AWARD

Scaling autonomous logistics

D5.7 Public architectural model for fleet management and control services

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List of acronyms

ADV	Autonomous Driving Vehicle
AWARD	All Weather Autonomous Real logistics operations and Demonstrations
API	Application Programming Interface
AV	Autonomous Vehicle
FMS	Fleet Management System
KPI	Key Performance Indicator
ODD	Operation Design Domain
OMS	Operation Management System
RSU	Road Side Unit
UML	Unified Modeling Language
URL	Uniform Resource Locator
WP	Work Package

Glossary

Autonomous Driving Vehicle	A connected and automated heavy commercial vehicle
Situation	An event which affects the vehicles and/or users in the logistics chain. Situations are reported with a start time and location, optionally an end time. Examples: Broken down vehicle blocking a road, oil spill, planned closure of an area for traffic, fire in a production hall

1. Executive Summary

The fleet management and control services developed as part of the AWARD project fulfill the role of orchestrating the operations of the fleets of autonomous vehicles deployed at the different pilot sites. The Fleet Management System collects information from a number of different entities, ranging from sensors to human users. It uses the information to build a comprehensive picture of the operations and operating conditions on site, and uses this to optimise the execution of jobs on the one hand, and making operations as safe as possible on the other, taking into account both equipment and road users.

The current architectural model is the result of both discussions inside WP5 and information and material coming out of WP2 (“Identification of end-users’ needs and requirements”) and WP7 (“Testing methodology and evaluation”). The design of the model shows the envisaged structure of the fleet management and control services, providing technical details on its core functions. It thereby forms the basis for the next working steps in WP5, which will see the implementation of the fleet management and control services. Further details, especially those relating to infrastructure available at the pilot sites, will be added as those pilots are being set up.

2. Introduction

2.1. Objective of the architectural model for fleet management and control services

The architectural model for fleet management and control services relies on two main aspects: the analysis of current fleet management and logistics operations, and the anticipated role of connected and automated heavy commercial vehicles in said logistics operations.
Compared to traditional vehicles, the fact that automated vehicles are connected opens up a myriad of possibilities for improving and optimising the use of the vehicles, and thus the parts of the logistics chain upon which they touch. The fleet management orchestrates this connectivity by connecting, processing and distributing information between the different parts of the logistics ecosystem, and managing the fleet of ADVs in an optimised way.

The architectural model upon which the fleet management is to be based must therefore fulfill a number of tasks. For the purpose of the AWARD project, it is important to not just ensure that operations are enabled but that the processes and all operational data resulting from them is reliably tracked and made available for later analysis in order to assess the impact of introducing ADVs into an existing logistics chain. Additionally, the requirements of users and stakeholders, as well as the functional requirements identified in WP2 (Identification of end-users' needs and requirements) must be respected when designing the architectural model in order to ensure that the fleet management is well suited for its designated role.

As the four pilots in the AWARD project are all very different from one another, the FMS used in each of them has to be adapted accordingly. This reflects the fact that the different industrial ecosystems in which the pilots take place have both different features and different needs. The architectural model must therefore respect these differences, all while establishing as much common ground as possible in order to provide a coherent solution and ensure that data from the different pilots can be compared and correlated in a later analysis.

2.1.1. Role of the fleet management and control services in AWARD

Acting as an information hub between not just different parts of the logistics chains of the pilots presented in AWARD but also between the systems surrounding the ADVs, the FMS is connected to and supports different aspects of the project.
The general setup of the FMS is shown in Figure 1. The figure illustrates the most fundamental idea behind the FMS, namely that a single entity should be able to make use of all the available information in an ecosystem in order to send out pertinent information to the different actors involved. A number of components are not explicitly shown in the figure, such as the EZ Fleet system and the teleoperations system. Note also that the FMS is generally connected to vehicles, which includes ADVs but also non-automated vehicles (as for the Hub-to-Hub pilot, which comprises an ADV as well as a non-automated backup vehicle). For non-automated

vehicles, the connection with the FMS may be established via interfaces the vehicles may have, or by equipping their human driver with adequate tools.

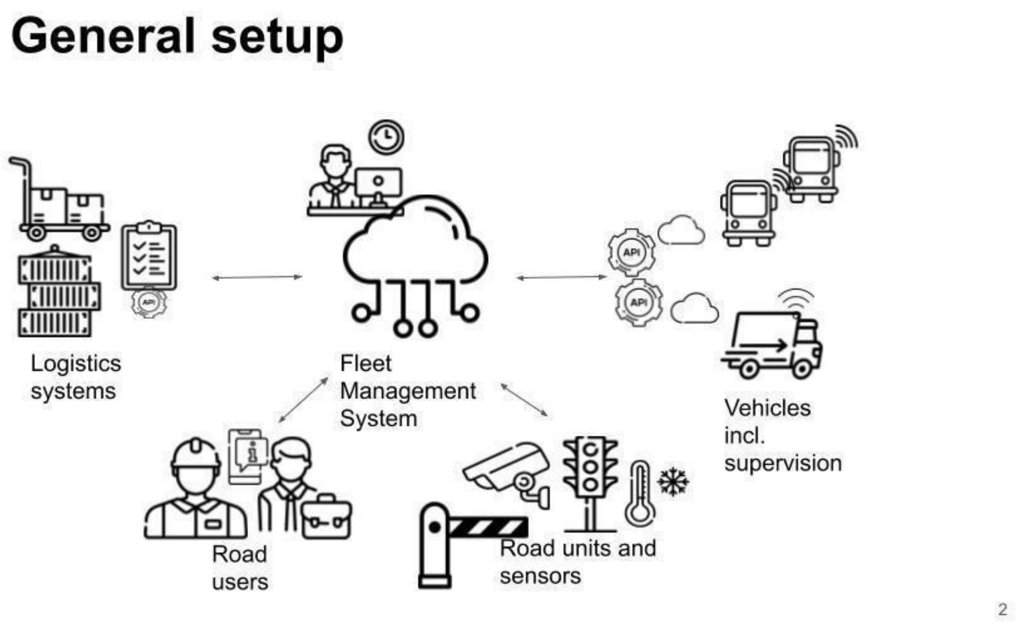

Figure 1: Fleet Management System and surroundings in AWARD

As presented in the description of action of the AWARD project, the FMS design is built on the following steps:

a. Review the existing fleet and logistics operation and establish an architectural model for the fleet and logistics operation (understand the process)
b. Optimise control methods that support an efficient, high capacity and safe operation of teleoperation-enabled, connected and automated heavy commercial vehicles with other parts in the logistics chain
c. Identify road infrastructure and vehicle capabilities necessary to provide the best road conditions for the logistics operations and other (vulnerable) road users
d. Establish necessary and standardised interfaces for efficient communication with vehicles, road infrastructure, logistics systems and other relevant road users
e. Identify necessary functional safety and cyber security requirements relevant for the Fleet management system
f. Define needed operational Data/KPIs for the fleet and logistics optimisations

All the above lead to input to the overall architecture for the FMS. The individual steps will be discussed in more detail below.

2.1.2. Aim for the Fleet Management System

The overarching aim of the FMS is to support smooth and efficient operations as well as the highest levels of safety on docks, open roads, ports and terminals.

This requires collecting and processing environmental and system data which is then used in order to define missions for the vehicles in the fleet and also to alert users. To this effect the FMS contains a control centre, allowing a human supervisor to monitor the flow of information if so desired. It should however be stressed that such a supervisor should never be required by the FMS: Fundamentally, the aim of connected autonomous systems is to control the fleet independently of human operators. Naturally, it is desirable to facilitate insights into the current state of every element that the FMS holds, as well as providing an override function. The control centre with corresponding user interfaces fulfils both of these functions. Additionally, the control centre permits a human operator to manually send out alerts and other relevant information to vulnerable road users and other stakeholders. Again, such manual input should be possible but also highly exceptional, as the FMS aims to issue information to all parts of the system automatically, including users connected via external interfaces such as websites. The expectation is that an automated system such as the FMS will be more cost effective, reliable and timely than existing systems.

2.2. Scope of document

This document describes the initial architecture of the FMS and how it interacts with the connecting systems in the AWARD context. The document represents deliverable D5.7, "Public architectural model for fleet management and control services".

As with any architecture design, it is to be expected that the final architecture will differ from what is described here. With the pilots taking place on real, living industrial sites, the ecosystems at hand will not be static over the course of the AWARD project. Accordingly, the requirements and needs as established in WP2 will be changed and updated, and the FMS be adapted in turn. At the time of writing, a number of details from implementation of the vehicles and specifics of different road infrastructure and logistics systems have not been finalised yet, such that these falls outside of the scope of this document.

The document focuses instead on the analysis of the fleet management and autonomous logistics operations that are envisaged in the different pilots, based on the present circumstances. Based on this analysis, designs for processes for managing the ADVs, road infrastructure and other parts of the logistics chains are presented.

2.2.1. Process of establishing the architecture

Throughout the work with the Fleet Management System architecture, the different AWARD partner's experiences, needs and solutions regarding the state-of-the-art logistics have been presented and analysed, together with the ambitions of the different pilots and vehicles. For this purpose, introductory meetings were held and all partners in WP5 were asked to fill in a questionnaire detailing their respective starting points. This resulted in a description of components that partners already have in place (maybe as part of existing operations) and that they anticipated connecting to or becoming part of the FMS. At the same time, the partners were asked to describe if they already saw any potential improvements to these components or adjustments that should be made as part of the AWARD project.

In weekly meetings, the current picture was presented, and gaps were identified. This allowed to highlight and come to a better understanding of the possibilities and limitations of the FMS, especially with regards to the fact that it is to be implemented on industrial sites that already have an existing logistics flow today and will continue to operate after the AWARD project is finished. The focus thus shifted from the individual partner's technology and expertise to a discussion centered around the pilots.

Throughout the discussions, new insights achieved from WP2 were taken into account to design the most pertinent FMS possible. While all pilots have different needs and resources, it was nonetheless felt that in order to be able to do a sound technical evaluation as envisaged in WP7, certain commonalities had to be established. The trade-off between designing a coherent system and including as many functionalities as possible was extensively discussed and ultimately resulted in the architecture design that is presented here.

3. Fleet Management System Architecture

3.1. Overview

The Fleet Management System's main task is to optimise the utilisation of the available vehicles according to the transport needs and road conditions in a safe manner.
The main functions for logistics operations are:

- Dispatch, including handling orders
- Manage assets
- Handle road conditions
- Remote vehicle assistance
- Monitor operation and provide KPIs
- Provide end user information

and will be described in the following sections.

As the FMS is an integration platform, where third party systems shall provide or receive data, it is crucial that the interfaces are handled in a secure and reliable manner, see Figure 2.

Figure 2 shows the generic concept of the FMS integration architecture. Note that the diagram shows components and their dependencies for the purpose of illustrating the security concept, and does not provide information on any data flow. The core FMS consists of a backend enterprise solution and a frontend for possible user interaction. The red boxes indicate the external systems that will be integrated to the FMS through different types of protocols.

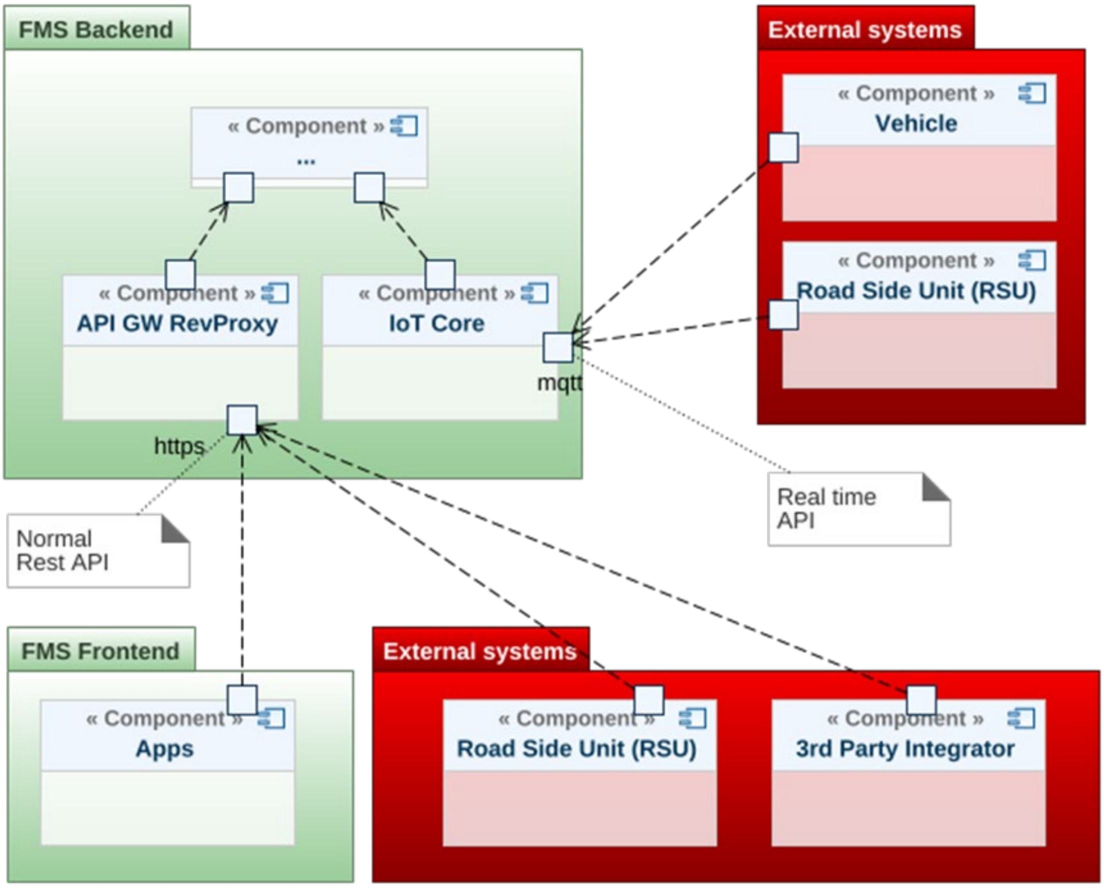

Figure 2: Generic overview for AWARD Fleet Management System (FMS) and its external systems: components and dependencies.

Since the FMS integrates external systems with different functionalities and purposes, the architecture has two main API-ways into the FMS as shown in the figure above. These are the Rest API called API GW (Gateway), and the MQTT API called IoT Core. In the backend of the FMS, the Rest API is connected via a GW Reverse proxy (denoted RevProxy in Figure 2 above), which is used for balancing load. The table below describes which interface is suitable for the different functionalities. The specific interfaces in AWARD will be described in D5.2 "Standardisation, safety and security requirements for fleet management and control services".

Integration interfaces	**API GW** (Rest API) Sync callable	**IoT Core** (MQTT API) Realtime
Deliver telemetry and/or status, receive configuration and commands (Typical vehicle and roadside unit integrations)	✔ [1]	✔
Booking of vehicle assignment	✔	
Deliver events / exception reports	✔	✔
Adjust operational area	✔	
Get analytic extracts	✔	

Table 1: Generic description of integration interfaces towards FMS

3.2. Use cases and Sequences

In order to provide more concrete information about the workings of the fleet management, the main functions of the FMS are explained in more detail in the sections below, illustrated by use cases and sequences that are used.

3.2.1. Dispatch

Generally, the main function of the FMS is to perform an efficient dispatch function which fulfils the logistics order requests in a safe and optimal way. Figure 3 shows an overview over components of the dispatch (shown in UML). The dispatch function communicates with the Fleet Management, a Logistics system, and also the vehicles in a fleet. It schedules, monitors and orders the execution of assignments, but does not manage the fleet in any other way and receives any special operation orders via the Fleet Management (and not for example from any external systems).
If there are several vehicles in a fleet and multiple route alternatives are available, the dispatch will encounter the different parameters in planning and executing the order requests:

1. Select a vehicle among the assets that can transport the requested payload
2. Select a vehicle among the assets that are available and have sufficient energy at the requested time
3. Select a route suitable for the vehicle and safe according to the road conditions

[1] Possible when other protocols are not available, it's done as an exception because of scaling and limitations, cannot send vehicle commands in real time.

4. Arrange the assignment list according to order priority and optimal utilisation of the vehicles
5. Monitor the assignment list and transport executions in real time, and re-evaluate the assignments on interruptions or delays

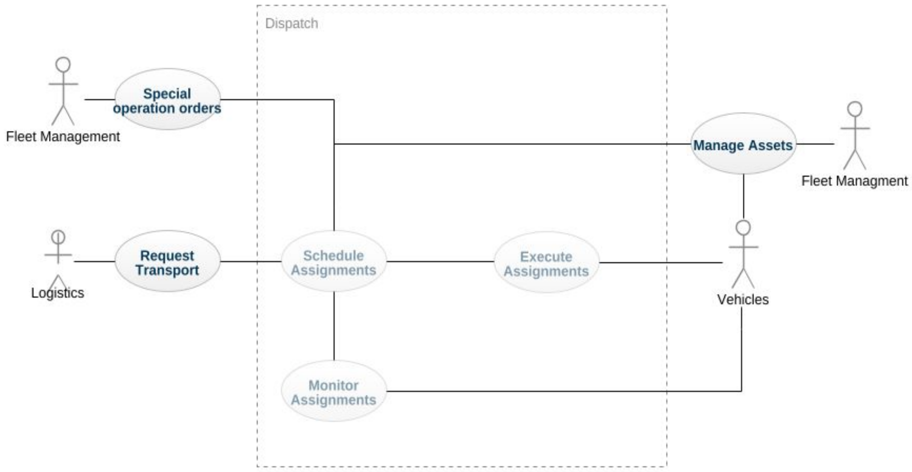

Figure 3: Dispatch

A transport order usually comes from the logistics system (transport goods from A to B), but the dispatch function also needs to handle orders from other systems (special operations orders) to go to specific places or alternative routes in case of, for example:

- Planned or immediate need for the vehicle to go to the battery charger
- Emergency situations in an area meaning that the vehicle needs to go to one of a number of predefined locations
- Road closure resulting in a detour or wait which needs to be planned, and subsequent rescheduling of the assignment
- The order list is empty, and the vehicle needs to wait in a safe place

In order to optimise the efficiency of the dispatch, the FMS uses an optimisation algorithm. The larger the fleet, the more important it becomes to take into account the different capabilities and statuses of the vehicles in the fleet. In order to optimise the execution of the functions listed above, the algorithm takes into account the following parameters:

- Infrastructure data
    - Locations:
        - All possible pickup and drop-off locations
        - Base location(s) of the vehicle (where it is located during idle times)
    - Map/Route network (also route network within the terminal / company compound)

- Vehicle data
    - Maximum capacity:
        - Maximum number of items that can be loaded
        - Maximum size or volume
        - Maximum weight
    - Average speed of the vehicle
    - Availability
        - Time window: start and end time of the operating time
    - Current position
        - Coordinates
    - Current vehicle status
        - Status: what is the vehicle currently doing? Is it on route, loading, unloading, coupling, available, out of service, …
        - State of charge

3.2.1.1. Request Transport

The nominal orders in the system are goods transports requested from the logistics system, but the system will also use the dispatch system to order the system to execute other tasks as illustrated in Figure 4. The identified types of requests can be described as:

- Transport goods from A to B (time, details about the goods)
- Transport empty from B to A (time)

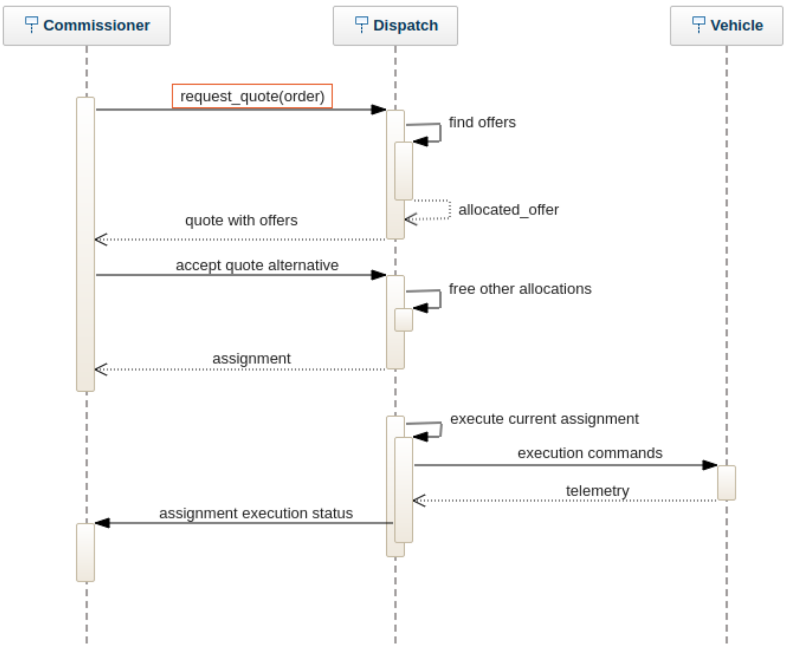

Figure 4: Request Transport

3.2.1.2. Special operations orders

Special orders can be generated from the FMS itself, or indirectly from a third-party system or an operator tool. These orders are defined as GoTo-functions, the locations given are defined by their coordinates.

- Go to charger X (time)
- Go to idle position (garage, service, temporary waiting position) (time)
- Go to safe waiting position (Now)

3.2.1.3. Manage Assets

The Manage Asset activity is an FMS internal function that keeps track of the fleet status and their possible and available usage. The Dispatch function will always select a vehicle that is available for the task, can operate in the environment and is able to transport the requested goods. In order to optimise the operations, the distance of a vehicle to the goods is also taken into account.

3.2.2. Handle road conditions

Handling road conditions is an important function for the FMS in order to execute correct dispatch and fulfil the transport assignments. In Figure 5below, different road actors which can provide information about the roads are identified using UML notation.

The architecture provides a common generic structure for handling the inputs, and if equipment shall be purchased or implemented, the architecture shall be considered where possible. But due to the nature of the different pilot areas in AWARD, there might need to be adjustments to integrate systems using other standards.

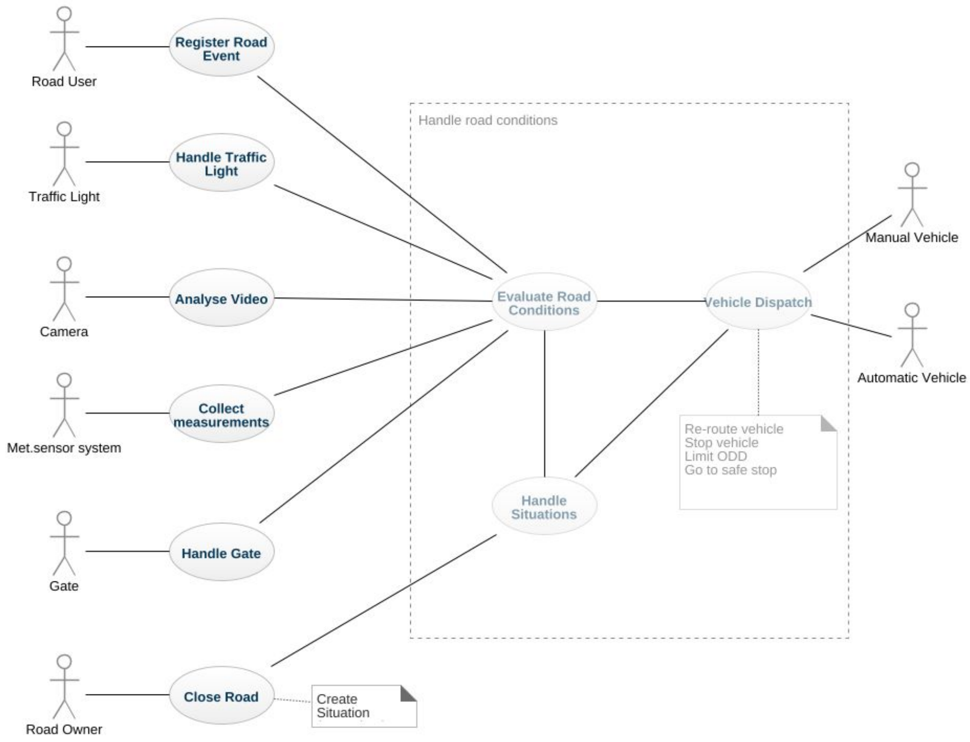

Figure 5: Handle Road Conditions

Register Road Event: The other road users of any one pilot case or the safety operator of the autonomous vehicles can register events or situations that they observe on the road, such as potholes, snowbanks or accidents. The FMS might provide a web-app solution for this if relevant.

Handle Traffic Light: The Hub-to-Hub pilot has identified a need for regulating the traffic on a public road to ensure safe operation of the autonomous vehicle. Additionally, WP2 has identified that most people at the site also believe that traffic regulation will be necessary for safe operations. Most likely, the vehicle can communicate with the traffic light system through V2X standards. Additionally, the status of the traffic light should be visualised in real time in the FMS for monitoring and post-analysis purposes.

Analyse Video: Cameras can be used to evaluate road conditions, traffic or access control for the vehicles. At the time of writing, none of the pilots will involve the FMS handling video analysis.

Collect Environmental Data: AWARD is about performing logistics operations in harsh weather conditions. Therefore, meteorological sensors as well as sensors providing data on road conditions will be important to obtain knowledge of the road and vehicle sensor conditions. The FMS will use this environmental information to ensure safe and the most efficient operation of the vehicle in different conditions. The airport and Hub-to-Hub pilots have identified meteorological sensors, the Hub-to-Hub pilot will also use a road sensor.

Handle Gates: Different pilots have different gates that the vehicles must pass. Some require access control regarding the assignment, some are open during working hours, and some can be opened remotely by an operator. How the gate systems need to interface with the FMS is still yet to be described in detail. It has been identified that gates will be handled in both the Hub-to-Hub and Port pilots.

Close Road: A road owner wanting to close down a particular road or restrict traffic on it can use the FMS control centre to register a Situation in the area concerned. The FMS detects this Situation and dispatches the vehicle according to possible mitigations (re-route, stop, GoTo…). Examples of Situations might be bad road conditions, emergency situations or VIP transport arriving.

3.2.3. Remote vehicle assistance

If the vehicle comes into a situation where it cannot itself resolve the situation or operation, there needs to be assistance available for the vehicle. In the case of the vehicle having no operator on board, this assistance may be provided from a control centre.

Two different forms of assistance are identified:

1. **Operate specific vehicle functions**

Examples may be: re-arm vehicle (meaning that the vehicle is put into an autonomous mode once more after disengaging from this mode), provide new mission/re-route, open doors, driving performance (ODD) setting (no, limited, reduced, full), validation (confirming that the vehicle may drive ahead at for example a junction or zebra crossing)
For this to be available for the FMS, the vehicle-API needs to support access to provide this kind of commands.
Available now for the AWARD vehicles API are:

- Provide new mission/re-route
- Validation
- Re-arm

2. **Remote driving**

If the vehicle is stuck, for instance in front of an obstacle on the route, and cannot by itself or with the help of a safety operator pass it by creating an alternative route, the remote driving function is used. Remote driving entails that an operator in a control centre can operate the vehicle using a system of steering wheel and throttle, high resolution and very low latency video of the vehicle's surroundings to manoeuvre the vehicle around the obstacle and to a place where automated driving can be resumed. Remote driving functionality will be implemented in the Hub-to-Hub pilot.

The remote driving system needs to be connected to both the driving functions of the vehicle and the FMS to ensure a safe handover between automated and remote driving, and information exchange about what assignment the remote driver shall perform. This is illustrated in Figure 6.

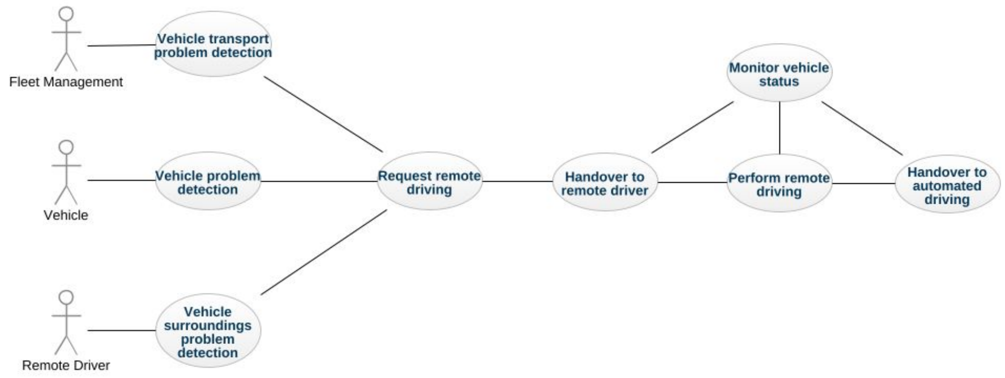

Figure 6: Remote driving

3.2.4. Monitor operations and provide KPIs

The FMS shall continuously monitor and store information about the transport operations to visualise in real time their status and to be able to provide reports and analytics on historical data.
During operation, real time information (telemetry or events) will be available for transport observation in the control centre. Video-streams from vehicles or road infrastructure can also be observed if available for the FMS.

Some of the key parameters to be continuously stored for analytics may be:

- Orders and assignments: originals and updates, status, deviations
- Vehicles: position, speed, heading, assignment, driving statuses, route, deviations
- Road Condition: RSU telemetry
- Road Users: reported Situations

The KPI's for the FMS are typically:

- Transport order precision
- The best utilisation of the vehicles
- Transport performance in different weather conditions
- Interrupted transports and reasons for the interruptions

Examples of data to be collected in order to evaluate the KPIs:

- Driving speed (max, average)
- Load carrying capacity
- Loads moved per day
- Idle time
- AV availability
- Average cargo weight
- AV battery levels (for calculating energy efficiency)
- Kilometers driven (to see optimisation of driving pattern)
- Transfer time (to move load from A to B)
- Number of teleoperation interventions

- Time spent in manual mode
- Time spent in autonomous mode
- Time spent in teleoperation mode
- Time spent on maintenance tasks
- Location log
- Charging time and frequency
- Harsh weather related issues (type, frequency)
- Intrusion detection, access attempts
- E-stop frequency
- Localisation quality (measure to be specified)

The analysis of the data and evaluation of the KPIs is part of WP7 and will therefore not be further discussed here. Care has been taken to align the data collection abilities of the FMS with the needs of WP7 in order to ensure that all necessary information is registered.

3.3. Information model

The information model which describes the data types around the FMS will become available through the API-documentation in the Applied Autonomy developer-portal.
Access will be given to a limited pool of developers only.
The API-portals for the FMS-external systems the FMS need to connect to, will also be listed here when available (vehicles, logistics and RSUs).

4. Pilot-specific architecture

While a more detailed description of the pilots can be found in deliverable D2.1 "System scope", the features of the pilots which are relevant to the FMS are summarised here. As mentioned previously, the list of features is by no means final but merely the best possible assessment, based on the information available at the time of writing. An updated list will be provided in D5.6 "Final report".
A tabled summary can be found in Annex 8.1 Pilot cases.

4.1. Pilot 1: Hub-to-Hub

The Hub-to-Hub pilot involves a challenging route along a public road and operation of a timetabled shuttle service between two industrial hubs. The FMS will make use of a number of sensors and features which will be connected either directly or indirectly. These include:

- Fire alarm
- Weather station at one of the hubs
- Road-side weather station
- Gate to one of the hubs
- MD30 road sensor
- Traffic light system
- I/O device at the terminals

In particular the different sensors will provide crucial data for the envisaged all-weather operations and also allow the FMS to define appropriate mission parameters for the ADV in order to operate it safely in all conditions.
The I/O device at the terminals (for example a touch screen) serves two main functions: To inform workers at the terminal about the state of the operations (including the location of the shuttle and when it is next due to depart), and also to allow them to indicate to the FMS when the loading/unloading of the ADV has been completed earlier than scheduled. This allows stepping outside of the timetable and making the operations more efficient and convenient for the workers. Should the ADV be unavailable for any reason, the manual replacement vehicle will be connected to the FMS and the function of the I/O device will thus be maintained.

4.2. Pilot 2: Port

Access to existing logistics operations at the port site are managed through the DFDS GEMINI system. GEMINI acts as a gateway to other, internal DFDS systems, thus reducing the complexities and transparency needed. This includes amongst others the authentication of vehicles and drivers entering the restricted port site, gate control, cargo monitoring, allocation of parking spots for trailers, as well as the management of manual vehicles and their drivers. In order to be able to add the ADV proposed in the AWARD project to these operations, the FMS will therefore act alongside GEMINI, without taking over any of its functions. Instead, a dialogue will be held between the two systems, with GEMINI requesting a transport FMS, which then defines a mission using the dispatch and other functions as described above in section 3.2. In order to ensure continued smooth operations at the site, the FMS will ask

GEMINI for approval before starting the mission. Should the AGV be unavailable or unable to fulfill a transport request, the FMS will signal this to GEMINI, which will then in turn move the transport request to a manual vehicle instead.

4.3. Pilot 3: Forklift

As of today, the part of the operations at the forklift pilot site which take place outdoors and entirely manual, relying on driver's experience and ability to react to events. Introducing an automated forklift vehicle into these operations is therefore the first step in moving towards an environment where infrastructure, vehicles and other parts of the ecosystem may be connected.
The FMS will serve to connect the ADV to the logistics chain by receiving status signals from an insertion point occupation sensor, which detects when a container has arrived for the ADV to be moved. The detection results in a transport request, which the FMS then manages.

4.4. Pilot 4: Airport

The use of an ADV at the airport requires comprehensive communication with both ground handlers, who attach and detach dolly trains to and from the vehicle, and also supervisors and duty managers, who will make transport orders and inform the FMS about emergency situations, road closures (for example due to VIP presence at the airport), etc. The FMS will also be connected to a weather station located at the airport, using the weather data to ensure that the ADV operates in the safest possible way.
A management application provided by TLD called "LINK FMS-OMS" implements specific Operation Management System (OMS) capabilities for the control of airport ground handling operations such as baggage logistics. Processing data streams from airlines and airport authority updates enables the application to reconcile last-minute changes of flight data (estimated time of arrival/departure, parking stand…) with baggage container, unit or bulk identifiers assigned to the flights, and make decisions related to the creation of baggage logistics tasks, their scheduling, their assignment (automatic or manual) to human resources and baggage tractors, their rescheduling or reassignment in real time, and finally the control of their progression by reaching some predefined milestones (e.g., conditioning baggage items in containers, loading of containers on dollies, departure from gallery, arrival at parking stand, unloading, deconditioning of baggage items, departure from gallery, return to a gallery or workshop, etc.). The use of ADVs raises the problem of decision making related to assignment (automatic or manual) of ADVs to baggage logistics tasks and the specific control requirements of this use case of ADVs.
The LINK FMS-OMS application will be integrated in the FMS at two different levels: user interface and data levels.

At user interface level:
The LINK FMS-OMS web application will be embedded in an interface of the FMS. An example of what this may look like is shown below in Figure 7, with the grey boxes acting as placeholders for other information, such as vehicle status, sensor information, etc. An advantage of embedding the LINK FMS-OMS web application in the FMS interface is the ability

to offer users the control of airport baggage logistics without leaving the FMS. Business logic that is highly specific to the 'airport baggage transportation' use case will remain on the LINK FMS-OMS server application, but the user interface of the FMS will retrieve LINK FMS-OMS panels/dashboards via requests to specific URLs.

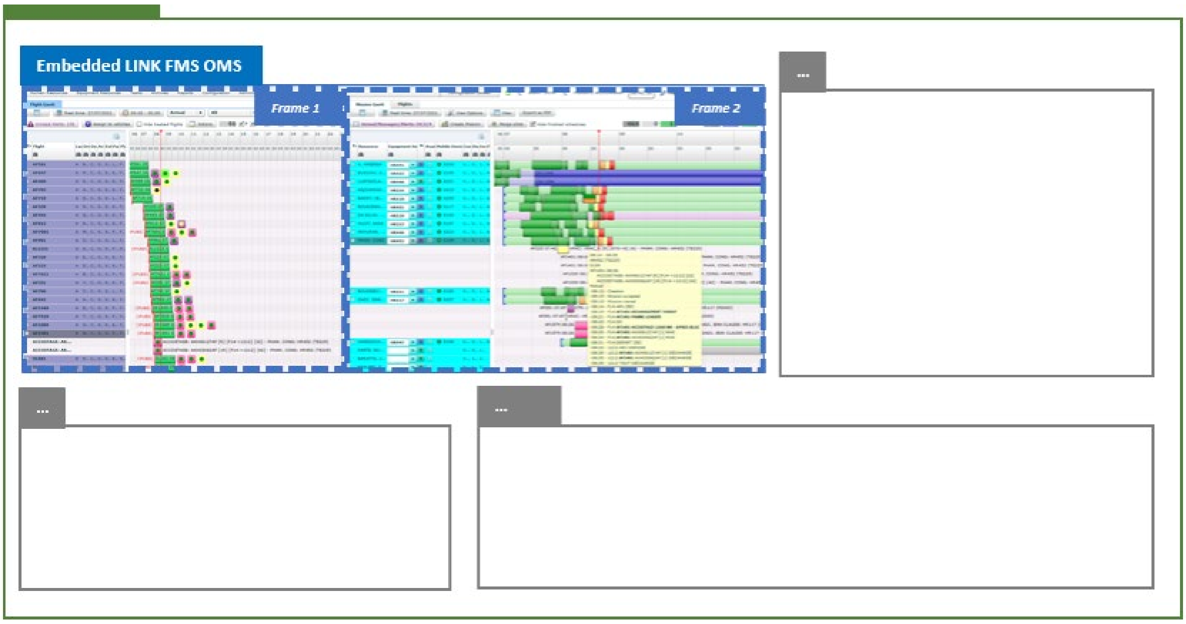

Figure 7: Embedding of the LINK FMS-OMS in the FMS

At data level:
The FMS uses an API of the LINK FMS-OMS to retrieve any data needed by the FMS related to airport baggage logistics tasks (e.g., source, destination, start, end, milestones, multiple-rotations, alerts, baggage identifiers...), specific vehicle properties and some human resources properties (access control identifiers, qualifications...). This is illustrated in Figure 8 below.

Figure 8: Data sourcing from LINK FMS-OMS API

4.5. Other considerations

As noted above, the logistics ordering systems or mechanisms are very different on the different pilot sites. That implies that ordering goods transport needs to adapt to this, but at the same time, have a generic and agnostic handling inside the FMS. This will allow identifying important KPIs, as required by WP7.

Even though the different pilots will use vastly different types of vehicles, the following will be true for all pilots and ADVs:

- All the ADVs in the pilots will be using the EasyMile automation system and therefore will be standardised regarding the integration APIs towards the FMS.
- The FMS will not be a direct part of the safety chain of the vehicle, but will provide a monitor, dispatch and asset management function that can ensure that the vehicles do not operate under road conditions not suitable for the vehicles' ODD.

As part of FMS's contribution towards making operations as safe as possible on all pilot sites and for all users (personnel on site), the FMS will also provide an information dissemination system. Depending on what information is available at the different sites, workers, drivers and other stakeholders will be able to use a web-based interface to view the ADVs' status, as well as any other information that the FMS holds that may be relevant to their safety. This includes for example reported road incidents, weather warnings or Situations reported by another user.

5. Strategy for implementation

The present architecture design represents a solid overview of the work that needs to be done in order to implement an FMS that supports operations in all pilots. However, as further details are expected to emerge as the project progresses, there is little value in drawing up an implementation plan for the architecture as a whole: With ecosystems necessarily evolving and changing during the implementation, such a plan could not adequately address the current needs of any of the pilots.

The strategy for implementing the FMS is therefore by increments, allowing adjustments and updates between each such increment. Additionally, an incremental approach significantly reduces the complexity of debugging and other error handling.
The time frame of the implementation is dictated by milestone MS6, "Fleet management system and HMI ready for pilots", which is planned for M22 (October 2023). This allows planning a fixed number of implementation rounds, with each round containing a set number of functionalities to be implemented.

In order to establish a prioritised list of functionalities to be implemented, the external needs and the availability of the surrounding systems have to be taken into account: As the stakeholder needs crystallise and the pilots become more clearly defined, it is to be expected that external factors will put certain constraints or demands on the implementation of the FMS. Furthermore, integration of a component or functionality will be dependent on the relevant system being available both for the actual integration and the subsequent testing.

Thorough testing as well as demonstration of a newly implemented functionality of each increment will ensure that the system developed is within the goals of the project. Additionally, demonstrating functionalities early on allows collecting feedback from users on the pilot sites and adapting future rounds of implementation accordingly.

In order to coordinate the implementation of multiple functions for multiple pilots simultaneously, there will be monthly alignment meetings where the partners of WP5 will present the current state of their respective tasks. Additionally, there will be quarterly review meetings, where the progress of the implementation activities will be assessed and discussed. Following the review, a progress update will be published. This includes making new API information available on the API portal described in section 3.3. A schedule for this implementation strategy is shown in Figure 9 below.

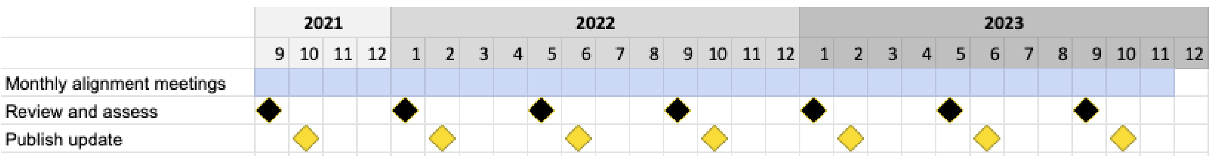

Figure 9: Gantt chart of implementation

6. Risks

Table 2 below lists the risks identified in this stage of developing the FMS architecture regarding achieving the AWARD project goals.
For a complete list of the project risks with inherent and residual probability and impact scores, see the AWARD risk matrix.

Risk	**Consequence**	**Mitigation**
FMS Architecture is set up to be finalised before the requirements analysis in WP2 is finalised and new requirements come up too late	Late changes. Need to change the architecture (time and cost)	1. Closely discuss with WP2 during the process 2. Revise the FMS architecture at a later stage
FMS Architecture is set up to be finalised before the pilots and interfacing systems are known and described	Late changes. Need to do special implementation that deviates from the architecture to fulfill the needs (time and cost)	1. Ask for Pilot sites to describe the different infrastructure and logistics systems. (June 2021) 2. Revise the FMS architecture at a later stage
Many different stakeholders, interests and products in the consortium. Lack of overall product architect to prioritise and ensure project goal achievements	Overall system is made bottom-up and will become sub-optimal. The FMS architecture needs to include many special solutions (time, cost, function)	Clarifying the reason for integrating a system (reason and function) FMS is designed with adaption on the edges and a structured internal data model that can handle new systems

Table 2: Risks

7. Conclusion

The current architectural model presented in this document is the foundation of the fleet management and control services developed in WP5. It takes into account the different functions that the FMS will be required to fulfil, while leaving enough flexibility in order to adapt to different components and infrastructure, the exact nature of which will become apparent as the pilots are being put in place at the respective pilot sites.

In particular, the current model is able to respond to the requirements identified in WP2, and also ensures that data required for later analysis in WP7 is collected. This ensures that the FMS developed in WP5 connects not only logistics systems, vehicles, road users and sensors, but also provides a bridge between the analytical and the empirical aspects of the AWARD project.

8. Annex

8.1. Pilot cases

Table 3 sums up the specifics of the different pilot cases that shall be implemented and tested during the AWARD project. A full description can be found in AWARD deliverable D2.1 “System scope”.

Pilot case - responsible partner	Logistics system	Vehicles	Infrastructure	Route	FMS
Airport - Avinor Oslo	Manual	1 TLD/SAS TractEasy	Weather station	Proximity storage to simulated aircrafts through a tunnel, interacting with some other road users	Schedule and execute transport orders. Report status and ETA on deviations. Use Geofence to control the operations in different areas. Re-route/stop on road clearance (VIP). Send to charging. Handover to remote driver when needed. Calculate KPIs.
Port - DFDS Rotterdam	DFDS GEMINI	1 Terberg	Gate (managed by GEMINI)	1. Internal: pickup place, temp storage, near ship 2. External: pickup place, through gate, temp storage, near ship	Schedule and execute transport orders. Report status and ETA on deviations. Use Geofence to control the operations in different areas. Re-route/stop on emergencies. Send to charging. Calculate KPIs.
Hub-to-Hub- DB Schencker/ Rotax Gunskirchen	Fixed plan	1 Kamag Wiesel + 1 manual vehicle	Weather stations Traffic lights Gate Road sensor Emergency alarms	1. Pick-up from 2-3 different DB-S ramps, through gate, wait for green light, through gate, deliver at Rotax ramp. 2. Pick up from Rotax ramp, through gate, wait for green light, trough gate, deliver on specified ramp at DB-S	Schedule and execute transport orders. Report status and ETA on deviations. Optimise on vehicle usage. Use Geofence to control the operations in different areas. Re-route/stop on emergencies. Send to charging. Calculate KPIs.
Forklift - Linde Aschaffenburg	E'tricc sensor active when load is ready for transport	1 KION	E'tricc sensor	Pick up at insertion point at factory and deliver to storage yard	Treat E'tricc sensor as an order request (ASAP). Executing transport orders. Report status

Pilot case - responsible partner	Logistics system	Vehicles	Infrastructure	Route	FMS
					and ETA on deviations. Use Geofence to control the operations in different areas. Re-route/stop on emergencies. Send to charging. Calculate KPIs.

Table 3: AWARD pilot specifics regarding to FMS functionality