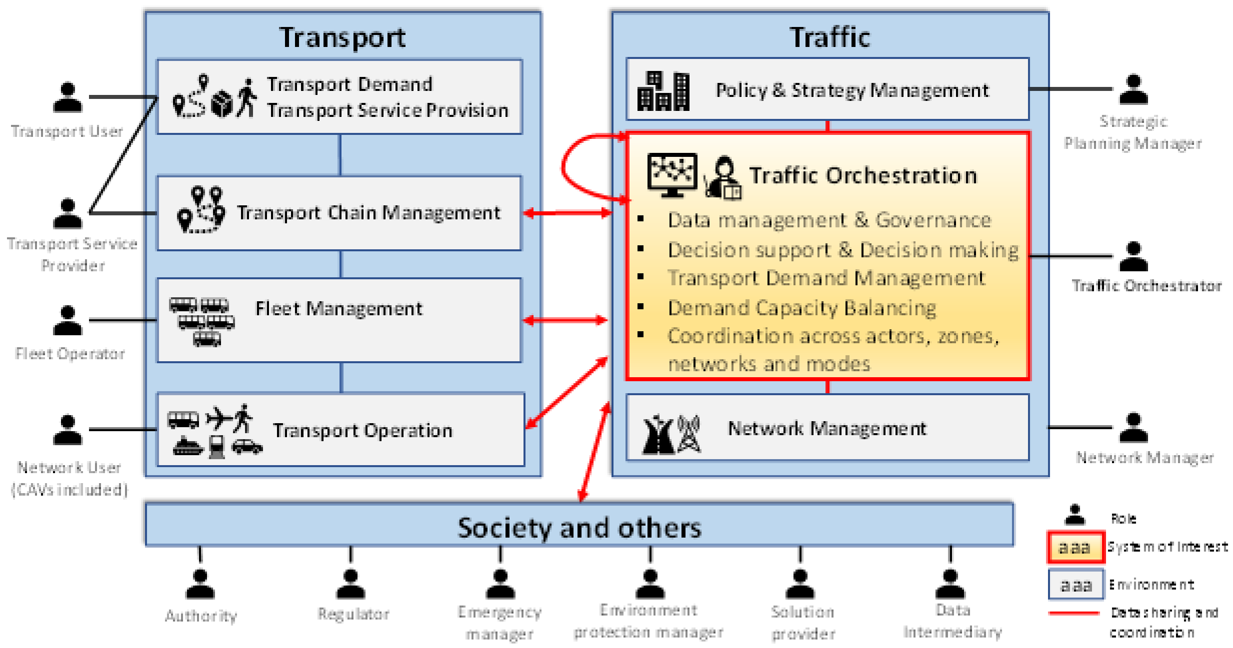

Figure 7: Multimodal Traffic Management Ecosystem (MTME) with System of Interest in its environment

It is a system of systems working together to facilitate MTM. The ecosystem has three main parts – *Transport*, *Traffic* and *Society and others*. These parts are further described below.

The stakeholder archetypes involved in MTME are depicted outside the main parts of the ecosystem. They represent generic *roles.* The *roles* represent non-overlapping responsibilities, and in the real-world one *actor* may fulfil more than one *role*. In addition, there will be many *actors* with the same *role*. These actors can represent different companies, modes, vehicles/vessels, countries and governance levels (international, European, national, regional, city, private area, etc.).

Transport

Transport, shown in the upper left of Figure 7, is about the transport of persons and/or goods from a start location to a destination by means of one or more transport legs, within one or more transport networks. Fulfilment of transport operations are according to the following roles:

- **Transport Users** define *transport demands*. They book services from a Transport Service Provider and follow up the execution of the service. This involves both mobility of people and goods.
- **Transport Service Providers** provides transport services to Transport Users. Ideally, multimodal transport and door-to-door transport may be provided as one service. Transport Service Providers can also do *transport chain management* where the transport chains may comprise legs involving other Transport Service Providers in a hierarchy.
- **Fleet Operators** do fleet management. They optimise the use of resources, including personnel and vehicles/vessels, to accomplish transport operations. One operation may fulfil requests from one or more Transport Service Providers and transport demands of one or more Transport Users.
- **Network Users** carry out transport operations, utilising resources of the relevant transport network. Examples include passenger cars, vans, trucks, buses, trains, airplanes, vessels, bikes and pedestrians. In the MODI case, the Network User may be a fully automated L4 CCAM vehicle or have an operator onboard (L2). The transport operation carried out by the Network User may be a private journey, or an operation supervised by a Fleet Operator.

To optimise its operations according to actual and predicted traffic situation, both Transport Service Providers, Fleet Operators and Network Users need to exchange information with transport orchestrators. This should preferable be done by digital means.

Traffic

Traffic, shown in the upper right of Figure 7, is the negative consequence of the transport demand and operations. The aim of traffic orchestration is to influence, support and manage traffic to make transport more resilient, safe and efficient, including minimising negative impacts on the planet, environment and society. Note that the traffic part of MTME comprises parallel subsystems covering the different transport networks and modes. The roles relevant for the traffic part are:

- **Strategic Planning Managers** are those responsible for establishing transport policies and related transport strategies. This planning happens at different governance levels (e.g., international, European, national, regional and local). Strategic planning also involves establishment of collaboration and coordination with other networks and modes, and defining procedures and technologies to use.
- **Traffic Orchestrators** aim to arrange for transport in compliance with the directions provided by Strategic Planning Managers. The Traffic Orchestrators implement measures towards Transport Service Providers, Fleet Operators and Network Users. The traffic flow and the use of the transport network are guided, influenced or controlled to arrange for safety, efficiency and optimal utilisation of the network. This also includes smooth, efficient, and safe inclusion of Connected and automated vehicles/vessels (CAVs) in the traffic.
- **Network Managers** plan and operate transport networks. They are responsible for the Physical and Digital Infrastructure (PDI) in their respective networks. This includes the collection, management and sharing of data relevant for traffic orchestration.

Society and Others

Society and others, as shown at the bottom of Figure 7, comprises other domains and actors that influences, or are influenced by the MTME. Roles associated with this includes **Authorities** and **Regulators**, **Emergency managers**, **Environment protection managers** and **Solution providers**. The **Data Intermediary** role is fulfilled by actors providing federated services for data discover, data sharing and data governance. This should be in accordance with the Data Governance Act, and the strategy of the EU Commission on common European data spaces.

Despite real world traffic management is conducted by a range of traffic orchestrators and network managers with different geographical scopes, types of road networks, funding (both public and private), and responsibilities, three main roles are almost always performed on behalf of these road authorities. The strategic planning manager looks months and up to years ahead in shaping regulations and infrastructure as well as planning long-term maintenance and investment planning for road infrastructure. The traffic orchestrator makes tactical and operational decisions with a time horizon of hours to weeks in planning and prioritising the mobility infrastructure to fit the anticipated demand in a multimodal manner. The network manager manages the mobility network with a real-time operational scope and responds to unexpected incidents and events for example.

The transport sector also comprises of a wide variety of stakeholders, stakeholder departments and operators, which can be aggregated into four main types. The transport user is the 'client' requesting shipping goods from A to B with certain demand characteristics (e.g. price, speed, etc.). The transport service provider then plans the best transport chain to be used for shipping these goods based on anticipated infrastructure status, fleet availability, driver availability, opening hours, etc. with a days-weeks-months' time horizon. The fleet operator gets requests to operate certain stretches of these logistic chains with corresponding characteristics of the task to be carried out, and decides when and how to perform the task. The network user would be the driver of the vehicle, performing the specific freight route with a vehicle.

Roles within the 'society and others' category have a wide variety and are therefore identified on the basis of specific use cases. In the context of transport, it is for example expected that roles such as customs, emergency services and adequate legislation are relevant across all MODI use cases.

5.2 Role adaptation for use and alignment in the context of MODI

In the context of L4 freight driving, the roles related to traffic are not expected to change in scope compared to current logistic operation. The character of these roles might change in that they will be more digitised and algorithmic, however they will roughly have the same responsibilities as is described in the MODI user and stakeholder requirements deliverable D1.1[11]. Therefore, these Traffic Orchestration roles are seen as future proof and usable for shaping long-term collaboration schemes. As for transport, some adaptations are foreseen to support L4 freight driving. Especially the roles of the fleet operator and network user is expected to change when L4 freight vehicles reach a larger share in vehicle fleets. It could be possible that operational planning of freight routes is still performed by comparable planning departments of shipping companies, however they are expected to increase the use *Transport Management Systems* (TMS) as their main tool. These TMS systems are provided by intermediary Transport Management System providers, providing software combining planning, routing, fleet management and on-route navigation within one package. Here a planner of a shipping company could insert a certain route request with certain characteristics, and these fully digitised platforms would make sure an automated truck would arrive in time to perform these tasks. Consequently the ‘network user’ will change as this entity will gradually shift from a ‘driver’ towards a ‘vehicle’ without a human driver (actively) involved.

Moreover, despite very little difference between traffic management on public road and traffic management on a confined area seen from a high-level, the functional architecture includes the role of ‘*confined area operator*’ as a traffic-orchestrator version on private terrain. This distinction is made as in several use cases as described further in this deliverable, the means and ability of a confined area operator to manage traffic upon its own terrain are limited in volume of vehicles, geographical scope and operational limits in comparison to a public road traffic orchestrator.

Finally, for the sake of clarity and the required level of detail on the specific different roles required for extending the TM2.0 collaborative framework, the roles mentioned are inspired by the ORCHESTRA project, and directly related to the roles and stakeholders described in MODI deliverables on user and stakeholders requirements (D1.1), the validated interface for Coordinated CCAM (D4.1) and the optimal design for Physical Digital Infrastructure (D4.2), be it in somewhat different wording. For example, where this deliverable refers to a confined area operator, the D4.1 CCAM interface relates to a ‘Terminal operator’, and where this deliverable specifies a TMS as intermediary planning/routing/navigation tool, the D4.1 CCAM interface names this a Logistics Management System. On a functional level these stakeholders are the same, however naming is different across the different framework scopes within MODI WP4.

5.3 Roles performed within the MODI use cases

The several roles as described in chapter 5.1 are performed by different actors in different local contexts. These roles are all involved in one or more MODI use cases. How the MODI use cases involve one or more of these roles is described below.

Netherlands

Use case Netherlands within MODI revolves around integrating automated freight vehicles in logistics operations in the port of Rotterdam, in two parts. The first part relates to vehicles arriving, entering, operating and leaving the confined area APM Port terminal from and to the public road, and the second part relates to these freight vehicles driving a drayage route between the APM Port terminal confined area over public road to a freight drayage location within the Rotterdam Port area. These freight vehicles will within the pilot be provided and operated by the truck manufacturer, however may in the future be operated by a variety of logistics stakeholders ranging from transport users, service providers and logistic operators. The confined areas are operated by the confined area operating centre which serves as a road operator for this confined area, in this case by APM Terminals. The (local) public road is monitored and managed by the Municipality of Rotterdam, with a short connection to the main road network operated by Rijkswaterstaat.

APM aims to maintain a safe and efficient 24/7 operation on the terminal. This means that trucks are provided with a timeslot in which they could enter the confined terminal area, enabling continued throughput of vehicles for freight operations within the terminal. These operations come with peaks (e.g. rush-hour, around weekends, etc.) which are managed through using a parking ground at the entrance as buffer zone. Alignment with regard to oncoming and leaving traffic could help reduce slack in the logistics chain and improve customer satisfaction for the logistics location. Within the APM terminal the APM control centre operates as ‘private traffic orchestrator’.

Road operators in the area, Municipality of Rotterdam and Rijkswaterstaat, are responsible for monitoring and managing traffic on public roads within and around the Rotterdam port area. Given the geographical layout of the Rotterdam Port area, trucks quickly enter the one highway going to and from the port area, and local traffic levels are relatively low overall. Incident management however is very important and challenging given the long travel distances and the little route alternatives om the highway network.

The vehicles operating on and around the APM terminal are operated by freight service providers and logistic operators, often also individual truck drivers (freelancers). The truck drivers book timeslots through a booking service by hand, and manage on-route navigation themselves or through a Transport Management System based on the provided timeslot and anticipated delays to be compensated by arriving earlier.

Given that the port area is an industrialised and controlled environment, involvement of societal stakeholders is limited and traffic management orchestration is rather single-modal with a specific focus on freight vehicles and passenger cars. Multimodality is not an active topic as leaving the vehicle within the confined area terrain generally is forbidden. The Rotterdam site does however specifically represent the several logistics roles, as well as traffic orchestration in a confined area context: Manage which vehicles (are allowed to) go where within the operational process on the terminal itself.

Germany

Use case Germany within MODI revolves around the transition from a motorway to a confined area while passing through industrial and urban areas of the City of Hamburg. The consistent change of the operation domains (ODDs) from simple to complex traffic situations during the defined route in combination with the Operational Design Domain (ODD) defined by the Original Equipment Manufacturer (OEM) will trigger several starting points for the transition processes from highly automated driving to manual driving. The use case involves Green Light Optimal Speed Advisory (GLOSA) services along the route provided by existing C-ITS infrastructure, as well as crossing several mixed traffic intersections in a city.

The focus of this use case is on the interaction between the vehicle and the C-ITS infrastructure on public road. Consequently the main involved roles in the pilot are the OEM of the vehicle, a transport chain manager, as well as the road authorities for the federal motorway, the urban and the port area.

In this use case the vehicle will cross several road operator service areas, and consequently will need to understand where which information needs to be retrieved or is valid both for the day-ahead planning as well as same-day and on-route navigation operations. Moreover these road operators will need to be aligned in terms of active traffic scenarios and policies. The roles active within the Hamburg use case will primarily lay upon the traffic orchestration side, as multiple road operators are actively involved in providing information and configuring the ITS systems, and less on the logistics roles as OEMs and one transport chain operator are involved.

Sweden

Use case Sweden, focusing in and around the Gothenburg area, revolves around L4 driving on and off public roads in mixed traffic situations. Using L4 vehicles several sub-usecases are demonstrated such as gate access and automated loading/unloading at a confined area, demonstrating integrated operations between several OEMs and a confined area operator. Moreover, the usecase demonstrates public road operations on a long highway stretch, showing mixed driving L4 operations supported by local C-ITS infrastructure, demonstrating integrated operations between multiple OEM's and multiple road operators.

In this use case the emphasis is on the integration between several transport roles such as fleet management, transport management and confined area operations as well as integration between transport management and traffic orchestration on the side of the several road operators (public for the public road and private for the confined area). Despite the use case focusing on rather 'local' use cases consisting of one vehicle and one confined area operators, the public road management will require alignment and sharing of information on road status towards transport stakeholders.

Norway

Use case Norway, focusing on crossing the border between Norway and Sweden, emphasizes driving in mixed traffic and transitioning between road operator service areas. These transitions will both be between national road operators, between regional and local road operators, private confined area operators as well as customs possibly acting as local road operator in the customs area.

In this use case the alignment of information provisioning from road operators will be an active subject, as well as safe and effective transitioning of vehicles between several operator service areas. This corresponds to a transition at a physical gate at a confined area as well. Here both the planning component on what a vehicle can expect in terms of delays, operational exceptions, etc will be vital, as well as dynamic information on for example which vehicle will have to enter the customs area on short notice to be checked at the border. The Norway use case also involves the vehicle entering the port area in Moss, and entering the gate of a container terminal. Consequently, this use case will emphasize the road-operator interaction and integration, as well as the chain management handling of operational uncertainties at cross-border and transitioning situations.

CCAM Test corridor

The MODI CCAM Test corridor use case will focus on understanding and overcoming the regulatory barriers and PDI shortcomings on this specific motorway corridor with all road authorities, logistic operators and OEMs of this project involved. By covering the entire distance from Rotterdam to Oslo, this UC aims to identify challenges and barriers from an OEM, logistics operator and road authorities´ perspective, identify critical parts of the PDI, validate critical parts, and assess PDI adaptation needed in preparation for automated driving at SAE L4.

This use case will assess the readiness of the corridor regarding L4 international vehicle operations, however will not actively drive the route using L4 vehicle operations. Nevertheless, the use case will emphasize alignment between several road authorities in terms of traffic operations policies (including signage, markings, etc.) as well as data-provisioning and exchange (Availability of required data on for example road maintenance, incident handling, etc.).

6 Towards TM2.0 for CCAM Functional Architecture

6.1 Potential benefits to stakeholders

The potential benefits of increased collaboration between the field of traffic management and the field of logistics were widely acknowledged both within and outside the MODI consortium. Both fields anticipate clear benefits for their own responsibilities and operations, which will be described below. It became clear however that most stakeholders identified benefits that were related to day 1 or day 2 CCAM deployments around 'digitalisation' of the logistics and road operator domains due to lower investment requirements, required organisational changes and shorter ROI, and benefits related to day 3+ CCAM features around actual 'automation' of these operations were more extensive versions of these 'digitalisation' benefits. An overview of the several foreseen benefits by different stakeholder groups is provided in table 1.

		Identified potential benefits			
		nr	**'Digitalisation'**	**nr**	**'Automation'**
Stakeholder groups	**Logistics**	*1*	Improved real-time and day-ahead data quality and availability on current/expected road status and measures	*8*	Active management of vehicles on last mile from warehouse or terminal (external buffering/peak shaving)
		2	Real-time data exchange between confined area and vehicle on last mile (reliable ETA, external buffering/peak shaving)	*9*	Towards 24/7 operations on near-site logistics routes
		3	Easy and reliable availability of maintenance/events of public roads for L4 vehicle operations	*10*	Full technical alignment between confined area infrastructure and public road infrastructure
		4	Alignment and optimization of planning across multiple actors in the logistics chain		
	Road operators	*5*	Improved real-time data on road status for better TM and roadworks management	*11*	Increased influence on route through TMS/OEM
		6	Individualized traffic management based on vehicle and goods characteristics	*12*	Towards 24/7 operations might enable better peak-shaving through incentives
		7	Safety: traffic measures for specific hazardous vehicle types or goods	*13*	Avoid congestion backlash around logistical areas through active guidance

Table 1: Overview of potential benefits as foreseen by logistics and road operator stakeholders

From the logistics stakeholder group it became apparent that any perceived benefits should have their impact in the short term already, due to small profit margins and consequent investment levels, as well as a need to optimise the freight system that exists today. Therefore, many benefits focused on exchanging reliable ETA's of vehicles and dynamic adaptation of warehouse and terminal timeslot planning based on increased connectivity and more reliable and available information on current and future road status and incident management. This would help align the planning of multiple consequent freight stakeholders, would help shave peak demand at terminals or confined area gates, and would optimise day-ahead logistical planning. When the benefits of 'automation' were considered, these earlier benefits were further extended: not only having better information through more reliable ETA's, but also coordination mechanisms from a terminal/warehouse towards a vehicle to actively influence the ETA somewhat.

The road operator stakeholder group also emphasized the short-term potential of improved and increased data sharing with foreseen gains such as individualized traffic management capabilities, by enabling advising different vehicle types to follow different routes or other traffic measures, by exchanging information with transport stakeholders of intermediary TMS providers. This also had a safety aspect as it would enable quickly reaching specific risky or hazardous vehicles or types of goods in case of incidents and emergencies Also increased data exchange with connected vehicles in general could provide valuable real-time and detailed insights into road status and road maintenance priorities. When extending these benefits towards L4 driving, the road authorities also could extend their influence through not merely 'informing', but also actively guiding or requesting certain behaviours from (groups of) individual vehicles.

Three benefits out of the 13 listed here are seen by the stakeholders as relevant benefits worth pursuing, however they are seen as outside of the scope of this research. Benefit 4 on alignment across the logistics chain will primarily involve digitalisation and standardisation of logistics related data, processes and supply-chain collaboration. Several bodies are already working on such alignments, and as this does not particularly focus on CCAM and/or the mobility aspects of logistics vehicles, this benefit has not been further pursued within this research. Benefit 9 on 24/7 operations is relevant as well, however the main challenges particularly lie on organisation, workforce, and B2B collaboration, not involving public-private and/or particular CCAM/mobility advancements. Therefore, this benefit has also not been further pursued within this task. And finally, benefit 10 on technical alignment between public and private road and operations is seen as particularly relevant for the scope of MODI and this task, however is also mainly addressed in MODI in other WP4 tasks on optimal design for Physical and Digital Infrastructure on particularly this benefit. Consequently, this benefit has not been pursued within this task.

6.2 Task scenarios to achieve potential benefits

In order to address the long list of benefits in an aggregated manner, four main task scenarios are described that will be further developed towards a dedicated functional and high-level technical architecture. These four use cases are seen as representative and scalable for needs across the MODI corridor. The ground assumption is that if these use cases are properly addressed in the interactive traffic management collaborations, all listed benefits will be met when implementing these collaboration schemes. The intent and scope of these task scenarios as starting points for the functional architectures are described below.

Task scenario 1: Day-ahead exchange of road infrastructure information and anticipated freight movement.

This task scenario involves the exchange of static information and anticipated information for the purpose of logistics movement planning as well as traffic management operations planning for (at least) at time-horizon of one day before the vehicle actually departs. It thereby enables benefits 1, 3 and 4 of Table 1. Exchanging information between involved stakeholders will on the one hand help logistics planners to optimize planned/anticipated operations by having the latest reliable information on road status (e.g. planned road closures, anticipated road capacity and travel times, reroutes, access regulations/geofence zones, access time windows). On the other hand having an improved understanding of anticipated freight movement, volumes, routes etc could help traffic orchestrators in effectively planning road maintenance and limiting disruptions, and having a context of anticipated movements when incidents occur at a later stage. This task scenario will primarily focus on direct exchange of data and information at Collaboration Levels 1 and 2 (see Figure 3) between (private) logistics operations (by use of a TMS) on the one hand and (public) traffic orchestrators on the other.

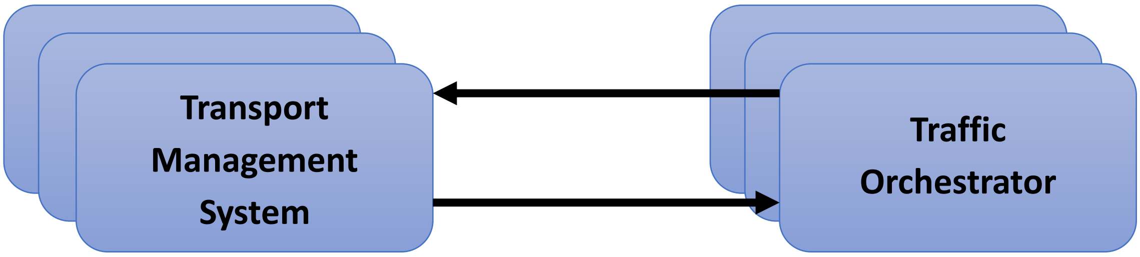

Figure 8: Initial collaboration scheme task scenario 1

Task Scenario 2: Same-day exchange of road infrastructure information and anticipated freight movement.

This task scenario involves likewise data exchange as task scenario one, with a change in time horizon. For this Use Case the focus is on real-time to same-day data exchange for active operational services in logistics and road operations. It thereby enables benefit 1, 2 and 5 as shown in table 1. Within this time horizon a vehicle is almost or already on route, and both logistics stakeholders and traffic orchestrators are constantly monitoring operations and reacting to unexpected events. As these events are unexpected, the mitigating measures can also not (or very limitedly) be planned. Therefore, this information exchange is characterized by being able to exchange dynamic mobility data as well as characteristics of unexpected events and mitigating measures that might impact other involved stakeholders. Examples on traffic orchestrator side will be dynamic road status information (travel times, parking occupancy, city hub availability, etc.) as well as traffic incident characteristics such as duration, impact on road capacity and which mitigating measures are taken, but also unexpected unavailability of movable bridges and tunnels. Examples from logistics operators (by use of a Traffic Management System) could be real-time travel times, event observations, reroutes, occupancy rates, hazardous goods information, etc. This Task Scenario will primarily focus on direct exchange of data and information at Collaboration Levels 1 and 2 (see Figure 3) between (private) logistics operations (using a TMS) on the one hand and (public) traffic orchestrators on the other.

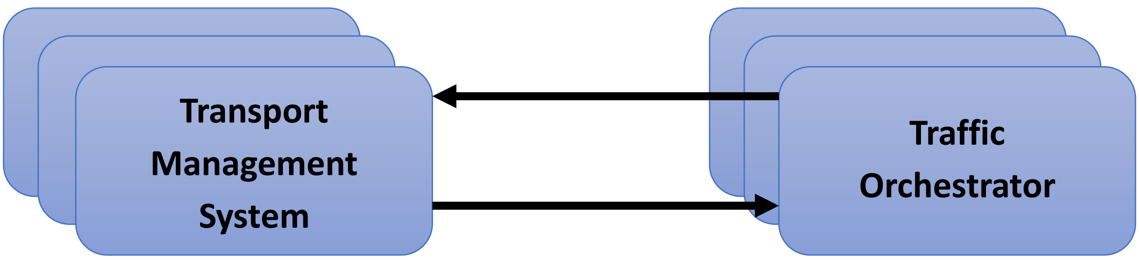

Figure 9: Initial collaboration scheme task scenario 2

Task Scenario 3: Last-mile interaction between traffic orchestrator and confined area.

This task scenario focuses specifically on solving last-mile issues near confined areas through direct cooperation between the confined area operator, the local traffic orchestrator and the vehicle(s) at this location. It thereby enables Benefit 2, 8 and 13 of Table 1. Here traffic orchestrators and confined area operators collaborate to anticipate and solve issues either due to confined area operation issues leading to congestion backlash by trucks on the local public roads, or local issues on public roads leading to congestion at confined area gates due to a large peak of vehicles arriving to, or leaving from the confined area gates at the same time. In this use case the involved stakeholders monitor their own operations specifically for potential impact on the continuation of operations of other stakeholders, and actively inform each other on expected issues and effective mitigating measures to avoid congestion backlash on public roads as well as confined area operation issues. The to be exchanged data could refer to anticipated vehicle volumes and travel times, real-time gate access capacity, local parking availabilities, route guidance for vehicles based on confined area planning, etc. This Task Scenario will primarily focus on direct exchange of data and information at Collaboration Levels 1, 2 and 3 (see Figure 3) between (private) logistics operations (through use of a TMS), (public) traffic orchestrators as well as individual vehicles in the vicinity of the local site.

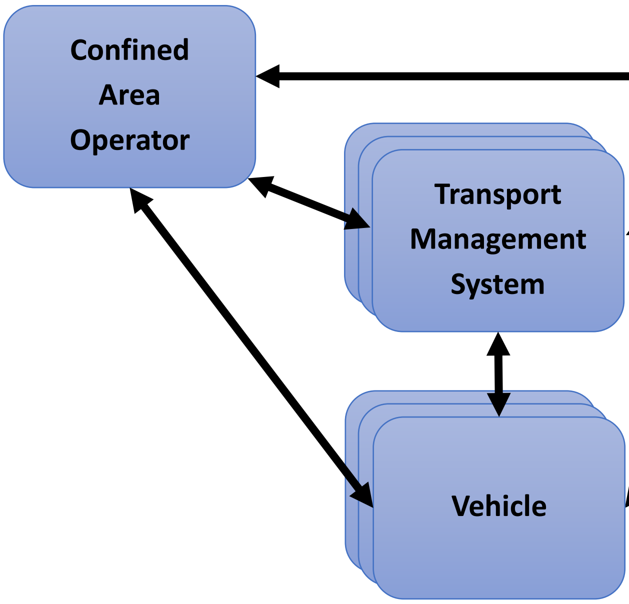

Figure 10: Initial collaboration scheme task scenario 3

Task Scenario 4: Target-group based and diversified Traffic Management.

This Task Scenario focuses on enabling road operators to diversify traffic measures and guidance advice between groups of vehicles based on certain characteristics. This would enable traffic orchestrators to provide target group-based information and measures, spreading out and/or prioritizing mobility modes, further improving measure effectiveness and follow-up rates. On the part of the logistics services this could enable traffic priority, more reliable or shorter travel times, and increase logistics operation efficiency. This use case thereby enables benefit 6, 7, 11 and 12 of Table 1. These target-groups could be based on static vehicle characteristics as currently is regularly used such as weight category, emission category, size, etc., as well as dynamic vehicle characteristics such as freight classification, actual weight, occupancy rate, origin-destination information, logistics planning, drive mode (manual – automated) etc. This Task Scenario will primarily focus on direct exchange of data and information at Collaboration Levels 1, 2 and 3 (see Figure 3) between (private) logistics operations (through use of a TMS), (public) traffic orchestrators as well as (groups of) vehicles. The Transport Chain Manager is also included as any adaptations of TMS planning/operations will always have to be checked with the TMS client, a role which is performed by the transport chain manager.

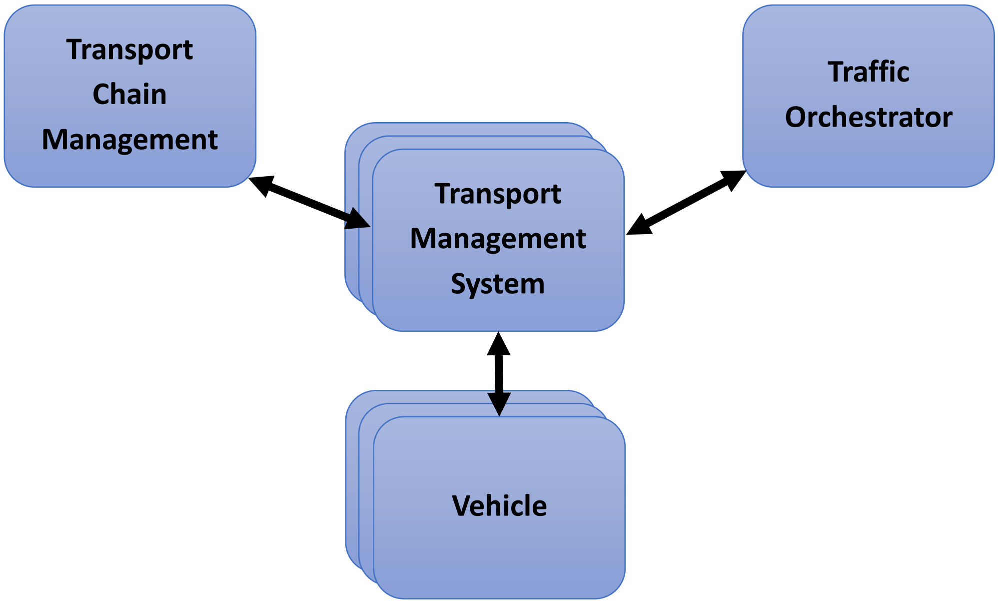

Figure 11: Initial collaboration scheme task scenario 4

6.3 Task Scenario development and reflection

The four Task Scenarios have served as a starting point in researching if deployment of these use-cases would lead to achieving multiple and mutual benefits, as well as which implementations or technical means are already available or known to be in development that will enable one or more of the task scenario features. On the one side this reflection and research shows the viability of achieving these mutual gains as a first step towards the functional architectures, and on the other side provides the first basis of the high-level technical architectures on how these use cases could be deployed in practice.

Task Scenario 1: Day-ahead exchange of road infrastructure information and anticipated freight movement.

Functional viability

The mutual data and information exchange between a public traffic orchestrator and a private TMS tool was not widely supported among the task participants. Although both sides would gain in such data exchange, the public traffic orchestrator will always have the responsibility to share reliable data and insights on what is to be expected on the road infrastructure availability to as many stakeholders and end-users as possible, without any need to receive data/insights in return. The expectation that these receiving stakeholders will use that information to prepare for any expected disruptions will already achieve the main objectives for these traffic orchestrators. Traffic orchestrators do not expect to widen that range of capabilities and means when anticipated freight movements are received through for example aggregated origin-destination data, as the orchestrator has very limited means to act upon that information in another way than it normally would. Transport Management Systems and related logistics clients will benefit hugely from receiving reliable information from road operators in a scalable manner, as this would help adapt to any disruptions, changes and events that are foreseen to impact logistics operations. This will result in less disruption impact, and therefore result in gains for the traffic orchestrator as well. The data that the TMS would have available to offer the traffic orchestrator will be of commercial nature, and challenges are expected in sharing that information to public authorities and other stakeholders given that his would sometimes have to be tendered or at least contractually agreed. This brings a particular need for these receiving stakeholders to foresee benefits of using that data, which currently is not the case. One example in which data from a TMS towards a road operator is seen as valuable is receiving information on vehicle exceptions (e.g. oversized, overweight, dangerous goods, etc.) and exceptional cargo movement permits that are planned. In this way the road operator will have the ability to understand if mitigating measures for roadworks will be sufficient to also enable exceptional cargo movements across those corridors, or that specific measures will have to be taken. This task scenario is seen as viable and achieving benefits for stakeholders involved, be it on a level 1 collaboration level, through largely one-way data exchange from traffic orchestrator to mobility stakeholders including Transport Management Systems.

Technical and legislative viability

A large majority of the data types foreseen to be exchanged between stakeholders in this task scenario is already available or in preparation (e.g. agreements and specification of data standards and international data governance structures) within the European Union. In particular, the legislative developments regarding the EC ITS Directive [16], the Single Digital Gateway [17], the NAPCORE project [18] and EC directives regarding Safety-Related Traffic Information (SRTI) and Real-Time Traffic Information (RTTI) [19] are seen as particularly relevant for this task scenario. Regarding available and/or agreed technical data standards DATEX II [20] is seen as particularly relevant, supporting almost all data fields required for the data-exchange within this task scenario.

The ITS directive mandates availability of data types such as planned and actual roadworks, maximum speeds, physical/digital signs, planned and active traffic management plans in a scalable manner across the European Union. The governance for this is organised within the NAPCORE project, and the technical basis for this exchange is founded in DATEX II development. Moreover, SRTI and RTTI will mandate availability of safety-related information such as incidents and related measures, planned and active events, static and dynamic speed limits, etc. For several newer data types such as exchange of preferred routes, UVARs and environmental zones, and static/dynamic parking availability, DATEX supports the basic data format, and ongoing legislative processes such as the Single Digital Gateway will promote and eventually mandate the availability of these information types for mobility stakeholders across the union. For all these data fields, the task relies on these developments to enable scalable technological exchange of this data.

Regarding the specific interest in sharing vehicle exceptions and exceptional cargo movements from TMS to traffic orchestrator, the availability of technical standards that are widely adopted is limited. DATEXII does contain data fields regarding exceptional height/width/length and weight of vehicles for parking space availability purposes, however traffic orchestrator was unaware of these capabilities and related active implementations. For enabling this exchange, both further development of such standards and visibility and adoption of these standards should be main priorities.

Task Scenario 2: Same-day exchange of road infrastructure information and anticipated freight movement.

Functional viability

The assessment of the functional viability of this task scenario is related to the functional viability assessment of task scenario 1, in that two-way data communication was not seen as providing more value to the stakeholders than merely sharing information from traffic orchestrator to Transport Management System. Regarding the real-time and same-day time horizon the assessment also was that through sharing reliable and usable information from traffic orchestrator to the TMS, the TMS and related clients improve their capabilities to adapt to unforeseen events, thereby limiting the impact of these events on road safety and capacity. Data exchange from TMS to traffic orchestrator was again seen as serving very limited purpose due to the limited means of the road operator to act differently upon that information, and the large challenges foreseen in exchanging such commercial data. This also goes for the exceptional cargo data, as in the same-day and real-time horizon the road operator will have no capabilities to act upon any challenges that arise in due time. This task scenario is seen as viable and achieving benefits for stakeholders involved, be it on a level 1 collaboration level, through one-way data exchange from traffic orchestrator to mobility stakeholders including TMSs.

Technical and legislative viability

The assessment of this task scenario technical and legislative viability is also strongly related to the ongoing developments as mentioned with task scenario 1. Many of the ongoing data governance and standardisation initiatives already support the exchange of all foreseen data types. However with the developments of capabilities related to sharing this information being largely ongoing, the main challenge in this task scenario will be on providing reliable data on a larger scale in the first place. For most generic data types such as sharing actual roadworks and actual speed limits, this is already taken care of through for example FCD data. However given that the time horizon is sharp and effective acting upon information requires high availability and high reliability of this data, meeting the requirements for sensors and data sources is seen as the main challenge for this task scenario. For example, for any effective dynamic parking scheme with heavy duty freight vehicles, a reliable overview of available truck parkings is required. This means a real-time overview of the availability of high numbers of parking spots over multiple truck parkings in a region, and due to the length of these vehicles often requiring two or more sensors per truck parking to monitor availability as also a small car parking there would block the location from being available to a truck. Moreover, any dynamic scheme regarding environmental zones, UVAR zones or any other dynamic traffic management plan would require real-time availability of activated zones and its consequences to a wide range end-users in a very tight geo-zoned format, especially if sharing that data is related to actual enforcement of abiding by such zones.

Task Scenario 3: Last-mile interaction between traffic orchestrator and confined area.

Functional viability

From the three task scenarios the mutual gains for both public and private stakeholders were perceived to be the greatest in task scenario 3. With both sides being impacted by the consequences of misalignment and disruptions at confined area gates, both sides also have significant buy-in in solving such issues together. There is wide agreement among stakeholders that improved collaboration and data exchange between a confined area owner and a local road authority would lead to concrete mutual benefits in either avoiding the disruptions altogether or at least having improved means to limit the impact upon its own operations if these issues occur. The confined area operator should be enabled to alert local traffic orchestrator of gate process issues, and alert oncoming vehicles of these issues and relevant mitigating measures focussed on dynamic parking or 'disentanglement' of truck-congestion by prioritizing trucks that are late for a loading vessel over trucks that are arriving early for a next vessel. A confined area operator should also be able to understand local/regional parking availability as potential means to mitigate issues, as well as understand local/regional road status and potential impact on its own operations and planning. A local traffic orchestrator should be able to understand the gate issues and particularly its impact on road capacity, and be able to take mitigating measures when this occurs (probably in the form of activating a pre-defined local traffic management plan). For mitigating measure purposes the traffic orchestrator should be able to monitor and share real-time truck parking availability in the region, as well as alerting the confined area operators of last-mile road condition/capacity issues. In order to 'disentangle' congested routes by prioritising trucks, the instructions towards vehicles should be vehicle-specific. As traffic orchestrators will not get involved in active guidance of individual vehicles the TMS, should be able to renew last-mile routing based on the planning priority and road status information. Moreover, the TMS should build capabilities to enable long-distance ETA management in alignment with terminal capabilities and planning.

The main discussion regarding this task scenario focuses on the need and ability to scale such collaboration forms and related required technological means, as the occurrence and character of these types of issues are dependent on very specific local circumstances. The locations known to face these issues all have a specific combination of a logistics operation known for recurring peak-loads of traffic such as roll-on roll-off shipping operations, limited geographical space to manage parking or buffer-zones for managing peak loads of truck traffic (due to the confined area being surrounded by urbanised areas, by mountains or by water) and mostly also limited routes to reach the confined area from the main highway corridors (e.g. due to relying on one or two bridges, or due to the last-mile being dependent on one specific busy highway stretch prone to congestion issues). Although this misalignment issues at confined area gates is a widely known issue in the logistics domain for several important locations, the local impact of these issues and the dependency on the local context also suggest solving these issues in a local manner. For example, improving communication between this one confined area with the two specific local road operators through a lean and mean structure, instead of developing a scalable governance and data framework for such issues that could be of use across the European Union.

An important argument for designing scalable solutions for these issues is the means of communication with the vehicles and TMS. These vehicles should be provided with information in a standardised way as these drive from one terminal to the other, crossing country boundaries and therefore moving largely outside of the specific geographical scope of these alignment issues at terminal gates. The exchange of information should be the same in a given situation, disregarding where the local issues occur.

This task scenario is seen as viable and achieving benefits for stakeholders involved, where depending on the local situation sharing information (level 1) towards coordinated joint public-private actions (level 3) would be suitable.

Technical and legislative viability

In contrast to the first two task scenarios the technological assessment showed very little available standards or technology for exchanging these types of required information, at least in a scalable manner. For specific segments such as parking provision local services and apps might be available (showing availability of parking), however active prioritisation of logistics vehicles based on confined area planning priority before these vehicles actually arrive at the confined area for example is a use case now known to be in operation just yet. It might be that in local context a confined area operator is aware of local road status either based on own experience or basic real-time traffic information, however this is not actively provided by the local orchestrator. Moreover, the local traffic orchestrator might have traffic management scenarios available for operational issues at larger logistics locations, however activates them based on own observations and not due to active involvement of the confined area operator itself. At several sites there is an informal agreement to call known individuals at logistics sites or local road operators to inform them of any disruptions, however this is not a structured way of working and ad-hoc based on how the problem is perceived by the traffic orchestrator. The technological architecture for this task scenario would largely have to be set up based on partly existing building blocks and fit for purpose on location. Existing building blocks are traffic orchestrator sharing road status information, navigation systems being able to interpret alternative advises, and parking monitoring systems for local/regional situations. Large unknowns remaining would be the digitalized way of coordination on behalf of the confined area operator and digital interfaces for sharing information from confined area to surrounding traffic orchestrators and relevant TMS providers for oncoming vehicles.

Task Scenario 4: Target-group based and diversified Traffic Management.

Functional viability

The functional viability of this task scenario is assessed as very high, given several implemented or ongoing examples of such target-group based traffic management use cases for other road modalities such as cars, public transport busses and local implementations for heavy duty trucks (e.g. green-waves for trucks on local logistics corridors). The primary link that needs addressing here is the data exchange between the traffic orchestrator and the TMS, with the vehicle and the logistics chain management as necessary components for the TMS to assess alternative routes and actions (e.g. they must fit within the logistics capabilities of the client as well as the operational capabilities of the vehicle). Across this interface between TMS and traffic orchestrator, the main challenge is scalability and standardisation, as many ongoing examples on smaller scale -either geographically or focussed on specific vehicles- show the capabilities and results of such an interface. For example, within the Socrates 2.0 project, the traffic orchestrators were enabled (through navigation service providers) to reroute vehicles during highway incidents around a city that had no need to be in the city itself, and let vehicles that had the city as their end-destination continue on their route unchanged [21]. Moreover, in Germany road operators have means to restrict and reroute heavy trucks in order to avoid bridges with a weight restriction through real-time weight measurements and targeted communication towards these vehicles [22]. And finally, in several instances local implementations are active in which specific trucks that regularly drive between two logistics centres (e.g. between the flower auction hall near Amsterdam, and Amsterdam Schiphol airport) are actively given priority at intersections, whilst other vehicles (including other trucks) are not prioritized [23]. Regarding functionality, the means of road authorities to differentiate advice and information between vehicles, modes, and other specific target groups have shown to have value, and required technical means also have been shown in several specific and local contexts. When considering the context of L4 heavy duty logistics, these target-group based Traffic management means could enable dynamic UVAR use cases (e.g. only rerouting heavy vehicles to avoid bridges with weight limitations, only rerouting/restricting vehicles during active UVAR hours, access management/prioritization based on occupancy rates, etc.).

Important to note here is that traffic orchestrators will not (and in many cases may not) be involved in active guidance of individual vehicles, as using prioritization-schemes for individual vehicles might damage fair data exchange principles and enable discrimination. Traffic orchestrators are mandated to communicate the legislative frameworks to all road users in the same manner, so the target-group approach will merely be suitable for communicating extra information, advice and guidance, and not for any legally bound rules and regulations. Moreover, the road operator will only do this per target-group, and not per specific vehicle, as the TMS will remain responsible for interpreting the target-group specific request, assess safety and viability of accepting the request for each individual vehicle, and incorporate the response into the route-guidance and/or command towards individual vehicles.

This task scenario is seen as viable and achieving benefits for stakeholders involved, with either level 2 or level 3 cooperation models.

Technical and legislative viability

The several local/specific implementation examples have shown the technology to be working for target-group based information exchange, such as the development and deployment of “service requests” through the DATEX TMex extension [24]. Through this interface road operators can for example request service providers and TMS providers to avoid using certain road stretches or locations for groups of vehicles with specific characteristics. The service provider can then assess per vehicle if this is a viable option, and choose a suitable mitigating measure for these vehicles. Especially regarding scalability, the challenge primarily lies within the governance framework. Not only will TMSs have to be able to understand which traffic orchestrator are relevant for specific planned vehicle routes and have means to communicate with them, but also road operators will have to be able to publish their requests/advice/guidance towards an open platform where all relevant TMS/Service providers can then access that information. Moreover, when growing towards level 3 collaboration and contractual agreements on if/how to follow up on those requests by traffic orchestrator, likewise ‘scalable’ agreements will have to be made on how private companies are adapting their service to accommodate ‘public’ needs wider than their own client base. This is not an issue if the advice is directly in line with the gain/benefit of the vehicle (e.g. this brings a shorter travel time to the vehicle in comparison to rejecting the request), however will be particularly challenging when the service for this vehicle/client is reduced to accommodate these public needs (e.g. the reroute will take this vehicle(s) longer to arrive at the destination, but will help alleviate a congested area). In those cases agreements could be made on how to ‘compensate’ the reduction in service for these clients. This compensation should not have to be financially, but could also occur through sharing particular detailed and reliable information on incident management/duration/impact for use of service improvement in other cases.

7 TM2.0 for CCAM in logistics functional architecture

The results from the design of the task scenarios and the reflection upon have been aggregated into a comprehensive overview of how the collaboration between these several roles could work in order to enable as many potential benefits as possible. This functional architecture between these roles shows how exchange of information, strategies and requests could enable mutual collaboration resulting in mutual benefits. The overview of this functional architecture is shown below in figure 12 and elaborated further below.

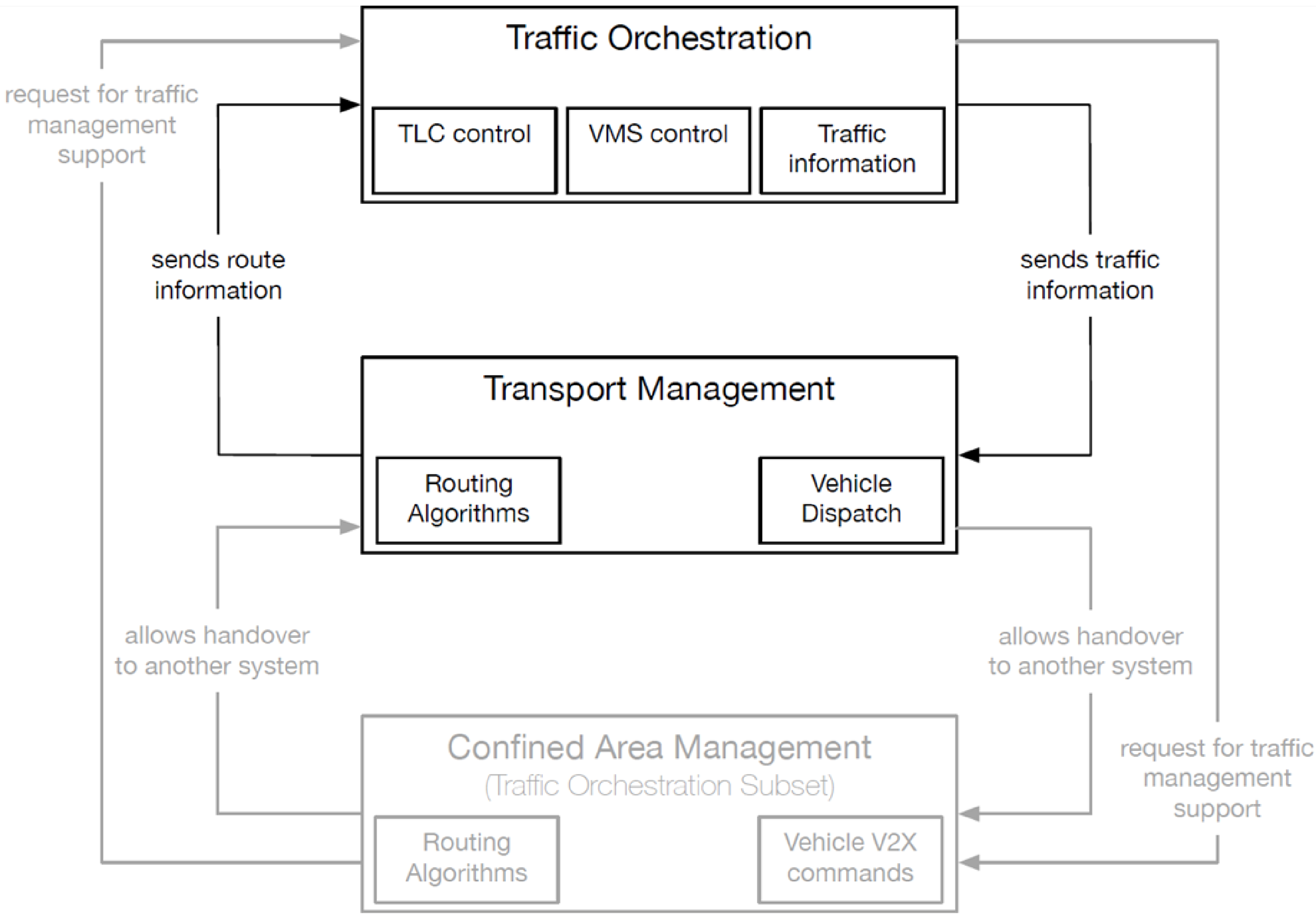

Figure 12: Collaborative Functional Architecture

The functional architecture shows on a high level how most relevant roles in the context of these collaborations can work together on a level 1 to level 3 collaboration basis, in order to achieve a mutual win-win outcome. Three main roles are defined: **Traffic Orchestration** for public road, **Transport Management** and a subset of Transport Orchestration for private road, the **Confined Area Management**. As this deliverable focusses on interactive traffic management on public road, the confined area management role is seen as less prevalent in the functional architecture as the on-premises traffic management is regarded as out of scope. The role is relevant however for a task scenario 3 context in which any operational issues in the (public road) last or first mile of vehicles arriving at, or leaving from, a confined area can be solved through collaboration between the traffic orchestrator and confined area operator.

Traffic Orchestration, performed by public road authorities on national, regional and local level, is responsible for safe and efficient public road management. This is typically done by traffic lights, variable message signs and traffic information systems. With its main focus on optimising the road network capacity for a collective of road users, the Traffic Orchestrator focuses on informing, guiding and managing groups of road users. By sharing traffic information with Transport Management, both day-ahead and same-day, the traffic orchestrator improves its own means of informing logistics planners, drivers and automated vehicles on what to expect on public road infrastructure and how to cope with events or incidents. In some cases the traffic Orchestrator can also improve its own means by using Transport Management information, such as floating car data from freight vehicles as well as receiving information regarding exceptional cargo permits and operations.

Transport Management, performed by freight vehicle transport operators and by use of a Transport Management System, is responsible for optimising the transport operations of one or more freight vehicles under the supervision/management of this transport manager. This stretches from transport planning and fleet management to on-route navigation. In the context of L4 automated freight vehicles this would also constitute vehicle remote operations, or sending out route requests/commands to the responsible remote vehicle operations system. By receiving traffic information, planning and operations of the vehicles can be improved, and by sharing route information with the road operator any potential issues regarding required road infrastructure can be made known to the traffic orchestrator. When automated vehicles reach a confined area, the collaboration between transport management and a private area traffic orchestrator (confined area management) is represented by a vehicle handover between these roles.

Confined Area Management, performed by a private local operator of a logistics confined area, is responsible for safe and efficient private road management upon its own confined area. This role therefore is a sub-set of a traffic orchestrator with the focus on private terrain. Although on a high level the roles of a public road traffic orchestrator and a confined area manager are comparable, the means with which the confined area manager can monitor and influence traffic are different, and in most cases more limited. With confined area traffic management being out of scope for public road interactive traffic management, this role is of lower importance for the scope of this report than the other two roles primarily active on public road domain. However, especially in the case of optimising last-mile logistics for vehicles arriving at a confined area, or first-mile logistics for vehicles leaving a confined area, this role is of importance. Given the mutual dependence of a public traffic orchestrator and a confined area manager in solving these local issues this role is specifically taken into account in the functional architecture. For these issues, both the traffic orchestrator and the confined area manager can improve their own operations by mutually requesting traffic management support.

8 TM2.0 for CCAM high level technical architecture

The TM2.0 collaborative functional architecture shown in Figure 12 serves as an initial blueprint for how to implement these different forms of collaboration in practice. The actual effective technical implementation for these collaborations is dependent on many factors such as the foreseen collaboration level, the geographical scope of the collaboration (e.g. local, regional or national), local governance structures, local common information exchange standards, and others. On the other hand, given the fact that for many heavy duty freight vehicle operations these logistics operators are active on an international level, interoperability and standardisation are also key in making these schemes work for all stakeholders involved. In order to enable finding this balance between effective local implementation and logistic operations and interoperability and scalability, the high-level technical architecture shown in Figure 13 provides a first instance of how these collaborations could be set up, and which supportive standards could enable this.

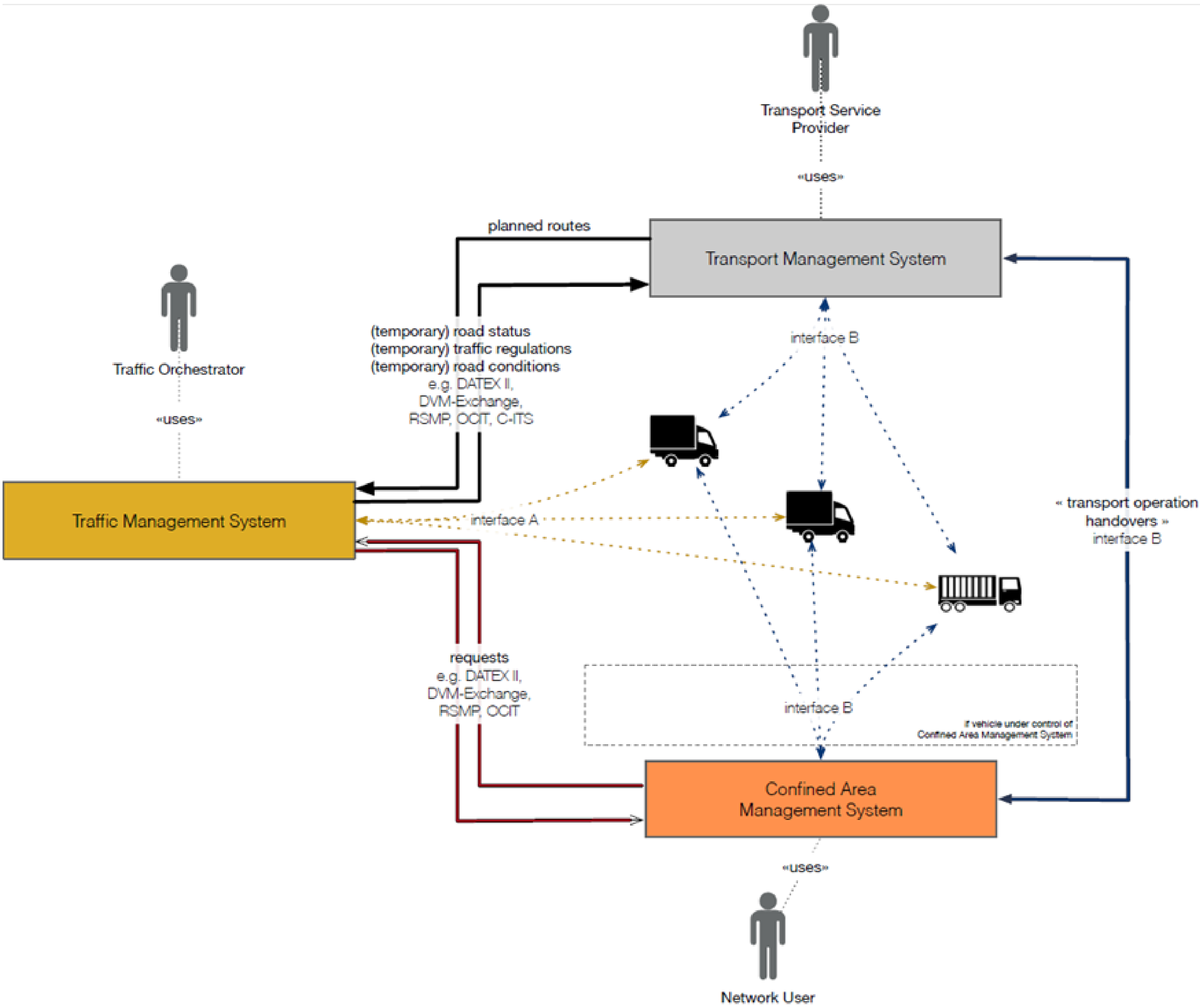

Figure 13: High-level Technical Architecture

The high-level technical architecture shown in figure 13 shows through which technical means the inter-role collaboration between the traffic orchestrator (through use of the Traffic Management system), the Transport Manager (through use of the Transport Management System) and the Confined area Manager (through use of the confined area management system) could be implemented. The data exchange by a public traffic orchestrator towards both transport management and a confined area manager can most effectively be performed by using an internationally known and scalable data exchange protocols such as DATEX II. This protocol provides a basis for all required data exchange where the traffic orchestrator is involved in the functional architecture. In some cases however, traffic orchestrators will primarily be supporting one or more protocols used in one or more European Member states such as DVM-Exchange [25], OCIT [26], or RSMP [27]. In addition many member states are also making this information available in the context of a European Mobility Data Spaces (EMDS) [28]. This initiative will also focus on reliable and scalable exchange of traffic data that will be of use in these collaborations. Direct information exchange between a transport management system and a confined area management system may be limited in the context of the collaborative traffic management scheme, apart from a handover (as foreseen in the MODI interface B shown in figure 6) when vehicles cross from public to private road or vice versa.

9 Conclusions

This deliverable provides a structure in understanding which roles are relevant in achieving mutually beneficial traffic management collaboration schemes in the context of CCAM L4 automated vehicles, and how these collaborations could work in several scenarios. These blueprints for collaborative architectures are provided in a functional architecture, with a related high-level technical architecture providing initial steppingstones for implementing data exchange between these entities. This chapter summarizes the main findings described in this deliverable.

When exploring interactive traffic management schemes in the context of CCAM L4 freight operations in logistics, three roles are seen as most relevant. First, the Traffic Orchestrator representing the public road management which is responsible for safe and efficient use of public road infrastructure. Second, the Transport Manager representing a logistics stakeholder responsible for optimising the transport planning and operations of one or more freight vehicles. And third, the Confined Area Manager as a sort of private sub-set of a Traffic Orchestrator. By exchanging information and understanding each other's operational issues they can better adapt to certain situations, and both improve their own strategies as well as the strategic effectiveness of the other.

When understanding the potential benefits of these collaborations, stakeholders showed that the initial benefits will already be shown far before actual widely deployed L4 automated freight vehicles are in operations. In particular the extended digitalisation of the logistics domain will already improve data availability, data exchange and mutual understanding, contributing to effective collaborations.

In sketching the several task scenarios in which TM2.0 collaboration could enable a win-win for these involved roles, stakeholders expressed that traffic orchestrators see extensive value in merely being able to share their traffic information in an open and scalable manner to multiple transport managers, and limited value in receiving information from these transport managers. Just by improving the understanding of traffic managers on what their vehicles will face when driving on public road will already help them adjusting to events or incidents consequently already reducing negative impacts on road capacity and safety and thereby contributing to road operator effective strategies. Traffic orchestrators were interested in receiving floating car data from transport managers, however the examples in which they can actually effectively act upon these new insights in practice was seen as limited. Especially regarding exceptional cargo operations data exchange was seen as valuable, as sometimes road operators overlook exceptional size/weights when providing rerouting information.

The functional and high-level technical architecture provided in this deliverable serve as blueprint in starting these collaboration schemes in local, regional, national or even international contexts, and provide the first instances in how such data exchange could be implemented on a technical architecture level. Through providing these architectures, this deliverable complements the work on designing the Physical Digital Infrastructure within the MODI project.

9.1 Discussion

In this chapter, the findings described in this deliverable are further discussed regarding their validity, wider impact and needs for further research. Given that from all the MODI use cases the German use case best represents public-private CCAM vehicle operations and involves several road operators, a workshop was held with these stakeholders in which the findings were presented and the validity of these findings were discussed. The outcomes of this workshop served as main input for the discussion upon the deliverable findings and are described in this chapter.

The value of enabling these new forms of public private collaboration is widely acknowledged among the stakeholders when considering higher levels of automated freight vehicle adoption on public roads. The more automated freight vehicles there are, the more information will be available to vehicle operators, and this information could be of high value for traffic orchestrators. The other way around, the value of having ‘road infrastructure optimization’ considerations somehow being included in the ‘transport optimisation’ by traffic managers was also widely acknowledged, as this was seen as one of the only ways of having these societal objectives being taken into account in automated vehicle operations. A concrete example was having more means for guiding heavy construction traffic to inner urban construction sights, as current designated driving routes were often blocked for these heavy vehicles and being able to transmit route-updates to these vehicles when this occurs was seen as a valuable short-term gain already. Among these stakeholders the view that ‘digitalisation’ would already bring many of the potential benefits to reality was shared with both private and public stakeholders, with full ‘automation’ being the cherry on top which could extend these benefits further.

Traffic orchestrators also shared doubts if these collaborative structures as described in this deliverable would work in their context. For example, with extended data exchange being a nice addition to the overview that traffic orchestrators have, they will still manage automated vehicles through their own infrastructure such as traffic lights and traffic regulations. These could be digitally communicated and therefore vehicles could be made aware of this earlier, but still the direct influence over these vehicles would remain within the responsibility and the infrastructure of the road operator, and will not be shared or transferred towards private entities. In that regard they expected the investments for making this happen not being in line with the ‘nice to have’ character of these extended capabilities. Moreover, differentiation of traffic management information exchange to specific target groups was seen as problematic, as public authorities are not permitted to discriminate between road users. Traffic orchestrators also commented that they actively want to keep away from becoming (or feeling) responsible for guiding specific target groups of end users across their road infrastructure, stating it is their responsibility to inform drivers of the active traffic regulations which all road users should abide by. These traffic orchestrators in many cases did see the potential improvement of effectiveness of traffic measures if they could be focused on specific target groups, however they were not convinced that their current responsibilities and mission allowed them to make such distinctions in practice. In the context of level 3 collaboration schemes, traffic orchestrators agreed that including contractual agreements would not be possible within the current legal framework.

9.2 Recommendations

Further research on the topic of TM2.0 collaboration between traffic orchestrators and the logistics stakeholders should further explore how data exchange could not only be a ‘nice to have’ for traffic orchestrators, but could really significantly improve their strategy effectiveness. Moreover, research could focus on exploring how innovative forms of public-private data exchange, could be fitted into existing legislative frameworks, or what is required for these collaborations to work for public entities. And finally, with any effective collaboration scheme finding the right balance between scalability and interoperability on the one hand, and adapting to the local context and operational issue on the other, further research should explore how internationally acknowledged data standards (e.g. DATEXII) could serve as a mutual base for public and private stakeholders throughout the European Union to share traffic and transport data and eventually also solve smaller scale local operational issues in smaller municipalities or smaller confined areas.

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