eco-FEV

combining infrastructures for efficient electric mobility

Deliverable D400.1

Evaluation Methodology, Test and Evaluation Plan
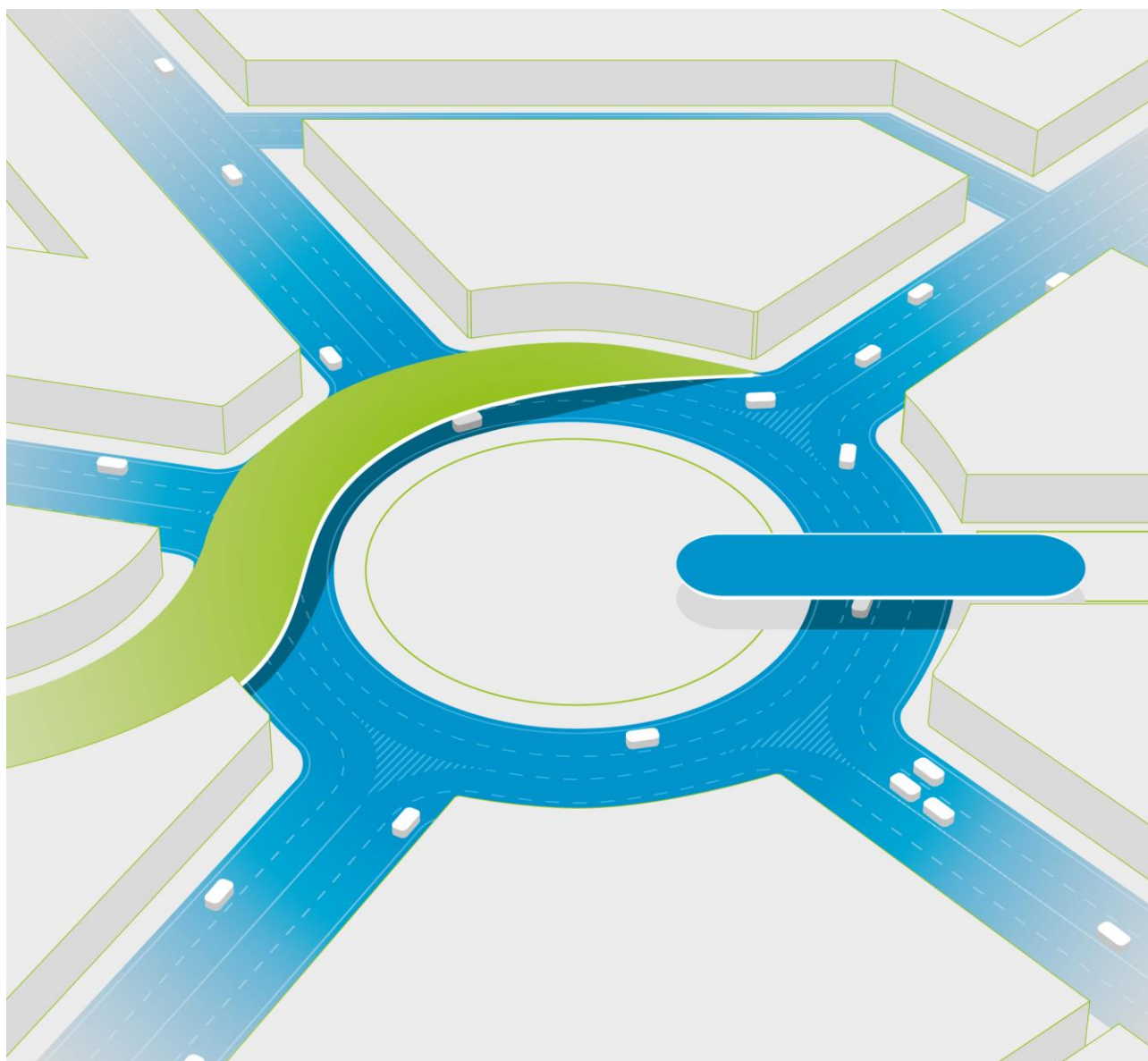
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Revision and history chart

Version	Date	Comment
0.1	10.07.2013	Initial template
0.2	02.08.2013	First draft
0.3	11.09.2013	Comments and revisions from Bruno + minor updates
0.4	04.10.2013	Text updates and assignment of specific sections to partners
0.5	30.12.2013	Extended versions of Sections 3, 4 and 5
0.6	21.01.2014	Section 4.1 edited (CRF OBU subsystem)
0.7	23.01.2014	Updates on Sections 3 and 5, first version of Conclusion section
0.8	28.01.2014	Updates of eCo-FEV backend sections
0.9	05.02.2014	More details on system verification and system validation
1.0	21.02.2014	Final contributions, overall editing; ready for review
1.1	07.03.2014	Revision and comments by the two reviewers
1.2	14.03.2014	Final version after review

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List of Abbreviations

C/S	Charging Station
C/S CU	Charging Station Control Unit
CI	Charging Infrastructure
CWD	Charge While Drive
DENM	Decentralized Environmental Notification Message
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FEV	Fully Electric Vehicle
HMI	Human Machine Interface
ICE	Internal Combustion Engine
ITS	Intelligent Transport Systems
OBU	On-Board Unit
POI	Point of Interest
POTI	Position and Time Information
RSU	Road Side Unit
SoC	State of Charge (Battery)
SoH	State of Health (Battery)
VDP	Vehicle Data Provider
VRM	Vehicle Relationship Message
WPT	Wireless Power Transfer

Executive Summary

The eCo-FEV project aims at achieving a breakthrough in Fully Electric Vehicle (FEV) introduction by proposing a general service platform for integration of FEVs with different infrastructure systems cooperating with each other – thus allowing precise FEV telematics services and charging management services based on real time information.

The general concept of eCo-FEV is based on the development of an innovative next generation e-mobility infrastructure by mutual system cooperation among FEV and independent FEV-related infrastructures being networked. The cooperative e-mobility infrastructure enables information exchange between independent infrastructure systems in order to provide efficient telematics and ITS services to FEV users. For this purpose, an eCo-FEV system is defined and being developed by the consortium, which includes subsystems integrated at FEV, at road side, at charging infrastructure and at backend to realize FEV assistance services before and during a trip and charging.

The objective of this deliverable is to define the methodology for testing and verification of the whole eCo-FEV system and functionality. Based on the use cases and requirements defined in WP200, it describes the overall procedure for the verification and validation of all systems being developed and integrated in WP300. The methodology defined here will be applied throughout eCo-FEV tests in WP300 and WP400.

Given the twofold aim for the recharging system, to be useful both for inductive and conductive recharging, the verification will take into account also and in particular flexible infrastructures, wired and wireless.

1. Introduction

The eCo-FEV system being developed throughout WP300 will be tested and evaluated in WP400, with two main objectives: on one hand, to ensure that the envisaged system is properly working; on the other, to assess whether it may have a positive impact on the transport system as a whole, from the energy, environmental, motorized mobility viewpoints, including user acceptance.

This goal will be reached through an evaluation that will cover the following aspects:

- definition and set up of the evaluation methodologies, including the verification and validation plan
- measurement of the system performances at the test sites
- technical verification of the functionality of the system
- assessment of benefits of the eCo-FEV system in terms of overall energy consumption and traffic flows
- quantification and characterization of the demand for FEVs related to the recharging scenarios, by considering both the transport mode share and the market penetration.

The first phase of this work package, WP410, defines the evaluation guidelines and methodology, which will be implemented throughout the actual eCo-FEV tests to be performed in WP300 (as part of the component and subsystem development tasks WP310-WP330 and the integration task WP340), as well as in the rest of WP400 for testing and validation at a system level. WP410 compiles its results in two reports:

- evaluation and validation methodology (D400.1, the current deliverable)
- evaluation database description (D400.2)

The evaluation and validation methodology presented in this deliverable covers:

- the identification of the validation and evaluation performance indicators,
- the guidelines for test data collection during the execution of tests,
- the guidelines for applying the test methodology in the test sites.

The validation and evaluation task takes as reference the work of WP200, with the purpose of verifying that the developed systems and components are compliant with the specifications

(D200.3), and the use cases being evaluated satisfy both functional and operational requirements (D200.1).

A step-by-step validation and evaluation procedure is followed, as for the development procedure. This method will allow the detection of potential problems at each step of the development and take corresponding actions in time. It will considerably reduce the time required for the reversed problem solving at a later stage.

2. Testing and Evaluation Methodology

The eCo-FEV Project employs the systems engineering approach for ITS [1][2] as guidance for its development and testing. Since the eCo-FEV system is an artefact that consists of components or blocks that pursue a common goal that cannot be achieved by each of them separately, in the system we need to include both software and hardware, operated by the actors that are the integrating them, and ITS parts of the system itself. Each component of the system and its behaviour are strictly connected to the other components.

Therefore we need the systems engineering approach, which implies the traceability of specifications (WP200 and other, hereafter reported in this document) from customer requirements through production, operation and disposal, passing through test and maintenance phases. In this sense it integrates all specialty groups forming a structured development process ("top-down" approach).

Considering the commonly used "V" Model in this approach [1], depicted in Figure 2.1, eCo-FEV's WP400 is mainly concerned with the *Unit Testing*, *Subsystem Verification*, *System Verification*, and *System Validation* phases, as indicated with orange markers in the figure.
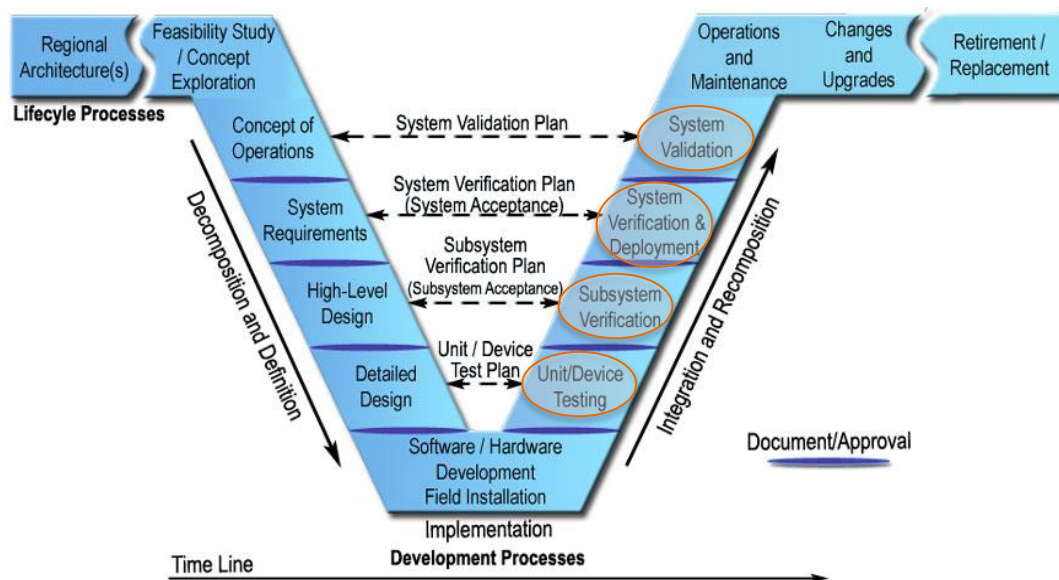
Figure 2.1: Main phases of the generic systems engineering approach (Source: [1])

For developing the whole process we must analyse how eCo-FEV can be organised. In this sense, the V model describes the life cycle of it. The left side represents the system decomposition and requirements definition, followed by product and process design; while the right side represents system production, integration and verification.

Following this whole process, the evaluation will start with the _unit testing_ of low-level individual components of the eCo-FEV system defined in D200.3. The unit testing should verify the internal functionality of each component and that they meet the design specifications and requirements.

Once the individual components are verified, they are integrated to form the subsystems specified in the high-level design in D200.2, which will then be evaluated in the _subsystem verification_ phase in order to confirm that all interfaces have been correctly implemented and all requirements have been satisfied for each subsystem.

The _system verification_ phase is concerned with the evaluation of the system as a whole, ensuring that the system behaves as expected, taking the use cases defined in D200.1 as the main input.

Once the eCo-FEV system is verified for its error-free design and operation, the last phase of the evaluation, _system validation_, ensures that the system is effective, for the given performance metrics, in meeting the intended purpose and needs defined at the beginning of the project. Figure 2.2 provides an overview of this testing and evaluation methodology for eCo-FEV, which also highlights the project deliverables used for defining the specific inputs for each testing and evaluation phase.

The following four chapters of the present deliverable will describe in turn each of the above four phases of the evaluation methodology.
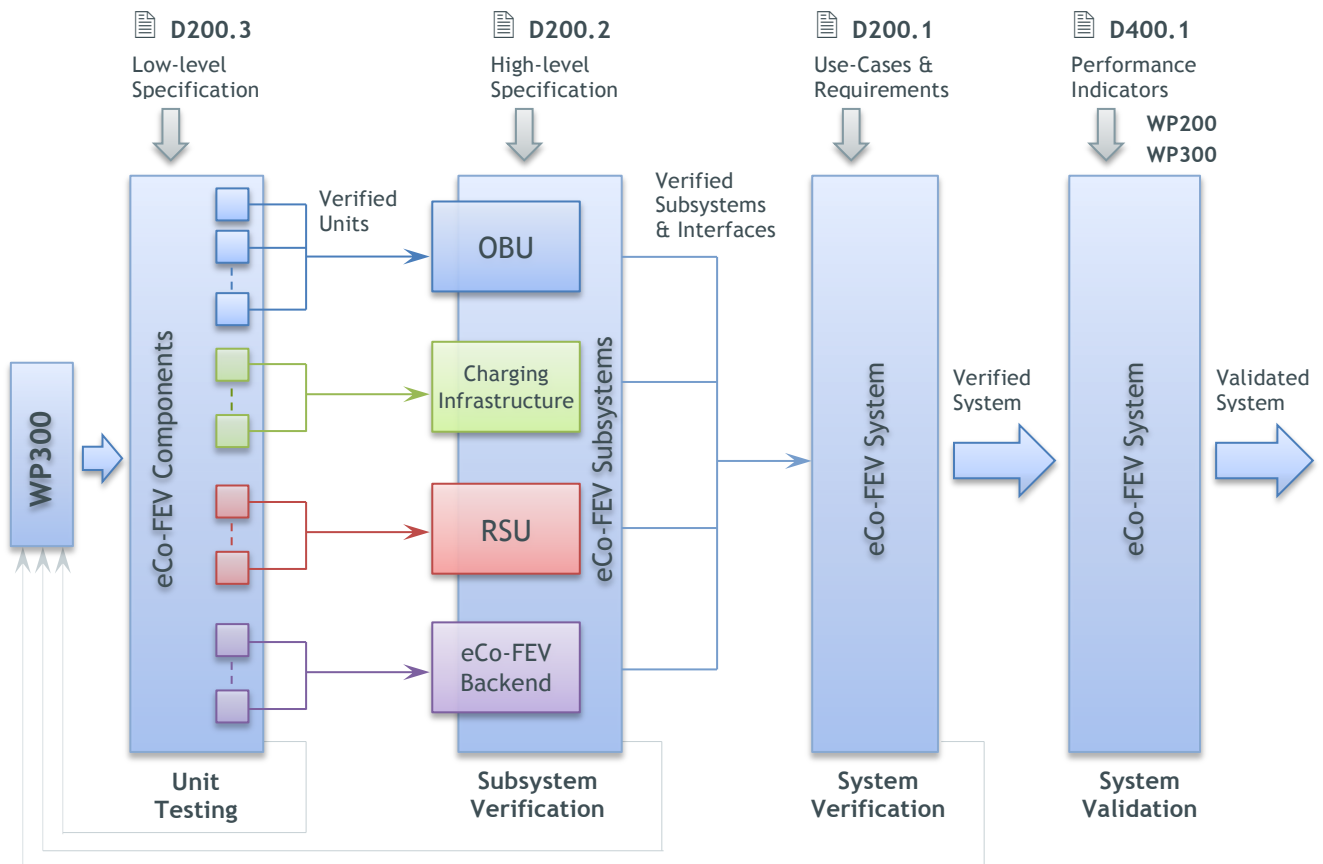
Figure 2.2: High-level overview of the four-phase evaluation methodology of eCo-FEV

3. Unit Testing
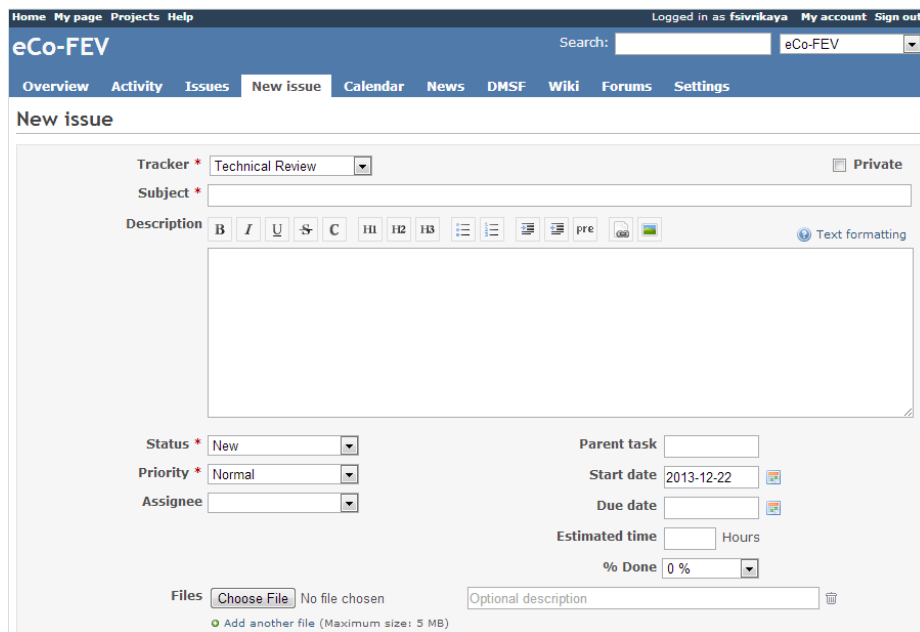
Unit Testing is concerned with the testing and verification of low-level components developed in WP310, WP320 and WP330 of the eCo-FEV Project. Each individual component therein will define its own set of unit tests. Unit testing applies only to the software / hardware components that are implemented or modified in the scope of eCo-FEV, omitting off-the-shelf components. Each task in WP300, corresponding to the eCo-FEV subsystems OBU, CI, RSU, and Backend, will specify and execute their individual component tests, which would be employed not only after the completion of implementation but also to be applied throughout the development. An example unit test template is provided in Table 3.1.

Unit Id / Name	
Tested By	
Tested On	

Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1			PASS	
2			FAIL	
3				
4				
5				

Table 3.1: Example unit test template

The eCo-FEV Redmine tool, described in D101.3 [3], will also be used for reporting and tracking of software bugs and other issues discovered during testing. For the testing of individual components that involve only a single partner, the intermediate steps for tracking and fixing minor bugs in software may be skipped. However, any new issue that could not be resolved within one week should be added on Redmine as a new issue (see Figure 3.1) for the transparency of development and testing status among partners.

Figure 3.1: Adding a new issue on eCo-FEV Redmine tool

D200.3 will be the main source of information on the list of eCo-FEV software components subject to unit testing. In addition, the hardware components involved in the realization of the eCo-FEV system will also be tested and verified for the integrated eCo-FEV system to be validated in test sites. This will be further elaborated in Section 6.3.

4. Subsystem Verification

Here we provide the guidelines for the functional and technical verification of each eCo-FEV subsystem, to be applied once the relevant modules that make up that subsystem are developed, tested and integrated.

Subsystem verification in eCo-FEV corresponds to the testing of its four high-level components as individual blocks. As described in detail in D200.2, and depicted in Figure 4.1, these high-level components (subsystems) consist in:

- On-Board Unit (OBU)
- Charging infrastructure (CI)
- Road Side Unit (RSU)
- eCo-FEV Backend
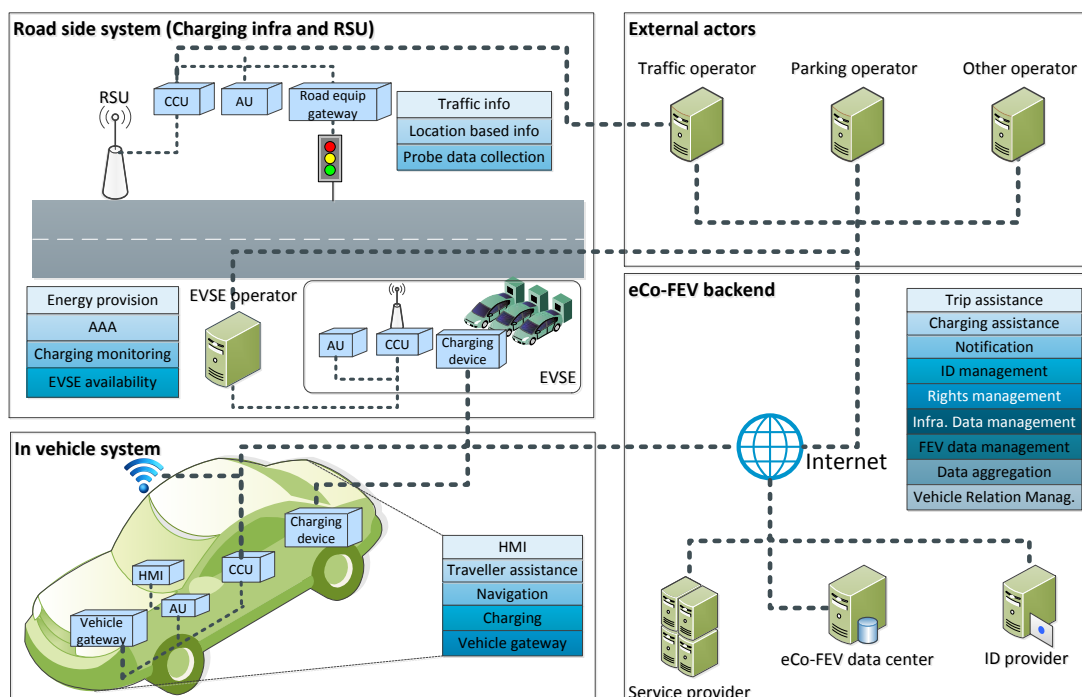
Figure 4.1: eCo-FEV system high level architecture and subsystems [5]

The focus of subsystem verification will be on testing the coherent operation of individual functional blocks of a subsystem (_modules_ as we will call them in this section) and the internal interfaces among those modules that make up a single subsystem.

Any bug or deviance from specified functionality or interfaces detected at the subsystem testing level must be immediately reported on Redmine as a new issue, which should include the main responsible person (assignee) and the deadline for resolving the issue (due date). The status of the issue should also be updated at intermediate steps, whenever possible, before the due date.

4.1. OBU

The OBU subsystem is integrated in FEVs, providing telematics services and charging assistance for FEV users. In eCo-FEV, there are two different instances of OBU design and implementations, provided by the partners CRF and REN. Although they have some differences in their characteristics and functionality, the two OBUs share the common key functions that form the basis of the subsystem testing specification in this section. Further refinements of these specifications and test cases will be handled in WP420, aligned with the ongoing work in WP300.

The OBU subsystem is composed of an Application Unit (AU), a Communication Control Unit (CCU), and a Human Machine Interface (HMI) device. The OBU technical testing shall verify and validate that the subsystem is properly operating as defined in D200.2 and D200.3.

The AU is connected to the Ethernet or to the Wi-Fi network managed by the CCU. The higher level of the AU is the *Application* layer and is composed of:

- *V2G (Vehicle to Grid)* – this application manages the FEV interaction with the wireless charging station for battery charging control. It also enables FEV user to trigger the charging procedure and sends the charging identity information to enable the AAA for charging.

- *Fleet delivery* – this application is a special implementation of trip (navigation) assistance for the delivery use cases using FEV fleet and is guiding the FEV driver to follow the delivery itinerary, the delivery FEV charging plan and manages the FEV autonomy limitations. When unexpected situation happens or there is an adjustment request, this application will receive the new itinerary and charging plan.

- *Notifications*: C/S POI, abnormal traffic information, battery state of health (SoH) notification, battery state of charge (SoC) deviation.

The *Facilities* layer of the AU is composed by:

- *VRMessage (Vehicle Relationship Message)* is a periodic message that provides key EV information and is sent by FEV OBU to eCo-FEV Backend: FEV position, SoC, activities status, report, etc.

- *VDP (Vehicle Data Provider)* is the counterpart endpoint of the CAN gateway. It implements CoAP client side functionalities to receive CAN data from CAN GW; upon reception message, VDP provides the decoded vehicle data to any function of AU who requests the information.

- *POTI (Position and Time Information provider)* receives position and time update information from CAN GW and makes the data available to other functions of AU.

- *HMI Support* – the Human Machine Interface (HMI) support function is achieving the full duplex liaison between the OBU applications and the HMI of the driver. It harmonises the multimedia data transfer, requests and responses between the applications and the head unit via the local Wi-Fi network. It arbitrates the exchanges in case of multiple interactions according to their respective priorities.

For each of these modules of the eCo-FEV OBU, a test case description table is provided describing the expected results:

Module	OBU → V2G				
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	V2G_ID	Right ID of FEV is sent to CS		
2	V2G authentication	Make sure that the interaction between the two OBU and the CS result in either success or reject, in case the ID is authorized or not, respectively.		
3	AU_V2G communication integrity	The integrity of the signal values inside each transmitted/received message is assured		

4	AU_V2G charging control	The charging process is properly working including the limitations and faults management.		

Module	OBU → Fleet delivery (navigation assistance)			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	navigation guidance display	The display of the navigation guidance information to driver is properly done.		
2	KML decoding	The received KML messages from eCo-FEV backend for navigation guidance are successfully decoded.		
3	Map display	The map display works properly.		

Module	OBU → Notification			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	relevance of received notification	Only the notification messages relevant to user- and vehicle-context are taken into account.		
2	display of notification to HMI	The notification messages are displayed on the HMI.		
3	Map display	The map display works properly.		

Module	OBU → VRM			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks

1	VRMessage encode	The encoding of the VRMessage payload is successfully performed.		
2	VRMessage transmission frequency	The real frequency of the messages transmission is in line with set-up value		
3	VRMessage data	All the data needed to construct the message are received from the Vehicle data provider.		

Module	OBU → VDP			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	CAN messages decode	The received CoAP message from CAN Gateway are decoded.		
2	CAN data transmission	All the data coming from CAN are available to the other AU applications		

Module	OBU → POTI			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	position and time information availability	The position and time information is correct and available to the other apps		

Module	OBU → HMI			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	Apps request handling (user request and display information)	The arbitration between the simultaneous requests is properly done as imposed by the predefined prioritisation		

4.2. Charging infrastructure

The Charging Infrastructure subsystem in eCo-FEV strongly depends on the different site-hardware implementations, which will shape up more concretely within WP300. However, the specification of the Charging Infrastructure provides a unified set of functionalities provided over the exposed interfaces, defined in D200.3. This way it can be integrated within different FEV service platforms, such as the eCo-FEV Backend, or other actors in the e-mobility Landscape.

In order to ensure such integration, the technical testing of the Charging Infrastructure subsystem would verify and assert the correctness and validate the performance of the functionalities as defined in D200.2 and D200.3. Different functionalities of the Charging Infrastructure are provided by the components that are implemented on two different and cooperating entities: the *Charging Station Control Unit (C/S CU)* and the *EVSE Operator*, as shown in Figure 4.2.
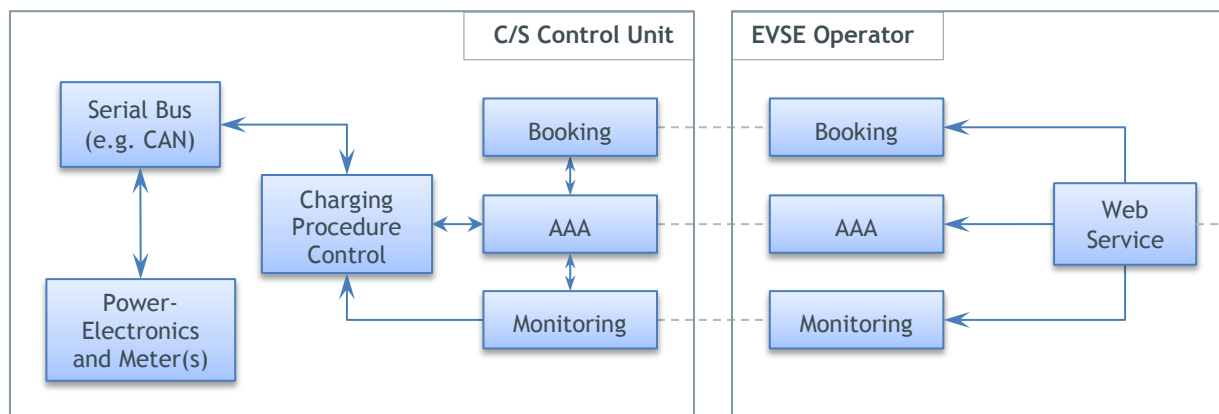
Figure 4.2: Charging Infrastructure components, spanning over the *C/S CU* and *EVSE Operator* entities

The Charging Infrastructure *subsystem verification* would holistically check the correct implementation of all components illustrated in Figure 4.2. The internal interfaces among these components is verified in this testing stage, while the interactions of the Charging

Infrastructure with other eCo-FEV subsystems or any external entities would be verified later in the *system verification* stage.

4.2.1. AAA module and interfaces

As depicted in Figure 4.2, the *AAA* functionality is realized jointly by the two corresponding entities on the *C/S CU* and *EVSE Operator* components. Hence, the tests need to ensure that each of those two entities performs the expected tasks properly, and that the interactions between them also fulfil the required functionality. Furthermore, the AAA component interacts with other components within the Charging Infrastructure subsystem, such as Charging Procedure Control (CPC) and Monitoring. These interactions also need to be covered in the subsystem testing.

Module	CI → AAA				
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	CSCU_AAA ID acquisition	Right ID of FEV can be acquired at the AAA front End		
2	CSCU_AAA authentication request	Make sure that the interaction between the two AAA Components result in either success or reject, in case the ID is authorized or not, respectively.		
3	EVSE_Operator_AAA authentication response			
4	EVSE_Operator_AAA Accounting	Actually charged energy in KWh can be determined and retained at EVSE-Operator		

4.2.2. Booking module and interfaces

The *Booking* component is also realized on the two entities, similar to the AAA component; a booking request arriving at the EVSE-Operator's Webservice Component will be routed to the respective Charge point where the CS/CU would lock this Charge point for the respective FEV ID.

Module	CI → Booking			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	Booking routing	Booking request (or Cancellation) is routed to the respective C/S CU		
2	Booking execution	The C/S CU locks the Charge Point for the respective FEV ID		
3	Booking timeout	The C/S CU cancels the booking in case the FEV does not show up at the respective Charge Point after a given timeout		

4.2.3. Monitoring module and interfaces

The Monitoring Component at each charging station sends status information to the monitoring component at the EVSE-Operator, which in its turn makes this information available to other subsystems using the Webservice component.

Module	CI → Monitoring			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	AAA Status	CS/CU sends the AAA status to the EVSE-Operator including the logged (charging) in FEV ID and their meter values		
2	CPC Status	The CS/CU send the CPC status to the EVSE operator including the power at which the FEV is charging, the internal status the CPC State, and eventually the electrical failures in case they occur (CB, RCD …)		

3	Booking status	The Monitoring component retains the information of the bookings and booking cancellations		

4.2.4. Charging Procedure Control module and interfaces

The Charging procedure control is implemented on the CS/CU. It communicates with the power electronic over a protocol to be defined in WP 300.

Module	CI → Charging Procedure Control (CPC)			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	CPC triggers for the Power electronics	The CPC can trigger the power electronics to turn on/off the power		
2	CPC FEV ID Management	The CPC can communicate the authorized FEV IDs with the power electronics, and is able to reset these IDs		
3	CPC Meter Values acquisition	The CPC can acquire the Meter Values at the Power Electronics (for calculating the energy provided by the Charge point to the FEV)for a given FEV ID		

4.2.5. Web Service module and interfaces

The Web service module is implemented at the EVSE Operator. Its main responsibility is to provide the eCo-FEV Back End with information about the charging infrastructure, after gathering these from the different CSCUs. It mainly retrieves the information of the ECSE-Operator Components and implements the external interface with the eCo-FEV Backend.

Module	CI → Web service				
Test case Id	Test case Description	Expected Result	Actual Result	Remarks	
1	Information retrieval from the EVSE-Operator Component	Necessary Information available at the EVSE-Operator Components are represented at the Web Service Component			
2	Interface with the eCo-FEV Backend	Web Service implementation according to the agreed Interface as described in D200.3			

4.3. RSU

The RSU subsystem is integrated at road side, providing telematics services and charging assistance for FEV; it is mainly composed of an Application Unit (AU) and a Communication Control Unit (CCU). The RSU technical testing shall verify and validate that the subsystem is properly operating as defined in D200.2 and D200.3.

The AU is connected to the Ethernet or the Wi-Fi network managed by the CCU. The RSU also provides Internet router functionalities for FEV users if necessary, e.g. for communication between FEV and EVSE operator in charging procedure.

4.3.1. CCU module and interfaces

The functional architecture of RSU Communication Control Unit (CCU) is illustrated in Figure 4.3. For each of the main modules of the RSU CCU, namely *Access Router, Addressing and Config Management*, a test cases description table is provided describing the expected results.
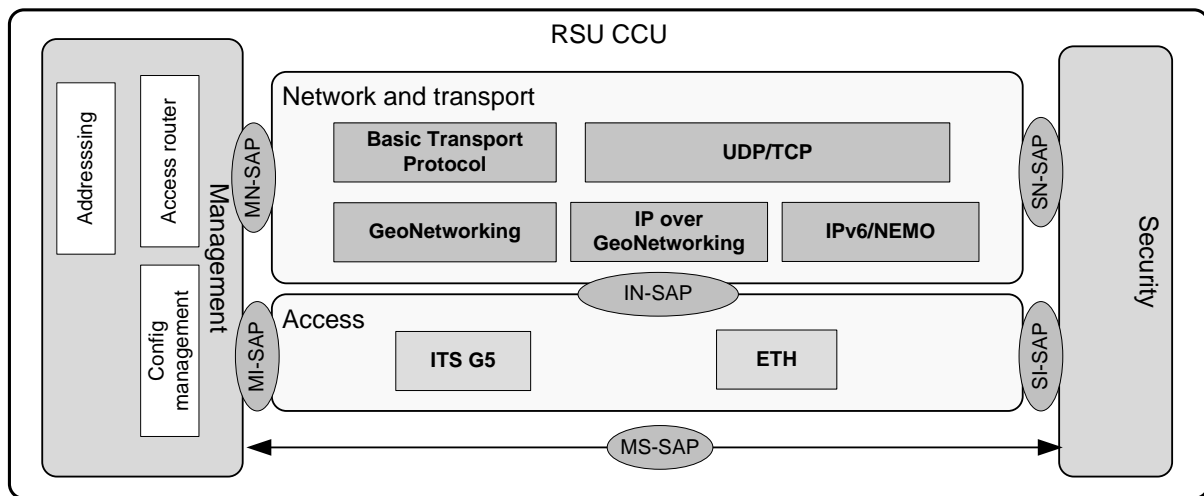
Figure 4.3: eCo-FEV RSU Communication Control Unit functional architecture [6]

Module	RSU → Access Router			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	Router Advertisement messages	Periodic advertisement messages are sent from the RSU every 100ms in time or every 250m in space based on the configuration.		
2	Handover support	Adjacent RSUs along the road are able to support network handovers		

Module	RSU → Addressing			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	DHCP for private IPv4 address allocation	RSU is able to reserve local/private IP addresses to be assigned to OBUs		
2	Native IPv6 connectivity	When available, RSU is able to bridge native IPv6 connections between two ends		

Module	RSU → Config management			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	Configuration of D_{inter} (inter-RSU distance along the road)	An admin/user of the RSU is able to set the D_{inter} parameter to match the proper deployment situation		
2	Configuration of addressing options	An admin/user of the RSU is able to set DHCP parameters or other addressing options		

4.3.2. AU modules and interfaces

The functional architecture of RSU Application Unit (AU) is illustrated in Figure 4.4. For each main module of the RSU AU, namely *Traffic info notification, POI notification, In-vehicle signage and DATEX II*, a test cases description table is provided describing the expected results.
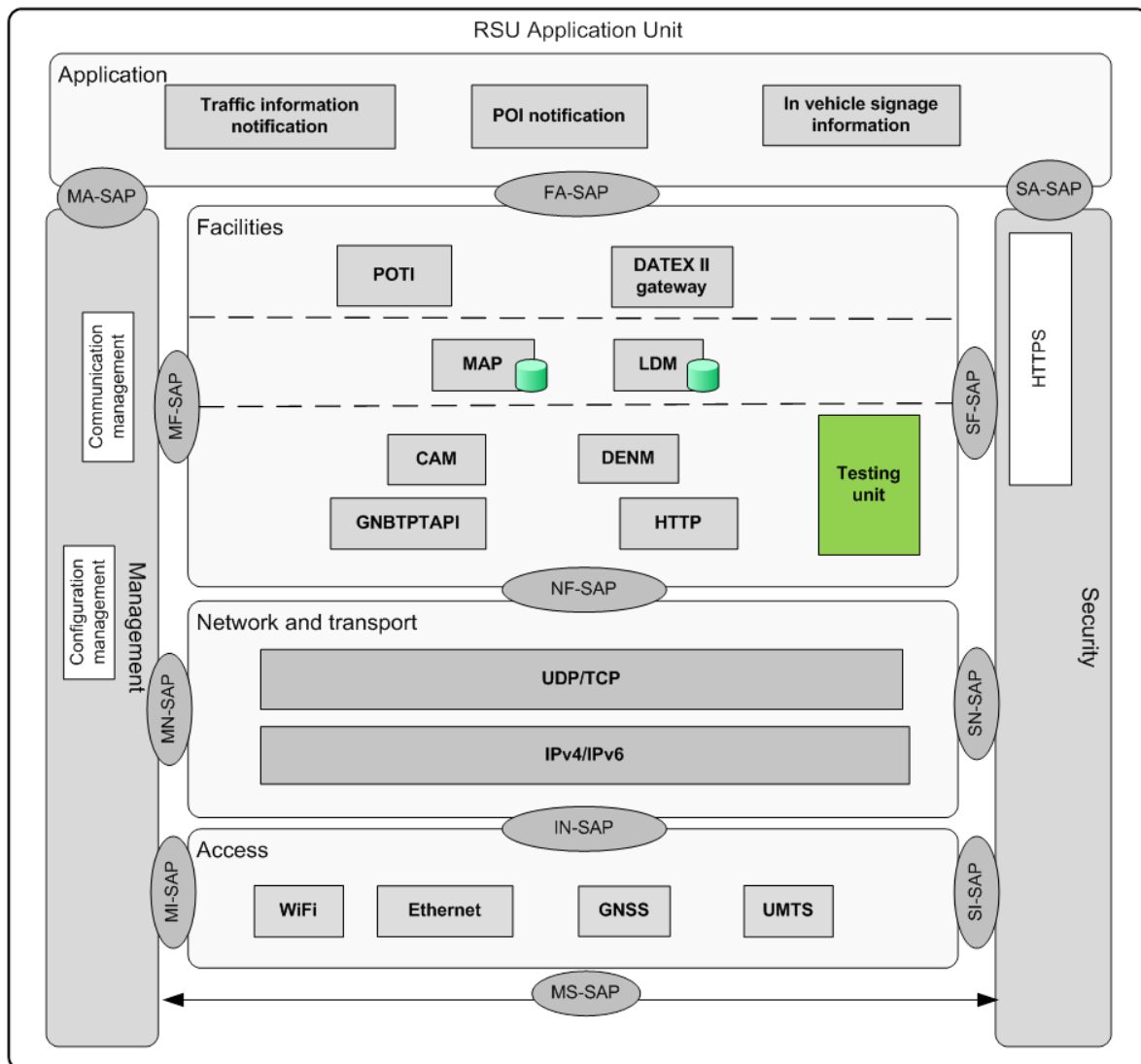
Figure 4.4: eCo-FEV RSU AU functional architecture [6]

Module	RSU → Traffic info notification			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	DENM transmission	RSU is able to transmit DENM message		

| 2 | DENM encoding | RSU is able to encode DENM message | | |

Module	RSU → POI notification			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	POI message transmission	RSU is able to transmit POI notification message		
2	POI encoding	RSU is able to encode POI message		

Module	RSU → In-vehicle signage			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	In vehicle signage message transmission	RSU is able to transmit in-vehicle signage message		
2	In vehicle signage encoding	RSU is able to encode in-vehicle signage message		

Module	RSU → DATEX II			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	DATEX II encoding/decoding	RSU is able to decode and encode DATEX II message		

4.4. eCo-FEV Backend

The purpose of eCo-FEV backend technical testing is to confirm if the developed eCo-FEV subsystem behaves as specified in the component and system specifications described in D200.3. This behaviour is measured in terms of various parameters derived from measured technical values. These values are to be recorded during the technical tests.

These technical tests must check the correctness, performances, and reliability of the eCo-FEV backend sub system before system verification tests.

The verification of the eCo-FEV backend subsystem mainly consists of verification of eCo-FEV backend components and interfaces as illustrated in Figure 4.5 and as defined in D200.3. The outcome of the technical verification tests is the validated eCo-FEV backend subsystem that serves as the basis for the technical and functional validation tests of the integrated eCo-FEV system as a whole.

In the remainder of this section, we provide the test case tables for each of the major modules that consist in the eCo-FEV backend subsystem. Refinements and further details on those test cases may be done in WP420.
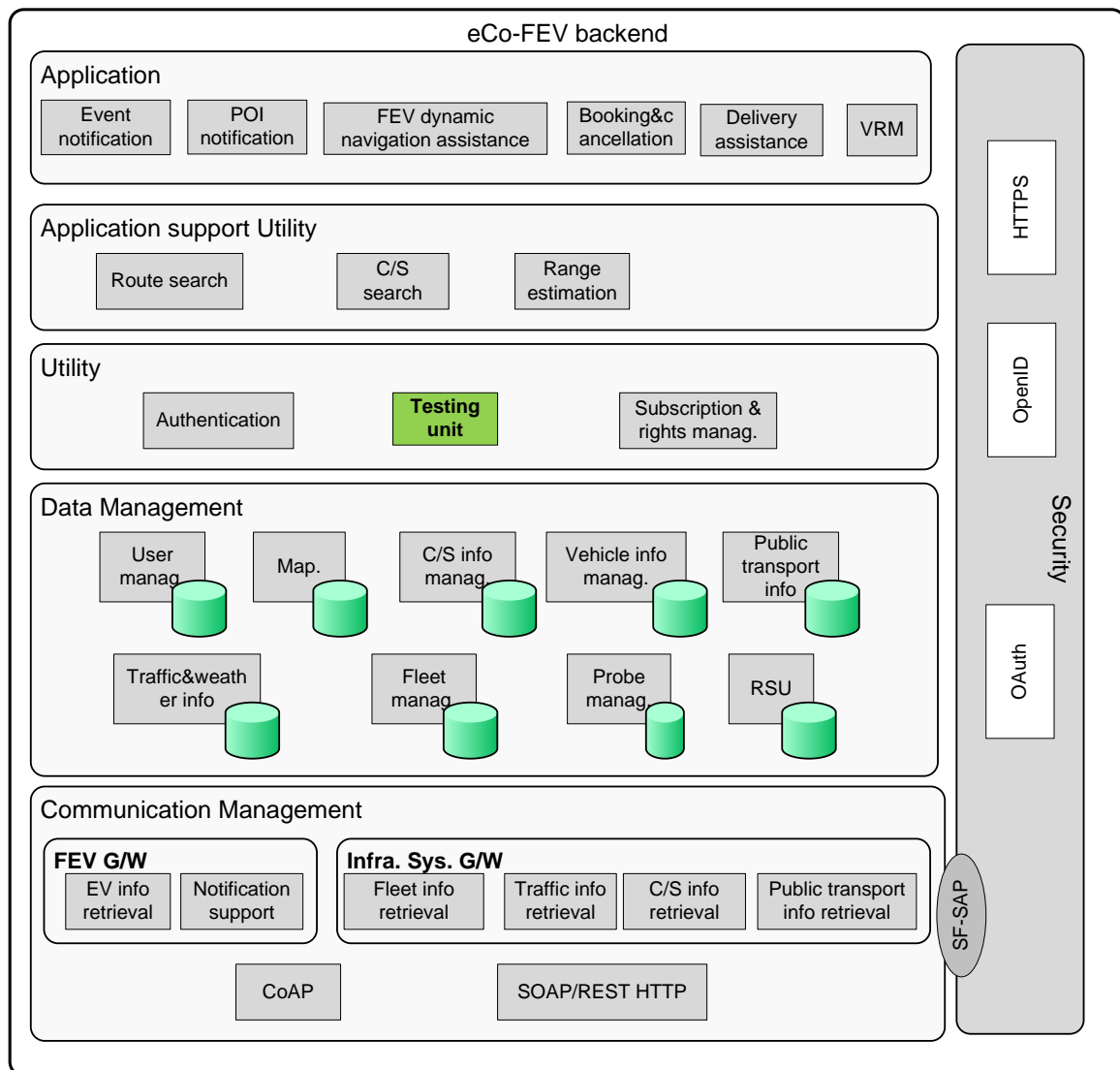
Figure 4.5: eCo-FEV backend subsystem functional architecture [6]

4.4.1. Communication management modules and interfaces

The communication management modules interface with other eCo-FEV sub systems and external infrastructure systems for data collection and data distribution. It also ensures the information exchange with other eCo-FEV backend modules, e.g. database modules at data management layer.

Module	Backend → EV info retrieval			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	Decode VRM message	VRM message is successfully received and decoded		
2	VRM message rate	Receiving rate of VRM reception is identical of VRM transmission		

Module	Backend → Notification support			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	Encode notification message	Notification message is successfully encoded and transmitted		
2	Notification message content	Notification message includes required content for receiving vehicle to inform eCo-FEV users, including notification type, relevant position and time, targeted destination FEV.		
3	Notification request	The module is able to process request from any eCo-FEV backend component and informs the processing result		

Module	Backend → Fleet info retrieval			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	Idem to EV info retrieval			

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Module	Backend → Traffic info retrieval				
Test case Id	Test case Description	Expected Result	Actual Result	Remarks	
1	Decode DATEX II message	Received DATEX II message is correctly decoded			
2	Encode traffic info retrieval request message	eCo-FEV backend sends request to traffic operator to retrieve traffic info			
3	Traffic info retrieval request	The module is able to process request from any eCo-FEV backend component and informs the processing result			

Module	Backend → Traffic info retrieval				
Test case Id	Test case Description	Expected Result	Actual Result	Remarks	
1	Decode DATEX II message	Received DATEX II message is correctly decoded			
2	Encode traffic info retrieval request message	eCo-FEV backend sends request to traffic operator to retrieve traffic info			
3	Traffic info retrieval request	The module is able to process request from any eCo-FEV backend component and informs the processing result			

Module	Backend → C/S info retrieval				
Test case Id	Test case Description	Expected Result	Actual Result	Remarks	
1	Decode C/S status message	Received C/S status message is correctly decoded			
2	Encode C/S info retrieval request message	eCo-FEV backend sends request to C/S operator to retrieve C/S info			

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| 3 | C/S info retrieval request | The module is able to process request from any eCo-FEV backend component and informs the processing result | | |

Module	Backend → Public info retrieval			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	Decode public info message	Received public info message is correctly decoded		
2	Encode PT info retrieval request message	eCo-FEV backend sends request to PT operator to retrieve PT info		
3	PT info retrieval request	The module is able to process request from any eCo-FEV backend component and informs the processing result		

4.4.2. Data management modules and interfaces

Module	Backend → User info management			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	User info access request	The module is able to process user info access request and provides response, if the requesting party is confirmed to be authorized to access the user info database		
2	User info data base update	The module is able to update the user info database		

Module	Backend → Map database				
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	Map access	The module is able to process map access request via Map API and provides response.		

Module	Backend → PT info management				
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	PT info access	The module is able to process PT info access request and provides response		
2	PT info push	The module is able to push the PT info to requesting component when an update of the requesting data is detected		
3	PT info database update	The module is able to update the PT info database when PT info is received by eCo-FEV backend		

Module	Backend → Traffic & weather info management				
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	Traffic and weather info access	The module is able to process traffic and weather info access request and provides response		
2	Traffic and weather info push	The module is able to push the traffic and weather info to requesting component when an update of the requesting data is detected		

| 3 | Traffic and weather info database update | The module is able to update the traffic and weather info database when received by eCo-FEV backend | | |
| 4 | Location referencing | The module should convert the location referencing data of the received DATEX II message to a location referencing data (i.e. openStreetMap) compliant to the usage of eCo-FEV backend applications | | |

Module	Backend → C/S info management			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	C/S info access	The module is able to process C/S info access request and provides response		
2	C/S info push	The module is able to push the C/S info to requesting component when an update of the requesting data is detected		
3	C/S info database update	The module is able to update the C/S info database when received by eCo-FEV backend		
4	Location referencing	The module should convert the location referencing data of the received C/S info message to a location referencing data (i.e. openStreetMap) compliant to the usage of eCo-FEV backend applications		

Module	Backend → Vehicle info management			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	Vehicle info access request	The module is able to process vehicle info access request and provides response, if the requesting party is confirmed to be authorized to access the vehicle info database		
2	Vehicle info data base update	The module is able to update the vehicle info database		

Module	Backend → Probe management			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	Probe info access	The module is able to process probe info access request and provides response		
2	Probe info push	The module is able to push the probe info to requesting component when an update of the requesting data is detected		
3	Probe info database update	The module is able to update the probe info database when received by eCo-FEV backend		
4	Location referencing	The module should convert the location referencing data of the received VRM to a location referencing data (i.e. openStreetMap) compliant to the usage of eCo-FEV backend applications		

Module	Backend → Fleet management			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	Idem to probe management			

Module	Backend → RSU management			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	RSU info access request	The module is able to process RSU info access request and provides response, if the requesting party is confirmed to be authorized to access the RSU info database		
2	RSU data base update	The module is able to update the RSU database		

4.4.3. Utilities modules and interfaces

Module	Backend → Authentication			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
2	User ID acquisition	The module receives request from user to access to an application, then sends request to ask for user ID information.		
3	Check the validity of openID provider	The openID provider as included in user ID is recognized by the requesting application		

4	Redirect user to ID provider	Send information to user in order to redirect him/her to openID provider for authentication		
5	Trust verification	eCo-FEV backend negotiates the trust level with ID providers for a given user		
6	Auth token verification	eCo-FEV backend verifies the auth token provided by user for user authentication		
7	Authentication response	eCo-FEV backend provides verification result to user as authentication response		
8	Temp token request	The module sends request to acquire a temp token when requested by an application.		
9	Authorization request	The module sends authorization request to user for authorization to access to user data		
10	Access token request	The module sends request to acquire an access token when requested by an application, after receiving confirmation from user.		

Module	Backend → ID provider&rights management			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	ID provider	The module provides functionalities and interfaces as defined in openID protocol		
2	User data access management	The module provides functionalities and interfaces as defined in Oauth protocol		

4.4.4. Application support modules and interfaces

Module	Backend → route search			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	KML generator	The module generates KML message with the calculated route information		
2	Application route search request	The module receives route search request from application and triggers route calculation function		
3	Application route search response	The module sends response to application, either a KML message, or a failure message in case route search is failed		

Module	Backend → C/S search			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	C/S search result message	The module generates message with the C/S search results		
2	Application C/S search request	The module receives C/S search request from application and triggers C/S calculation function		
3	Application C/S search response	The module sends response to application, either a C/S result message, or a failure message in case C/S search is failed		

Module	Backend → Range estimation			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	*Range estimation result message*	The module generates message with the r*ange estimation* results		
2	*Application range estimation request*	The module receives r*ange estimation* request from application and triggers r*ange estimation* function		
3	*Application range estimation response*	The module sends response to application, either a r*ange estimation result message*, or a failure message in case r*ange estimation* is failed		

4.4.5. Application modules and interfaces

Module	Backend → Event notification			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	*Notification request and response*	The module is able to receive user requests for notification and sends response to user		
2	*Notification message trigger*	The module sends notification request and notification content to notification support module		
3	*Authentication*	The module sends requests to authentication module for authentication.		
4	*Event relevance check*	The module is able to verify if a detected event is relevant for a user.		

Module	Backend → POI notification			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	*POI request and response*	The module is able to receive user requests for *POI* notification and sends response to user		
2	*POI notification message trigger*	The module sends *POI* notification request to notification support module		
3	*Authentication*	The module sends requests to authentication module for user authentication.		
4	*POI relevance check*	The module is able to verify if a *POI* is relevant for a user.		

Module	Backend → Dynamic navigation assistance			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	*Trip plan request and response*	The module is able to receive user requests for trip planning and sends response to user		
2	*Trip plan result message*	The module sends *trip plan result* notification to requesting user.		
3	*Authentication*	The module sends requests to authentication module for user authentication.		
4	*Route search request*	The module sends route search request to route search module.		
5	*Rerouting estimation*	This module triggers an recalculation of trip plan, when the actual trip progress differs too much from the planned trip.		

Module	Backend → Booking and cancellation			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	*Booking request and response*	The module is able to receive user requests for C/S booking and sends response to user		
2	*Booking schedule result message*	The module sends *booking schedule result* notification to requesting user.		
3	*Cancellation result message*	The module sends cancellation result notification to requesting user.		
4	*Authentication*	The module sends requests to authentication module for user authentication.		
5	*C/S booking request*	The module is able to send booking request to EVSE operator and receives response from EVSE operator.		
6	*C/S booking cancellation request*	The module is able to send booking cancellation request to EVSE operator and receives response from EVSE operator.		

Module	Backend → VRM			
Test case Id	Test case Description	Expected Result	Actual Result	Remarks
1	*User request and response*	The module is able to receive user requests for VRM monitoring and sends response to user		
2	*Anomalies message*	The module sends *anomalies* notification to requesting user.		

| 3 | *Authentication* | The module sends requests to authentication module for user authentication. | | |
| 4 | *Anomaly estimation* | The module is able to detect anomaly situation of a vehicle based on predefined conditions | | |

5. System Verification

5.1. Scenario-based Testing

Overall system verification will be mainly based on the system's ability to realize the use cases defined in D200.1 [4], which were further detailed and revised in D200.2. In this deliverable, we need to revisit those use cases as they are the basis of system testing; however, while doing so, we try to avoid repeating the information given in the earlier deliverables and provide a different view of the uses cases instead, by presenting a logical sequencing and clustering of them, as given in Figure 5.1. This will also allow us to combine a series of different use cases, resulting in various *scenarios* to be tested for the overall verification of system behaviour according to the requirements defined in D200.1. An example scenario, consisting of a series of use cases for a FEV traveller, referring to the use cases depicted in Figure 5.1, is given below:

1. A FEV traveller (user) **subscribes** to eCo-FEV by creating an account; i) via a Web interface using a PC or mobile device, ii) via the OBU.
2. User **logins** to her eCo-FEV account by Web or via the OBU.
3. User sends a **trip planning request** to eCo-FEV backend via OBU.
4. The backend responds with a set of route plans with a combination of driving, parking + charging and public transport options.
5. Based on the user's choice among the proposed route options, the backend performs parking/charging **facility booking** for the user.
6. User arrives at the charging facility – optionally using the **driving to the charging facility assistance**.
7. eCo-FEV performs **facility access control** through the involvement of OBU, charging infrastructure and eCo-FEV backend.
8. The user leaves her car for parking and charging and continues her trip with the public transport, according to the route plan provided by eCo-FEV backend.

During the execution of system testing, a variety of such scenarios will be employed, starting with simple two- or three-step combinations of use cases, and extending them to complex scenarios for realizing eCo-FEV in practical real-life situations. Some of these use cases or scenarios, e.g. subscription, login, trip planning, may be performed through an emulated FEV environment (using a standalone OBU) and the backend components. Such tests can be performed at an earlier stage in the project, without waiting for the deployment in pilot sites.

Other tests that involve charging or parking facilities will be employed on the pilot sites. The two pilots envisaged in eCo-FEV, French and Italian sites, are briefly introduced in Section 6.3.
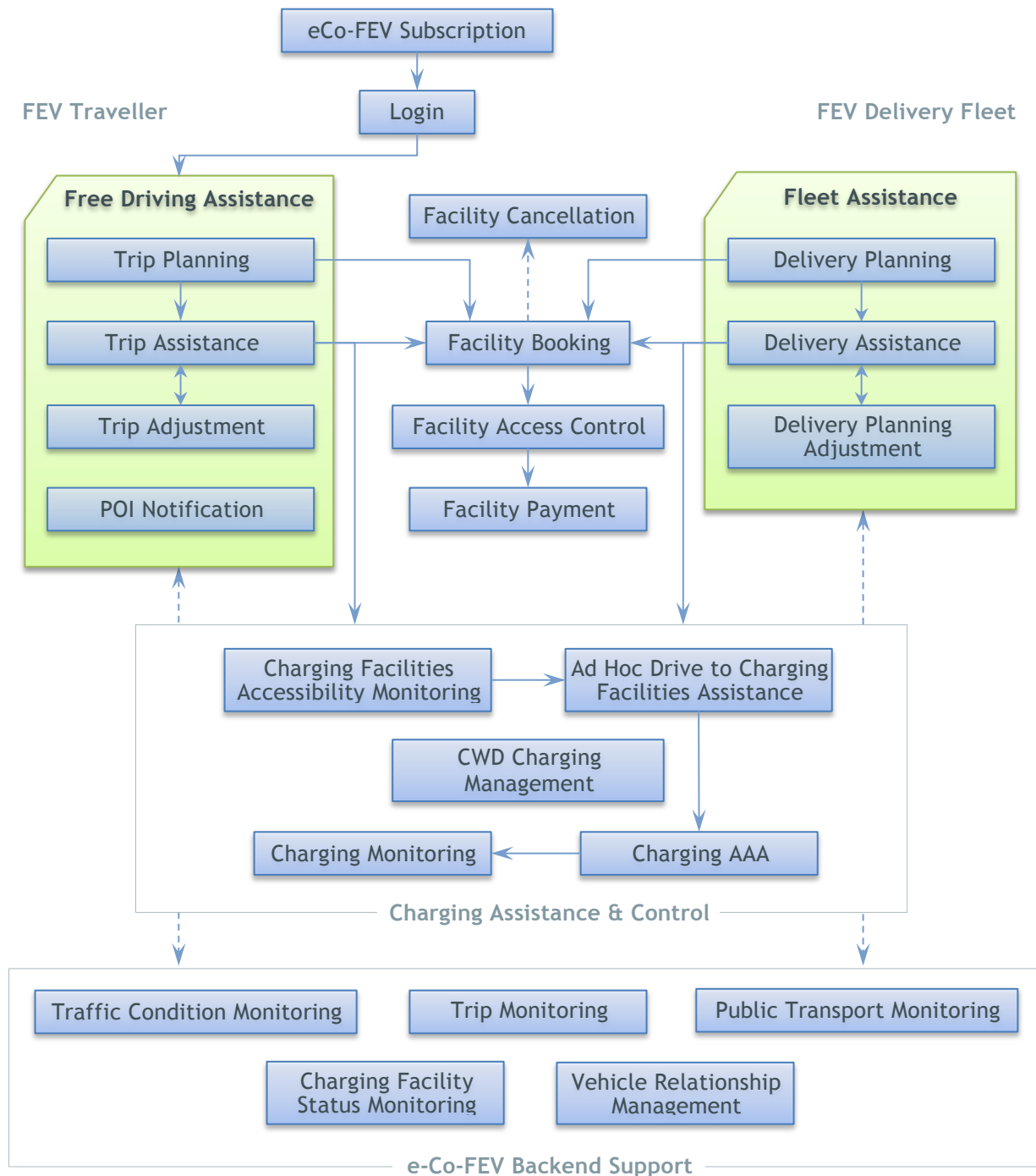
Figure 5.1: eCo-FEV use cases clustered and arranged in logical ordering

5.2. Mapping of Use-Cases to eCo-FEV Exposed Interfaces

Once the implementation of each eCo-FEV subsystem is individually tested and verified in the *subsystem verification* stage, the *system testing* would focus on testing the interfaces among different subsystems, using the use case scenarios as a basis. Verification of those interfaces ensures the coherent operation of all subsystems together, hence the successful operation of eCo-FEV system as a whole.

Figure 5.2: Illustration of interfaces between high-level eCo-FEV entities

The interfaces among high-level functional blocks of eCo-FEV was given in D200.3 [6] as depicted in Figure 5.2, which are also listed and described in Table 5.1.

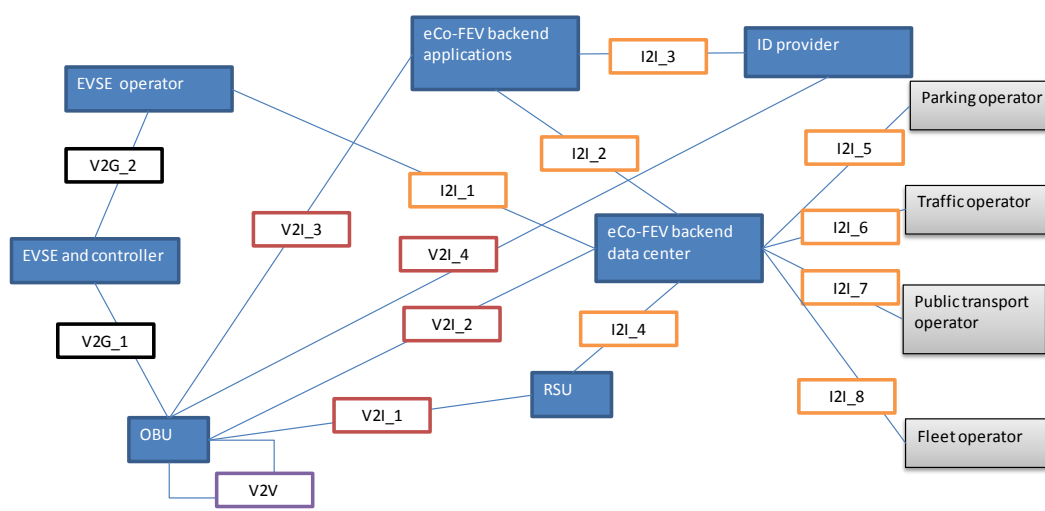| Interface ID	Description
V2V	Vehicle to/from vehicle communication
V2G_1	Vehicle to/from EVSE communication, ISO 15118 and extensions for CWD
V2G_2	EVSE to/from EVSE operator communication
V2I_1	RSU to/from vehicle communication
V2I_2	Vehicle to/from eCo-FEV backend data centre communication
V2I_3	Vehicle to/from eCo-FEV backend applications centre communication
V2I_4	Vehicle to/from ID provider communication
I2I_1	eCo-FEV backend data centre to/from EVSE operator communication
I2I_2	eCo-FEV backend data centre and applications centre communication
I2I_3	eCo-FEV backend application centre to/from ID provider communication
I2I_4	RSU to/from eCo-FEV backend data centre communication
I2I_5	eCo-FEV backend data centre to/from parking operator communication
I2I_6	eCo-FEV backend data centre to/from and traffic operator communication
I2I_7	eCo-FEV backend data centre to/from public transport operator communication
I2I_8	eCo-FEV backend data centre to/from and fleet operator communication

Table 5.1: List of exposed interfaces between high-level eCo-FEV entities

In Table 5.2, we try to map each use case to the exposed interfaces. Wherever possible, we indicate the sequence of interfaces utilized in the execution of the use case by arrows. Testing specific scenarios as a series of use cases, as described in the earlier section, will verify or reveal any issues in the correct implementation of interfaces involved in those use cases.

Use Case	Involved exposed interfaces
eCo-FEV subscription	V2I_3, I2I_3
Login	V2I_3, I2I_3
Free driving assistance	V2I_3 → I2I_2 → V2I_2
Trip planning	V2I_3 → I2I_2 → I2I_5, I2I_6, I2I_7 → I2I_1, V2I_2
Trip assistance	
Trip adjustment	
POI notification	V2I_3 → I2I_2 → I2I_4 → V2I_1
Delivery planning	V2I_3 → I2I_2 → I2I_8 → I2I_1, V2I_2
Delivery assistance	
Delivery planning adjustment	
Facility booking	V2I_3 → I2I_2 → I2I_1
Facility cancellation	V2I_3 → I2I_2 → I2I_1
Facilities access control	V2G_1 → V2G_2 → I2I_1 → V2I_2
Facility payment	V2G_2 → I2I_1 → V2I_2
Charging facility accessibility monitoring	V2I_3 → I2I_2 → I2I_6
Ad hoc drive to charging facility assistance	V2I_3 → I2I_2 → I2I_1
CWD charging management	V2G_1, V2G_2 → I2I_1
Charging AAA	V2G_1 → V2G_2
Charging Monitoring	V2I_3 → I2I_2 → I2I_1
Traffic Condition Monitoring	I2I_6
Trip Monitoring	V2I_3
Public Transport Monitoring	I2I_7
Charging Facility Status Monitoring	I2I_2 → I2I_1 → V2G_2
Vehicle Relationship Management	V2I_3, I2I_1

Table 5.2: Mapping of individual eCo-FEV use cases to the exposed interfaces

As part of the testing of exposed interfaces, the successful exchange of all messages through those exposed interfaces, as introduced in D200.3 (Tables 4.1 – 4.15), will also be tested and verified during the system testing.

5.3. Interface Test Cases

As the development and partial integration of various components progress in WP300, interface testing among specific eCo-FEV subsystems has also started at the time of this writing. Here we provide two example test cases for the interface testing between OBU-Backend and between Backend-EVSE. Full specification of interface tests and the results will be reported in WP420 and WP430, as well as in WP300 in eCo-FEV.

5.3.1. OBU - Backend Interface Testing

#	case	sender	receiver	pre-condition	procedure	expectation
1	send VRM message	OBU	BE	-	OBU sends PushVehicleRelationshipRequest	1. BE receives PushVehicleRelationshipRequest
2	create a session for WebSocket	OBU	BE	-	OBU sends request w/ VIN (and User ID) to creates a session	1. BE receives the request w/ VIN 2. BE creates a session for the sender
3	close the session	OBU	BE	session opened	OBU sends request to close the session	1. BE receives the request 2. BE close the session for the sender
4	request route search	OBU	BE	session opened	OBU sends RouteSearchRequest	1. BE receives RouteSearchRequest 2. BE sends RouteSearchSuccessResponse 3. OBU receives RouteSearchSuccessResponse
5	request CS search	OBU	BE	session opened	OBU sends CSSearchRequest	1. BE receives CSSearchRequest 2. BE sends CSSearchSuccessResponse 3. OBU receives CSSearchSuccessResponse
6	request CS availability check	OBU	BE	session opened	OBU sends CSAvailabilityCheckRequest	1. BE receives CSAvailabilityCheckRequest 2. BE sends CSAvailabilityCheckSuccessResponse 3. OBU receives CSAvailabilityCheckSuccessResponse

7	request CS reservation	OBU	BE	session opened	OBU sends CSReservationRequest	1. BE receives CSReservationRequest 2. BE sends CSReservationSuccessResponse 3. OBU receives CSReservationSuccessResponse
8	request CS cancellation	OBU	BE	session opened	OBU sends CSCancellationRequest	1. BE receives CSCancellationRequest 2. BE sends CSCancellationSuccessResponse 3. OBU receives CSCancellationSuccessResponse
9	notify	BE	OBU	session opened	BE sends Notification	1. OBU receives Notification
10	send alternative route	BE	OBU	session opened	BE sends PushAlternativeItinerary Request	1. OBU receives PushAlternativeItineraryRequest
11	return response to alternative route	OBU	BE	session opened	OBU sends PushAlternativeItinerary SuccessResponse	1. BE receives PushAlternativeItinerarySuccessR esponse

5.3.2. Backend - CI Interface Testing

#	case	sender	receiver	pre-condition	procedure	expectation
1	push C/S info status	EVSE	BE	-	EVSE sends PushCSInfoRequest	1. BE receives PushCSInfoRequest
2	pull C/S info status	BE	EVSE	-	BE sends PullCSInfoRequest	1. EVSE receives PullCSInfoRequest 2. EVSE sends PullCSInfoResponse 3. BE receives PullCSInfoResponse
3	request C/S availability check	BE	EVSE	-	BE sends AvailabilityCheckRe quest	1. EVSE receives AvailabilityCheckRequest 2. EVSE sends AvailabilityCheckResponse 3. BE receives AvailabilityCheckResponse

4	request C/S reservation	BE	EVSE	-	BE sends ReservationRequest	1. EVSE receives ReservationRequest 2. EVSE sends ReservationSuccessResponse 3. BE receives ReservationSuccessResponse
5	request C/S reservation commit	BE	EVSE	C/S reserved (case 4 done)	BE sends ReservationCommitRequest	1. EVSE receives ReservationCommitRequest
6	request C/S reservation abort	BE	EVSE	C/S reserved (case 4 done)	BE sends ReservationAbortRequest	1. EVSE receives ReservationAbortRequest
7	request C/S cancellation	BE	EVSE	reservation committed (case 5 done)	BE sends CancellationRequest	1. EVSE receives CancellationRequest 2. EVSE sends CancellationSuccessResponse 3. BE receives CancellationSuccessResponse

6. System Validation

This section provides the guidelines and the indicators / metrics for the performance and usability oriented testing and validation of the overall eCo-FEV system. The output of this section will be fed mainly into WP440.

6.1. eCo-FEV Performance Indicators

The evaluation purpose of the eCo-FEV system includes both technical and non-technical aspects (e.g. environmental impact, user acceptance). Through the system validation, eCo-FEV will try to assess, quantitatively or qualitatively, the impact of using FEVs and other assistant services developed in the project. The analysis will consider, among others, the practical aspects of FEVs, e.g. distance to travel, mass, autonomy, actual possibility to verify the residual charge of batteries, recharging needs, recharging methods, overall energy consumption including the efficiency of the recharging method.

In this section, we start with a list of performance indicators for the joint operation of eCo-FEV subsystems and services from the perspectives of service quality assessment. Some of those in the list are specific to a single eCo-FEV subsystem, while many others would be affected by the joint operation of multiple (possibly all) eCo-FEV subsystems. We use a common template for introducing the performance metric, its brief description, target values, and the relevant eCo-FEV subsystems affecting its behaviour. The same template will later be utilized in the testing and validation work of WP400 by filling in the observed value or behaviour for all defined metrics, and reporting and commenting on any deviations from the target values.

We do not aim to be comprehensive in providing this list at this stage and avoid synthetically defining some performance indicators that may not be aligned with the end system. The list of performance indicators will be extended and enriched within WP420 as the technical work in WP300 progresses and as the pilot sites mature.

Performance Indicator	Description	Target Value / Range	Observed Value or Behaviour	Related Subsystems
Average time spent for eCo-FEV registration	The overall time required for a user to fill in all required fields and successfully register for eCo-FEV	TBD. Device dependent (PC, tablet, OBU, etc.)		Backend
eCo-FEV Backend Message process latency	Average time difference of probe management database update time and VRMessage time stamp	$\leq$ 10 sec.		Backend
eCo-FEV Backend Message process rate	Average time interval of probe management database update	$\leq$ 60 $\pm$ 10 sec.		Backend
Route search latency	Average time interval between route search request time stamp and KML time stamp	$\leq$ 10 sec.		Backend
eCo-FEV Backend Application process validity	Percentage of failure responses[1] to application requests	$\leq$ 10%		Backend
IP connectivity latency through the RSU	Time for an OBU to get a usable IP address assigned by the RSU for Internet connectivity of the OBU	$\leq$ 5 sec.		OBU RSU
Time to find and book an available charging station	Average time to locate and book an available charging station spot for an eCo-FEV user	$\leq$ 60 sec.		OBU CI RSU Backend

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[1] An application failure is defined as an event of application request processing error. Such failure may be caused by multiple reasons, e.g. communication failure, required data for processing being unavailable, algorithm bug, etc. However, if the eCo-FEV Backend is able to process the application request but cannot provide a positive reply, i.e. cannot fulfill the request, for example, due to all charging stations being occupied; then this event is not counted as application failure because such operational behaviour is out of control of the eCo-FEV system.

Time to authenticate for charging	Average time that elapses from the initiation of charging request to the reception of authentication (before the start of energy flow).	≤ 5 sec.		CI
Accuracy and timeliness of charging status accessibility information	Success (correctness) ratio of available/busy status indicators for EVSEs provided by eCo-FEV to the user (ability to cope with accessibility changes)	≥ 95%		CI Backend RSU
Improvement in delivery fleet efficiency	Estimated average gains (energy, time, overall resource efficiency) of a fleet operator due to the use of eCO-FEV solution	TBD.		OBU CI RSU Backend
Efficiency of eCo-FEV trip / driving assistance	Ability of eCo-FEV to reflect external factors, traffic and charging facility availability conditions in proper planning of requested trip	Positive user ratings (≥ 80%)		OBU CI Backend

Table 6.1: Initial list of performance metrics for eCo-FEV service quality assessment

6.2. Impact Assessment Methodology

The assessment of the overall impact of eCo-FEV on the electrical mobility may consider several aspects including:

- analysis of the demand and user acceptance;
- overall consumption analysis (environmental impact);
- charging network and autonomy of FEVs (w.r.t. energy needs);
- queuing problems;
- parking problems;
- traffic analysis;
- scalability.

These aspects will be defined and analysed in more detail specifically in WP440 (Impact Assessment) and will be reported in deliverable D400.4. In this deliverable, we provide an introduction to the subject with a brief overview of a select set of those aspects, including the EV usability study, traffic flow analysis related to CWD, and simulation studies on EVSE management.

6.2.1. Usability analysis for electric vehicles

In regard to the use of electric vehicles, given the technologies available today for traction and related batteries, the possibility to apply the full electric traction to different categories of vehicles can be analysed. The first step is to estimate the energy consumption of different kinds of vehicles, private cars, light duty and heavy duty ones, depending on the mass and the type of vehicle. In the car area, passenger vehicles with a curb mass lower than 2500 kg are considered. The aim is not to obtain precise values, but to estimate a range of energy consumption in order to understand if it is possible to reach, given the available batteries and the charging methods, performance level comparable to the ICE vehicles, focusing on the requirements in terms of driving range.

To this purpose, we may refer to typical distributions of travels as those collected in literature in terms of frequency and distances run with private cars; these data have been collected also with recent analyses conducted by Politecnico di Torino, concerning the use and distances daily covered by drivers.

Several EVs already available on the market can be considered in their above-mentioned categories. Their mass values can be used as a starting point to estimate energy consumption. Combining them with considerations about energy consumption it is possible to estimate the competitiveness range for them. It is important to consider that the limits can be evaluated basing on combined driving cycle performances. Given the estimated energy consumption range [Wh/km], different aspects of the vehicle performances can be analysed.

The batteries' sizing is a crucial point in designing a fully-electric commercial vehicle, according to the competence area of the vehicle that could be done in substantially different ways. Generically referring to freight transportation, it is necessary to recall that a significant part of the gross vehicle weight rating must be dedicated to payload function.

6.2.2. Impact assessment of CWD on traffic flow

The proposed methodology to assess possible impacts of a CWD service on traffic is based on simulation. In order to give a framework for possible applications of the analysis, the methodology could be applied, for example, to a freight distribution service. Indeed, the FEV traffic simulation is compatible with a flow of light vans that could be generated by a logistics centre for multiple deliveries, where the vehicles follow fixed routes that can be planned in advance including the CWD usage in order to allow vehicles to cover greater distances, avoiding them to waste time for a stationary recharge and to contain the mass of the batteries.

6.2.2.1. Impact of a design setting on the vehicle SOC

The Electric Vehicle Supply Equipment (EVSE) of the CWD technology is macroscopically designed on the basis of a simplified model. The analysis could be applied to a 20 km roadway scenario with three-lanes where the right-hand lane is reserved for the charging activities, as shown in Figure 6.1.
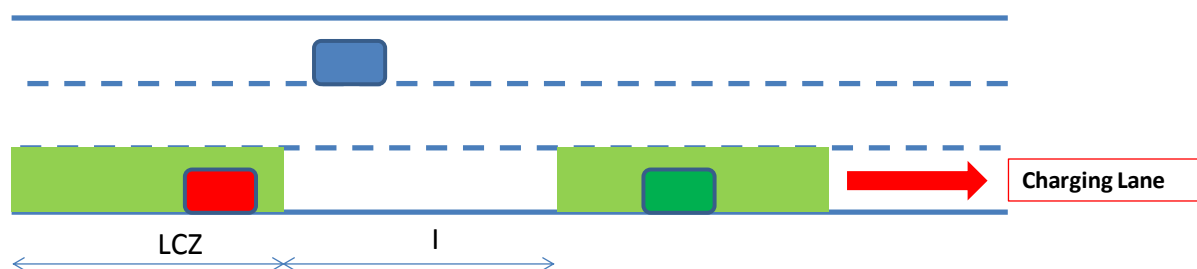

Figure 6.1: Scenario's layout for CWD charging zones

Taking into account that the electric vehicle used in this analysis is a light van, a provided power of 50 kW /m in the charging zones (CZ) is assumed, while the vehicle on-board device that receives the energy has been set with a longitudinal dimension of 1m. Adopting a system efficiency in the 80-90% range (from grid distribution to EV battery) at full power, in order to design the charging infrastructure it is necessary to analyse how the state of charge of the vehicles changes with the length of the charging zones (LCZ), their inter-distance (ID) and the vehicle's speed.

In the CWD lane, a balance between the energy consumed for vehicle motion and the energy provided by the charging zones should be carried out in order to evaluate the SOC of the vehicle's batteries.

The model used for estimating the vehicles consumptions should be based on the resistances to motion. Assuming, for sake of simplicity, that in the considered scenario the average slope is zero and that the vehicles are driving at constant speeds, the resistance force due to slope and acceleration can be neglected.

The energy received from the vehicle by a coil is strictly related to the dimension of the elements of the system (coil and on-board device), to the power provided and to the occupancy time.

6.2.3. Simulation model for the EVSE management

The choice of the traffic modelling derives from the specific requirements of the CWD system, which has been assumed installed only along the single right hand lane of the motorway, since it is usually used by slower vehicles. From operational issues the charging lane can be used by different classes of vehicles on the base of their charging needs and related speeds. One of the possible approaches to model this kind of problem could be micro-simulation, where single vehicle trajectories are modelled as well as their interaction on the road. Anyway, in this case the energy management also affects vehicle behaviour; in particular, when the SOC is low, vehicles tend to enter the charging lane and when the SOC of the vehicles that are charging on the CWD is sufficiently high they try to exit. Therefore, some specific rules need to be defined and implemented in order to obtain realistic results from the traffic model that can also be considered useful for the energy management point of view, because the energy provided in the CWD should be modulated over time in relation to the actual traffic along the charging lane.

In the traffic model, illustrated in Figure 6.2, vehicles are traced node by node along the road: the arrival time of a vehicle at the node (i) is estimated, in a first step, on the base of its arrival time at the node (i-1) and its desired speed and it is then adjusted, in a second step, according to the feasible headway for vehicles on the lane. The vehicle's battery SoC, monitored along the road at every defined node, plays a crucial role, since it is used by the drivers to choose if and when they have to get into the right-hand lane to recharge and to set the appropriate vehicle speed. In the model, the entries to the right-hand lane are managed according to a cooperative behaviour: each vehicle that needs to recharge is moved into the CWD lane at a node, creating the necessary gap in the vehicles flow by slowing down the following vehicles. This assumption, which works at discrete space steps, may describe in a

real scenario a vehicle behaviour that can be managed by drivers or by the cooperative system along the entire section before the node where the model acts.
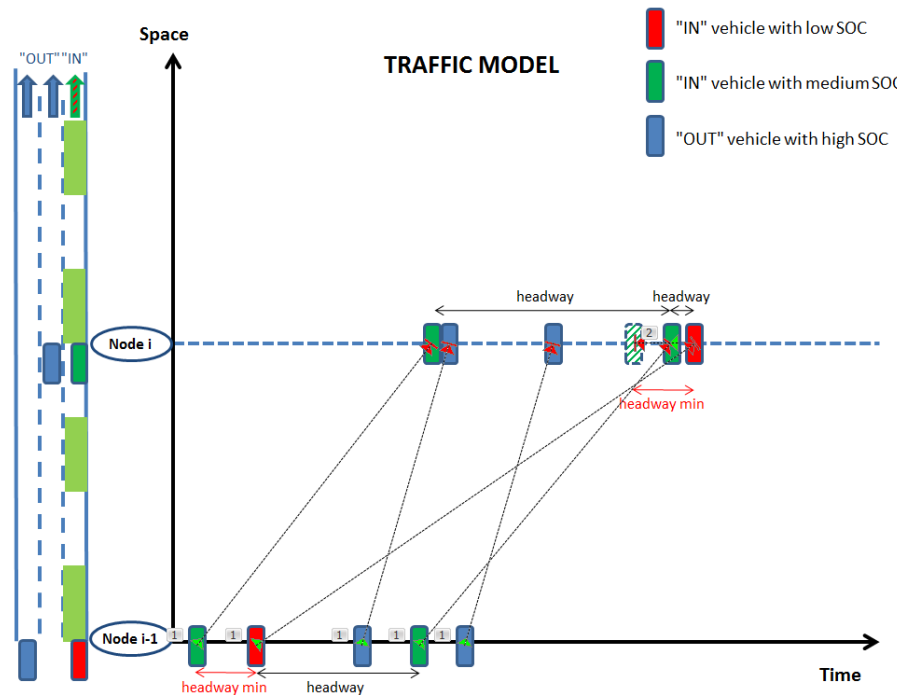

Figure 6.2: - Some trajectories in the time-space diagram for different vehicle types to trace their arrival time at consecutive nodes.

In order to trace the relevant energy end traffic information over time at any node (i), the traffic simulator will work according to the following scheme:

- It corrects the vehicle headways, and consequently the vehicle times, at node (i-1);
- It classifies the vehicles that are overtaking on the node (i-1);
- It calculates the average effective speeds on section before the node (i-1) and evaluates the SOC of the vehicles at node (i-1);
- It updates the vehicle SOC due to the overtake manoeuvres performed between node (i-2) and (i-1);
- On the base of the SOC in section (i-1), it defines the position ("IN" or "OUT" of the charging lane) and the status ("emergency" or "charge") of each vehicle at node (i);
- It calculates the predicted time at node (i).

During the simulation experiments, a reference scenario will be set according to the preliminary analysis by individuating the most adequate layout for charging zones length, their inter-distance and the power provided for the selected vehicle. Furthermore, a second scenario will be explored in order to analyse how the system performances could be affected by the increase of both the FEV traffic and the minimum allowed technical headway on the CWD lane: this means that vehicles can be generated closer at the entrance, but they cannot stay too close while charging, thus creating delay phenomena with vehicle platoons in queue. In the following tables, some representative data related to basic traffic features and infrastructure layout parameters are reported for the reference scenario, indicating between brackets the changings possible variations introduced for an alternative scenario.

TRAFFIC		
Average density for input traffic flow	10 (20)	vehicles/km
Critical density corresponding to max capacity	30	vehicles/km
Number of simulated vehicles	500	Vehicles
Coefficient of variation of headway	0.2	
Minimum traffic headway	1.5	s

INFRASTRUCTURE		
Total length of the road	20	km
Average slope	0	
Sections length	1	km
Chosen length of charging zones	20	m
Chosen inter-distance	30	m
Transition coefficient	1	
System efficiency	0.85	
Power for unit length	50	kW/m
Minimum headway	1.5 (3)	s

The evaluation methodology performed in simulation considers even the overtaking cases: a cooperative overtaking model at constant speed is implemented and the vehicle does not recharge during the manoeuvre outside the charging lane.

After defining the CWD layout, it is useful to estimate the quality level for the charging service and the type of distribution of the electrical power that should be supplied at each node. This implies an implementation of the model for the simulation of the traffic flow along the road as defined previously. In WP440 activities, traffic and energy results will be analysed in two different operational scenarios.

6.3. Implementation in the Test Sites

The testing and evaluation activities should also take into account the specific environment and requirements of the test sites in order to develop and implement a realistic test plan. Therefore, it is imperative to define the common test site functions and those specific for the individual tests sites, which should form the basis of the guidelines for the implementation of the test methodology in the test sites. In this section, we provide a general overview of the Italian and French test sites in eCo-FEV as an input for the next tasks in this work package.

6.3.1. Italian Test Site

The Italian test site is located in Susa (TO) near by the toll motorways, hosted inside the "Guida Sicura" (safe driving) circuit, so any activity can be safely performed.

The components involved in the wireless power transfer (WPT) test site are divided into the following sub systems:

- the power room;
- the control room;
- the CWD equipment;
- the static charging equipment;
- the external communication equipment.

The power room is located inside the main electric distribution cabin of the whole test site, in which, together with the existing devices, a series of devices for the electrical distribution of the WPT have been added:

- power sections for the energy to be delivered to the vehicle;
- power section for the control room;
- power section for the essential devices;

- AC-DC conversion with metering and protection for the DC distribution.

Each element needs to be tested and validated.

The control room will host the main test site information management and the nodal connection of all communications. It is mainly composed of:

- cooling and heating system together with any element for human activity
- computer for the plate recognition camera;
- the UPS for the power supply of non-interruptible devices;
- network connection with the WPT test site.

Each element needs to be tested and validated.

The CWD equipment is composed of several elements and divided into two sub parts:

- an external small cabin containing all the power and communication equipment:
    - DC-HF power conversion;
    - measurement equipment;
    - EVSE control unit;
- the coils for the CWD.

Two different power lines will be provided: one for the charging station (either static and while driving) and another for other electrical equipment. The power from the power room to the charging cabins will be distributed in DC. Each element needs to be tested and validated.

The static WPT is similar to the CWD one but the coils are placed and designed in a different way.

The external communications are supplied by the UPS system and are of two different types:

- two RSU elements;
- the plate recognition camera (ANPR).

These devices are supplied with line under UPS and wire connected with the main switch in the control room. Each element needs to be tested and validated.

6.3.2. French Test Site

As regards the French territory, one site will be equipped for the eCo-FEV project. The test site is a co-modal site named "Parking 105F". The test site will be hosted at CG38 facilities and will target in particular at the co-modality between public and private transport options.

Main features of the French Test Site will be:

- Free access open cark park with 70 car slots and bike parking slots
- Located on the motorway A48 Lyon-Grenoble (100 000 vehicle/day) heavily congested during peak hours of the morning, and served also by RD1532/RD105F roads
- Served by CG38's intercity express bus lines and by a bus lane on the A48 motorway to Grenoble
- Served by a greenway linking Grenoble
- Variable message sign to inform the occupancy of parking and encourage modal shift
- Electricity and internet connection
- Traffic information
- 4 Conductive (standard and quick) charging spots for EV
- V2X-based RSU for the area (parking, D1532/D105F/A48)

The parking itself is already in place. The charging infrastructure and the communication and IT equipment will be installed according to the eCo-FEV project requirements.

The "Parking 105F" is used as a park and ride (car and bike) for users of the intercity express bus lines. The parking is also used for recreational users of the greenways along the banks of Isere. By its configuration it allows the management of modal shifts: vehicles, buses, alternative modes (bicycle, pedestrian), eco-fret and carpooling.

This innovative parking will be able to provide:

- information on the number of:
    - places available (all vehicles);
    - places available for EV (with type of charge);
    - available space placeholders for car-sharing vehicle (EV slot or not);
    - in and out (arrivals and departures);
- warnings if unauthorized vehicle in a EV slot
- detection of long vehicle staying

- statistics: occupancy by date, time of each slot, duration of occupation, geographic distribution of vehicles, etc.
- real time schedule of intercity bus lines
- traffic Information for RD1532/RD105F and A48
- all information for EV management

Aggregating these information with data from other streams (traffic road and bus information) will provide a set of functions (dissemination of information and services) to help the end user in his EV mobility. In particular, vehicle travel time, bus travel time and next bus time schedule (this is location-based), are essential to managing a multimodal site.

V2X Road Side Units (RSUs) and parking facilities will be connected to the Internet. The RSUs will be used for disseminating of traffic data and will offer the Internet connectivity for the G5 equipped cars. The parking facilities will communicate with the eCo-FEV backend and will offer the Internet connectivity using classic WI-FI technology.

The testing campaign for the French site will be focused on the IT solutions and will follow the charging infrastructure test approach proposed in Section 4.2, the RSU test approach proposed in 4.3 and the OBU tests defined in 4.1. Some tests will also be necessary for the integration of the traffic information proposed by the CG38 traffic management center.

During the RSU testing, special attention will be paid to the communication and the usage of the RSU and 802.11p as an access points to the Internet offered to the OBUs. The interoperability with the Renault OBUs and its network mobility (NEMO) implementation will be verified.

After the unit testing the scenario oriented tests will be performed from the vehicle. The primary use cases like trip planning, trip assistance and trip adjustment are to be tested. The simplicity of all interactions (e.g. between the driver and the parking/charging facilities) will be analysed.

7. Conclusion

Defining the testing and evaluation framework for a large-scale project is not a straightforward task. In a European-scale project focusing on the rapidly advancing electro-mobility domain, it should be expected to have changes in the specification of the hardware and software components envisioned in the early system design. Such changes would also naturally affect the verification and validation steps and or the context for the testing.

In this deliverable, we provided the general methodology for the testing and evaluation of eCo-FEV system, from the verification of individual components and subsystems to the overall verification and validation of the system as a whole. Even though the individual components or even the subsystem specifications may be subject to changes throughout the development phases, the high-level methodology defined here based on the V model should remain valid.

We also identified an initial set of key performance indicators that will be used as a basis for the validation of eCo-FEV system in the next phases of WP400. The next deliverable of this task, D400.2 "Evaluation database description", will focus on identifying the dataset to be collected during the tests for the validation and evaluation purpose.

The current deliverable presented the general methodology and the initial baseline for the testing and evaluation of the eCo-FEV system, which will be complemented and expanded in the scope of WP420 (Test preparation and execution), WP430 (Technical evaluation) and finally WP440 (Impact assessment). The results will also be reported and disseminated in the public deliverables D400.3 and D400.4, for the technical evaluation and impact assessment, respectively.

8. References

[1]   "Systems Engineering for Intelligent Transportation Systems", U.S. Department of Transportation, Office of Operations, Washington, DC, January 2007.

[2]   Pyster, A. and D.H. Olwell (eds), "The Guide to the Systems Engineering Body of Knowledge (SEBoK)," v. 1.2. Hoboken, NJ: The Trustees of the Stevens Institute of Technology. www.sebokwiki.org/, Last Accessed: Jan 2014.

[3]   Massimiliano Lenardi et al., eCo-FEV Deliverable D101.3 "Guide to Redmine: Setup of shared online work space", November 2012.

[4]   Witold KLAUDEL et al., eCo-FEV Deliverable D200.1 "Use cases and requirements for an efficient cooperative platform", May 2013.

[5]   Daniel Roiu et al., eCo-FEV Deliverable D200.2 "Overall Architecture and Functional Design for E-mobility Cooperative Infrastructures", July 2013.

[6]   Lan Lin et al., eCo-FEV Deliverable D200.3 "System and Component Specifications", December 2013.

[7]   EUROPEAN COMMISSION, "Well-to-Wheel analysis of future fuels and powertrains in the European context," WELL-to-WHEEL REPORT, Version 1b, January 2004.

[8]   The FRAME Architecture - http://www.frame-online.net/

[9]   International Test and Evaluation Association, http://itea.org/learn/about-itea.html, Jan 2014.