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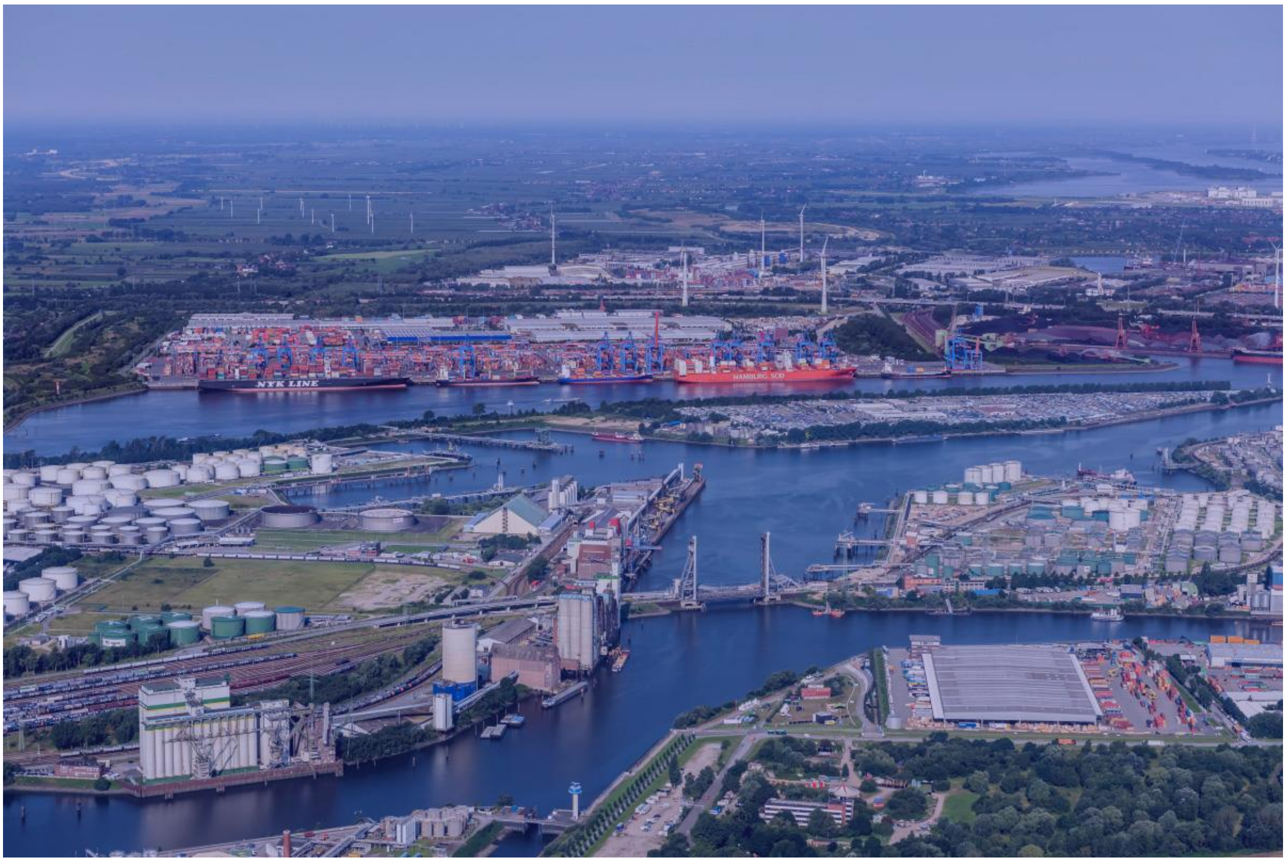
A leap towards SAE L4 automated driving features

Common evaluation framework for MODI-demonstrators

28th September 2023



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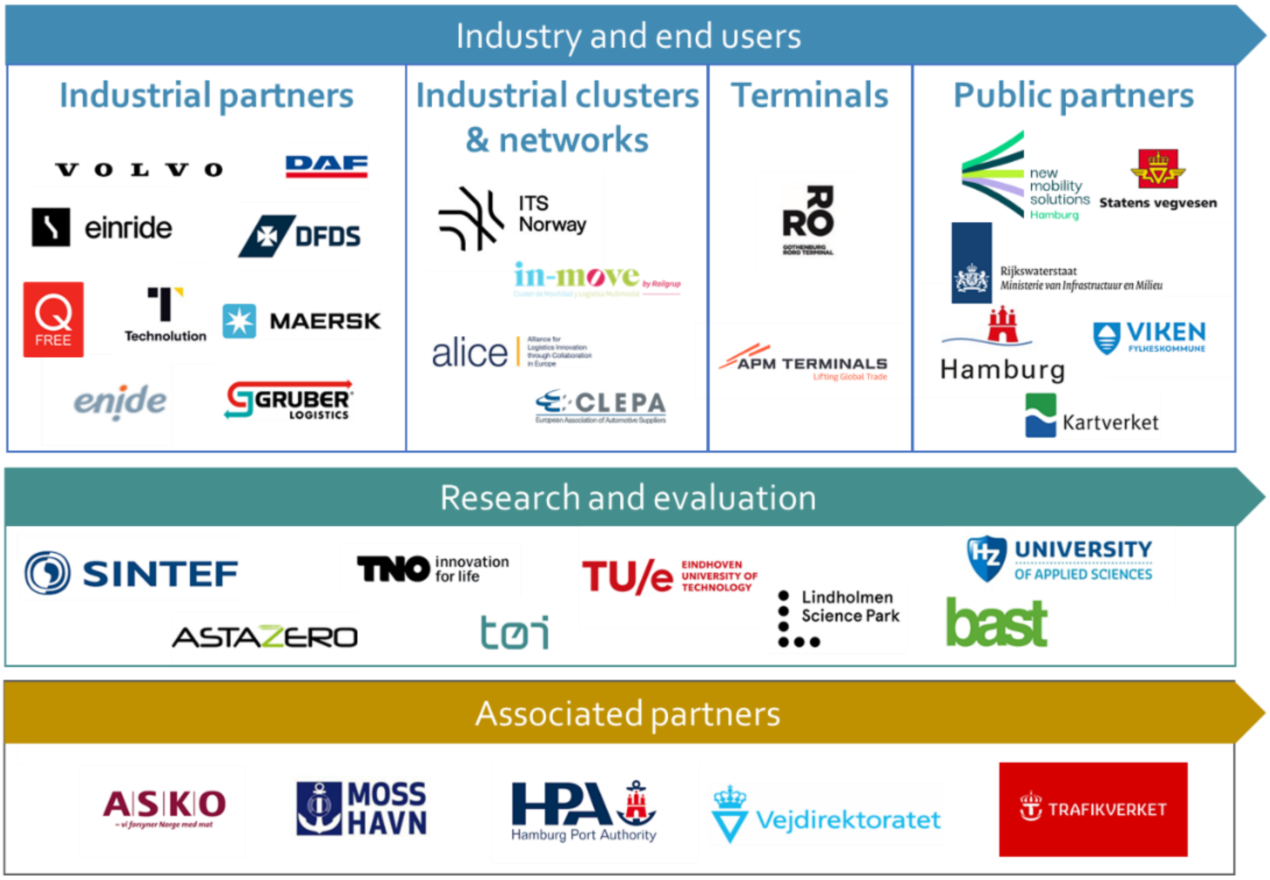

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Terms and abbreviations

Term / Abbreviation	Description
AGV	Automated Guided Vehicle
AV	Automated Vehicle
CCA	Co-creation arena
CCAM	Connected, Cooperative and Automated Mobility
C-ITS	Cooperative Intelligent Transport Systems
DOI	Digital Object Identifier
DSF	Data Sharing Framework
EC	European Commission
EV	Electric Vehicle
FAIR	Findable, Accessible, Interoperable, Reusable
FESTA	Field opErational teSt supporT Action
FOT	Field Operational Test
GDPR	General Data Protection Regulation
GHG	Greenhouse gases
GNSS	Global Navigation Satellite System
ITS	Intelligent Transport Systems
KPI	Key Performance Indicator
L2, L4	SAE Level 2, and SAE Level 4 of driving automation[1]
Lidar	Light detection and ranging
NDS	Naturalistic Driving Study
N-FOT	Naturalistic Field Operational Test
ODD	Operational Design Domain
OEM	Original Equipment Manufacturer
PDI	Physical and Digital Infrastructure
RQ	Research Question
SAE	Society of Automotive Engineers
SSH	Social Science and Humanities
TRL	Technology Readiness Level
UC	Use Case
UC CCAM	Use Case CCAM Test Corridor
UC GE	Use Case Germany
UC NL	Use Case Netherlands
UC NO	Use Case Norway
UC SE	Use Case Sweden
VRU	Vulnerable Road User
WP	Work Package

It is to be noticed that there is a plethora of terms used to refer to the CCAM solutions/vehicles to be used in the project (e.g., L4 CCAM vehicles, L4 CCAM automated vehicles, CCAM vehicles, CCAM AVs). To ensure coherence, the term "CCAM vehicles" (which in this project refers to either L4 or L2 automated vehicles) is used throughout the document.

[1] https://www.sae.org/blog/sae-j3016-update

Executive Summary

The present document titled "Common evaluation framework for MODI-demonstrators", representing deliverable D2.2, has as purpose to provide an overview of the methodologies selected for evaluation of the MODI project focusing on the five Use Cases (UCs) to be tested.

The main purpose of this document is to specify the evaluation methodology that the MODI project will use. This is part of the Task 2.2 in Work Package 2 of the project, in which three specific points are defined in the project description - the evaluation methodology will:

a. collaborate with the FAME[2] (HORIZON-CL5-2021-D6-01-06) project.
b. tailor the evaluation methodology to the specific needs of the UCs of MODI, including identifying the input required from each UC to perform the evaluation.
c. specify common and preferably standardised data formats, in coordination with the UCs and aligned with the FAME project.

The collaboration with the FAME project is an established and ongoing process, and the development of this document has been in coordination with key members of the project (point a). This also ensures that the data formats presented here are common for both the MODI and FAME projects (point c). Moreover, this document is structured in relation to the 5 UCs and their respective needs and impacts (point b). As such, the work in this document has also been carried out in close collaboration with all the UC leaders and the project partners responsible for the impact and gap analyses.

The plan for the evaluation methodology presented in this deliverable is based on the FESTA methodology, which is slightly modified when applied to the project. Additionally, the methodology has been supported by perspectives of i. social science and humanities perspectives (SSH) and ii. a framework for measurement validity. The inclusion of these two approaches enhances the FESTA methodology to properly adapt its approach to the aims of the MODI project.

Thus, this document presents the different evaluation methods to be applied to the analysis of the four impact areas (environment, safety, traffic (included in operational activities) and socio-economic impact) in relation to the UCs. A list of Research Questions, and suggested Key Performance Indicators has been defined, and allows the specification of the data needed to collect by each UC to answer the research questions and achieve the project objectives. In addition, other important aspects for the conduction of the UCs have also been defined (i.e., experimental environments and evaluation tools). Most of the different stages of the project demand a careful attention to ethical and legal issues that may arise, and as such the document provides a general overview of these aspects as guidelines for the project partners.

This deliverable (D2.2) is the first version of the Evaluation Methodology, delivered in accordance with the project timeline (i.e., month 12 – September 2023). It is however to be noted that this deliverable is considered within the project to be a "living document" and as the project progresses, modifications can appear. The task 2.2 will continue its course until month 20 of the project, in which an updated version of this deliverable can be developed.

[2] Complete project name: Framework for coordination of Automated Mobility in Europe.

1 Introduction

1.1 Project summary

MODI Ambitions: A leap towards SAE L4 automated driving features

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

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

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

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

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

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

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

1.2 Aim of the deliverable

The purpose of this deliverable is to present a first version of the framework for the evaluation of the demonstration sites. This deliverable is named D2.2 Evaluation Methodology and is the first version of the evaluation framework for the MODI UCs. This deliverable will be updated over the course of the project since the UCs in the MODI project will develop in stages. The deliverable can be updated when Task 2.2 *Specify* *evaluation methodology* is ending (in Month 20) and as a part of Task 2.4 *Apply common evaluation framework on demonstrators*. The current version is reflecting the status of planning in Month 12.

1.3 Relation to MODI output

This document is an important input for Task 2.3 *Development and utilisation of CCAM data sharing platform*, and Task 2.4 *Apply common evaluation framework on demonstrators*. In addition, due to the focus of the evaluation framework to the impact areas of the project, it receives and provides input to Task 2.5 *Impact analysis*, and Task 2.6 *Gap analysis of the technological and the societal readiness*. This document also functions naturally as a "roadmap" for the conduction of the project, in particular the UCs, and as such it is expected that this can serve all the MODI project partners.

1.4 Structure of the report

This deliverable is structured in six chapters: (1) Introduction, (2) Methodological approach, (3) Preparation plan, (4) Evaluation plan, (5) Conclusions, and (6) References. From the six chapters, chapters 2 to 4 are the main sections of the document, as they comprise the following:

- Chapter 2 Methodological approach provides the description of the selection process for the evaluation methodology, the description of the FESTA methodology and of the complementary methodological approaches to be used. Finally, it provides the established methodological approach to be applied in the MODI project.
- Chapter 3 Preparation plan follows the FESTA-V diagram by presenting the project objectives and the description of the Use Cases (UCs). This chapter also provides a full list of the project's research questions (RQs) and suggested key performance indicators (KPIs), and describes important aspects of the study design, such as the experimental environments and the evaluation tools to be used in each UC.
- Chapter 4 follows the FESTA-V diagram by addressing the details concerning the data collection process. It includes the categorisation of the data and metadata, the data acquisition methods, the concept for the MODI data-sharing platform, and guidelines for the data analysis and the evaluation of the RQs. The chapter finalises providing an overview of the main aspects and methods to be used for the impact and gap analyses.

Finally, it is important to notice that due to the complexity of the project, each section from the Research Questions to the evaluation of these (Chapters 3 and 4) include a sub-section especially dedicated to discuss possible ethical and legal aspects that may arise during the project.

2 Methodological Approach

2.1 Selection of an evaluation methodology

The overall objective of the MODI project is to "*speed up the introduction of CCAM vehicles for logistics by demonstrations and to overcome barriers for the roll-out of automated transport systems and solutions in logistics*"[3]. For this purpose, the project aims to demonstrate well-integrated CCAM systems for use cases along a transport corridor through five European countries. Seeking to demonstrate CCAM systems along a transport corridor implies that Field Operational Tests (FOTs)[4] are a natural choice for such demonstrations in use cases. FOTs are considered a common evaluation method to test the effects of automotive systems in real-world scenarios. Indeed, a number of projects make use of FOTs to evaluate and demonstrate different transport technologies.

Using the database of EU-funded projects – CORDIS – a review was performed to explore the number of projects dealing with automated vehicles or CCAM for the last ten years (i.e., 2013 – 2023). The objective of the search was to identify projects that included FOTs in their research design and to explore the evaluation methodology used by them. The initial set of results found 24 projects focusing on automated vehicles. Twelve of the 24 projects (50%) included FOTs, of which six used the FESTA Evaluation Methodology [1]. These projects are: AUTOPILOT (autopilot-project.eu/), INFRAMIX (www.inframix.eu/), L3Pilot (l3pilot.eu/), MAVEN (www.maven-its.eu/), SerioT (seriot-project.eu/project/) and SHOW (show-project.eu/).

Following the scope of Task 2.2, in which this deliverable is included, the MODI methodology collaborates with HORIZON-CL5-2021-D6-01-06 (Project name: Framework for coordination of Automated Mobility in Europe, short: FAME)[5] to ensure harmonisation. As such, it is worth noting that the FAME project makes use of the FESTA methodology to build up an European Common Evaluation Methodology (EU-CEM) to develop and validate common methodologies and tools that can be used across the CCAM community to share best practices and lessons learned [2]. Due to the established communication between MODI and FAME, points and aspects described in this document can also contribute to FAME and the development of the EU-CEM.

The FESTA methodology was developed in the FESTA project (Field operational test support Action, 2007-2008), created with the objective of providing a complete guidance to support the testing of European FOTs. The creation of a common methodology for pilots of automated driving, a task undertaken by FAME using FESTA, is an important endeavour to gather all knowledge from different FOTs and pilot studies in order to have a unified understanding of the impact of automation.

Considering that the objective of MODI is to speed up the introduction of CCAM vehicles in Europe by cooperating and co-creating with relevant stakeholders, it becomes logical to join efforts by following a common methodology which can contribute to a shared understanding of the implementation and impact of CCAM on European roads. The results, based on a well-described evaluation process, will serve not only the MODI project, but to other future projects with similar objectives, and increase the understanding of CCAM.

Based on the project objectives, the collaboration with FAME project (as stated in the project description), and the search among the EU-funded projects dealing with automation, this document presents the evaluation methodology of MODI based primarily on the FESTA methodology (see Section 2.2), and supported by complementary methodological approaches (see Section 2.3).

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[3] Retrieved from the MODI Project Plan.

[4] FOT is defined by the FESTA Handbook as "*a study undertaken to evaluate a function, or functions, under normal operating conditions in road traffic environments typically encountered by the participants using study design so as to identify real-world effects and benefits*".

[5] See https://www.connectedautomateddriving.eu/about/fame/ for more information.

2.2 FESTA Methodology

As indicated earlier, the FESTA project produced the original FESTA handbook in 2008 as its main deliverable. The handbook was then updated after support actions from the FOT-Net, CARTRE and ARCADE consortia. The handbook is of public open access[6], allowing its use to ensure comparability among different FOTs and to improve the relevance of FOT results at European levels.

The FESTA methodology is represented in a V-diagram, in which the top of the V represents general definitions, such as the study goals and a global impact assessment, while the lower and narrow part of the V represents the steps which require a higher level of detail, such as performance indicators and data collection. Both sides of the V present different steps arranged in a linear direction showing the dependency between them (see Figure 1).

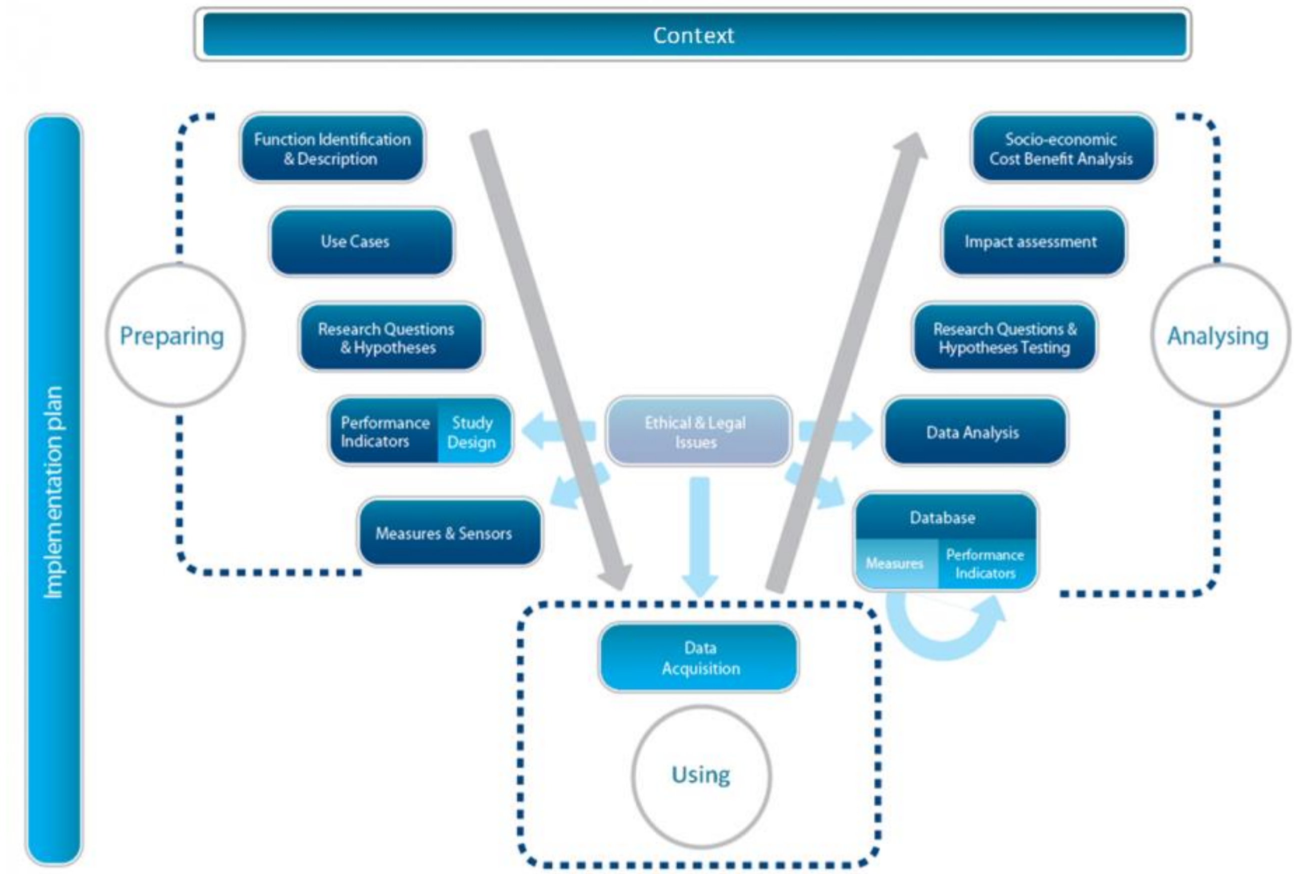


Figure 1: The FESTA-V methodology showcasing the different steps to consider in projects including FOTs. Source: FESTA Handbook [1].

Although the steps are arranged in a linear way, this does not imply that designing and running an FOT is a linear process. The steps from both the left and right side present correspondence, indicating an iterative process in which there might be needed to go back to a step and refine it.

In general, there are four important considerations in the implementation plan of FOTs:

[6] The FESTA Handbook is presented as owned, developed, and updated by the large FOT community, and it is thus of public access. Its most recent version (v.8, Sept. 2021) can be downloaded from: https://www.connectedautomateddriving.eu/methodology/festa/

1. Preparing: Selection and description of functions to be tested, the definition of use cases and situations, identification of the research questions and creation of hypotheses, link hypotheses with performance indicators for quantitative/qualitative analyses, and study design defining possible use of measures (defining data to collect, tools, and data structure), sensors, video annotations, among others.
2. Using: This considers the data acquisition, in which the type of data to collect is defined. This implies not only objective but also subjective data.
3. Analysing: This part includes the data analysis in relation to data quality, data processing, its relation to the performance indicators, hypothesis testing and global assessment (including impact assessment and socio-economic cost benefit analysis).
4. Ethical and legal issues: Legal and ethical issues affect the whole project from initial agreement to data re-use after the project, but these issues have stronger impact on the lower part of the V-diagram, particularly related data collection and analysis, approval for on-road use, system safety, insurance, responsibilities, data protection and data ownership.

Although the first step is expressed as the identifications of the functions, this does not mean that this should be necessarily the starting point, as an FOT may be driven by a research question. Although the FESTA-V diagram offers a static linear picture of the complexity of executing FOTs, a more flexible and iterative process might be performed depending on the needs and aims of each project. This deliverable (D2.2) is scheduled for M12 in the MODI project, while the task will continue after the deliverable is handed in. This ensures that the process of updating the KPIs and data sources can be continued also after the deliverable is handed in.

Finally, on top of the diagram a bar denoting context is shown. This indicates the need to recognise the context in which the FOTs will be carried out to be able to analyse whether it can be related to a wider perspective. To reach such a conclusion both the description of the function to be tested in an FOT and the context in which it operates are relevant to be able to evaluate the generalisability of the results. According to the FESTA Handbook, an FOT can always be related to a wider perspective.

This section has provided a summarised overview of the FESTA-V approach, for a more comprehensive description of the methodology and its parts, please refer to the FESTA Handbook [1].

2.3 Complementary methodological approaches to be used in the MODI project

To ensure that the objectives of the project are met, MODI will also complement the FESTA methodology with other relevant perspectives and approaches. Following the principles guiding the Common Evaluation Methodology (CEM) developed in the FAME project, we will apply the "comply-or-explain principle" and explain why the MODI methodological approach is dedicating attention to social science and humanities (SSH) perspectives [2]. In particular, the MODI project will complement the FESTA methodology with i) SSH perspectives, as asked for in the call text and specified in the MODI application, and ii) a framework for measurement validity to ensure that the project will measure both quantitative and qualitative variables in a coherent manner.

2.3.1 Social science and humanities perspectives

The Horizon Europe work programme aims at integrating SSH in relevant topics. SSH consists of many different disciplines, including sociology, economics, political science, history, cultural science, law, and ethics. The recommendations made by Net4SocietyHE, the transnational network for Cluster 2 in Horizon Europe, states that inclusion of SSH is needed to provide evidence-based knowledge, provide advice for policymaking and to ensure multidisciplinary solutions [3]. Multidisciplinary research, including SSH, is also called for by the academic community on automated transport at large as well, e.g., [4]–[6].

When investigating the implications of automated transport some areas within SSH have historically not been a focus within the literature [5]. However, a broad understanding and inclusion of SSH approaches and disciplines is needed to understand the societal dimension in the MODI project. A bibliometric literature review finds that less than 5% of the papers published between 1969 and 2018 are focusing on nontechnical issues [7]. Hence, there is a need for stronger incorporation of the societal dimension of transitions within the mobility sector [8], going beyond more traditional SSH approaches such as conducting acceptance studies [5], and moving towards for instance how cooperation could be carried out in a way that facilitates learning across professions, domains, and sectors [9]. With insufficient knowledge about the "implications, benefits and impacts of integrating CCAM solutions into the mobility system" p. 22, [10], the use of innovative approaches from SSH can be invaluable to capture and document the on-going deliberation by relevant stakeholders. As rapid technological development meets regulatory consideration, stakeholders need arenas to deliberate and cooperate to solve fast-moving and complex challenges.

SSH perspectives will give a better understanding of how and why the UCs work, the roles of the users/stakeholders, businesses, and authorities in processes to understand the complex system of the demonstrators, as illustrated in Figure 2.

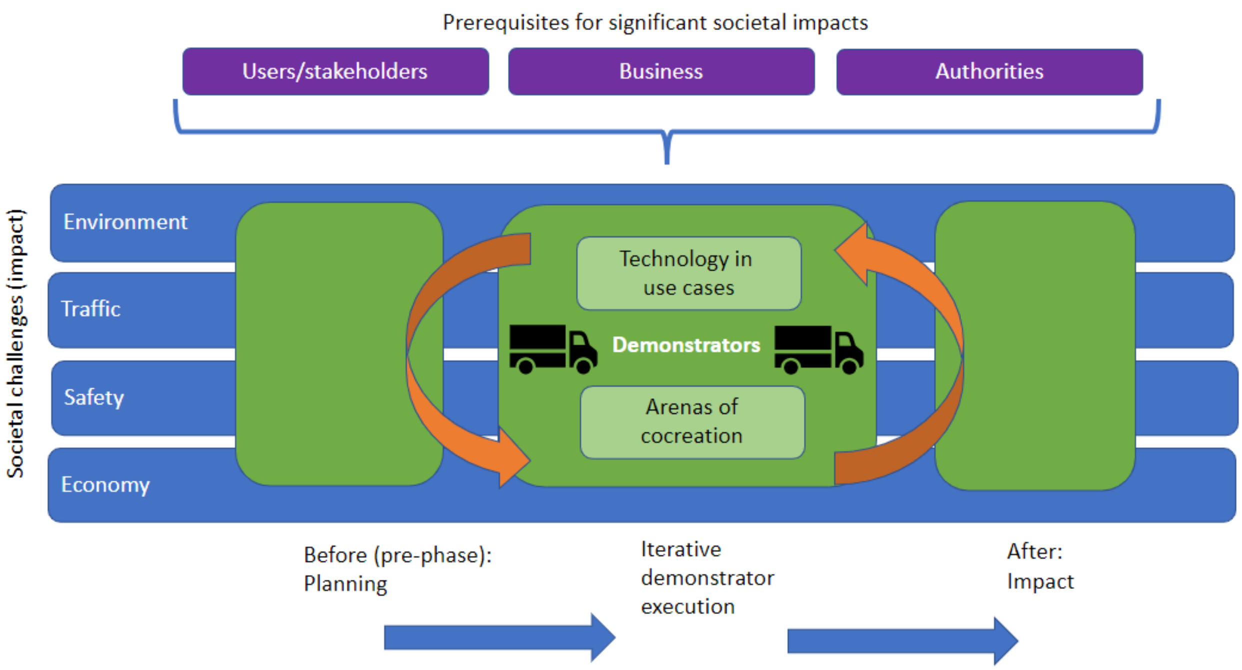


Figure 2: The MODI project in a social perspective.

The MODI project will complement the traditional FESTA methodology with innovative use of SSH perspectives, and there is therefore also a need for a unified approach on how to ensure that reliability and validity can be handled across different perspectives and disciplines. This is a key concern when measuring concepts. As indicated previously, the narrow lower part of the FESTA-V diagram entails the aspects that require deeper reflection and a higher level of detail.

Although SSH has been engaged within the field of automated transport, the engagement has been focused on "a narrow spectrum of issues" [11]. This is also illustrated in the bibliometric literature review of Gandia et al. [7] where only three non-technical categories are represented in the top 20 categories of the studies on automated vehicles: operational research management science, business economics, and psychology. By employing a wider range of SSH disciplines, the contributions of SSH are expected to broaden as well [5].

SSH perspectives can enable [12]:

- Assessment of fidelity[7] and quality of implementation
- Clarifying causal mechanisms
- Identification of contextual factors

The problems targeted in the MODI demonstrations are highly complex (e.g., driver shortage, climate crisis, pressure on urban areas), and these issues are difficult to understand without in-depth knowledge [12]. We therefore need to look at the (social, political, economic) systems in which the vehicles will operate. Information about the social perception of the automated vehicles tested is often well known among the project participants. The competence of a research project is a complex combination of competencies of different individuals and organisations, and the capability to solve a problem is dependent on how they utilise both the explicit and tacit knowledge within the consortium [14]. Tacit knowledge is when an individual has collected knowledge while performing different tasks and duties in different contexts and situations within the project, a kind of practical knowhow [14]. To secure knowledge and experience transfer within and beyond the MODI project, it is crucial to utilise both the explicit and the tacit knowledge, for instance to ensure a joint understanding of the UC objectives, their societal implications and how the UCs can add value to society, and how to share best practices.

The transport system represents a “complex system” [15], and there is a need for a clearer understanding of the (social, political, economic) systems in which the vehicles will operate within. MODI therefore need to look inside the so-called "black box" to see what happened in the project and how that could affect project impacts or outcomes [6], [16], [17]. Furthermore, the effects of the demonstrations are delivered within a social system that responds in unpredictable ways to new innovations, and it is challenging to know whether effect sizes of a technology might be replicated in a different context, or whether trial outcomes can be reproduced [12]. For instance, public acceptance is often treated as a something that must be improved or how barriers against public acceptance can be removed. However, this approach neglects that public acceptance is not just connected to consumer-related issues, but it also includes other aspects such as job losses and health benefits [4]. In terms of freight transport, this includes understanding how the new technology affects for instance the jobs of people, and how their health might be improved, as these are important factors to user acceptance.

Hence, it is necessary to move beyond “does it work” towards combining impact assessments with approaches from various SSH disciplines. The ambition in the MODI project is to make tacit knowledge explicit and document this knowledge. The co-creation arenas (CCAs) is instrumental in this regard, which have been understood as “an instrument for user-centred development of products and innovations, particularly in the industrial sector" [18]. In the MODI project the inclusion of the CCAs represents a novelty. Each of the MODI UCs have their own designated CCA as well as a dedicated unified CCA for the entire project. The CCAs are designed to reduce tensions and ease collaboration between an industry perspective and the regulations perspective, where researchers can help to facilitate a joint understanding among these. By facilitating relevant discussions in a trustful environment where stakeholders can present their perspectives and deliberate, a foundation for collaboration can be established, where balanced and legitimate resolutions can be achieved through cocreated processes that link and recognise different perspectives.

The CCA also have another important function in the MODI project; namely, to be an arena to discuss the overall societal implication of the project. This “bird’s eye view” of the UCs and project as a whole ensures that the non-technical aspects of the project are thoroughly discussed by the UC partners [4] and can in turn reduce the barriers for deploying CCAM and achieve positive societal impacts that go well beyond the project.

From an evaluation and documentation perspective, the CCAs are also invaluable for data generation on the tacit project knowledge that develops during the project [14]. Therefore, ensuring proper methods of

[7] Fidelity refers to the degree to which an intervention or programme is delivered as intended [13].

documenting the co-creation process is vital. Qualitative methods are well suited to understand how complex processes stretch out, as they give "snapshots" of the different processes which unfolds in the project [15]. Information gathered from the CCAs include a range of different stakeholders within the project and can be used to assess different perspectives in a UC, relationships, and theories of change within the broader project and to make sense of project trajectories [15]. Participatory methods such as CCAs can be utilized both as means of bringing in the perspective of those involved in the project, as well as a method to check and present interim findings.

The documentation from the CCA is ensured through three steps: i) preparatory work (e.g., a survey) ii) written documentation from the arena meetings generated by the facilitation researchers, and iii) a reflection note written by the CCA leaders briefly after the arena followed by a debrief interview with the project partner responsible for the co-creation arenas in the project. This process-oriented approach visualised in Figure 3 ensures continuous improvement and learning over time.

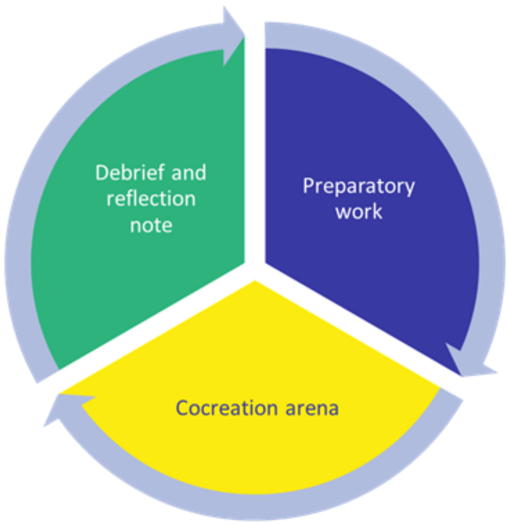


Figure 3: Process-oriented approach of the co-creation arenas.

These three steps constitute the main parts of an executive summary that the CCA leaders in each UC put together and distribute to the project partners after each arena, ensuring sharing and dissemination of experiences, recommendations, and development of best practices across use cases. These executive summaries, in turn, then act as input and preparatory work for the project CCA ensuring that the UC specific knowledge and experiences gets discussed and processed at the overall project level, which in turn will give input to several key deliverables, namely the gap analysis and the Book of Recommendations.

2.3.2 Shared framework for measurement validity

The validation of the project findings (as an important part of solid research efforts) is usually based on two measures of quality: reliability and validity. Reliability refers to the consistency of a finding, i.e., whether the results can be replicated under similar conditions across different researchers and different projects. Validity refers to the accuracy of a finding, i.e., whether the results represent what they are supposed to measure. Although both measures of quality are recognised as pivotal for any research endeavour and as such, attention to these should be devoted throughout the entire research process, many researchers seem to validate the findings when the research project has finalised rather than from the beginning and throughout the research process. In an evaluation methodology perspective, there is the opportunity to properly study each step of the process to ensure an appropriate methodological approach that can deliver robust and valid results.

Adcock and Collier [19] point out that many researchers make claims that assume the validity of the measurements that operationalise their concepts, but that measurement validity as such receives little attention. Measurement validity, as described by Adcock and Collier, is *"specifically concerned with whether operationalisation and the scoring of cases adequately reflect the concept the researcher seeks to measure"* [19]. This means that a measurement is valid when the observations (i.e., empirical data) capture the ideas contained by a defined concept (used in research questions/hypotheses). In simpler words, measurement validity refers to whether a variable measure what it is supposed to measure. This is a crucial starting point, because if an FOT seeks to provide valid results that can be generalised to wider levels, the collection of data and subsequent analyses are inherently connected to the pre-defined performance indicators. The performance indicators, at the same time, need to be derived from carefully developed concepts included in the research questions and hypotheses.

There is, however, an important detail that requires attention: a concept can be used in the research questions and hypotheses, but a concept does not need to be static. This is what Adcock and Collier described as "*issues that arise in moving between concepts and observations*", in which the concepts (even when used as operational concepts) can be refined and changed after collecting and observing the data. Due to this operationalisation and/or refinement of concepts, Adcock and Collier developed a framework that can be used by the research community, across different disciplines and different approaches. The "Shared standard for qualitative and quantitative research" by Adcock and Collier [19] is based on this two-way relationship between concepts (needed to define the research question, hypotheses and key performance indicators) and what they call observations (i.e., the data collected in the study). This two-way relationship is in line with the FESTA methodology, as it is indicated that "*decisions made at a certain stage of the FESTA V influence the next steps, and it is likely that there will be a need to sometimes go back and redo some steps*. *[…] For example, one may find that the measures and sensors available do not make it possible to investigate the hypotheses defined earlier, so adjustments to the hypotheses or performance indicators may be needed*" [1].

Thus, to appropriately address the greater need of focus that the aspects from the lower part of the FESTA V-diagram require, particularly to incorporate both quantitative and qualitative data, the "Shared Framework for Measurement Validity" developed by Adcock and Collier will be used and is here succinctly presented and explained in relation to the MODI project.

As previously discussed, the shared standard developed by Adcock and Collier [19] is based on the relationship between concepts and observations. This is described as a two-way relationship, in which not only observations derive from a concept included in performance indicators, but indicators and concepts are also modified based on the observed results, see Figure 4.

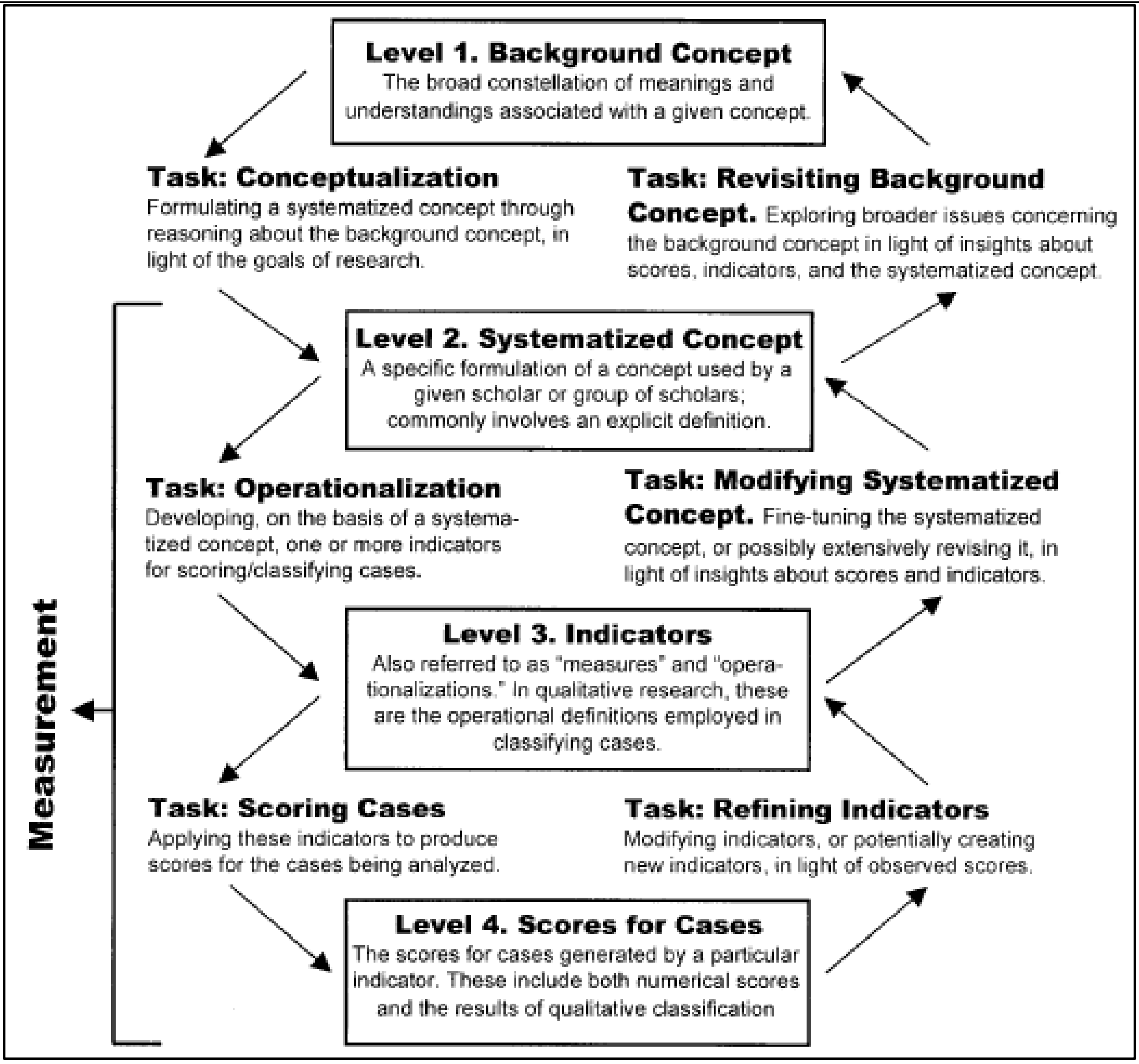


Figure 4: Levels and tasks of the shared framework for measurement validity. Source: Adcock & Collier [19].

The shared framework is based on four levels, in which the last three (from level 2 to level 4) form the basis for measurement validity. The process to go from one level to the next one is understood as research tasks (e.g., Conceptualisation, Operationalisation, etc). For a better understanding of the shared framework in the context of the MODI project, this will be further described by relating it to a term that will be used in the project as an example: *Environment* (ref. to KPIs for impact assessment described in Task 2.1).

- Level 1: The shared framework has as a point of departure a background level, which includes all the possible meanings of a term. In the case of the example Environment, the common definition provided by the Oxford dictionary is that environment is the "*surroundings or conditions in which a person, animal, or plant lives or operates*". The definition is more related to nature, but there is also another definition of environment related to the built surroundings provided by the Cambridge dictionary "*the conditions that you live or work in and the way that they influence how you feel or how effectively you can work*", e.g., a work environment. Moreover, the term is also related to an IT context, in which environment is also described by the Cambridge dictionary as "*the system in which a computer or computer program operates*". This divergence of meanings illustrates the range in which one background concept operates.

- Level 2: A systematised concept is defined at this level, in which a group of researchers agree on a specific definition of a concept in relation to their focus of interest. In the case of the MODI project, a logical selection of the concept environment would be the one related to nature, which is the conditions in which people lives and/or operates regarding transport.
- Level 3: The indicators are located at the third level. This level includes a scoring procedure, which could be quantitative indicators or qualitative classification procedures. Following the example of environment, one natural indicator, among many, for the effect of transport on the environment would be to measure CO_2 emissions.
- Level 4: At this level scores can be found, which are the scores (data) generated for each indicator.

As previously indicated, the process also opens for a revision of the concepts, as indicators may be refined after an assessment of the scores, and the systematised concepts can be fine-tuned after eventual refinement of the indicators.

Moreover, Adcock and Collier [19] also highlight the importance of context, as contextual specificity is important as differences in contexts can threaten the validity of measurements. This is also aligned with the aspect of context described for the FESTA methodology (see Section 2.2). Indeed, if an important contribution of an FOT is to evaluate whether the results can be generalised or not, it is crucial to establish the different contexts present in the project from which the results could be applied to, either at a local or a global level.

In the specific case of the MODI project, and based on the project plan, at the beginning of the project three different contextual differences have been identified, as example means:

- Conventional vs Digital Infrastructure: There should be considered that the results achieved under a road with only conventional infrastructure cannot necessarily be transferred to a road with both physical and digital infrastructure.
- Differences in UC operations: The different contexts of the five UCs of the MODI project should be contemplated. For example, a UC operates within a closed road whereas other operates on a public road. Likewise, while a UC focuses on port operations, another UC includes an international border crossing.
- Different societies in which the UCs will operate: Four different European countries will be part of the MODI UCs, i.e., Norway, Sweden, Netherlands, and Germany. Possible differences in politics, economy, or society to which the UCs will be applied should be given consideration.

Some other contextual differences that arise during the project should then be treated with caution. Although Adcock and Collier [19] indicate that generalisation should not be abandoned, there should be focus on context, as the interpretation of results in one context does not imply that the same results are automatically valid for another context. As some concepts may vary across the contexts, there should be a careful work at the level of indicators. For example, although the same indicator can be applied to all cases, these should be adjusted and weighted to compensate for the identified contextual differences.

2.4 Methodological approach for MODI

As previously stated, the evaluation methodology selected for the MODI project is based primarily on the FESTA methodology (see Section 2.2), and supported by complementary methodological approaches: Social Science and Humanities approach (see Section 2.3.1) and Shared Framework for Measurement Validity (see Section 2.3.2). A customisation of the FESTA-V diagram, including the different identified steps of the evaluation methodology adapted to the MODI project is presented in Figure 5.

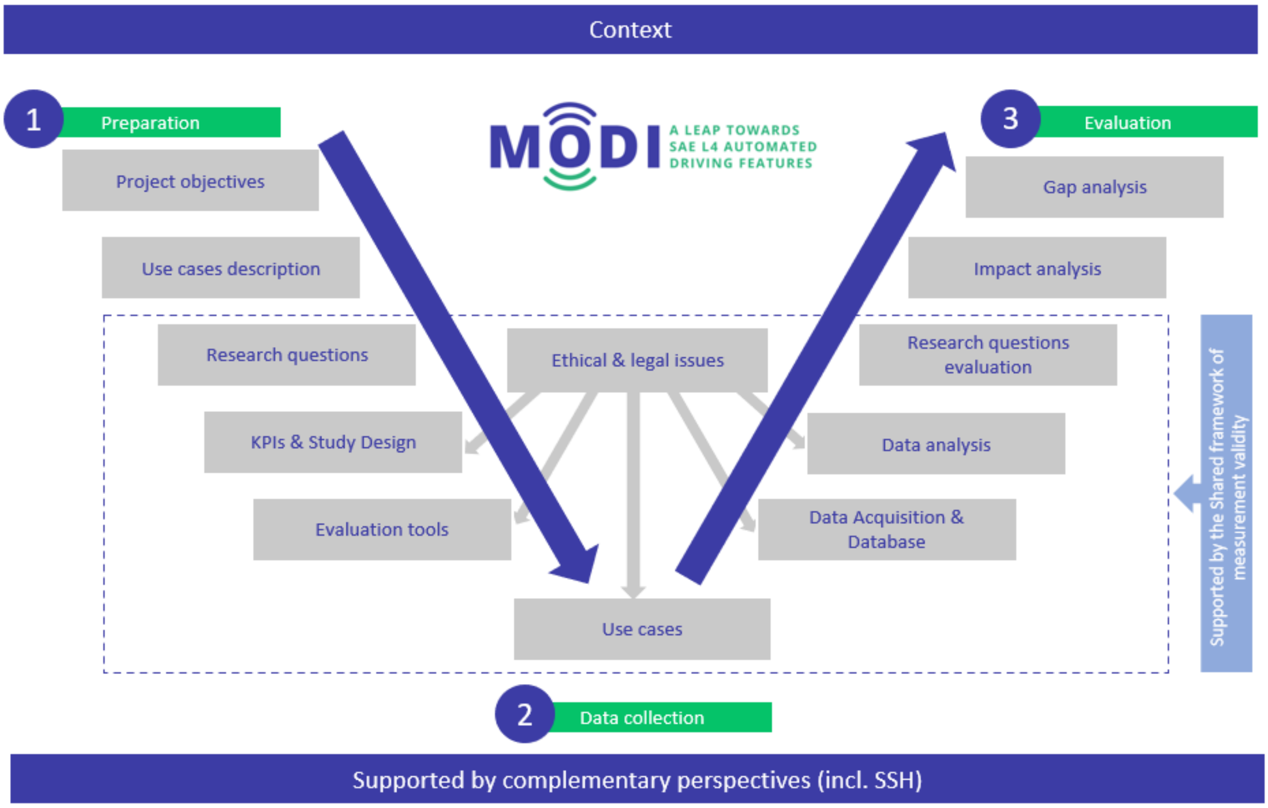


Figure 5:Adapted FESTA-V diagram for the MODI Evaluation Methodology.

The aspects of the FESTA V-diagram that need higher level of detail will be complemented by the "shared framework for measurement validity", an approach that also can be applied to qualitative methods. In addition, SSH (as complementary perspectives) are shown as a bar in the diagram, indicating the need to include such aspects during the complete course of the project. Furthermore, to better identify and define each step of the FESTA-V diagram in relation to MODI, this document uses the following relevant sources of information: i. project description, ii. information gathered in UC templates, filled out by each UC leader, and iii. the documentation from the co-creation arenas (CCAs), carried out separately for each UC where project partners involved in each UC participated.

It is important to remember that the FESTA methodology was originally developed to be used for FOT studies (see Section 2.2), where the focus is evaluation of functions or systems. The MODI project, however, is not solely focused on the testing of specific systems under controlled experimental conditions, but also on the evaluation of advanced technologies to be tested in natural traffic situations. This approach is recognised as Naturalistic Driving Studies (NDS) and adopts a more exploratory approach to collect knowledge primarily on road safety, but also to other factors, such as environmental factors or traffic management factors. Naturalistic Driving Studies are thus defined as studies that use "*unobtrusive observation or with observation taking place in a natural setting*" [20]. The NDS aim for deeper understanding of the driving scenarios themselves and explore their effects on safety and other aspects of driving. Furthermore, they are also interested in the identification of possible problems that may arise during the driving scenarios.

Another important difference between FOTs and NDS lies in the degree of experimental control used in the study: the FOTs have some degree of experimental control (e.g., specific ITS functions tested under baseline and experimental phases), whereas the NDS have little to no experimental control and is more focused on unobtrusive observation. These two types of studies are seen along a continuum of experimental control (from some to none), and there is an overlapping part between the two (see Figure 6). The overlapping relationship between FOTs and NDS is identified as Naturalistic FOT (N-FOT), indicating the sharing of some common methodological aspects. More specifically, the N-FOTs are defined in the FESTA handbook as studies dealing with both exploratory research (common in NDS), and the evaluation of technologies and solutions (common in FOTs).

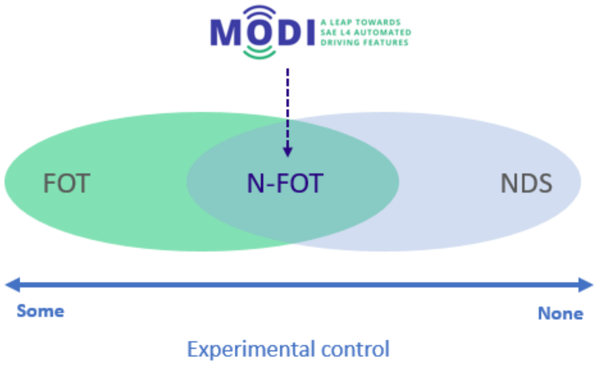


Figure 6: Diagram showing the different types of studies along a spectrum of experimental control and the positioning of the MODI project as N-FOT (Figure adapted from the FESTA Handbook).

Considering that the MODI project adopts both an exploratory approach and the development of new technologies to be demonstrated as CCAM solutions in operative environments, the project is considered to be an N-FOT and will thus be identified as such throughout the document. There is considerable difference between the different MODI UCs, and some of the UCs are likely to be similar to an FOT, while others may have more in common with an NDS. It must also be highlighted that the maturity of the UCs will continue to develop continuously throughout the project, and that the experimental control of the study may also change. This should therefore in the case of MODI be seen as a moving target, and not as a fixed placement on a scale.

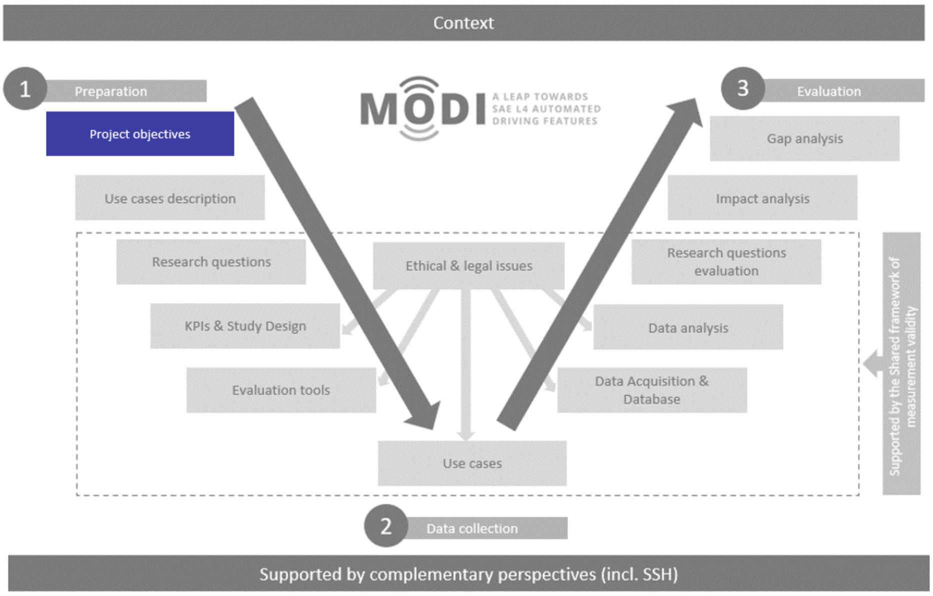
The deployment of the FESTA methodology in the project requires the positioning of the project as either FOT, NDS or N-FOT. Although the FESTA methodology was originally thought to be used by FOTs, it is also highly relevant for NDS and N-FOTs, some modifications are considered. For example, while an FOT focusing on testing a specific driving function will start by describing such functions, an NDS or N-FOT is more focused on the research questions (due to its exploratory focus), from which KPIs can be identified. The identification of the MODI project as an N-FOT will follow a slightly different progression of the FESTA-V, deriving the KPIs not from hypotheses but from the research questions (see Figure 5). Possible modifications required for an N-FOT are proposed by the FESTA methodology to be supplied with studies related to NDS. An example of this is the set of recommendations for a large-scale European naturalistic driving observation study [21]. Identifying MODI as an N-FOT is also one of the key reasons why SSH perspectives are needed.

Having established the methodological approach for MODI, the following chapters describe the different steps of the project based on the adapted FESTA-V diagram for the MODI Evaluation Methodology, listed in the order indicated in Figure 5. Although some steps in a research plan can be considered intuitive, logical and clear, others might need a more specific definition. If a step in the plan is not well-defined, it might lead to confusion or even more problematic, to a misuse of it. Misunderstandings of steps in a research plan is particularly critical when working across different disciplines, as it could lead to measure different indicators or interpreting results differently, and thus not having a unified approach to make the research solid. Thus, the document provides a general description of each step of the project, aiming to serve as a common understanding for the different phases of the MODI project. Definitions at a more detailed level are provided where appropriate, whereas other aspects will be further developed as the project progresses.

In an attempt to aid the reader, a grayscale figure of the adapted FESTA-V diagram is provided at the start of each section, highlighting the FESTA-V step that each section develops.

3 Preparation plan in MODI

3.1 Project objectives



The overall objective of MODI (see Section 2.1) is divided into four individual objectives, in which the first objective is later sub-divided to address different solution segments, as follows:

O1: Implement the latest technology and overcome major CCAM deployment barriers for logistics by demonstrating business-oriented and well-integrated CCAM systems for use cases (UCs) along a transport corridor and between hubs.

- O1.1: Develop and implement innovative technologies on a variety of CCAM vehicles for transport of goods.
- O1.2: Develop a standardised interface for coordinating automated vehicles as part of the digital infrastructure, which is validated in logistics operational use cases that have a high business prospect for deployment and are fulfilling the needs of logistics stakeholders.
- O1.3: Demonstrate physical and digital infrastructure solutions towards a successful and quick CCAM deployment in private areas and the public domain.
- O1.4: Demonstrate solutions for CCAM interoperability between countries and cross-border traffic and propose harmonization for regulations and border controls.

O2: Define recommendations for adaptations of supporting infrastructure, vehicle regulations and standards to enable broader deployment of CCAM, speeding up the introduction of CCAM vehicles and recommendations for further (e.g., large scale) piloting.

O3: Demonstrate business models and partnerships for the application of CCAM vehicles in logistics.

O4: Perform technical and socio-economic impact assessments and communicate them in the context of the best practices of the MODI CCAM solutions and systems for real-world conditions.

For a better understanding of the project objectives, Table 1 depicts each of the objectives (including the sub-objectives of O1) and indicates the focus of each objective and their expected results.

Table 1: Summary of the project objectives based on their focus and their respective expected results.

Project objective	Main focus	Expected results
O1	Technical improvements	
	O1.1: Innovative technologies on CCAM vehicles	CCAM Vehicles at TRL7 for freight operating in UC demonstrations.
	O1.2: Standardised interface	Coordination interface for CCAM vehicles to communicate with control and automation systems at port, customs stations, and road operators (traffic management systems).
	O1.3: Infrastructure	Adjustments to physical and digital infrastructure design.
	O1.4: Interoperability between countries	Design for automated and harmonised processes at national cross-borders.
O2	Infrastructure	Book of recommendations covering adaptation of infrastructure for freight transport, best practices for introduction of CCAM vehicles for freight transport, and adoptions and refinements to regulations.
O3	Good business cases	Examples of logistical business models that are profitable.
O4	Assessments of effects	Assessment of the impacts of MODI-CCAM solutions and use cases on: • Environment • Safety • Traffic (incl. in operational activities) • Socio-economics Gap analyses for deployment focused on: • Technology readiness • Societal readiness Recommendations about the best practices for CCAM operations in logistics.

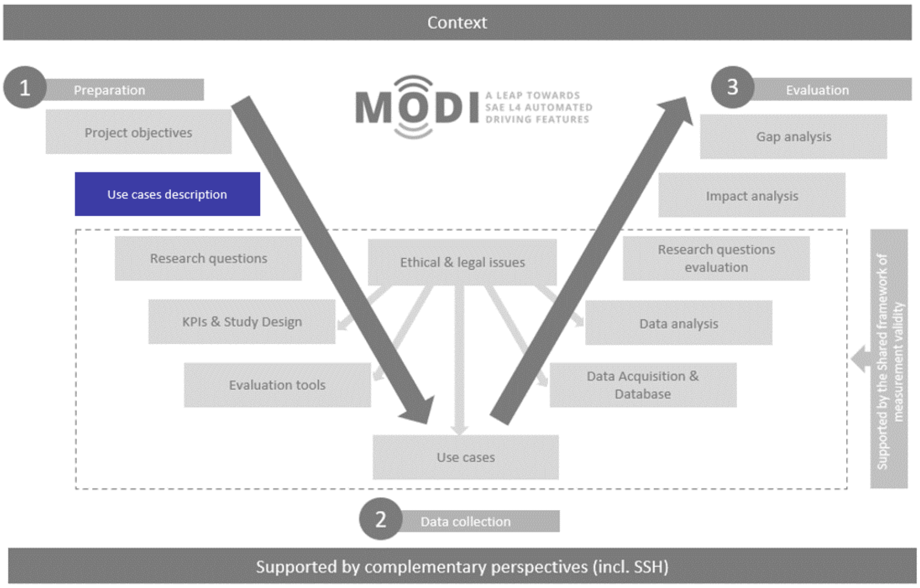
Regarding O4, the MODI project aims to achieve this by assessing the effects of evaluating the impacts on environment, safety, traffic, and socio-economy. This will be focused specifically on:

- Impact on environment: Life Cycle Analysis (LCA) as part of a sustainability assessment to address the environmental gains (including reduced carbon footprint and harmful emissions, increased energy efficiency).
- Impact on safety: Safety assessment of MODI solutions, including studies on interaction with other road users, such as Vulnerable Road Users (VRUs).
- Impact on traffic (as part of operational activities): Assessment of how the MODI solutions will impact traffic, meaning productivity and efficiency of transport, expressed via operational costs, travel time and speed, delays, amount of travel needed to deliver a certain amount of goods/tonnes, and more.
- Impact on socio-economics: Assessment of the viability of use cases, including valuing additional costs for CCAM solutions vs cost savings, including socioeconomics.

Furthermore, the FESTA methodology suggests using the following four distinct areas as a starting point: key safety, mobility, efficiency, and environmental impacts [1]. The MODI project is particularly concerned about the four main impacts as stated above (i.e., environment (regarding sustainability), traffic, socio-economy and safety). These four main impacts are considered to be equivalent to the identified four aspects from FESTA.

The description of the following sections (particularly the UCs and research questions) will thus be based on these four impact areas.

3.2 Use cases



All the UCs in the MODI project are located across a corridor going from Rotterdam (Netherlands) to Oslo (Norway). This connects the main ports of Rotterdam, Hamburg (Germany), Gothenburg (Sweden), and Oslo. Considering that the focus of the project is on transport systems in logistics, the use of Rotterdam, Hamburg and Gothenburg (among the top 20 ports handling freight in Europe) is particularly interesting to study.

While the FESTA methodology is focused on the testing of specific technological functions (e.g., forward collision warnings or lane departure warnings), the MODI project will make use of CCAM vehicles with many different technologies to be tested in different scenarios. Thus, the UCs described in this chapter are based on the scenarios selected within each UC to test a range of freight transport situations. The description of the UCs is thus directly related to three distinct steps in the general approach of the project: *i*. Develop solutions to overcome the challenges for the roll-out of automated transport systems in logistics; *ii*. Use a complete corridor to demonstrate solutions in five UCs, four of which are located at specific sites and the fifth being the corridor; and *iii*. Use the results of the two previous points (*i* and *ii*) to develop business models, assess impact and define recommendations for physical and digital infrastructure (PDI), and regulations/standards.

As such, specific business challenges have been identified, which have been divided in five different UCs in which these challenges are or may be present. By addressing these challenges in the five UCs, solutions for those challenges will be able to be developed (point *i*), and to be demonstrated (point *ii*). Moreover, the UCs consists of scenarios located in both public areas and confined areas, the latter to show the complete logistics business cases (related to point *iii*). Table 2 shows an overview of the UCs with their respective identified main foci.

Table 2: Main foci for each Use Case.

Use case	Main focus based on identified business challenges
Netherlands	Port operations: CCAM vehicles on port site
Germany	Transition from motorway to confined area: Approaching the harbour via a busy arterial road in the city

Sweden	Access control, loading/unloading, and charging
Norway	Port traffic, public roads and border crossing, including customs, between Sweden and Norway (from EU to non-EU country)
CCAM Test Corridor	Assessment of SAE L4 readiness, including identification of critical parts and PDI requirements, along the MODI corridor

The following sub-sections present a short overview of the main aspects of each UC, highlighting the foci and aims, and the partition into smaller sub-use cases (Sub-UCs). The description of the UCs is written with regards to what it is relevant for the description of the subsequent points from the FESTA-V diagram. For a further and more comprehensive information of the UCs, it is recommended to read the MODI project document D2.1[8].

Considering that the FESTA methodology focuses on the evaluation of any study on the impacts (see Section 3.3), the description of the UCs and Sub-UCs will focus on the description of the UC impacts concerning environment, safety, traffic (as part of operational activities) and socio-economics. The descriptions of the expected impacts of the UCs are at a general level and have been retrieved from internal documents of the project, as described by the UC leaders. It is to be noted that some impacts are presented as "not applicable" (N/A), as these are described as not applicable for the CCAM vehicles (without drivers). However, if tests using drivers arise within the project, the expected impacts might change accordingly. It is also important to note that these descriptions were developed at an early stage of the project, and they serve as a point of departure for the definition of the RQs and KPIs in the impact analyses.

3.2.1 UC Netherlands

Focus: The UC Netherlands focuses on the use of a mix of manual driven trucks and CCAM vehicles (i.e., L4-enabled truck) at a port terminal in Rotterdam, and a drayage via the public road to a nearby warehouse. The L4 truck will drive in automated mode among the normal operation of manual driven trucks, and thus the port terminal will operate as normally during testing. On the public road the L4 truck will drive in manual mode, with all sensing and communication active.

Aim: To have an L4-enabled truck that will follow the instructions from the MODI coordination system to drive in the complex terminal environment for the logistics operation of exchanging a container within the gate and exiting the gate to a warehouse via the public road.

Sub-use cases: The UC Netherlands will be divided into two Sub-UCs, i.e., Drayage (regular transport of containers over a short distance) and On-terminal automated driving. The Sub-UC Drayage aims to impact on the dissemination of the business potential of having automated operation on a public road, and the type of actions that can be taken to enable such service. This sub-UC will be executed with vehicles in which the steering and speed control are deactivated, and the L4 system is used for data gathering to assess the "readiness" of the driving environment for automated driving. The sub-UC APM Terminal focusses on automated driving at the port terminal, addressing the challenges of automated driving scenarios that are typical for a port terminal environment. The expected impact of the sub use cases is indicated in Table 3.

Table 3: Expected impacts of the Sub-UCs from UC Netherlands.

Sub-UC	Expected impacts	
1. Drayage	Environment	The driving is optimised for logistic operation and energy use. It will reduce emissions and idle time of the vehicles.
	Safety	N/A. Since the driving will be in manual mode this impact cannot be assessed.

[8] D2.1 Report on UC details (Sensitive).

	Traffic (incl. in operational activities)	N/A. Similar to the impact on safety, the driving will be in manual mode, making this impact not possible to assess.
	Socio-economy	The main target is to identify the business benefits of Drayage with CCAM vehicles
2. On-terminal automated driving	Environment	The driving of automated trucks on terminal can be more energy efficient.
	Safety	N/A. Truck drivers can rest while the truck is delivering and picking up a new container, contributing to safe operations avoiding tiredness among staff and reduce accidents and damages improving the safety of port terminal operations. Occurrence of safety incidents is rare; no significant data is expected for evaluation.
	Traffic (incl. in operational activities)	The driving on the terminal is aimed to avoid incidents or disruptions in the terminal operation. An unknown factor is how chauffeurs of manual operated trucks will respond to the driving style of the automated truck. These aspects could impact the productivity and efficiency of transport, operational costs, among other operational activities and traffic facets.
	Socio-economy	N/A. Truck drivers can rest while the truck is delivering and picking up a new container. This saves a significant share of driving time, leading to a cost reduction. Secondly, less incidents with damages can be expected, reducing disruptions in the terminal operation for logistic aspects. No significant data is expected for evaluation however.

3.2.2 UC Germany

Focus: The UC Germany focuses on the transition from a motorway to a confined area through industrial and urban areas of the Altona district in Hamburg. The route will cover driving in a dense urban environment with mixed traffic, industrial road sections within the port district as well as the German freeway.

Aim: The German use case will implement CCAM features targeted to improve the daily operations of logistic operators. The busy and highly frequented port roads will be testbed for efficiency improvement. For instance, a Green Light Optimal Speed Advisory (GLOSA) service can be deployed. The mixed traffic intersections of a city road will be used to demonstrate a VRU protection system. Those will support the driver or driving system of the truck in navigating busy roads.

Sub-use cases: The UC Germany will be divided into three sub-UCs, i.e., City traffic and VRU Protection, Port-road traffic optimisation, and Motorway & ODD transition. It is to be noticed that the name of these three Sub-UCs were updated from the names used in the Sub-UC templates.

Table 4: Expected impacts of the Sub-UCs from UC Germany.

Sub-UC	Expected impacts	
1. City traffic and VRU protection	Environment	Electrification and smoother driving style will contribute to lower emissions.
	Safety	Reduction in accidents from turning vehicles through better perception of other road users, incl. VRUs.
	Traffic (incl. in operational activities)	Allow more efficient turning of trucks through a more reliable situational awareness, positively supporting the operational activities.
	Socio-economy	Reduce driver workload and driving hours, implement VRUs and citizen feedback into development cycle to increase confidence in the interaction with automated systems on road

2. Port-road traffic optimisation	Environment	Less variations in the travelling speed, reduce the necessary energy usually wasted in stop and go traffic.
	Safety	Driver and driving assist system get precise information on upcoming traffic light changes. A decrease in light violations and decrease in casualties connected with the relation traffic lights and port-road users might be achievable
	Traffic (incl. in operational activities)	Reduce overall queuing through precise routing and speed advisory (affecting travel time, speed and delays), and thus promoting a more efficient port-road traffic system.
	Socio-economy	Reduce driver workload and driving hours
3. Motorway & ODD transition	Environment	Electrification and smoother driving style will contribute to lower emissions.
	Safety	Focus the drivers' attention on the most demanding task. ODD-info (e.g. speed, lanes, regulation) is automatically applied to ADAS, supporting the drivers and increasing motorway safety.
	Traffic (incl. in operational activities)	Allow for smooth transitions between different driving settings and types of roads, increasing efficiency of transport.
	Socio-economy	Reduce driver workload and driving hours.

3.2.3 UC Sweden

Focus: The UC Sweden will focus on the demonstration of the automation of transport of freight from a logistics centre to the port of Gothenburg.

Aim: This UC will demonstrate the full chain's automation, including loading and unloading, charging, access control, driving on, off and along public roads.

Sub-use cases: The UC Sweden will be divided into four sub-UCs, i.e.:

1. Gate access; dealing with the access to a confined area through access services including request, confirmation and passing based on proper document handling.
2. Charging; dealing with planned automated electric charging in standard operations.
3. Automated loading and unloading; focusing on testing one solution for automated loading and unloading at a cargo bay.
4. Driving on public roads; focusing on driving on public road at a maximum speed of 30 km/h, most probably in the Gothenburg region.

Table 5: Expected impacts of the Sub-UCs from UC Sweden.

Sub-UC	Expected impacts	
1. Gate access	Environment	N/A.
	Safety	A fenced area (private area) will keep unauthorised people out.
	Traffic (incl. in operational activities)	CCAM vehicles can reduce operational costs and increase efficiency of transport at the site.
	Socio-economy	Efficiency from a logistics perspective and thus valuable to create a sustainable business model for automated transport.
2. Automated charging	Environment	Implementing automated charging may contribute to increased use of electrical vehicles.
	Safety	Implementing automated charging in an automated logistic chain can eliminate the need of humans on site, which could be beneficial from a safety perspective.

	Traffic (incl. in operational activities)	N/A.
	Socio-economy	The automated charging could be beneficial for a business case in which there is no need for human operators.
3. Automated loading and unloading	Environment	N/A.
	Safety	Implementing automated loading/unloading in an automated logistic chain can eliminate the need of humans on site, which could be beneficial from a safety perspective.
	Traffic (incl. in operational activities)	N/A.
	Socio-economy	The automated loading/unloading could be beneficial for a business case in which there is no need for human operators.
4. Driving on public roads	Environment	CCAM vehicles usually drive smoother than humans thus potentially using less energy and/or fuel.
	Safety	CCAM vehicles will obey all traffic rules, thus increasing traffic safety and traffic flow.
	Traffic	CCAM vehicles will use public road services for improved planning, scheduling, routing and logistics operations and thus reducing congestion, waiting times etc. This will positively support the productivity and efficiency of transport.
	Socio-economy	Reduced waiting times, improved just-in-time operation for the benefit of the road operator and the logistic operator.

3.2.4 UC Norway

Focus: The UC Norway will focus on driving automated on public roads at the E6 motorway near Svinesund, crossing the border from Sweden to Norway, including demonstrating a customs control, and investigating connections to the Port of Moss.

Aim: This UC will investigate and demonstrate CCAM functionalities for port/terminal operations and public road driving including cross-border and customs. This will include the identification and implementation of PDI infrastructure needed for CCAM functionalities and a seamless integration of automated elements of the transport chain.

Sub-use cases: The UC Norway will be divided into four sub-UCs, i.e.

1. Border crossing; focusing on driving from Sweden on E6 to Norway crossing the Svinesund bridge without stopping. This includes switching between different Real Time Kinematic (RTK) correction (localisation)/connectivity providers, and getting permits in two countries.
2. Customs; focusing on passing through customs control using an automated vehicle while following the customs regulations proper to each country. This will include identification of future needs and gaps of customs declaration for vehicles with remote operators, including legal aspects, technology (such as C-ITS solutions), digital data flow (such as extension of the digitoll concept) and human machine interaction (Einride remote operator solution).
3. Motorway; driving with automated vehicle on E6 highway in mixed traffic. Focus on building a strong safety case and PDI implementation.
4. Port; focusing on automated solutions for a seamless automated transport chain such as automated gate at port to access the port area, automated vehicle to drive in the port area, sea drones to transport good over the fjord, and automated terminal tractors to move goods on the port area.

Table 6: Expected impacts of the Sub-UCs from UC Norway.

Sub-UC	Expected impacts	
1. Border crossing, and 3. Motorway	Environment	Smoother driving style and electrification of vehicles produce less pollution. If data can be shared and used to produce/update HD-maps and point clouds these will be produced at lower cost and benefit the environment.
	Safety	Increased traffic safety by enforcing speed limits and reducing the risk of fatigue among drivers. Reduce safety issues when interacting with other road users.
	Traffic (incl. in operational activities)	More efficient transportation overall as rest time regulations are unnecessary which reduce delivery time. More frequently updated HD maps and point clouds will lead to more efficient traffic.
	Socio-economy	New jobs opportunities in industry if jobs are more office related and less time in-vehicle, possible increased share of female employees in transport sector. Reducing problem of driver shortage.
2. Customs	Environment	Automated logistics on public roads/motorway driving through customs supposes a more efficient use of time. This can translate in less vehicles queue and driving time, thus positively impacting the environment.
	Safety	N/A.
	Traffic (incl. in operational activities)	More efficient customs process could have an impact on traffic efficiency through less waiting times.
	Socio-economy	An efficient handling at the customs is key to be able to create an efficient logistics chain. Using automated vehicles can deliver a reliable and cost-efficient solution in operation, at a regional, national, and international level. More predictable logistic services.
4. Port	Environment	Less driving through the Oslo city centre and using automated and zero emission transport chains will positively impact the environment.
	Safety	Fewer accidents in the port area (loading/unloading as risk for worker, which then is eliminated).
	Traffic (incl. in operational activities)	N/A
	Socio-economy	More efficient operations (around the clock operations possible due to reduction in noise, less restrictions on working hours). Less noise in the urban port area (due to electric vehicles/operations).

3.2.5 UC CCAM Test corridor

Focus: The UC CCAM Test corridor will focus on understanding and overcoming the regulatory barriers and PDI shortcomings on this specific motorway corridor with all road authorities, logistic operators and original equipment manufacturers (OEMs) of this project involved.

Aim: By covering the entire distance from Rotterdam to Oslo, this UC will identify challenges and barriers from an OEM, logistics operator and road authorities' perspective, identify critical parts of the physical and digital infrastructure (PDI), validate those critical parts, and assess PDI adaptation needs in preparation for automated driving at SAE Level 4.

Sub-use cases: The UC CCAM Test corridor will not be divided into sub-UCs at the initial stage of the project, but the focus areas - in terms of data collection and analysis - will be worked out at a later stage.

Table 7:Expected impacts of the Sub-UCs from UC CCAM Test corridor.

Expected impacts	
Environment	Electrification, more efficient logistic operations. Smoother driving style and general electrification of vehicles produce less pollution.
Safety	Increased traffic safety by enforcing speed limits.
Traffic (incl. in operational activities)	Driver shortage reduced/solved, more efficient logistic operations and more efficient traffic. More efficient transportation overall as rest time regulations are unnecessary which reduce delivery time. More frequently updated HD maps and point clouds will lead to more efficient traffic.
Socio-economy	Give input to necessary PDI implementation to realise SAE Level 4 driving and its cost benefit calculations. Mitigate problem of driver shortage, while making jobs in transport sector more attractive to women. By having less time in-vehicles, and more time in office, new jobs opportunities can arise.

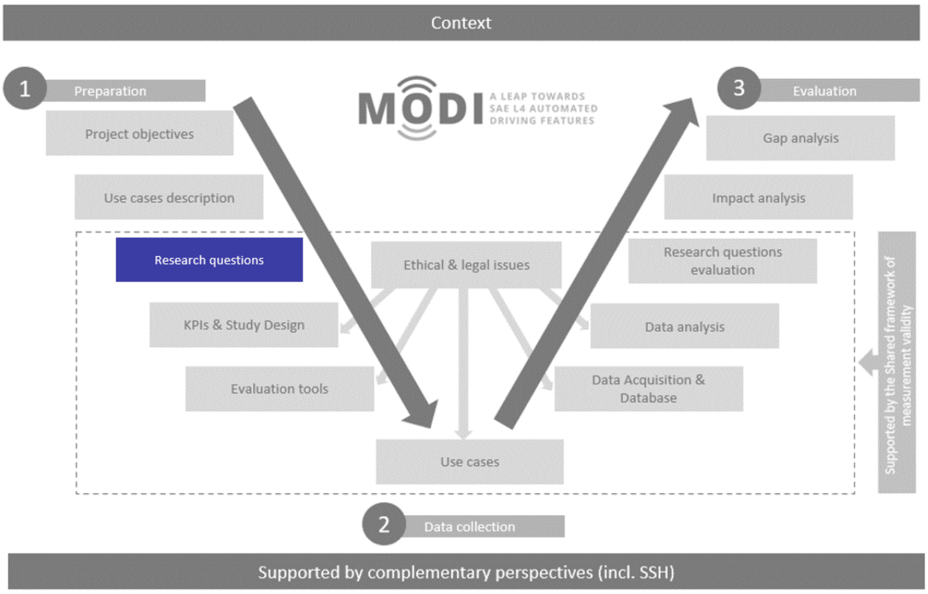
3.2.6 Matrix of the UCs and their impacts

Following the FESTA methodology, in which the subsequent step is to define the research questions based on the evaluation of the impacts, a summary of the impacts (divided in the four aforementioned areas, i.e., Environment, Safety, Traffic and Socio-economy) for each UC with their respective sub-UCs is presented in Table 8. Note that the lack of light blue colour denotes that such impact area is not applicable to the determined sub-UC.

Table 8: Matrix of impact areas for each UC and Sub-UC.

UC	**Sub-UC**	**Environment**	**Safety**	**Traffic (incl. in op. activities)**	**Socio-economy**
UC NL	Drayage				
	On-terminal aut. dr.				
UC GE	City traffic & VRU prot.				
	Port-road traffic optim.				
	Motorway & ODD				
UC SE	Gate access				
	Charging				
	A. loading/unloading				
	Driving on public roads				
UC NO	Border crossing				
	Customs				
	Motorway				
	Port				
UC CCAM					

3.3 Research Questions



In general lines, the goal of any FOT (or N-FOT) is to evaluate the different impacts that the technologies tested in the study have on real scenarios. As the FESTA methodology states, the research question should then focus on impacts, and can only be established once the project objectives are defined, as they have been described in this document.

As stated in Section 3.1 and Table 1, the MODI project is particularly focused on four main impacts: environment (in regard to sustainability), operational activities (including traffic), socio-economy, and safety. In addition, other research questions can also be added depending on the objectives of the project, as suggested by FESTA. Gap analyses for technological readiness and societal readiness are also crucial to the project, to assess the barriers for L4 logistics, so this will also be included as part of the project's research questions.

The gap analysis consists of technological readiness and societal readiness. The inclusion of these two aspects as evaluation points (in addition to the impact areas) address the project objectives directly. Whereas the impact analyses address O4, the gap analysis of the technological readiness is strongly related to O1 (technical improvements), and moderately related to O2 (Infrastructure). The societal readiness is strongly related to O2 (Infrastructure) and O3 (Business models).

Based on the four areas of impacts, two aspects of readiness, and the MODI project objectives, two different levels of research questions (RQs) are developed to better fit the impact areas to be studied within the project. These two levels also allow to differentiate common research questions that can serve to all or most of the UCs (general RQs) from the specific research questions proper to each UC (UC-specific RQs). By using this approach, it becomes easier to have the contextual factor from the FESTA methodology as a background for the project, in which the answers to the general RQs might be related to a wider perspective. Likewise, the answers to the UC-specific RQs could be related to specific context scenarios, as recommended by the shared framework of measurement validity (see Section 2.3.2).

It is worth mentioning that at the time this document was developed, the generation of the RQs was based on the information delivered by each UC leader in internal project documents and in D2.1 UC definition, of which some parts are presented in the description of the UCs and sub-UCs in the sections above. The descriptions of the impacts for each sub-UC were thus used as a guide for a first phase of generation of general stage RQs and stage 2 UC-specific RQs, with an aim to meet the objectives of the MODI project at large. Considering that this document has been developed at an early stage of the project, the RQs may vary and a stage three where more detailed RQs are developed may be necessary. Indeed, generating and prioritising RQs is an iterative and collaborative activity, which requires revision at different stages of the project and by different partners and stakeholders involved.

In the line of the Measurement validity framework, the two levels of RQs are applied as follows: General RQs are described from a stage 1 (described as general background concepts), and UC-specific RQs are described from a stage 2 (using systematised concepts). The stage 1 general research questions were hence selected as follow:

RQ1-E | Environment:

- How does the use of CCAM vehicles affect environmental impact of logistics/freight transport?

RQ1-S | Safety:

- RQ1-S01: What is the system-wide impact of the use of CCAM vehicles for logistics on road safety?
- RQ1-S02: What is the system-wide impact of the use of CCAM vehicles for logistics on occupational safety?

RQ1-T | Operational activities (included Traffic):

- RQ1-T01: What is the impact of the use of CCAM vehicles for logistics on productivity?
- RQ1-T02: What is the impact of the use of CCAM vehicles for logistics on traffic efficiency?

RQ1-SE | Socio-Economy:

- What are the quantifiable socio-economic impacts of the use of CCAM vehicles for logistics from the project?

RQ1-TR | Technological readiness:

- What is needed to bridge the gap between the current technology for CCAM vehicles and the desired technology for the same vehicles for their fully implementation in freight transport?

RQ1-SR | Societal readiness:

- What are the key changes in society needed to accelerate the adoption and the societal acceptance of CCAM vehicles for logistics by users/stakeholders, businesses, and authorities?

Following the shared framework for measurement validity, the definition of the stage two RQs will be described using systematised concepts, i.e., explicit definitions of concepts to be used as common understanding among the project group. To this end, the formulations of the impact concepts are based on the information provided in the project description and are indicated in the subsequent sub-sections.

3.3.1 Research questions for impact on environment

The systematised definition for this concept follows the dictionary definition stated as: "Environment - *the natural world, as a whole or in a particular geographical area, especially as affected by human activity*". The focus on environment will thus be on the impacts that zero-emission CCAM vehicles have on streamlining freight transport and traffic and thereby reduce energy use and emissions at the vehicle level. Such effects may arise from e.g., increasing the share of zero-emission electric vehicles (with SAE L3 and/or L4 technology) compared to the 2019 baseline level, avoiding driving during rush periods, eco-driving and platooning. In particular, this area focuses on the effects of the full life cycle of the CCAM vehicles as well as the necessary physical infrastructure, and what effect these might have on the energy use and greenhouse gases (GHG). Other environmental impacts such as local air quality, e.g. related to carbon emissions (CO_2) and harmful emissions (NO_x and particulates), will also be evaluated. To be able to quantify such impacts, life cycle assessments (LCAs) will be performed to identify direct and indirect environmental impacts. Here, the direct environmental impacts refer to the life cycle impacts of the vehicles themselves, as well as the necessary support infrastructure required to achieve L4 CCAM automation. Indirect impacts refer to the environmental impact or benefits arising from the systemic, widespread implementation of CCAM in logistics, namely traffic effects, e.g., traffic flow, congestion, and increased vehicle utilisation through shared mobility solutions. Such indirect, or transport system level effects, require assumptions surrounding the uptake of CCAM vehicles, such as the market penetration rates and the effect of CCAM vehicles on surrounding vehicles.

Table 9 presents the stage 2 research questions dedicated to the evaluation of the environmental impact of the CCAM vehicles.

Table 9: Research Questions for the evaluation of Environmental impact.

RQ-ID	Stage 2 Research questions	UC(s) involved
RQ2-E1	What are the direct life cycle impacts of using CCAM vehicles in logistics?	All
RQ2-E2	What are the key processes contributing to increases or decreases in the life cycle impacts of using CCAM vehicles in logistics compared to similar, non-CCAM vehicles?	All
RQ2-E3	What are the potential environmental impacts of using CCAM vehicles in logistics at the transport system level?	All

3.3.2 Research questions for impact on safety

According to Fraade-Blanar et al [22], road safety can be affected at and by different compositional levels within the automated vehicles. Ranging from micro to macro level, these are subcomponents and components of CCAM vehicles (e.g., lens, cameras, radar), their subsystems (e.g., for perception and planning), system components (i.e., passengers, vehicles, safety operators and environment) and the whole ecosystem (i.e., road-based transportation system). For safety evaluation in MODI, the macro-level system's components (i.e., system and eco-system) are relevant.

There are two types of safety considered in MODI – 1) road safety and 2) occupational safety. Road safety refers to the methods and measures applied to prevent road users from being killed or injured on public roads, while occupational safety concerns with the safety, health and welfare of people at work (in confined areas). In the context of MODI, the road safety could be also considered as work-related, because it is associated with e.g., work-related driving of CCAM vehicles and road construction workers exposed to traffic situations. However, on public roads, only other road users will be those affected by potential accidents with CCAM vehicles (as these vehicles will be driverless), while in confined areas only workers are affected. Therefore, in MODI, we define *road safety* as safety on public roads, while *occupational safety* as any safety incidents (including accidents between CCAM vehicles and other vehicles) occurring in confined areas.

Table 10 presents the stage 2 research questions dedicated to assessing how the implementation of CCAM vehicles for logistics impact on human safety.

Table 10: Research Questions for the evaluation of safety.

RQ-ID	Stage 2 Research questions	UC(s) involved
RQ2-S1	What is the impact of the use of CCAM vehicles for logistics on occupational safety at a confined area?	UC Germany UC Sweden
RQ2-S2	What is the impact of the use of CCAM vehicles for logistics on road safety at public roads in urban areas?	UC Germany UC Sweden
RQ2-S3	What is the impact of the use of CCAM vehicles for logistics on road safety at public roads (both secondary roads and motorways) in rural areas?	UC Norway UC Sweden

RQ2-S4	What are the safety challenges related to remote operation/surveillance of CCAM vehicles?	UC Norway, UC Sweden

3.3.3 Research questions for impact on operational activities (traffic)

Operational activities (or "traffic"), can include a wide array of topics, like fleet management, driving time, customer service, route planning and optimisation, loading and unloading, inventory management, documentation, and processing, etc. The use cases in MODI will touch upon a range of these, or related, activities. The evaluation of the operational activities relies on the UCs and their data collection, as well as information from the logistics companies regarding how the current practices and vehicles perform. The focus in the operational activities part is on costs and productivity, and we will concentrate our work around quantifiable effects. Hence, the following research questions will be grouped into "traffic" (T) and "operational costs" (OC). Table 11 shows the stage 2 research questions selected to evaluate how the implementation of CCAM vehicles can impact on traffic.

As described under safety, each use case contains different traffic and infrastructure characteristics with unique challenges. Therefore, the methodology of research analysis will be different for each use case. Each use case will be treated as individual, unique N-FOT. More detailed descriptions of the data collection will come when the details of the various UC/sub-UC are finalised.

Table 11: Research Questions for the evaluation of operational activities (traffic).

RQ-ID	Stage 2 Research questions	UC(s) involved
RQ2-T1	OC: What is the impact of the use of CCAM vehicles for logistics on vehicle operating costs? (Overall, public, confined)	All
RQ2-T2	OC: What is the impact of the use of CCAM vehicles for logistics on the cost of transporting a tonne of goods? (Overall, public, confined)	All
RQ2-T3	T: What is the impact of the use of CCAM vehicles for logistics on travel time/speed? (Overall, public, confined)	All
RQ2-T4	T: What is the impact of the use of CCAM vehicles for logistics on amount of travel? (Overall, public, confined)	All
RQ2-T5	T: What is the impact of the use of CCAM vehicles for logistics on number of vehicles/transports needed? (Overall, public, confined)	All

3.3.4 Research questions for socio-economic impact

The socio-economic impact is a compilation of the effects one manages to identify in the UCs. The socio-economic analysis, also referred to as the cost benefit analysis, in the MODI project includes the impact of the UCs on society, like changes in emissions, operational costs, safety impacts and implementation costs (e.g. investments in and maintenance of physical and digital infrastructure). The impacts are thus collected from the UCs (project tasks 2.5.1, 2.5.2 and 2.5.3), and if needed, supplemented with information from relevant sources like the LEVITATE[9] project.

Considering that the impacts are collected from the UCs, the viability of the UCs is a particular study of interest, as an evaluation of the additional costs for CCAM solutions will be compared to the potential cost savings after the solutions are implemented. This will provide a clearer picture of the economic effects of the CCAM vehicles, yielding information for the evaluation on whether the business models that are profitable (related to project objective O3, see Section 3.1).

Table 12 shows the stage 2 research questions selected to evaluate the socio-economic impact of the implementation of CCAM vehicles.

[9] https://levitate-project.eu/

Table 12: Research Questions for the evaluation of socio-economic impact.

RQ-ID	Stage 2 Research questions	UC(s) involved
RQ2-SE1	What are the implementation costs for PDI of CCAM vehicles for logistics in the various UCs?	All
RQ2-SE2	What is the quantifiable socio-economic effect of having CCAM vehicles for logistics compared to manual logistic vehicles in the various UCs?	All

3.3.5 Research questions for technological readiness

MODI aims to demonstrate the CCAM systems in their operational environment, i.e., Technology Readiness Level (TRL) 7 at the end of the project. This entails different developments, improvements, and integration of various systems as identified in the work of the relevant technology-related tasks and deliverables in the MODI project. The developments consist partly of developing new vehicles, and partly on placing additional hardware (e.g., sensors) on existing electric vehicles (EVs) to be able to prepare them for a higher speed than currently available, and most importantly, to prove that the tested CCAM systems are safe and valuable. Thus, the systematised concept for technological readiness is related to the description and specifications of the technical CCAM systems needed for L4 driving. Functionality and aspects which are required but not directly related to the L4 technology, will be included as appropriate. It is important to remember that technological readiness within MODI, will not be addressed as an impact, but as part of a gap analysis at the end of the project. As such, the analyses on technological readiness will be focused on the identification of the current maturity state of the CCAM technological systems, the identification of where the status should be in order to provide market-ready solutions and systems, and on suggestions to close potential gaps encountered. Table 13 shows the stage 2 research questions selected in the MODI project to evaluate the technological readiness. Both the current and required state of technology will be assessed during and at the end of the project. Combining information about the current level of development and where the status should be in order for L4 driving to represent a relevant and viable alternative for the logistics industry, will provide insight into the components of the technology-related gaps, how these gaps evolve during the course of the project, and what it will take to close these gaps. Specific KPIs for the individual components of the technology readiness gap have not yet been defined but will be identified during the course of the project, based on input from the MODI UCs, other MODI WPs, MODI project partners and other relevant stakeholders.

Table 13: Research Questions for the evaluation of technological readiness.

RQ-ID	Stage 2 Research question	UC(s) and partners involved
RQ2-TR1	What is the current state of technology for CCAM for logistics?	All
RQ2-TR2	Where should the status be to provide market-ready solutions and systems for CCAM for logistics?	All
RQ2-TR3	What are the technological gaps for CCAM vehicles and required solutions to be fully implemented in freight transport, and how can they be closed?	All

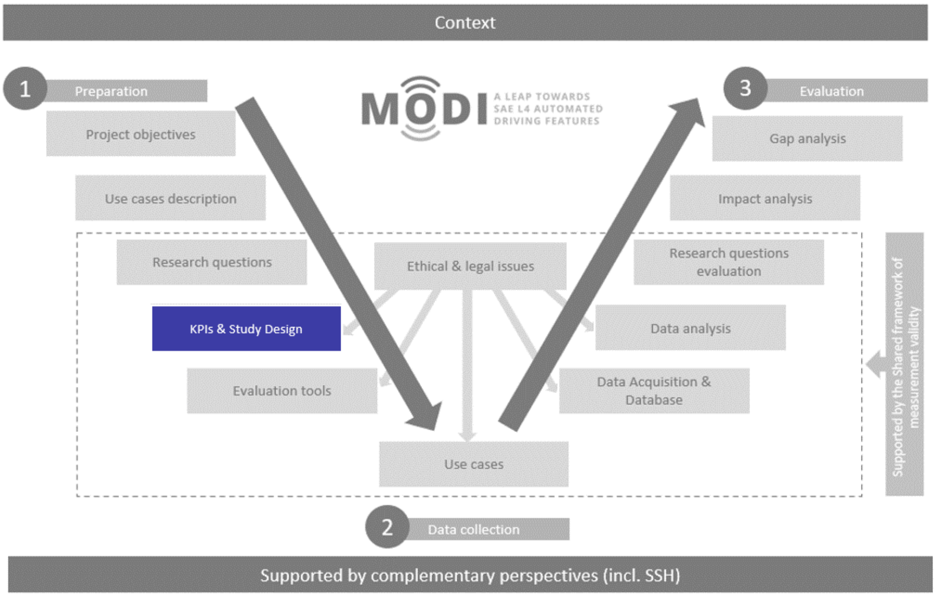
3.3.6 Research questions for societal readiness

The systematised concept for societal readiness is based on the assessment of the level of societal adaptation of the particular technologies and solutions demonstrated within the project. It focuses on analysing whether such tested and demonstrated solutions can be integrated into society, and if not, what are the missing links for them to be integrated. The study of societal readiness as part of the gap analyses will focus on the readiness of three specific target groups: users/stakeholders, businesses, and authorities, and cover topics related to e.g., acceptance, regulatory readiness, organisational and commercial issues and market readiness. As for the technological readiness, the analyses on societal readiness will be focused on the identification of the current maturity state of the societal readiness, the identification of where the status should be in order to be able to adopt and operate solutions and systems for L4 driving, and on suggestions to close potential gaps encountered. Table 14 shows the stage 2 research questions selected in the MODI project for the evaluation of societal readiness. Both the current and required state of societal readiness will be assessed during and at the end of the project. Combining information about the current level of development and where the maturity status should be in order for the relevant sectors and aspects of the society to be ready for allowing and facilitating L4 driving to represent a relevant and viable alternative for the logistics industry, will provide insight into the components of the societal gaps, how these gaps evolve during the course of the project, and what it will take to close these gaps. Specific KPIs for the individual components of the societal readiness gap have not yet been defined but will be identified during the course of the project, based on input from the MODI UCs, other MODI WPs, MODI project partners and other relevant stakeholders.

Table 14: Research Questions for the evaluation of societal readiness.

RQ-ID	Stage 2 Research question	UC(s) and partners involved
RQ2-SR1	What is the current state of societal readiness for CCAM for logistics?	All
RQ2-SR2	Where should the status of societal readiness be to enable market-ready and desirable solutions and systems for CCAM vehicles for logistics?	All
RQ2-SR3	What are the main societal gaps to be closed in order to accelerate the uptake and acceptance of CCAM vehicles for logistics, and how can these gaps be closed?	All

3.4 Key performance indicators (KPIs)



3.4.1 Overall approach for the definition of the KPIs

As stated in the FESTA Handbook, all the KPIs are based on measures (i.e., the way in which the data of a particular KPI will be collected). There are four different types of measures often used in FOTs (or N-FOTs), i.e., direct measures, indirect measures, self-reported measures, and situational variables. The description of these different types of measures can be found at the FESTA Handbook [1].

Considering the early stage of the MODI project in which details of the UCs are still not well defined, the KPIs for each impact area are listed in the following sub-sections presenting only a limited set of description points. This means that further information regarding the KPIs will be expanded throughout the development of the project. For example, when the descriptions of the sub-use cases are finished, KPIs on sub-use case level will be established. For now, the current document presents the suggested KPIs divided by impact area, providing a brief description of them, their unit, the needed measure(s), whether the data is quantitative or qualitative, and their relation to each listed RQ. For better identification and reference of the KPIs, these are identified with proper codes.

3.4.2 Suggested indicators for Environment

Indicators and measures

The environment KPIs are calculated from life cycle assessment (LCA), which requires input regarding the physical and energy inputs and outputs for the automated vehicle and associated infrastructure. This input is preferentially provided by project partners (UCs), supplemented by literature values or assumptions as required to fill data gaps. Standard commercially available life cycle databases will also be used to supplement the analysis.

The material and energy inputs and outputs associated with the vehicles refer to all life cycle phases of the CCAM vehicles; manufacturing, operation, and end-of-life. For manufacturing, a bill of materials and technical specification of the equipment or components on board the vehicle would be an example of the required data. Examples of required operational data includes energy efficiency (kWh/vkm driven or kWh per use case driven) and time and location of charging. As a benchmark to measure the effects of CCAM vehicles on total environmental effects, it is suggested that the same data are provided for the equivalent non-automated vehicle (battery electric, operating in the same corridors). Here, greenhouse gas emissions and energy intensity are used as a proxy to represent environmental impacts, however, due to the method used in the environmental impact analysis, additional categories, such as toxicity and terrestrial acidification, can also be easily calculated.

Table 15: Suggested KPIs for environmental impact.

KPI ID	Name/Description	Unit	Needed measures	Quan/ Qual	Related RQ-ID
KPI-E01	Carbon intensity of freight transport using CCAM vehicles, operation phase (per tkm)	kg CO_2-eq/tkm	Measured travel time, load factor and distance travelled Derived vehicle lifetime Measured energy use for the automated vehicle	Quan	RQ2-E1, RQ2-E2, RQ2-E3
KPI-E02	Energy intensity of freight transport using CCAM vehicles, operation phase (per tkm)	kWh/tkm	Measured travel time, load factor and distance Measured or derived vehicle lifetime Measured energy use for the automated vehicle	Quan	RQ2-E1
KPI-E03	Carbon intensity of freight transport using CCAM vehicles, manufacturing phase	kg CO_2-eq/tkm	Derived lifecycle material and energy input for production of CCAM vehicles Measured or derived vehicle lifetime	Quan	RQ2-E2, RQ2-E3

KPI-E04	Carbon intensity of freight transport using CCAM vehicles from supporting infrastructure	kg CO_2-eq/tkm	Derived lifecycle material and energy input for manufacture and operation of supporting infrastructure	Quan	RQ2-E2, RQ2-E3

Ethical and legal aspects

No legal issues are foreseen with the data collection related to environmental KPIs; however, it is important to notice that not all data may be available due to Intellectual Property Rights (IPR).

3.4.3 Suggested indicators for Safety

Indicators and measures

The suggested indicators for safety present a mixture of qualitative and quantitative indicators. The required measures present a mixture of direct, derived and self-reported measures. They will be collected by various methods, such as interviews and external video observations or by utilising data collected by CCAM vehicles. When suggesting the safety indicators, the relevant parts of Deliverable D1.2 (Safety and security requirements) were considered as well. Regarding traffic safety, D1.2. deals with road traffic safety (related to risk of traffic accidents), cybersecurity and criminality. Traffic accidents, particularly, represent an obvious safety indicator. However, traffic accidents are very rare and the lack of them do not entail that a specific situation can be considered safe. As such these are deemed not suitable as safety indicator for the MODI UCs. Therefore, crash related events are considered a more appropriate KPI to act as surrogated to accidents, see Table 16 below.

Table 16: Suggested KPIs for impact on safety.

KPI ID	Name/Description	Unit	Needed measures	Quan/ Qual	Related RQ-ID
KPI-S01	Incidents and accidents between CCAM vehicles and other users of confined areas Single incidents and accidents of CCAM vehicles	Types of incidents and accidents per exposure measure	Types and severities of incidents and accidents Measure(s) of exposure (such as hours of operation, traffic load, type pf traffic, etc.)	Quan	RQ2-S1
KPI-S02	Behaviour of users of confined areas in encounters with CCAM vehicles	Perceived Safety Scale Types of encounters with CCAM vehicles	Experience and perception of users about their encounters with CCAM vehicles	Quan + Qual	RQ2-S1
KPI-S03	Incidents and events between CCAM vehicles and other road users of public roads, including VRUs Single incidents and accidents of CCAM	Types of accidents and incidents (separately for urban roads, secondary rural roads and motorways) per an exposure measure	Incident and accident types and severities Measure(s) of exposure (such as hours of operation,	Quan l	RQ2-S2, RQ2-S3,

	vehicles on public roads		traffic load, type of traffic, etc.)		
KPI-S04	Behavioural adaptation of public road users in encounters with CCAM vehicles	Types of behaviour (separately for urban roads, secondary rural roads and motorway)	Observed behaviour	Qual	RQ2-S2, RQ2-S3,
KPI-S05	Challenges of remote operators of CCAM vehicles to solve the edge cases	Types and descriptions of challenges	Self-reported challenges	Qual	RQ2-S4
KPI-S06	Safety issues of CCAM vehicles related to infrastructure (e.g. traffic signals or ITS along the motorway)	Types of safety issues	Description of safety issues	Qual	RQ2-S2, RQ2-S3,

Ethical and legal aspects

As most of the KPIs will be derived from interviews and video observations, the following legal and ethical aspects must be considered:

- Consent of the participants of interviews (incl. information about their rights, voluntary participation, right to withdraw at any time).
- For video observations we consider using a portable, camera-based traffic data collection device Miovision Scout that can be temporarily attached to a fix object (e.g., a light pole; a traffic sign; a tree) in the proximity of the observed area. The camera provides a 120° horizontal view and records in a resolution of 720 x 480. Such low resolution does not allow to recognise sensitive personal details (e.g., gender or licence plate) and therefore a permission to record in public spaces and confined areas is not needed. This however should be confirmed prior to carrying out the video observations.
- On the other side, if cameras with higher resolutions are used, such permission will be needed. Likewise, in the event in which it is necessary to observe either the driver or remote operator of the vehicles, pertinent permissions will be collected.
- For interviews we do not consider collecting personal data (i.e., age, gender) therefore there is no need to register the data collections to any ethical data boards.

3.4.4 Suggested indicators for Operational activities (Traffic)

Indicators and measures

The KPIs are calculated based on input from partners and checked in the literature. Some of the KPIs include some elements of direct measures, as amount of driving and travel time, however, most involve either derived measures or self-reported measures like interviews with the demonstrators to get additional UC-specific information.

Table 17: Suggested KPIs for impact on operational activities (traffic).

KPI ID	Name/Description	Unit	Needed measure	Quan/ Qual	Related RQ-ID
KPI-T01	Current costs of manual vehicles and costs on the demonstration vehicle	Cost per tonne per km	Self-reported and derived	Quan	RQ2-T1
KPI-T02	Current costs and costs of delivering of goods	Cost per tonne per km	Self-reported and derived	Quan	RQ2-T2
KPI-T03	Travel time and speed for manual vehicle and demonstration vehicle	Travel time and speed Delays Congestion	Direct, self-reported and derived	Quan	RQ2-T3
KPI-T04	Amount of travel to deliver a certain amount of goods/tonnes	Km driven / tonnes per vehicle	Direct, self-reported and derived	Quan	RQ2-T4
KPI-T05	Number of vehicles/transports needed	Number of transports	Direct, self-reported and derived	Quan	RQ2-T5

Ethical and legal aspects

Most of the KPIs will stem from UCs and project partners, so the main legal aspects are how to handle confidential and competition sensitive information. The sensitive KPIs will not be reported on, just used in the overall analyses. Furthermore, the information provided will not be possible to calculate based on the published results, and we also consider using approximations or rounded input data to further conceal the data.

3.4.5 Suggested indicators for socio-economic impact

Indicators and measures

While some of the KPIs are calculated based on input from partners and literature reviews, the result of the socio-economic analysis/CBA is a calculation based on the outputs in the other sub-tasks in the task impact assessment, as well as the other KPI in the sub-task.

Table 18: Suggested KPIs for socio-economic impact.

KPI ID	Name/Description	Unit	Needed measure	Quan/ Qual	Related RQ-ID
KPI-SE01	Investment costs related to CCAM PDI	Euros (e.g., per UC)	Self-reported and derived	Quan	RQ2-SE1
KPI-SE02	Operational costs related to CCAM PDI	Euros (e.g., per UC)	Self-reported and derived	Quan	RQ2-SE1

KPI-SE03	Quantifiable socio-economic effect of having CCAM vehicles for logistics, compared to manual logistic vehicles in the various UCs	Euros (will be showed for the various UCs, but likely also more detailed per UC like monetised environmental effect, monetised safety effect, etc.)	Self-reported and derived	Quan	RQ2-SE2

Ethical and legal aspects

Similar to the ethical and legal aspects related to the KPIs for Operational activities (traffic), most of the KPIs will stem from the UCs, project partners or other sub-tasks. This means that, as for the operational activity (traffic), the main legal aspects are how to handle confidential and competition sensitive information. Thus, a similar strategy than the one adopted for the operational activities will be used, i.e., KPIs used in overall analyses and/or use of approximations or rounded input data.

3.4.6 Summary of the KPIs in relation to their RQs

To aid readability, this subsection offers graphical representations of the relation between the KPIs and the RQs in both stages (i.e., 1 and 2) and for each impact area. Please note that due to space restrictions, some names of the KPIs and/or RQs are shortened.

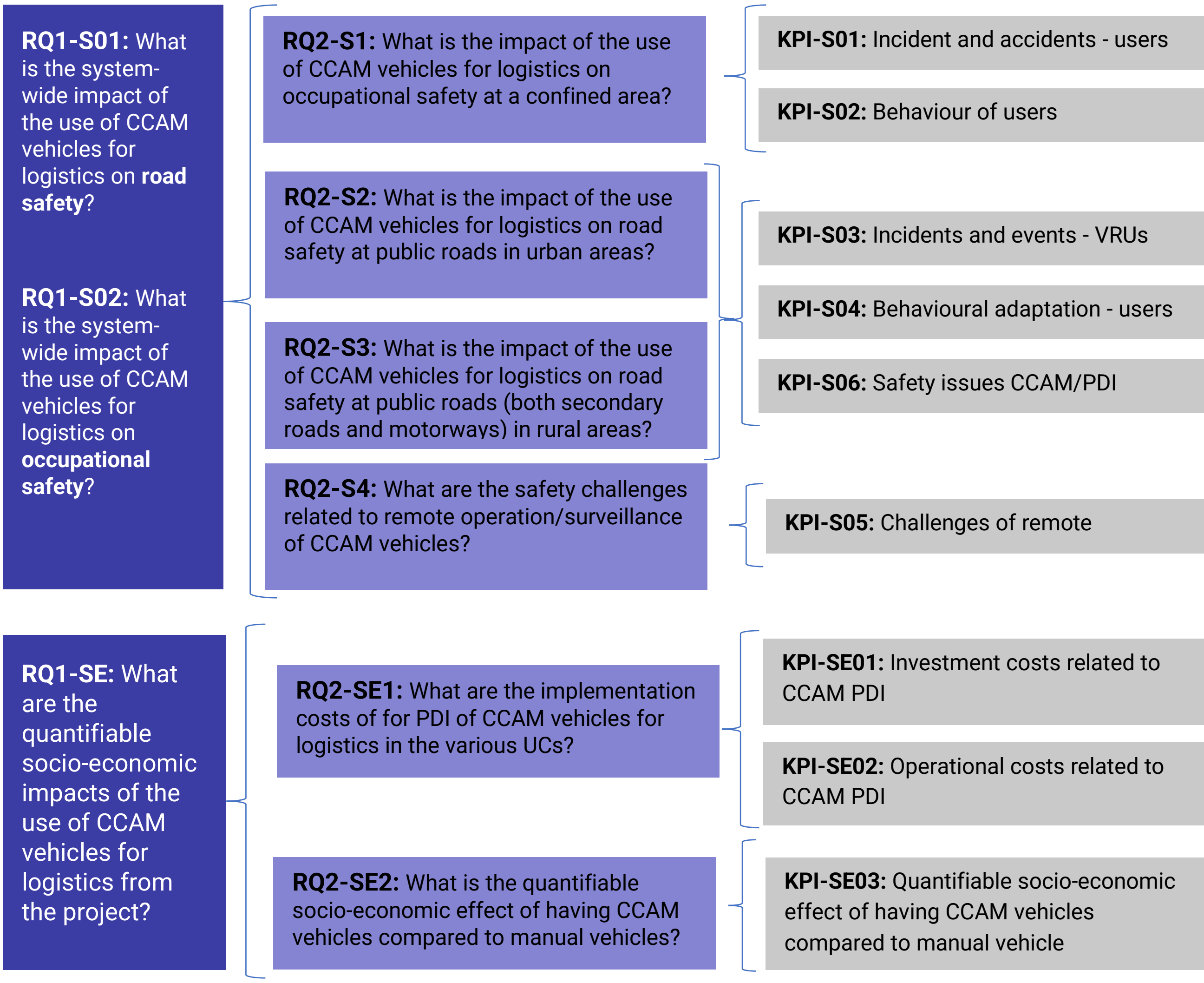
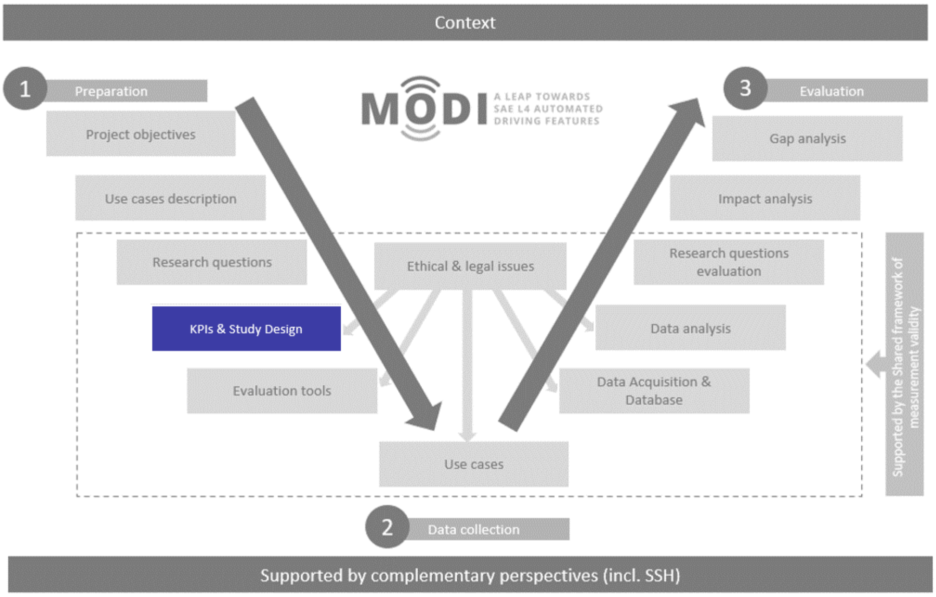


Figure 7: Relation between the RQs and KPIs for the safety and socio-economic impacts.

Figure 8: Relation between the RQs and KPIs for the impact on environment and operational activities (traffic).

3.5 Study design



The study design of an FOT, as stated in the FESTA Handbook, is strongly linked to the description of a study with an experimental focus. This implies following a common standard form, in which, e.g., materials, participants, procedures and measures are important general topics to define before running any experimental test. The experimental design will thus provide the details around the data collection for better control of the assessed scenarios, ensuring that conclusions derived from the study are solid and valid. Indeed, validity is a crucial aspect in any research project, as stated in Section 2.3.2. Internal validity specifically, is concerned with identifying and minimising the threats to a study design, so that researchers are confident that their results are due to their evaluated factors and not by other external and confounding factors.

Considering that the MODI project deals with different scenarios, in which different type of data will be collected, it becomes crucial to describe the different aspects of the experimental environments in which the UCs will need to operate. Considering that the project is at an early stage, the study design for each UC is not yet defined. However, important aspects related to the experimental environments and the evaluation tools are provided. These aspects will serve as a starting point of discussion for defining the UCs, and at the same time, will allow to identify potential threats to the validity of the project results. To this end, the FESTA methodology is used for the description of different experimental aspects, which are listed in the following sub-sections. Being this a living document, the description of the study design for each UC will be updated as the project progresses.

3.5.1 Experimental environments

The aspects of the experimental environments (in the case of MODI i.e., the environments in which the UCs will operate) that require specification are, according to the FESTA Handbook: geographical location, road type, traffic conditions and interactions with other road users, weather conditions, and time of day and seasonal effects. Although this list enumerates some important aspects for the description of any experimental environment, it does not mean that it is an exhaustive list, as several other aspects proper of specific scenarios may arise during the project. In such case, it is recommended, when possible, to conduct pilot tests which can serve to both assess the evaluation process and to recognise possible new aspects that could be threats to the data collection and thus to the project results. The following points discuss the aspects related to the experimental environments as listed and described by the FESTA methodology [1]:

- Geographical location: The geographical location is probably the aspect that presents more conditions to consider for the different tests performed within each UC. For the MODI project, the geographical location is intrinsically linked to the project objectives, as they were selected due to their characteristics needed to collect specific data in the study (i.e., the solutions to the identified challenges, see Section 3.2). Indeed, the challenges addressed in the project are based not only on distinct geographical locations but also on specific location scenarios in which the solutions will be demonstrated. Such is the case of the UC Netherlands for example, as its location is based on testing the CCAM vehicles in specific port operations. Another example is the UC Norway, which is specifically designed to address the challenges related to a border crossing scenario.
- Road type: While the geographical location is probably the aspect including more elements to consider, the road type is identified as the aspect that plays a larger role on the behaviour and performance of road users, and thus having repercussions on the impact areas of the project. Although the FESTA Handbook indicates that there is currently no standard European classification of roads, the European Commission provides a road classification relative to traffic safety and established based on defined functions. These are: arterial or through traffic flow routes, distributor roads, and access roads [23]. However, following the description given by FESTA, this document will use the FESTA classification of road type, using three categories, i.e., urban, rural, and motorway. Moreover, other characteristics of the road type must also be taken in consideration, such as the physical features of the road, speed limits, number of lanes, and the presence of traffic signs and/or lights that could influence the driving behaviour. It is important to notice that there is no standard European classification for road types, and these might vary across the different countries participating in the MODI project.
- Traffic conditions and interactions with road users: While the road type includes conditions related to the traffic (such as the speed limits and traffic signs and/or lights), the traffic conditions described here are concerned with the actual characteristics that determine the driving environment. Examples of these are: density (i.e., number of vehicles travelling in the specific road), speed (i.e., not based on the regulated speed limit as defined in the road type, but to the average speed of the real traffic conditions), and composition (i.e., types of vehicles that drive along a specific road, e.g., light or heavy vehicles, motorcycles). Furthermore, both the speed and the composition of the traffic are also related to the interactions with the road users, as they describe their driving behaviour (speed), and the type of vehicle they drive or in which they are passengers (composition).
- Weather conditions: The weather conditions relate to the atmospheric events (e.g., cloudiness, sunshine, wind, rain, snow) that may occur at a particular location. As naturally expected, no weather condition can be fully controlled, and although there are currently tools and services to emit weather forecasts, these are hardly 100% reliable. In line with identifying possible threats to the data collection and validity of the study, the weather conditions must be considered as possible confounding factors[10]. Although weather conditions cannot be controlled, they can and should be registered to include (or exclude) them in the subsequent data analyses. To this end, three different approaches can be used: sensors measuring and registering weather (either in vehicles or roads), subjective data informed by a person present at the test site, or post-hoc analyses of the weather conditions present at the date and time in which the tests were performed.
- Time of day and seasonal effects: Unlike the weather conditions which cannot be fully predicted nor controlled, the conditions related to season and time of day can be controlled. Indeed, the operation of an FOT or a N-FOT can be designed to be performed at specific seasons (e.g., winter vs summer) and specific times of the day (e.g., day vs night). This is naturally related to the project objectives of the study, e.g., the evaluation of vehicles in harsh winter conditions containing snow, or during night-

[10] In research, confounding factors are factors that are not part of a study design and/or its scope but that could influence its results causing a false association.

time with reduced visibility. Other example of issues that can arise during testing include disruption of normal traffic flow due to external societal activities (e.g., temporal events such as parades in specific road segments, or periodical events such as neighbouring school opening or closing times), ambient light levels, glare disrupting drivers or vehicles sensors (e.g., due to low solar elevation during winter season), or other temporal traffic disruptions.

Considering the aspects of the experimental environment listed above, Table 19 presents the conditions of the experimental environments for each UC, focusing on the geographical locations, road type, traffic conditions and interaction with road users. The information shown on Table 19 is based on the information retrieved from the document concerning the user requirements identification from WP1[11]. The aspects regarding weather conditions and time of day and seasonal effects are provided as text below the table due to their equal value across all UCs, i.e., it is the same for all UCs.

Table 19: Experimental environment conditions to consider for each UC.

UC	Geographical locations	Road type	Traffic conditions and int. with road users
UC NL	• City of Rotterdam • Port operating terminal • APM Terminal: Confined area incl. private roads • Drayage: Mixed traffic (driving in confined area and public road segments)	• Urban roads • Private urban roads • Roundabout • Railway crossing • Interaction with traffic systems and traffic lights • Signalised intersections	• Density: possible traffic congestion • Composition: Trucks and truck drivers, transporters and terminal operators
UC GE	• City of Hamburg • Driving transition from confined area to city roads • Driving around port areas, to and from confined areas owned by logistics companies and onto public roads • Driving transition from German motorway to city streets of Hamburg	• Urban roads • Possibility of driving over high bridges and/or tunnels • Possibility of driving on narrow, slow speed roads	• Density: Often-congested low-speed city streets • Speed: High-speed traffic • Composition: light and heavy vehicles
UC SE	• City of Gothenburg • Gate access: Driving from public roads to confined area through gate access • Charging, and loading/unloading: Fenced off area (possible Gothenburg RoRo terminal) • Driving in mixed traffic on urban roads: From public roads between the DFDS port in Gothenburg and a DFDS warehouse in Borås, Sweden.	• Public urban roads • Private urban roads	• Density: possible traffic congestion at certain hours. • Speed: High speed L2 at the public road between GRT in Gothenburg and DFDS warehouse in Borås. L4 at a public road with a speed limit of 30 km/h • Composition: mixed traffic, trucks, trailers

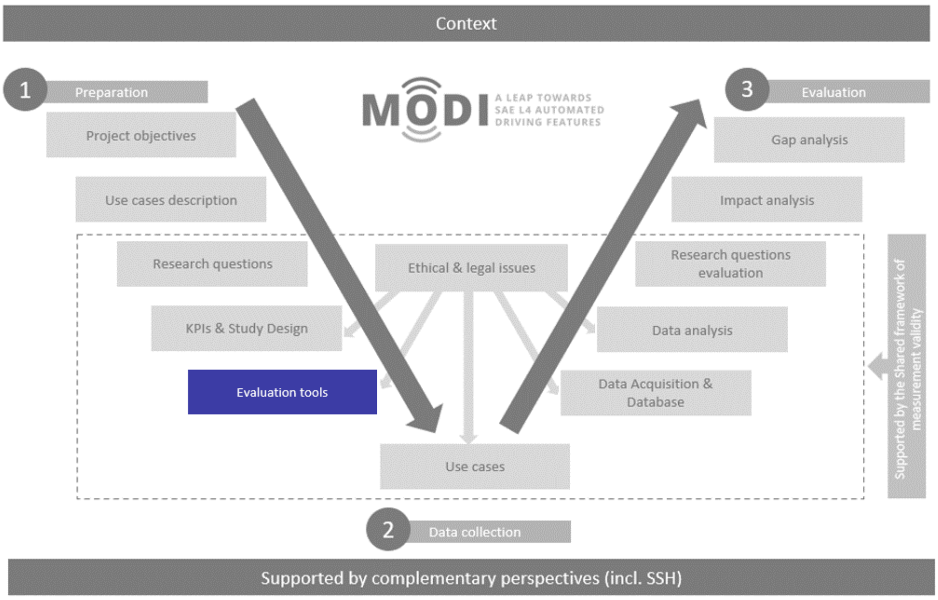
[11] Scenarios used in user requirements identification v2.pdf. WP1, T1.1 User and stakeholder requirements. Last accessed: 22.03.23.

UC NO	• Border crossing and customs: From Sweden to Norway driving over the Svinesund bridge, passing through customs • Motorway: Driving on E6 highway on the Norwegian side • Port: If possible, terminal manoeuvres at ports	• Public urban roads • Driving on custom area, access from public road motorway E6 • If possible, confined area	• Density: Possible traffic congestion at the border and customs • Speed: Speed around 60 km/h for test vehicle • Composition: mixed traffic (light and heavy vehicles)
UC CCAM	• From Rotterdam (NL), through Germany, through Denmark, through Sweden to Oslo (NO)[12] • Motorway / rural roads	• Public roads • Crossing several borders and customs • Tunnels, bridges and ferries etc. included.	• Density: Possible traffic congestion • Speed: No automated driving, following normal speeds. • Composition: mixed traffic (light and heavy vehicles)

The UCs need to consider that carrying out the test scenarios may happen under different weather conditions (e.g., clear sky with sun or overcast sky). However, challenging weather circumstances such as winter conditions (e.g., snow, rain, wind, sun, or high/low temperatures) might suppose a risk to the data collection for all the UCs. For example, the presence of snow might cover lane markings or might disrupt the functioning of vehicle sensors. Thus, the MODI UCs should strive to carry out the data collection in a season that do not present such challenges. If, for different reasons, an UC needs to be carried out during winter, risk reducing measures must be undertaken.

Another possible threat to the data collection for all the UCs is the poor visibility in e.g., fog or low light levels. Although the UCs should strive to drive during a time of day in which there is sufficient daylight, lower daylight levels might be possible experimental conditions only under satisfactory road lighting. Another possible threat associated to the time of day might be related to sunrise or sunset times, as low solar elevation in clear skies might produce glary conditions that could disrupt the cameras or sensors of the vehicles.

3.5.2 Evaluation tools



[12] https://storymaps.arcgis.com/stories/343210bf9eb347498a2bd7f8b07ffdb2

As stated in the description of the scenarios used in user requirements identification from WP1, T1.1, the description of the vehicles to be tested within the UCs is scarce at this early stage of the project. This also includes the corresponding technologies for connectivity and automation. This is natural at this stage of the project, as it is expected that the automation technology set-up will be defined and further developed during the project course and demonstrated in 2025.

One aspect that already is defined is the use of L4 vehicles or vehicles fitted with L4 automation technology and connectivity. These, together with the technology and physical objects described by each UC, are briefly described in the subsequent sections.

Vehicles

As defined for the project, a L4 vehicle (or a vehicle equipped with L4 automation technology and connectivity) operates with a set of on-board automated driving features bounded by an operational design domain[13] (ODD) based on physical and digital infrastructure (PDI) available for the vehicle operation. Indeed, the PDI as a context in which the vehicles operate is an important aspect to consider, as the functioning of these vehicles is strongly related to the road elements and traffic conditions.

The vehicles to be tested within the project UCs are expected to navigate automated in the defined areas selected for each UC. Nonetheless, a human operator may still be needed (either in person or remotely) in situations where the vehicle needs assistance to solve challenges due to unexpected events along the roads. After the situation is solved, it is expected that the human operator will return the vehicle to its automated features to continue its route.

Technological and physical objects

A preliminary conception of the technological and physical objects needed to run the UCs, as described by the UC leaders and documented on the description of scenarios, is provided in Appendix III: Technological and physical objects needed as defined by the UCs. It is important to mention that the list provides only a general overview of the equipment needed. A more comprehensive list of the technological equipment (including measures and sensors) related to the KPIs and defined by the data needs will be detailed at a later stage as the project progresses.

Ethical and legal aspects

Before addressing specific ethical and legal aspects, it is important to mention two principles that should be remembered throughout the project life:

- Ethical aspects: Ethical guidelines should govern the project. MODI is an EU-funded research project, and the "European Code of Conduct for Research Integrity"[14] should be a reference for all the research activities. In addition, the project document D7.3 Ethics, security and gender equality plan from WP7, and both European and local guides to General Data Protection Regulation (GDPR) should be followed.
- Legal aspects: All UCs (including the evaluation tools to be used) should follow the legal rules and requirements of the jurisdiction in which they will operate. Complying with local and international legal regulations is also an act of research integrity and ethics.

This section aims to list aspects that must be considered when preparing both the vehicles and the technological objects that will be either embedded in the vehicles or placed along the road. Although it is not

[13] Operational design domain (ODD) refers to the conditions needed to ensure that automated vehicles operate in a safely manner.

[14] Document can be retrieved from: https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/guidance/european-code-of-conduct-for-research-integrity_horizon_en.pdf [Last accessed: 30.03.23]

possible to determine an exhaustive list of all the legal and ethical issues that may arise in the study, the following aspects indicated in the FESTA Handbook, are identified as relevant at this stage of the project:

- Legal permissions: MODI will encompass testing in four different countries (i.e., UCs in Norway, Sweden, Germany and Netherlands), and will involve a fifth country (Denmark) in the UC CCAM Test corridor, the project notes that specific laws and regulations may vary across countries. Furthermore, although some European regulations are the same for all the participating countries, the interpretation of these might also vary between the countries. In such case, it is recommended to establish and maintain communication with both the local regulatory authorities and with the project management team to avoid incurring in involuntary legal mistakes. For example, when planning both the UC CCAM Test corridor and the UC Norway which include cross-border traffic, legal regulations should be properly identified and complied. Likewise, proper permits are needed for the conduction of all the UCs that involve driving in open roads.
- Risk assessment and safety (incl. insurance): Due to the nature of the UCs and the type of technological objects to be used, a comprehensive risk assessment plan should be developed, in which possible hazards should be identified. Although both the vehicles and the technological objects to use should be properly evaluated prior to the conduction of the UCs to ensure their safety, possible unexpected technological deviations that produce hazards may arise. These hazards can be related to the malfunction of equipment and vehicles and/or their inadequate use. After a preliminary safety testing, a risk assessment plan should be established, indicating their possible mitigation measures. Furthermore, as the FESTA Handbook indicates, there might be insurance requirements related to the vehicles and equipment to be used and their implications to human safety. Such insurance requirements differ between countries, and as such it is recommended to seek legal advice regarding this aspect, which is highly sensitive.
- Responsibilities and legal liability: In line with the previous point, possible hazards or dangerous situations within the use of vehicles and technological objects for the conduction of the UCs may arise. In unwanted scenarios in which damage, injury or accident happen, liability and responsibility should be determined based on different factors, such as (but not limited to): legal regulations of the country in which the incident took place, the conditions in which they happened, the type of damage, and contractual agreements between the project partners (e.g., liability and responsibility of a manufacturer for a faulty component). As with the risk assessment plan, this aspect is also highly sensitive. It is thus recommended that the responsibilities and legal liabilities should be determined prior to the conduction of the UCs, as long as it is possible. If needed, legal advice regarding this point should be sought.

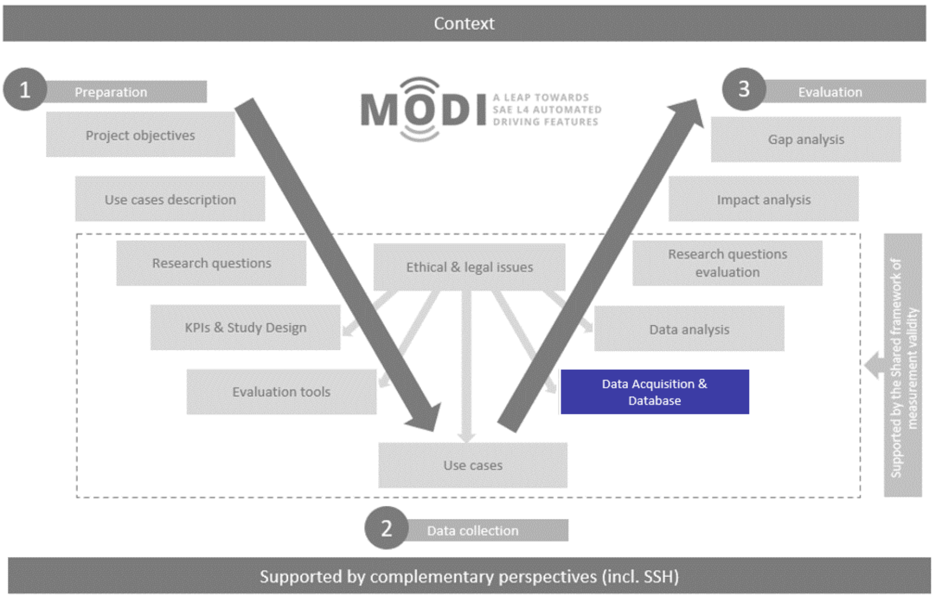
4 Evaluation plan in MODI

This chapter describes the type of data that the MODI project will collect, store, share and preserve throughout the project's lifecycle. This will serve as input for Task 2.3 in the MODI project, which will develop the CCAM data sharing platform. Although the wording used in this document (and in the FESTA Handbook) refers to only *data*[15], it is important to remember that *metadata*[16] is also included in this chapter. The Data Sharing Framework document[17] [24], which is complementary to the FESTA methodology, is used as basis for the data type definitions and categories and is referred in this document as DSF.

The type of data follows two categorisations. First, at a more general level, the data is categorised depending on the type of information they aim to collect and has a basis the categories given by the DSF. A second level is based on the categories provided by the project document D7.2 Data Management Plan and is particularly specified for the MODI project.

It is important to notice that this document provides general descriptions related to the data acquisition, storage, and processing. A more specific presentation of the data type of the MODI project is suggested to follow the example provided in Annex I. Furthermore, general guidelines regarding data sharing according to the FAIR[18] data principles [25] and the allocation of resources for proper data management will not be described here as they can be found in D7.2 Data Management Plan.

4.1 Data acquisition and Database



4.1.1 Data type

This section presents the categorisation of data based on the information needed to address the objectives of the MODI project. As previously stated, the data type follows a categorisation in two levels: the first general level entails the three categories for data and four categories for metadata, and the second level includes three

[15] Data refers to "*any information whose value might be used during analysis and impact its result*" [7].
[16] Metadata refers to "*any information that is necessary in order to use or properly interpret data*" [7].
[17] https://www.connectedautomateddriving.eu/data-sharing/methodology-data-sharing-framework/
[18] FAIR data are data that meet principles of Findability, Accessibility, Interoperability, and Reusability (Acronym: FAIR) to optimise their reuse.

categories based on the information for the MODI project. These different categories are described in the following sub-sections.

Data categories

A succinct description of the data categories in relation to the MODI project can be found in Appendix II: Descriptions of categories for data and metadata, and data acquisition methods. For further reading, please refer to the DSF document prepared by FOT-Net [24]. The following categories are based on the DSF: Context data, Acquired and/or derived data, and Aggregated data.

Metadata categories

Metadata supports the analysis and interpretation of data by providing description and information of the data. As established in D7.2 Data Management Plan, the metadata for the MODI project will be licensed under CC BY 4.0[19], and will provide information about, e.g.: Data origin (e.g., from a specific UC), date and time of deposit, description of any embargo (if applicable), authors and their respective organisations, and persistent identifiers. Considering that metadata can provide different types of information, it can be divided into different categories. As with the categories of data, the categories of metadata are based on the categorisation provided by the DSF [24], as follows: Descriptive metadata, Structural metadata, Administrative metadata, and Execution documentation. A description of these types of metadata in relation to the MODI project can be found in Appendix II: Descriptions of categories for data and metadata, and data acquisition methods.

4.1.2 Data types in MODI

The second level of data categorisation, which is specified for the MODI project is based on three categories, as given by D7.2, i.e.:

- Data related to vehicles and digital infrastructure.
- Data related to the vehicle's environment.
- Data related to (test)-persons and stakeholders.

These three categories were based on the data collection purposes of project and taking in consideration the specific scientific research objectives of the MODI project. For further information regarding the data collection purposes and examples of types of data for each of these three categories, please see the project document D7.2 Data Management Plan.

The two levels of categorisation presented in this document respond to two aims. First, to follow an already established data framework to build on the existing knowledge and processes among the scientific community working with automated transport. Thus, the categorisation provided by the Data Sharing Framework [24], which is complementary to the FESTA Methodology, is used as basis. The second aim is to have a joint understanding of the different data types and how these types relate to each other in function of the specific objectives for the MODI project. To this end, the categories established by the project management in D7.2 are used. These two levels of categorisation are complementary, as the 1st level of categorisation is sought to provide input to the three different categories in the 2nd level of categories. In other words, the data collection can follow a common data framework (as the one used here from the DSF), which will be later organised into the three categories specific to answer the MODI objectives, see Figure 9.

[19] https://creativecommons.org/licenses/by/4.0/

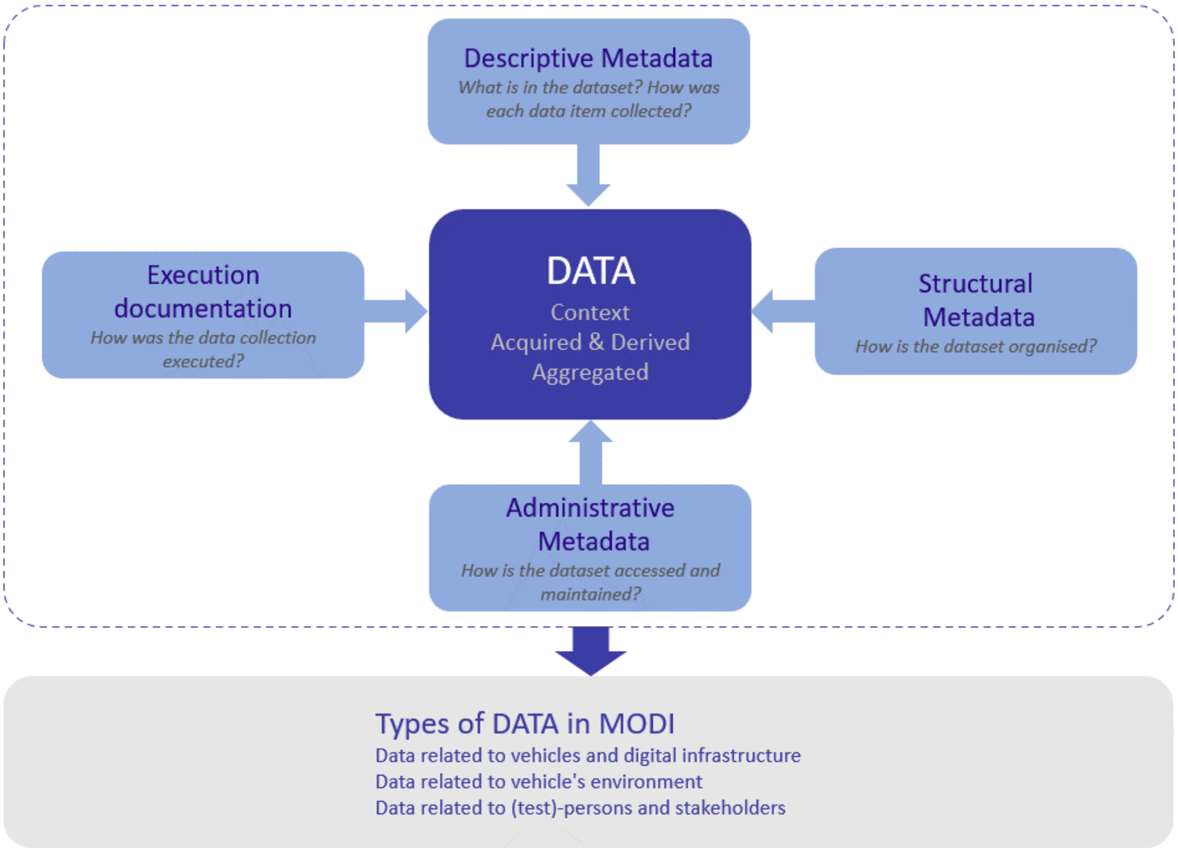


Figure 9: Relation between the data and metadata categories provided by the DSF and the types of data established for the MODI project.

4.1.3 Data acquisition methods

The collection of data is based on the KPIs and RQs, and the data needed in the MODI project have been categorised in the previous sections. Although this might seem an appropriate start to the data collection process, an important part of the process is to also define which data acquisition method to be used.

Data acquisition methods seek to, based on the project's objectives and RQs, collect the right data and apply it correctly to the project database for further processing and use. In general terms data acquisition methods can include converting, sharing, and purchasing data. However, this section is focused on methods for collecting new data only and presents a brief list of the methods of data acquisition in FOTs (or N-FOTs) proposed by the FESTA Handbook, as follows: Background data acquisition, In-vehicle data acquisition systems (In-vehicle DAS), Subjective data acquisition, Real-time observations, and infrastructure data acquisition. A brief description of the different data acquisition methods can be found at Appendix II: Descriptions of categories for data and metadata, and data acquisition methods. For a more comprehensive description, please read the FESTA Handbook and the DSF.

Considering both the types of data in MODI (see Section 4.1.2) and the data acquisition methods related to FOTs and N-FOTS presented in this section, Table 20 presents the suggested data acquisition methods relevant to each type of data in the MODI project. As previously discussed, being this a "living document" this table might change as the project progresses. For example, a specific method might or might not be used for specific data types or for selected UCs.

Table 20: Suggested data acquisition methods to be used for each type of data in the project.

Data acquisition method	Data related to vehicles and digital infrastructure	Data related to vehicle's environment	Data related to (test)-persons and stakeholders
Background data			
In-vehicle DAS			
Subjective data			
Real-time observations			
Infrastructure data			

Ethical and legal aspects

Similar to the ethical and legal aspects related to the evaluation tools of the project, this section seeks to indicate a (non-exhaustive) list of aspects that require careful preparation when planning the data collection.

- Data collection – video/audio recording: This point is specifically relevant for the tools (e.g., sensors, cameras) that will be used to collect data in the UCs. For some KPIs (e.g., the ones related to safety, in which people may participate), specific measures need to be taken. These include (but are not limited to): verbal and/or written information to the participants in which the participants rights are explicitly indicated and participants consent. The FESTA Handbook clearly indicates that "*where research involves human participants, there are numerous ethical and legal implications to consider*" [1, p. 30]. Indeed, some of these implications, particularly the ones related to human participants, have been already discussed from sub-sections 3.4.2 to 3.4.5. Furthermore, the UCs are sought to be carried out in areas in which other people might be involved. This means that the ethical and legal aspects are not only directed to the participants who may be recruited for a specific study within a UC, but also to e.g., road users that are nearby the UC area, who have not specifically consented to participate in the study but who might be affected by it. These are referred as "non-participants". This distinction is of particular importance, as due to the design of the UC in which different sensors and/or cameras embedded in the vehicles might record data around both private and public roads, the presence of non-participants needs to be considered for applying proper ethical and legal measures.
- Local permits for installing equipment close to a road: The installation of equipment close to a road often needs to obtain local permits first. Such permits might vary from country to country, and as such the UCs should contact local road authorities prior to the installation of any equipment on road or to other pertinent authorities for confined areas. Moreover, it is important to notice that the permits are not limited to the installation of physical objects, but there might also be permits specifically issued for working alongside a road (e.g., during installation), and that require previous training. An example of this is the special training course required to obtain an on-road work permit issued by the Transport Department of Norwegian Roads Administration (Norwegian name: *Arbeidsvarsling*) which allows working on or near the Norwegian road network. These permits safeguard road safety and the proper conduction of local traffic. It is thus expected that the UCs in the MODI project shall comply with the local (and possible international) regulations on roads safety.
- Protection of personal data – GDPR: For both participants and non-participants, the collection of personal data collected by the vehicles and technological objects should be handled with proper care. As the FESTA Handbook recommends, the collection and later processing of personal data should only be performed when this is essential to achieve a specific project objective. As such, personal data that is not strictly necessary to an objective, RQ or KPI, should not be collected. Considering that personal data needs to be collected, the protection of such data should be under what it is stipulated by the EU regarding the GDPR[20]. As rightfully highlighted by the FESTA Handbook and following our

[20] Complete guide to GDPR compliance (Europe): https://gdpr.eu/

ethical principles within research: "*it is absolutely vital for any organisation that host or process personal data in the European Union to ensure that personal data are managed according to the law*" [1, p. 31].

- Ethical approval: Needless to say, MODI is a project governed by ethics, among other aspects, and all the ethical regulations and recommendations should be followed by all project partners. In the case of data acquisition using vehicles and technological objects, ethical approvals processes should be undertaken for each country in which a UC will operate. As previously indicated, the European Code of Conduct for Research Integrity is a good starting point for this, but specific ethical reviews should also be sought. This applies for the case of a research project dealing with personal data, which needs to apply for approval to their country's ethical board (e.g., the Swedish Ethical Review Authority).

4.1.4 Metadata requirements for MODI

All metadata for all data sets in MODI should follow the Data Sharing Framework (DSF). As of now, the intention and preference is to use *.yaml* as the metadata format, but this choice can be aligned with the FAME project going forward. However, as stated in the Data Sharing Framework (DSF) all metadata should include all the metadata categories described in Section 0, as following:

- FOT/NDS/N-FOT study design and execution documentation
- Administrative metadata
- Structural metadata
- Descriptive metadata

"N/A" should be used as value to metadata if no information is provided or necessary for each data set. For the FOT/NDS/N-FOT study design and execution documentation metadata, a high-level description of the data collection and its objective should be provided. In MODI, this should be plain text in English. Following the recommendations in the DSF, for the administrative metadata the included parameters should be:

- Version number
- Archiving date
- Information about rights, reproduction, and other access requirements
- Archiving policy
- Digital asset management logs
- Documentation of processes
- Billing information
- Contractual agreements
- End of life of the data

Since the MODI project will work on a basis of a metadata database (see Section 4.1.5), the access requirements are needed to be described, either as a web-link, a contact person, or similar, on how to access the actual data. For the structural metadata the data base type (SQL, MongoDB, etc.), data format (.json, .csv, etc.) or file system of actual data should be described as described in the Data sharing Framework. For the descriptive metadata for each parameter in the data set the tables given in the Data Sharing Framework Tables 3-9 [24] should be used, with appropriate additions if applicable. In MODI, these parameters are linked to the identified KPIs (see Section 3.4), to identify the minimum required parameters to be included in the data set and described in the MODI data-sharing platform (to function as a metadata database).

The addition of a validation procedure to the content of the metadata file is considered. The plan is to make a web application as a feature to the MODI data-sharing platform where the *.yaml* file can be validated, or where metadata can be created using an online form. A working metadata example is attached with this deliverable, see Annex I.

4.1.5 Data-sharing platform

Although a number of projects working on automated driving have developed their own databases (e.g. Safety Pool or Waymo), to date there is still not a common solution for databases in projects dealing with FOTs. Naturally, the creation of databases is dependent on the type of data that need to be collected, and this varies greatly from project to project. Yet, a common denominator seems to be present among the projects including FOTs or N-FOTs: the database often includes a very large amount of data, particularly the ones related to the driving hours of the CCAM vehicles. Such large datasets become challenging to manage, to store and to analyse.

Considering the challenges associated with the storage and management of large datasets, the MODI project has a specific task aimed to facilitate data collection and sharing (i.e., Task 2.3 Development and utilisation of CCAM data sharing platform). This task will develop a cloud-based data-sharing platform (called MODI Platform in Figure 10) that will allow data access internally to the project partners for analysis (e.g., for impact and gap analyses). Such data-sharing platform may also be used to share data externally in the future, contributing to the combination of knowledge gathered across different projects. The management of the data available at the data-sharing platform will be in close cooperation with Task 7.3, in particular with the guidelines described in D7.2.

The creation of a data-sharing platform for the project is an ongoing process and follows an initial design concept illustrated in Figure 10.

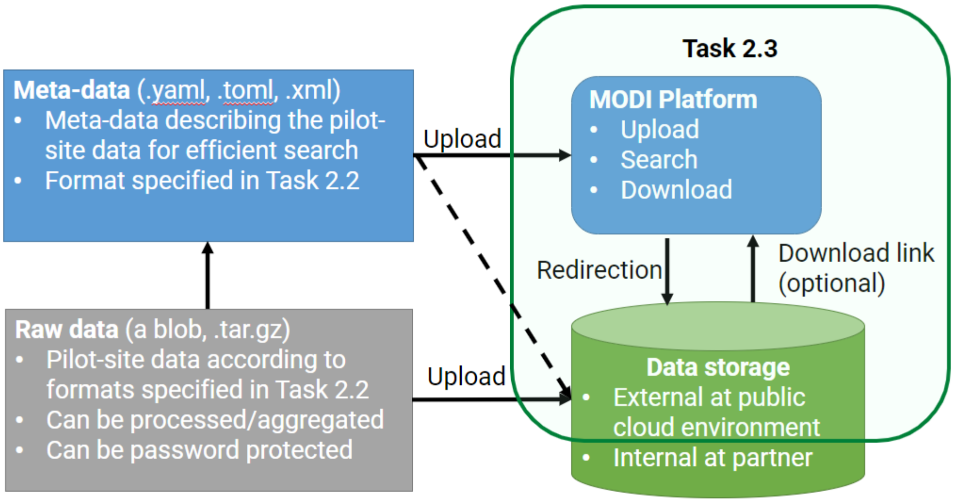


Figure 10: Illustration depicting the design concept of the data-sharing platform. Credit: Pavol Jancura, TUE.

The design concept for MODI data-sharing platform from Figure 10 can be described as follows:

- The raw data will be collected by the project partners, in particular the UCs (grey box).
  The raw data will be organised according to the formats exemplified in Annex I. Each partner in charge of the collection of data is responsible for the organisation of their data. Annex I describes the metadata needed to describe the data. The metadata follows the categorisation indicated in Section 4.1.1, to sufficiently describe the data for efficient search in the MODI data-sharing platform (blue box).
- The raw data can be stored both internally at each partner's own institutional database, and externally at a public cloud environment (green cylinder). For examples of external data repositories see chapters 3.2 and 3.3 of D7.2 Data Management Plan.
- The MODI data-sharing platform will have three components (i.e., upload, search, and download as functionalities) designed to facilitate the search/access the data (blue box with rounded corners).

It is to be noted that there is a difference between the data storage (green cylinder) and the MODI data-sharing platform (blue rounded box). While the first one entails all the databases and repositories owned by either the project partners or public repositories services, the second one (MODI data-sharing platform) is sought to function as a search and data access platform. As such, the MODI data-sharing platform will not function as (and should not be mistaken for) a database to store all the project data. The MODI data-sharing platform will thus be linked to the different databases in order to redirect the user to the adequate database in which specific data can be retrieved for further processing.

Ethical and legal aspects

As indicated in D7.2, the MODI project will work according to the FAIR principles [25], making data findable, accessible, interoperable, and reusable. Regarding the accessibility of the data generated and collected during the project, the project will strive to store as much data as possible in an open repository to be accessible to a wider audience, outside the project consortium. Yet, it is important to remember that not all data are suited to be openly accessible, as some data might be of a confidential commercial nature[21]. Due to this, ethical and legal aspects in particular require extra attention:

- Confidential commercial data: The DSF recommends that, when signing contracts among partners for generating/providing data, the level of data protection should be discussed and agreed upon. The data-protection measures are dictated by how sensitive the confidential commercial data are. This sensitivity level has been categorised by the DSF, as presented in Table 21. Special attention should be given to the proprietary data, as some partners might consider specific data as strategic for their organisations and thus might want to treat them as sensitive and not share them. If such cases are not indicated in the consortium agreement, special agreements must be signed as soon as possible.

Table 21: Categories of confidential commercial data. Adapted from DSF [24].

Data category	Ownership	Access
Open	Owned by all or part of the project consortium*	Open for all or certain project partners*
Licensed	Owned by the data provider (usually the data owner who holds the IP rights)	Open for all or certain project partners, with approval by the owner**
Proprietary		This data is never open/shared, as the commercial value is too high

*Table notes: *Needs to be agreed upon and signed by the project partners; **Licensed data could be made open by adding signals to convert the data to non-sensitive (recommended by the DSF).*

The MODI project will strive to identify in an early phase of the project possible confidential commercial data owned by specific partners of the consortium. To this end, work will be done within Task 6.3 Exploitation strategy and IPR management. In addition, it is important to note that specific requirements and/or inquiries should be addressed by the interested partners to the MODI Executive Board in proper time prior to the data collection.

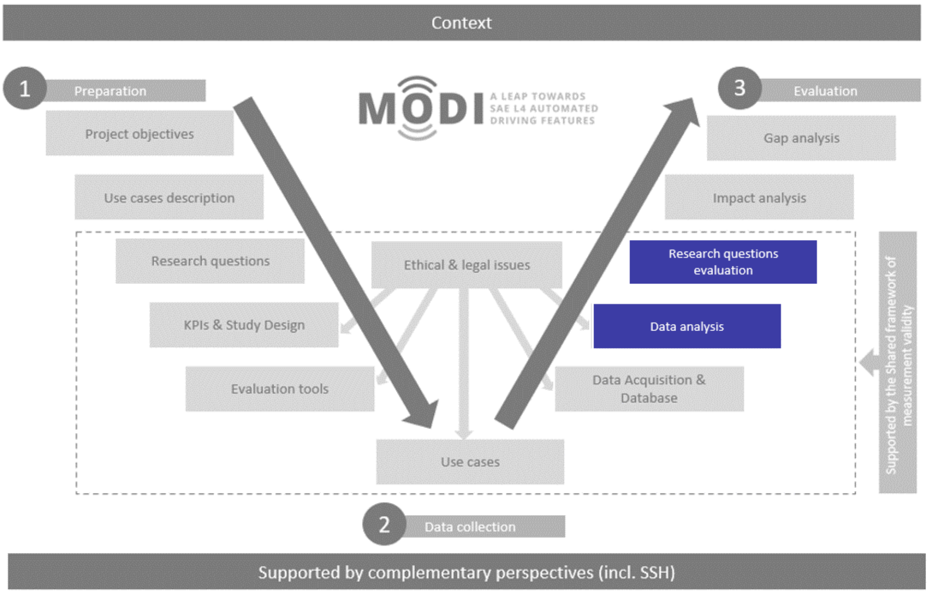
- Stakeholder confidentiality: The same dataset can have different levels, ranging from open and/or public data to a confidential level of data (see previous point). Confidential data could not only affect the analysis of the results, but also the public presentation of them. Although one partner could have the approval by the data owner to analyse a specific dataset, this does not automatically entail the publication of the obtained results. Partner confidentiality is then expected and requires non-disclosure agreements. As with the previous point, if such cases arise, it is the responsibility of the

[21] From the DSF: "*Confidential commercial data is information which an organisation has taken steps to protect from disclosure, because disclosure might help a competitor*", p. 32, DSF [24].

partner that owns data to notify the MODI Executive Board for the agreement and signing of such non-disclosure agreements.

- Data re-use: In research, it is common to introduce new research questions and/or topics that can be studied using the collected data in a specific project. This is called data re-use. In such cases, procedures should be defined, and proper agreements should be made. As indicated in D7.2, the MODI project will leverage data re-use by depositing most of its research data using the CC BY 4.0 license.

4.2 Data analysis and Research Questions evaluation



Data analysis is the process when the collected data is systematically evaluated in order to answer specific research questions. Although the data analysis is considered one of the last phases in any research study, and it is placed in the last part of the FESTA-V diagram (i.e., 3 – Evaluation), this step should always be planned from the start. This is a well-known and recommended practice among the research community, as this is an important point when discussing the validity of any study findings. As stated in Section 2.3.2, special attention should be devoted to the validation of the findings already from the beginning and throughout the entire research process. This is in line with the recommendations given by both the FESTA Handbook [1], as the main methodological approach, and the Shared Framework for Measurement Validity [19], as the complementary methodological approach.

In sum, in order to acquire valid results, we need to be sure that our research process is well established from the start. Accordingly, the FESTA Handbook recommends including analysts (i.e., partners responsible for the analyses of the collected data) in the selection of the RQs, KPIs, data requirements, and study design and planning. The MODI project, via this document focusing on the Evaluation Methodology, not only has involved the analysts (for both the impact analysis and gap analysis), but it has also included the input of the UC leaders as responsible for the data collection in each UC. This approach ensures that the strategy chosen for the data analysis procedures is robust.

As data analysis is strongly linked to the research strategy adopted early in a study, it is naturally strongly related to the evaluation of the research questions. In other words, we need to be confident that the results from the data analysis answer the project research questions. To this end, the FESTA Handbook suggests some strategic rules containing five links between the data and the answer to the project research questions. As indicated earlier, the MODI project identifies as an N-FOT, and as such it focuses on RQs rather than hypotheses (see Section 2.4). The strategic rules for data analysis suggested by FESTA [1] are thus slightly modified to adapt to the MODI project in Figure 11.

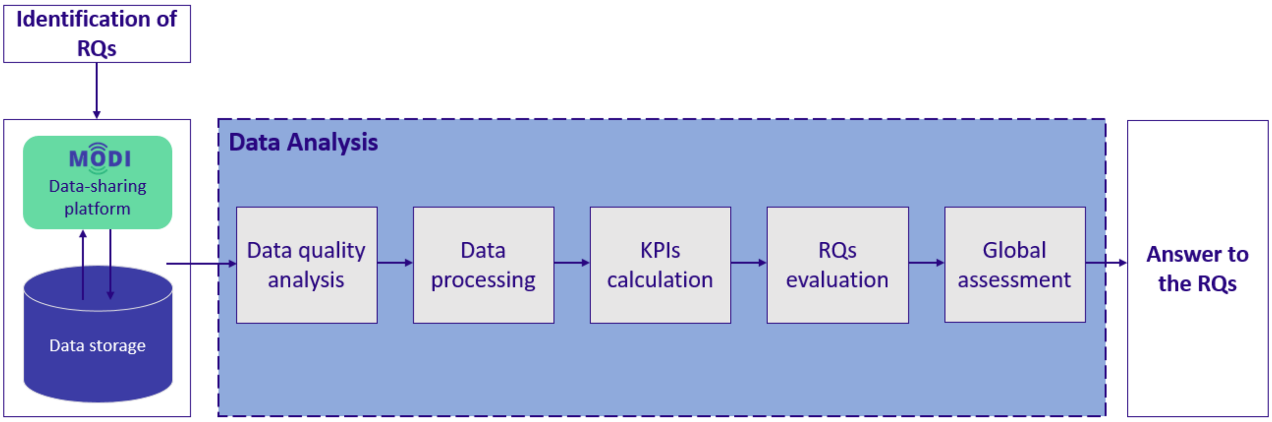


Figure 11: Strategic steps for data analysis in the MODI project. Adapted from FESTA Handbook [1].

The strategic steps for conducting the data analysis in MODI are described as follows:

- Identification of research questions: The data analysis starts by identifying the research questions that require answer. These are based on the four impact areas established for the MODI project and are described in Section 3.3.
- Data retrieval: This is performed via searching the MODI data-sharing platform to access the different databases in the project (see Section 4.1.5). An important aspect for the data search and adequate data retrieval is the metadata information, which needs to follow the formats exemplified in Annex I.
- Data quality analysis: Involving the assessment and quantification of missing data, the control of data values (i.e., ensuring that data values are within the expected range and units), and the assessment (in order to guarantee) that the data fulfil specific research questions conditions (e.g., systematised concepts in questions: that there is a common understanding of the concepts included and studied in the RQs). This step is especially critical, as failures encountered in the dataset could affect the data analysis, and thus potentially yield incorrect results. If such cases arise (i.e., fails are encountered within a specific dataset), the failure should be reported to the responsible partner who collected the data so the possible failures can be clarified and/or corrected. If the failure is of a larger nature that requires a new data collection procedure, the WP-leader and the project coordinator should be notified to avoid affecting other WPs and delaying the course of the project.
- Data processing: This is the step before the data analysis, as it prepares the data to respond to the project RQs. Steps for data processing include the filtering of data (e.g., eliminate unwanted elements from recorded signals), the definition of new encountered signals from the raw data, event annotation complementary to the recorded data and reorganisation of the data defining a useful time scale needed for the analysis. This step could also include data encryption, conversion, and/or enrichment depending on the RQ to evaluate.
- KPIs calculation: Implementing calculation methods (e.g., statistical tests as calculations for quantitative analyses) proper to the type of data that needs to be evaluated (i.e., context, acquired, derived, or aggregated). At the time this document has been developed, specific KPIs calculation methods are not yet defined, as the KPIs are still subject to discussion. However, a general overview of the methodological approaches for the impact analyses (in which the KPIs will be analysed) is provided in Section 4.3.2. Moreover, and as indicated by the FESTA Handbook, the KPI calculation needs to be performed in function of the type of context in which the data was collected. This will ensure that comparison can be performed among similar situations or contexts. Likewise, it will allow that differences can be easily identified from dissimilar contexts. Such contextual differences are also in line with the Shared Framework of Measurement Validity [2], which recommends special attention to contextual specificity, as contextual differences can threaten the validity of the results (see Section 2.3.2).

- RQs evaluation: For the MODI project, this step focuses on evaluating the feasibility of answering the RQ with the data at hand. This includes also assessing whether complementary research efforts (e.g., inclusion of qualitative methods together with quantitative analyses) are needed to provide robust answers to the RQs. The RQs will thus be evaluated based on the results of both the impact and gap analyses, in which the KPIs calculation will play a crucial role once these are defined.
- Global assessment: This step addresses the issue on whether the results of the study can be generalised to a wider perspective. The FESTA methodology indicates that the results of an FOT can always be related to a wider perspective, showing context as an important aspect denoted as a bar above the FESTA-V diagram (see Section 2.2). In particular, the FESTA methodology focuses on the generalisation of results from an FOT (or N-FOT) to roads at national or international level in three aspects: traffic safety, traffic flow and environment. At the current stage of the project, it is still uncertain whether the results from MODI can be generalised to a wider perspective as FESTA indicates. Although this is still under evaluation, a general overview of the scoping of the impact analyses that will support a potential global assessment is provided in Section 4.3.1. In the case that generalisation cannot be achieved, the results of the project will be properly specified taking in consideration the contextual differences, as discussed in Section 2.3.2.

The answers to the RQs are achieved after all the steps of the data analysis are performed. As stated in Section 3.3, the RQs are based on the four impact areas and the two aspects of the gap analyses, which at the same time address the project objectives directly. The answers to the RQs represent thus a pivotal point in the project, in which the project objectives are met.

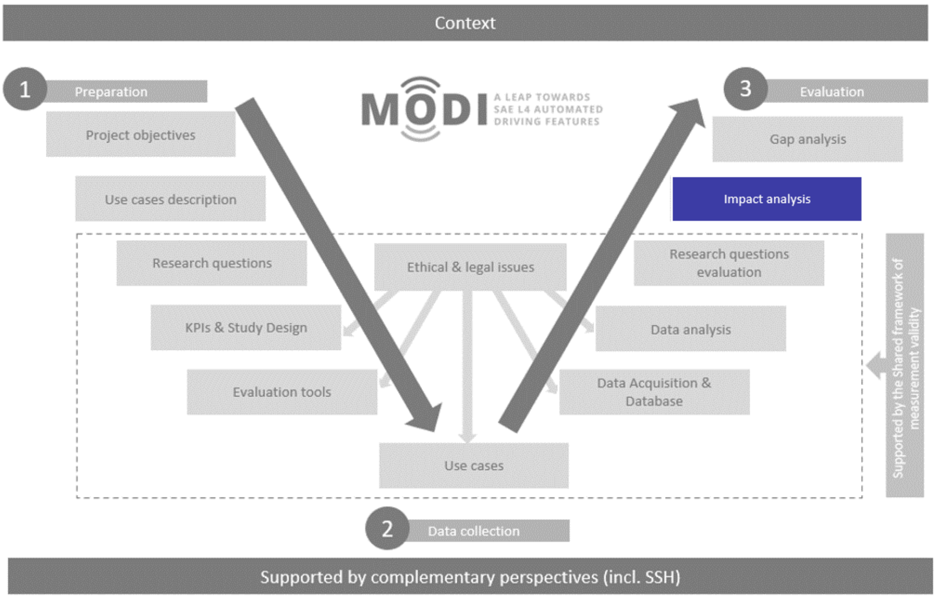
Ethical and legal aspects

The data analysis is the final stage in the FESTA-V diagram that requires special attention to possible ethical and legal issues. At this stage, three different aspects have been identified as susceptible to such issues.

- Issues related to data processing: This aspect might arise during the processing and filtering of the data, in which data may need to be encrypted. Data encryption is the process in which data is encoded for security purposes using an encryption key. A user or a limited number of users own the encryption key to be able to decrypt and access the data. Data encryption might be needed in cases of confidential commercial data or for GDPR purposes. In either case, the encryption of data should be carried out in communication with the relevant MODI partners and in line with the local or international regulations.
- Data preservation: In some cases, after data analysis has been carried out, there is a need to keep the data for a limited number of years. As indicated in D7.2, the data collected and processed in the MODI project can be potentially relevant to government and authorities, research community, reviewing organisations (for reviewing the MODI results) and OEMs (e.g., vehicle providers). These entities/persons might thus benefit for data preservation actions taken at MODI. Although a period of five to ten years is common in research [26], the appropriate amount of time for preservation of MODI data should be discussed with the relevant partners (as data owners), and the Executive Board of the project. As with other aspects, data preservation should be dutifully notified to relevant ethical boards.
- Interpretation of data: During data interpretation, as part of arriving to answers to the RQs, the research team including the analysts need to provide an accurate account of the yielded results. Achieving a higher level of accuracy is particularly relevant for the evaluation of the RQs, in which the immediate results might require extra research methods to be able to provide a more complete data interpretation. Examples of this are: using debriefing interviews to validate quantitative research, or on the other side, using validation numerical strategies to complement qualitative methods. In both cases, proper care should be taken to follow ethical guidelines related to e.g., GDPR in debriefing interviews or use of data for extra numerical strategies.

Finally, as with the other document sections (representing different stages of the project), it is important to remember that this list is not exhaustive, as other ethical and legal aspects might arise during the course of the analysis of the project/UCs data.

4.3 Impact analysis



4.3.1 Scoping and scenario development

Impact assessment studies can investigate the impacts of a system for a future time horizon. Those prospective studies make use of an ex-ante impact assessment, often based on literature review, simulation work and expert estimation. They are often comprehensive in scope, but they do not involve, or only to a limited extent, empirical data from real-life conditions.

MODI, however, is centred around several concrete UCs connected by a transport corridor, that are considered as N-FOTs, conducted in real-life conditions. Assessments of these N-FOTs will produce measured data about direct and possibly indirect effects of the studied measure (measure in MODI refers to the introduction of CCAM vehicles) that can be used for an impact assessment study.

Impact assessment studies on deployment of automated systems evaluate the impact that the full introduction or different penetrations of the tested system(s) have on a variety of impact areas such as driver behaviour, mobility, efficiency, safety, and environment. Predictions of the future, particularly over the medium or long term, cannot be precise. This argues for a scenario-based approach when developing forecasts of how future deployment of a system might turn out. In preparing to carry out an impact assessment, choices must be made about the deployment scenarios, the geographical scope of the assessment, the baseline, and the analyses to be carried out. The baseline is at the present defined as the same situation without the use of the systems (system off or non-present). However, how the baseline data will be collected is still to be decided, and it is subject to discussion between the evaluation team in WP2 and the UC leaders as these scenarios might vary across UCs. For instance, in the case of UC Germany, a tentative baseline scenario could be initial test runs with a manual truck, where information regarding energy use, travel times, and more, is collected.

It might not be possible to perform test runs in all sub-UCs, or it might not be appropriate, so another way of establishing a baseline could be to work with the demonstrators and estimate how manual freight vehicles perform. However, there are questions regarding e.g. what the appropriate baseline vehicle would be or if one should use a mix of vehicles (share of vehicles with different capabilities) to establish the relevant baseline.

Consequently, an appropriate baseline scenario will be defined for each sub-UC, in which detailed discussions such as the type of sensors to use for collecting data will be included.

Selecting the geographical scope is also an important step and has not been finalised. The two current options are illustrated in Figure 12.

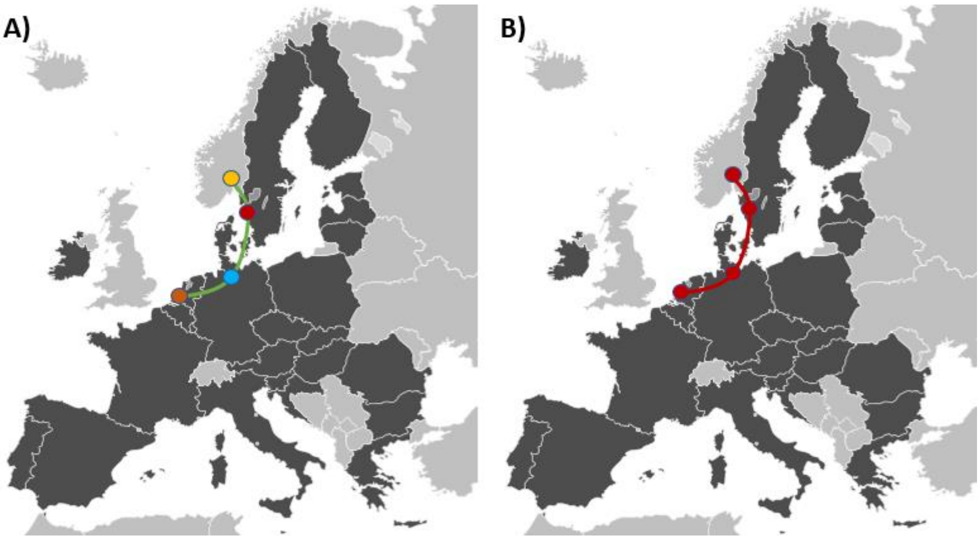


Figure 12: Alternatives for the selection of the geographical scope for impact analyses.

Both options from Figure 12 represent:

- A – Use Cases separately: Each of the UCs are studied separately so the results from the demonstration in the UC can be compared with the baseline. The results are extrapolated to obtain the results of a whole year.
- B – Combined effects of UCs along the MODI corridor: In addition to option A (i.e., study each of the UCs separately and comparison of the results from the demonstration in the UC with the baseline), option B also estimates the combined effects with data from multiple of the UCs. As with option A, the results are extrapolated to obtain the results of a whole year.

At the time this document is prepared, option B is considered a more sensible choice. However, this is to be discussed more thoroughly as the project proceeds, both within Task 2.5, but also with OEMs, UC leaders and other project partners and tasks. These discussions will also include the realism of collecting data for the various RQ and KPIs. Combining results from various sources is a likely outcome to both ensure more robust results and also having results.

4.3.2 Methodological approaches for impact analyses

Impact on environment

Environmental impacts and KPIs will be calculated using LCA. As LCA results are generally on the product (e.g., single vehicle) level, these will be scaled up as appropriate for the developed impact analysis scenarios. Calculations of both the product-level and upscaled scenario impacts will prioritise using primary data collected from the use cases and MODI partners where possible. Literature values or assumptions will supplement data gaps. These data gaps may include indirect effects of automated freight transport, such as effects on traffic flow, congestion and infrastructure (e.g., road) utilisation and are likely to be outside the scope of the MODI use cases. It is, however, likely that these factors will have significant influence on environmental impacts of CCAM [27]–[29]. Despite this, at the time of writing of this document, existing LCAs of CCAM vehicles did not consider these effects [27], [28], [30]. These effects are expected to have high uncertainty, both due to the current state of research on the technology, and due to the context sensitivity of these parameters. Consequently, a sensitivity analysis testing a combination and range of values for these parameters will be performed using an approach such as Monte Carlo [27]. This approach will thereby provide a range of possible results for environmental impacts. The KPIs will also be calculated for equivalent non-CCAM vehicles as a baseline for comparison.

Impact on safety

Impacts on safety in the MODI project is directed into assessing whether the implementation of CCAM vehicles can contribute to avoiding hazards in logistics that can lead to physical harm of individuals and/or society (i.e., system-wide safety impacts). This will be analysed in different traffic environments (i.e., safety impacts identified in individual UCs) where the deployment of CCAM vehicles could lead to interactions with different types of road users. Such interactions are foreseen to happen at both port sites, confined roads or areas, and public roads. The type of interactions is also of a different nature, e.g., with port workers during port operations or under common traffic environments with road users and/or vulnerable road users (VRUs).

System-wide impacts on safety: An estimate of system-wide impacts on road/occupational safety would tell us how many roads accidents/occupational incidents of certain types will be prevented under a certain market penetration level of CCAM vehicles. The knowledge on safety effects must be primarily gained from other sources. As conducting microsimulations is out of scope of WP2, it is necessary to utilise the MODI Use Cases to find out as much as possible about potential safety effects of CCAM vehicles and use that knowledge as input for system-wide safety impact analyses.

Safety impacts in individual Use Cases: The overall methodological approach to safety evaluation of UCs will be exploratory. Each UC contains a different context with various traffic and infrastructure characteristics and unique challenges. Therefore, the methodology of safety analysis will be tailored according to the specifics of each UC (i.e., each UC will be treated as individual, unique N-FOT).

The CCAM vehicles tested in MODI will include safety drivers and remote operators and these must be included in the analyses as well. Especially the addition of remote operators into the system creates a challenge that is unique to such drivers in charge of a vehicle that they are not physically occupying [31]. The following methods are suggested to evaluate safety in UCs (it is to be noted that not all methods will be applied in every UC. The selection of methods for each UC will be determined after discussion with UC leaders):

1. External video observation
2. Interviews with safety operators
3. Interviews with relevant persons involved in UC
4. Survey among workers in confined areas
5. Utilising data collected by CCAM vehicles
6. Obtaining existing safety data related to conventional logistic vehicles (baseline)

Impact on operational activities (traffic)

Impacts on operational activities will be calculated based on data from the demonstrations, e.g., speed and kilometres driven. Another example is data from relevant actors on how the measures affect efficiency, for example processing time on the border crossing, or how much labour are needed for the remote control of some of the vehicles relative to the labour of a driver. Some of the data will also be derived based on either one or two of the abovementioned sources, as well as input from literature or other sources. There are cases where parts of the operational data are confidential, so the analyst may aggregate or truncate the input data, and possibly also the results/KPIs.

To assess the impact on operational activities on a system level, the choice of scope is as described in Section 4.3.1. Option B will yield an approach to a system level impact, where we combine the various UCs and estimate how the operational activities with the demonstration vehicles differ from a baseline vehicle. On the UC level, the variables of interest might differ according to the specifics of each UC, and we might not be able to estimate all the KPIs listed in the table of suggested indicators for operational activities in 3.4.4. Steps will be taken to ensure that we either have KPIs that stem directly (via some calculations) from the demonstration in the UC we study, or KPIs that are derived from either other relatable UCs, literature, or estimations. The KPIs will also be calculated for equivalent non-CCAM vehicles as a baseline for comparison.

To assess the overall impact on operational activities, we will add together the various KPIs and create an overall assessment of the impact in operational activities, as well as highlighting the effect on each sub-UC.

Socio-economic impact

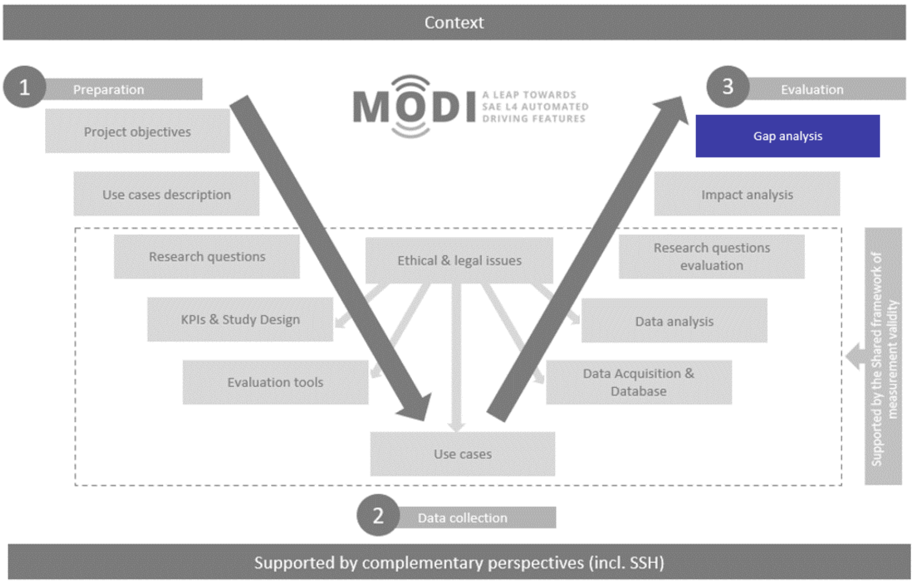
The socio-economic impact will be assessed using standard cost-benefit analysis frameworks and guidelines, such as the EU guide to CBA of investment projects [32] and the methods and principles in the LEVITATE project's methods for cost-benefit analysis to support decision making [33]. The input for the assessment will be data from the demonstrations, as described under the environmental impacts, output from sub-tasks like the environmental impact, safety and operational activities, and other variables like cost of infrastructure, repurposing of land, measures, etc. Transportation models and simulations will not be used. Assigning values and amounts to the latter will be conducted via interviews, literature review and calculations. The baseline results from the sub-task concerning environmental impact, safety impact and operational activities will be used to establish a relevant baseline case for this analysis.

However, there are questions and factors attributed to the analyses that are to be decided. For example, how the cost of physical and digital infrastructure needed for the operation of automated vehicles can be attributed to the few vehicles in the project. Another example is how to handle the fact that the L4-demonstration vehicles are produced on a small scale. This means that one will, most likely, not utilise the potential of economies of scale, and hence yield a higher production cost than if the vehicles were produced on a large scale. These two examples show that if we do not address these scaling-challenges, we could end up with too high investment costs, with could alter the final result in the analysis.

Another factor to address is how we use demonstration data to cover all the KPIs and variables we need to cover in the project. Some variables might only be collected from one UC, while it is necessary for the analysis of multiple UCs. One approach could be to assume that the result obtained in one UC is representative for similar use in the other UCs, while another approach would be to not include the "missing" variable in the analysis of the other UCs.

The demonstrations and other sub-tasks yield a range of data and results that will be used in the analysis. However, they only show the results from the observations, or demonstration runs. We cannot fully know, based on the demonstrations, how the results would have been with a larger quantity of vehicles or observations, how the results would have been if they were conducted in other, different geographical areas or conditions, how the adaptation to this new technology would be, how fast the technology would improve and hence how and when a higher level of autonomy would impact the variables we study. Therefore, the assessment of the socio-economic impacts will, like e.g., the assessment of environmental impacts, include sensitivity analyses to highlight the possible range of results. Furthermore, to not introduce the uncertainty concerning how future vehicles will behave, what they will cost, and their efficiency and impact on society, we will, as discussed in 4.3.1, limit the extrapolation and generalisation of data to one year.

4.4 Gap analysis



The gap analysis on technological and societal readiness will draw on results, findings, and contributions from all MODI activities throughout the project. This will involve not only the UCs, but also the CCAs, individual partners and relevant user groups representing different stakeholder perspectives on readiness status and requirements for CCAM to be a viable possibility in a real-life logistics operation. The analyses will focus on identifying of the current state of the CCAM systems, identifying where the status should be, and suggest how to close the gaps.

4.4.1 Methodological approaches for gap analyses

The gap analyses in MODI will be structured, planned, and performed along two main axes: technological and societal readiness. In order to utilise the wide range of expertise represented in the project, and to pursue a broad perspective on the issues covered by the gap analyses, the gap analyses for the two axes will be performed in close cooperation and coordination with the relevant project partners. This process will allow identification of relevant insights and requirements across all relevant stakeholders and actors and provide a comprehensive understanding of technological and societal prerequisites to enable a transition to CCAM for the logistics industry.

The gap analysis relies on input from all parts of the project where requirements for highly automated vehicles to be utilised in freight transport are identified and described. This will form the basis for the work related to research questions RQ2-TR2 and RQ2-SR2 "Where should the status be ...". One challenges in the gap analysis will be to structure the large range of topics and aspects in a coherent way, balancing varying levels of details and specification across the topics, and taking into account issues such as variation related to geography and roles in the ecosystem related to CCAM for logistics. Issues and structures already identified in early deliverables such as D1.1, D3.1 and D3.2 form a good starting point for this work.

The gap analysis will also coordinate with the impact analysis in several aspects: Results of the research questions RQ2-TR2 and RQ2-SR2 "Where should the status be ..." should be part of the basis for the impact assessments. To achieve a logic and coherent connection between the impact and gap analysis, these activities also needs to be aligned in terms of geographical scope, scenarios and other relevant system boundaries.

Identification of current status, remaining gaps and possible ways to bridge the gaps for the various technological and societal aspects and issues related to the identified requirements, will be based on reports and findings from activities related to development of UCs, as well as dialogue and surveys, targeting user groups, technology developers, authorities and stakeholders as integrated part of project activities such as CCA. The reports already available on requirements, to some degree also provide information about current status for issues relating to the identifies requirements. To get a full and consistent view of the current status and remaining gaps, will require coordination and collaboration, to make sure that updated information about current status is captured in the gap analysis, and that the relevant actors and stakeholders are involved in the assessment of necessary developments or actions to resolve the issues. This will be handled though engagement with those involved in the respective project activities.

Further detailing of the specifics of the gap analysis relies heavily on the requirements, status descriptions, challenges and barriers identified by the project partners during the course of the project. According to DoW, the gap analysis will formally start in M17. What is presented in this document regarding the gap analysis is thus a preliminary version.

Technological readiness

The gap analysis for technological readiness uses technical descriptions and specifications for CCAM KPI requirements for L4 driving and technical measurements from all UCs. Both technical requirements for vehicles and PDI will be defined for the UCs and for enabling CCAM vehicles in general, as an input to extending the future ODD. Examples of data that will be collected are connectivity and GNSS coverage or sufficient quality on road markings and signs for vehicles to read. For the UCs conducting demonstrations of CCAM vehicles, the requirements will be developed through literature review, workshops, technical and standards specifications, and vehicles and the infrastructure will be adjusted and developed for the demonstration purpose. The demonstrations will then serve to test the developments and measure the success rate or quality, e.g., package loss of C-ITS messages.

In addition, the process in defining and running the demonstrations will serve as background to identify further technical requirements to further improve the demo UC or extend it, e.g., to other routes or traffic/road challenges. For the UC CCAM, a large variety of technical measurements will be defined, based on identified important KPIs for the future CCAM vehicles such as connectivity, and measured for the route of Rotterdam – Oslo in the interest of assessing the readiness of the corridor. Here connectivity measures, video and lidar scanning, map data, weather and event detections are considered to be used.

The gap analysis of the technological readiness will also include functionality and aspects which are required but not necessarily directly related to the L4 technology. Following the project deliverable D3.1, the technological aspects can be analysed in accordance with the operational connectivity requirements of the project, i.e. based on the distinction between border crossing, customs, public roads and all other aspects of the project sub-UCs. Likewise, the gap analysis of the technological readiness can also follow the automation requirements from D3.2, which is divided in four distinct aspects (i.e. general safety, operational vehicle automation, operational integration, and vehicle sub-system). From D1.1, functional and non-functional solution requirements described by users and stakeholders, and requirements related to data and technology development will be included in the analysis of technological readiness. Additionally, D1.2 will also be considered for the safety and security aspects, particularly for cybersecurity.

Information about any additional functional requirements identified by logistics operators, authorities etc will provide input to the analyses of prerequisites for the technological systems and solutions for L4 driving to represent relevant and viable alternatives for the logistics industry, providing the basis for a scale impact.

Societal readiness

The gap analysis for societal readiness focuses on the prerequisites for significant societal impact, in particular the readiness of users/stakeholders, the businesses, and the authorities. D1.1 provides a structured description of user requirements, stakeholder requirements, functional and non-functional solution requirements, for a broad span of topics relating to e.g. rules and regulations, data, procedures, effects, commercial potential and value requirements. This will be a used as a starting point for the work on societal readiness and will be supplemented with information derived from CCAs and related activities.

To give an estimate of the readiness of society, the MODI project will include SSH disciplines. Documentation purposes, including collecting qualitative data, analysing the data, will be used to give recommendations. Qualitative data enables researchers to evaluate how the technology is implemented, how it is embedded in its context, and how and why it is working (or not working) [12]. Using such approaches will enable investigations of the roles of the users/stakeholders, businesses, and authorities in deploying CCAM technology into society, which again will be used to identify how ready society is for deployment.

The gap analysis for societal readiness also intends to expand on the TRL scale by assessing the current and desired state of societal areas such as market and business models, regulations and laws, acceptance and organisational aspects with a similar approach inspired by the methodology Balanced readiness level assessment [34], identifying corresponding scales for e.g. Market Readiness Level (MRL), Regulatory Readiness Level (RRL) Acceptance Readiness Level (ARL) and Organisational Readiness Level (ORL) for CCAM in logistics. This approach will be facilitated by surveys using structured questionnaires to relevant groups of actors, exploring levels of development for the respective societal areas. This work will be performed in close cooperation with the CCA activities. The intention is to provide a coherent view of the overall readiness for CCAM for logistics across a range of aspects, and how this develops during the course of the project.

Examples of data sources are interviews with stakeholders, observational data from CCAs, workshops and meetings, which can be supplemented with surveys for example. The CCAs in the UCs will be instrumental for collecting data. The CCA concept used in all UCs ensures that the same type of data is collected in all UCs, ensuring a coherent approach. The concept also allows the project to document participatory processes in the project, knowledge that often is of high importance to the project participants, but that remains tacit [14].

As described above, the basis for the gap analysis is multi-dimensional, and it can be structured in a variety of ways. This will be decided based on findings and input from project activities and partners. D1.1 on user requirements will be used, as well as other forthcoming activities in the project related to user perspectives. To ensure a consistent framing of the evaluation activities, definition of scope and system boundaries will be aligned across the impact analysis and the gap analysis.

5 Conclusions

The evaluation framework presented in this deliverable is based primarily on the FESTA methodology, a robust methodology tested and used by different research actions dealing with automated vehicles across Europe. Additionally, the FESTA methodology is supported by two complementary approaches, i.e., the Shared Framework or Measurement Validity and a Social Science and Humanities perspectives. As such, a plan of action is defined, ensuring the specification of every step of the project. This deliverable is planned to act as a "roadmap" for the conduction of the UCs which will collect the data needed, and for the evaluation of the project results.

The information presented in this document acts as an important input to the entire project, defining guidelines that will support both the preparation phase, the data collection, and the analyses of the results. This deliverable is thus particularly relevant for:

- Task 2.3 *Development and utilisation of CCAM data sharing platform*, as the requirements for the data/metadata formats are defined and presented, allowing a proper data collection and unified formats to be organised in the MODI data-sharing platform.
- Task 2.4 *Apply common evaluation framework on demonstrators*, as the conduction of the five UCs can be supported by the RQs and KPIs presented in this document to ensure a proper data collection.
- Task 2.5 *Impact Analysis* and Task 2.6 *Gap analysis*, as the evaluation of the project is strongly related to the areas in which the project has significant impact. These areas are defined as environment, safety, operational activities (incl. traffic), and socio-economic impact. In addition, the technological readiness and the societal readiness are also included to address the project objectives. The RQs and KPIs are thus derived from these six areas, allowing a unified and coordinated approach that will streamline the impact and gap analyses phase of the project.

Furthermore, the use of this evaluation framework as support for the conduction of the project, particularly the UCs, addresses the project objective 1 (i.e., the demonstration of the CCAM systems for UCs along a transport corridor and between hubs). The impact analyses (based on the defined four impact areas) address objective 4 (i.e., environmental, safety, traffic, and socio-economic impact assessments). The gap analysis of the technological readiness addresses objective 1 (i.e., related to technical improvements), and objective 2 (i.e., definition of recommendations for adaptations of supporting infrastructure, vehicle regulations and standards). The gap analysis of the societal readiness addresses objective 2 (e.g., related, but not limited to, behavioural law: national regulations in the participating states), and objective 3 (i.e., related to business models).

The preparation of this deliverable has been in coordination with the FAME project (as specified in the project documents) which also uses the FESTA methodology as basis. This approach is in line with the main objective of the MODI project, which seeks to accelerate the introduction of CCAM vehicles for logistics in Europe. It is thus reasonable to use FESTA, which is a common methodology that contributes to a shared understanding of the implementation challenges of automated transport systems in European roads. The MODI project joins efforts by following a common methodology, aiming to share the knowledge acquired in the project that can contribute to future research endeavours, and can thus accelerate the implementation of CCAM vehicles for logistics in Europe.

5.1 Recommendations

Considering that this document D2.2 is focused on the definition of an evaluation framework and is being delivered at an initial phase of the MODI project, this document cannot specify yet any technical, business, security, privacy, policy, or regulatory recommendation.

However, it is important to mention that this deliverable is considered a "living document", and as such, modifications might arise as the project progresses. This includes e.g., the RQs and KPIs which might be revised at a later stage. This is in accordance with the FESTA methodology which states that "*it is likely that there will be a need to sometimes go back and redo some steps*. *[…] For example, one may find that the measures and sensors available do not make it possible to investigate the hypotheses defined earlier, so adjustments to the hypotheses or performance indicators may be needed"*. As such, some points of action are recommended:

- The project should have continuous communication with the FAME project to ensure harmonisation of the evaluation methodology. This entails a revision of the EU-Common Evaluation Methodology (EU-CEM) document, to be produced by FAME in 2024.
- The UC leaders should evaluate the feasibility of data provision and the study design based on the guidelines provided by this document, to uncover possible deviations and/or challenges of what is proposed in this deliverable.
- If no deviation or challenge is encountered, the project data should be collected according to the guidelines and in constant communication with the relevant project partners.
- Likewise, the data should follow the metadata formats specified (and exemplified) in this document.
- The project data should be stored in the partner's own database and connected to the MODI data-sharing platform as soon as possible and not when approaching the end of the project. This will allow quality review at an early stage to ensure that the data collected across the UCs hold the same quality standard, thus ensuring comparability of the data sets and robust data analyses.
- Follow-up meetings should be held between all the UC leaders, impact and gap analyses teams and data sharing teams to revise possible challenges of the project that may require further modification of the RQs and KPIs.

Finally, some ethical and legal issues have been discussed throughout the document. This is a critical point for the project as the MODI team adheres to conduct the project in a correct manner and in fully respect of European and local laws, regulations, and ethical guidelines. As recommended by FESTA, if after preliminary testing of the vehicles, technological objects or study design, some ethical and legal issues arise that cannot be solved in a proper manner, rethinking of scenarios or renouncing of specific testing choices should be considered. If such case appears, this should always be done under continuous communication and coordination with the partners involved in the specific task/WP, the project coordinator and the MODI's Executive Board.

6 References

[1] FOT-NET Data, 'FESTA Handbook, version 8', Updated and maintained by FOT-Net, CARTRE and ARCADE EU Coordination and Support Actions., 2021. Accessed: Feb. 22, 2023. [Online]. Available: https://www.connectedautomateddriving.eu/methodology/festa/

[2] S. Innamaa, Y. Barnard, T. Geissler, I. Wilmink, and G. Harrison, 'Developing a common evaluation methodology for CCAM', presented at the 15th ITS European Congress, Lisbon, Portugal, 2023.

[3] N. Morazzo and L. Lirosi, 'Opportunities for Researchers from the Social Sciences and Humanities (SSH) in Horizon Europe. Analysis of SSH-relevant Topics in Work Programme 2023-24', Net4Society, 2023. Accessed: Sep. 27, 2023. [Online]. Available: https://horizoneuropencpportal.eu/sites/default/files/2023-02/ssh-opportunities_2023-24_final_for-publication.pdf

[4] J. Waltermann and S. Henkel, 'Public discourse on automated vehicles in online discussion forums: A social constructionist perspective.', *Transportation Research Interdisciplinary Perspectives*, vol. 17, no. 100743, 2023, doi: https://doi.org/10.1016/j.trip.2022.100743.

[5] T. Cohen *et al.*, 'A constructive role for social science in the development of automated vehicles', *Transportation Research Interdisciplinary Perspectives*, vol. 6, no. 100133, 2020, doi: https://doi.org/10.1016/j.trip.2020.100133.

[6] L.-E. Lervåg, 'Evaluering av intelligente transportsystemer. Utvikling av evalueringsmetodikk basert på tiltakets programteori.', PhD Thesis, Norwegian University of Science and Technology, Trondheim, Norway, 2021.

[7] R. M. Gandia *et al.*, 'Autonomous vehicles: Scientometric and bibliometric review.', *Transport Reviews*, vol. 31, no. 1, pp. 9–28, 2019, doi: https://doi.org/10.1080/01441647.2018.1518937.

[8] D. Milakis and S. Müller, 'The societal dimention of the automated vehicles transition: Towards a research agenda.', *Cities*, vol. 113, 2021, doi: https://doi.org/10.1016/j.cities.2021.103144.

[9] M. Ryghaug *et al.*, 'A Social Sciences and Humanities research agenda for transport and mobility in Europe: key themes and 100 research questions.', *Transport Reviews*, vol. 43, no. 4, pp. 1–25, 2023, doi: https://doi.org/10.1080/01441647.2023.2167887.

[10] CCAM European Partnership, 'SRIA: Strategic Research and Innovation Agenda 2021-2027', v1.4, 2022. Accessed: Sep. 27, 2023. [Online]. Available: https://www.ccam.eu/wp-content/uploads/2022/05/CCAM_SRIA-report_web.pdf

[11] D. Bissell, T. Birtchnell, A. Elliott, and E. L. Hsu, 'Autonomous automobilities: The social impacts of driverless vehicles.', *Current Sociology*, vol. 68, no. 1, pp. 116–134, 2020, doi: https://doi.org/10.1177/0011392118816743.

[12] G. F. Moore *et al.*, 'Process evaluation of complex interventions: Medical Research Council guidance.', *Research Methods & Reporting*, vol. BMJ 215;350:h1258, 2015.

[13] C. Carroll, M. Patterson, S. Wood, A. Booth, J. Rick, and S. Balain, 'A conceptual framework for implementation fidelity.', *Implementation Science*, vol. 2, no. 40, 2007.

[14] K. U. Koskinen, 'Evaluation of tacit knowledge utilization in work units.', *Journal of Knowledge Management*, vol. 7, no. 5, pp. 67–81, 2003, doi: https://doi.org/10.1108/13673270310505395.

[15] E. McGill, D. Marks, V. Er, T. Penney, M. Petticrew, and M. Egan, 'Qualitative process evaluation from a complex systems perspective: A systematic review and framework for public health evaluators.', *PLoS Medicine*, vol. 17, 2020, doi: https://doi.org/10.1371/journal.pmed.1003368.

[16] J. A. Bouffard, F. S. Taxmann, and R. Silvermann, 'Improving process evaluations of correctional programs by using a comprehensive evaluation methodology.', *Evaluation and Program Planning*, vol. 26, pp. 149–161, 2003, doi: 10.1016/S0149-7189(03)00010-7.

[17] T. W. Harachi, R. D. Abbott, R. F. Catalano, K. P. Haggerty, and C. B. Fleming, 'Opening the Black Box: Using Process Evaluation Measures to Asess Implementation and Theory Building.', *American Journal of Community Psychology*, vol. 27, no. 5, pp. 711–731, 1999.

[18] L. Gebhardt, 'Understanding different car users as starting point for future mobility concepts – A co-creation approach.', *Transportation Research Interdisciplinary Perspectives*, vol. 12, 2021, doi: https://doi.org/10.1016/j.trip.2021.100485.

[19] R. Adcock and D. Collier, 'Measurement Validity: A Shared Standard for Qualitative and Quantitative Research', *The American Political Science Review*, vol. 95, no. 3, pp. 529–546, 2001, doi: https://doi.org/10.1017/S0003055401003100.

[20] T. A. Dingus *et al.*, 'The 100-Car Naturalistic Driving Study, Phase II – Results of the 100-Car Field Experiment.', Virginia Tech Transportation Institute, Blacksburg, VA, NHTSA DOT HS 810 593, 2006. [Online]. Available: https://www.nhtsa.gov/sites/nhtsa.gov/files/100carmain.pdf
[21] F. Sagberg *et al.*, 'Recommendations for a Large-scale European Naturalistic Driving Observation Study. PROLOGUE Deliverable D4.1.' 2019. [Online]. Available: https://hdl.handle.net/2134/9390
[22] L. Fraade-Blanar, M. S. Blumenthal, J. M. Anderson, and N. Kalra, *Measuring Automated Vehicle Safety. Forging a Framework.* Santa Monica, CA: RAND Corporation, 2018. [Online]. Available: https://doi.org/10.7249/RR2662
[23] European Commission, 'Mobility & Transport – Road Safety: Road classification.' 2023. Accessed: Mar. 22, 2023. [Online]. Available: https://road-safety.transport.ec.europa.eu/statistics-and-analysis/statistics-and-analysis-archive/roads/road-classification_en
[24] FOT-NET Data and CARTRE Support Actions, 'Data Sharing Framework, version 1.1'. 2019. Accessed: Apr. 18, 2023. [Online]. Available: https://www.connectedautomateddriving.eu/data-sharing/methodology-data-sharing-framework/
[25] M. D. Wilkinson, M. Dumontier, J. Aalbersberg, and et al., 'The FAIR Guiding Principles for scientific data management and stewardship.', *Scientific Data*, vol. 3, no. Article nr. 160018, 2016, doi: https://doi.org/10.1038/sdata.2016.18.
[26] J. E. Sieber, *Planning Ethically Responsible Research—A guide for Students and Internal ReviewBoards.* Thousand Oaks, CA, USA: Sage Publicationa, 1992.
[27] J. H. Gawron, G. A. Keoleian, R. D. De Kleine, T. J. Wallington, and H. C. Kim, 'Life Cycle Assessment of Connected and Automated Vehicles: Sensing and Computing Subsystem and Vehicle Level Effects.', *Environmental Science & Technology*, vol. 52, no. 5, pp. 3249–3256, 2018, doi: https://doi.org/10.1021/acs.est.7b04576.
[28] P. Kopelias, E. Demiridi, K. Vogiatzis, A. Skabardonis, and V. Zafiropoulou, 'Connected & autonomous vehicles – Environmental impacts – A review.', *Science of the Total Environment*, vol. 712, no. 135237, 2020, doi: https://doi.org/10.1016/j.scitotenv.2019.135237.
[29] Ó. Silva, R. Cordera, E. González-González, and S. Nogués, 'Environmental impacts of autonomous vehicles: A review of the scientific literature.', *Science of the Total Environment*, vol. 830, no. 154615, 2022, doi: https://doi.org/10.1016/j.scitotenv.2022.154615.
[30] B. Sen, M. Kucukvar, N. C. Onat, and O. Tatari, 'Life cycle sustainability assessment of autonomous heavy-duty trucks.', *Journal of Industrial Ecology*, vol. 24, no. 1, pp. 149–164, 2020, doi: https://doi.org/10.1111/jiec.12964.
[31] C. Mutzenich, S. Durant, S. Helman, and P. Dalton, 'Situation awareness in remote operators of autonomous vehicles: Developing a taxonomy of situation awareness in video-relays of driving scenes.', *Frontiers in Psychology*, vol. 12, 2021, doi: https://doi.org/10.3389/fpsyg.2021.727500.
[32] D. Sartori *et al.*, 'Guide to cost-benefit analysis of investment projects. Economic appraisal module for Cohesion Policy 2014-2020', Directorate-General for Regional and Urban Policy, European Commission, Brussels, Belgium, 2014. [Online]. Available: https://www.iwlearn.net/resolveuid/719db343-4025-45dc-9e6f-541a2d43e482
[33] K. J. L. Hartveit and K. Veisten, 'Methods for cost-benefit analysis to support decision making.', Deliverable D3.4 of the H2020 project LEVITATE, 2022. [Online]. Available: https://levitate-project.eu/wp-content/uploads/2022/05/Levitate-D3.4-Methods-for-cost-benefit-analysis-to-support-decision-making.pdf
[34] J. Vik, A. M. Melås, E. P. Stræte, and R. A. Søraa, 'Balanced readiness level assessment (BRLa): A tool for exploring new and emerging technologies.', *Technological Forecasting and Social Change*, vol. 169, no. 120854, 2021, doi: https://doi.org/10.1016/j.techfore.2021.120854.

7 Appendix I: Data format yml suggestion – Example from a Norwegian Research Project


```
# This metadata format is based on the FOT-Net Data Sharing Framework (DSF).
# The DSF can be consulted if anything is unclear; each section in the format is directly
# or indirectly based on a section in the DSF document.
# https://www.connectedautomateddriving.eu/wp-content/uploads/2021/09/Data-Sharing-Framework-v1.1-final.pdf

# The summary should contain a thorough description of the study design and execution.
# The description must be complete and self-contained, but can contain links
# to images and further information (but keep in mind that the description
# must make sense even if those links should stop working.)
# Multiline strings can be written by starting the value with a pipe symbol (|).
Summary:

  why_was_it_collected: |
    To test if geo-fence zones with varying pricing could change the driving pattern
    of a group of test persons.

  How_was_the_collection_executed: |
    Volunteers were recruited in the Trondheim area. Their vehicles got an OBU that
    recorded their GNSS position and speed every second, as well as displaying a
    map with the various geo-fence zones and their pricing.

  Objectives: |
    Learn how road user charging together with geo-fencing was accepted by participants
    and investigate the readiness of the technology

  research_questions: |
    Would there be a change in behaviour as a result of the system? Is GNSS based road
    user charging practically possible for personal vehicles from an OBU perspective?
    Is there acceptance for such a solution?

  Experimental_plan: |
    The experiment was conducted for approximately two months, with different start ups
    and endings for all participants over a monthly period. In addition one pre-survey
    and one post-survey was conducted to capture 71cceptance data (not in this data set).
    The first two weeks, data was collected without showing the user any road charging or
    geo-fence information. These data were used as a baseline for driver behaviour.

  Sample_selection_criteria: |
    Drivers license required, living in or near the Trondheim area, and volunteering
    for the experiment.

  # A person that can be contacted for more information about this dataset.
  Contact_person: Petter Arnesen, petter.arnesen@sintef.no

  # Which entity produced this dataset
  producer_of_data: SINTEF

  # Which are the data are from. Can be an exact coordinate, a polygon, a town name, a country name, etc.
  # If providing coordinates/polygons, it must be encoded as WKT with an SRID of 4326.
  Data_area: Norway

  # Which type of data this is.
```

Must be one or more of:
survey, interviews, mobile network, itsg5, lane markings, signage, physical road infrastructure,
speed/acceleration, video, pictures, gnss, lidar, radar, weather, vehicle probe data, events, other.
You may add multiple data types if relevant, separated by a comma.
Data_type: GNSS, Vehicle probe data

Which of the use cases in MODI this dataset is related to.
Must be one of: UCNL, UCGE, UCSE, UCNO, UCCCAM, Other tasks
modi_use_case: UCNO

An approximate description of the size of this dataset
dataset_size: Approximately 1 135 000 000 data points.

A tiny sample of the dataset to show how it looks (if possible).
Dataset_example: |
0;1606311738.569;2020-11-25 13:42:18.569;00001234;SYSTEM_START;;
1;1606311738.751;2020-11-25
13:42:18.751;00001234;UPLOAD_SUCCESS;00001234_2020_11_25_14_41_31_csv_zip;
2;1606311740.075;2020-11-25
13:42:20.075;00001234;GPS;10.705565;59.433169;47.00;6.76;25.00;4;1;1.00;0.00;
3;1606311740.163;2020-11-25
13:42:20.163;00001234;GPS;10.705570;59.433191;47.00;6.76;25.00;4;1;1.00;0.00;
4;1606311740.269;2020-11-25
13:42:20.269;00001234;GPS;10.705576;59.433214;47.00;6.76;25.00;4;1;1.00;0.00;

5.3.3 Administrative metadata
"Administrative metadata are collected for the effective operation and management of data
storage and catalogues. This administrative information, covering various topics, is stored
along with the datasets. From a FOT data re-use perspective, the key role of administrative
metadata is to cover access conditions, rights, ownership and constraints."
Administrative:

The version number of this dataset, used to keep track of different
versions if it is uploaded multiple times.
The version number can be numeric, date-based, or anything else, but
it must be easy to see which version is newer without further knowledge.
Version_number: 1

The date this dataset was uploaded. Must be in ISO 8601 format (YYYY-MM-DD).
Archiving_date: 2023-06-02

A unique identifier for this dataset. This will be used to identify this and
future updates in the metadata database, and must never be changed after the
dataset has been uploaded for the first time.
Unique_dataset_id: geoflow_raw_data

Who has rights to use this dataset?
Rights: Limited rights, see Access for contact info

Does the dataset have a specific license for usage?
License: MIT

Who can access the dataset?
Access: limited, contact petter.arnesen@sintef.no

Any constraints in usage of the dataset?
Constraints: |

```
    Can not be presented anywhere in raw form, only after enough aggregation to anonymize
    each driver sufficiently.

  # Can the dataset be used for free, or does usage incur any costs/billing for the user?
  Billing: The dataset can be used without cost as long as access and constraints are agreed upon.

  # When the data set will stop existing (for example due to privacy regulations).
  # Must be in ISO 8601 format (YYYY-MM-DD).
  Data_end_of_life: 2023-10-01

  # A more detailed description of the various processes of the data collection,
  # for example the methods/tools used to collect the data, filtering, post-processing,
  # storage file structure, etc.
  # This should include information about relevant conditions during the data collection
  # (for example weather, climate, time of day, etc).
  # Each key under "processes" can be custom made, and there can be as many as is
  # necessary. The proposed keys are just examples.
  Processes:
    collection_preparation: |
      Volunteers were recruited through targeted social media ads and e-mails to relevant
      people or groups. Each volunteer got an OBU mounted in their vehicle.
    Collection: |
      The OBUs mounted in the volunteer's vehicles collected data from the first day they
      were operational. For the first two weeks, the OBUs collected data silently, without
      giving the driver any information at all. These data are used as a baseline for driver
      behaviour.
      For the next 6 weeks, the OBUs HMI interface was active, and drivers were informed about
      road pricing zones and costs.
    Anonymization: |
      All data are identified with the serial number of the OBU, and has no direct connection
      to the drivers. No further anonymization has been performed.
    Processing: |
      Data was collected by the OBUs in each vehicle, and stored locally. Each time the unit
      was turned on, it would upload previously collected data.
    Filtering: |
      This data set is the raw data, and has no filters.
    Aggregation: |
      This data set is the raw data, and has no aggregations.

# 5.3.2 Structural metadata
# "Structural metadata are used to describe how the data are structured in relation to other
# data. Data are organized into a system (e.g., a database and/or file system), a structure or
# database schema and a data content format. The aim of structural metadata is to facilitate
# the initial phase of data re-use by providing the necessary documentation about how the data
# is organized. The description should include the file system, the file structure and how to
# interpret the contents of a data container. All components of the dataset need to be
# described."
Structural:

  summary: |
    Each trip was recorded as a separate CSV file. Rows in the CSV file may not always contain
    all columns, the event_type column tells which other columns can be expected for that row.

  # File format. Please include attributes such as delimiter for CSV, decimal separator,
  # thousand separator (if any), and any other properties that is relevant for parsing the data.
  File_format: csv with ';' as delimiter, ',' as decimal separator.
```

```
  # Please describe the storage structure of the data. If it consists of flat files, the folder
  # structure and file naming can be relevant. If it is a database, a description of the relevant
  # tables, indices, triggers and views is important.
  File_structure: flat files in a single folder, file names consists of [OBU ID]_[date-time start of trip].csv

  # Which tools can be used to read the data. Especially important for non-standard formats.
  Required_tools: notepad, various CSV parsing libraries

  # If the files were made using a specific tool, the tool name and version may be relevant
  # for reading the data.
  Tool_versions: N/A

  # Additional keys and values can be added here if this is a non-standard format that requires
  # a more detailed explanation.

# 5.3.1 Descriptive metadata
# "Descriptive metadata shall include detailed information needed to understand each part of a
# dataset. The purpose is to describe the dataset and build trust in it—by providing not only the
# characteristics of each measure or component, but also information about how the data were
# generated and collected."
Descriptive:

  # The descriptions can vary by data type.
  # For each data field in your dataset, please fill out all relevant parameters from section
  # 5.3.1 of the DSF, and enter the attributes using the "Data description item" in lower-case
  # as the key. The following list lists the most relevant attributes from the tables, see
  # tables 3 to 9 in the DSF for full explanations.

  # - description
  # - data_precision
  # - unit
  # - sample_rate
  # - filter
  # - origin
  # - bias
  # - type
  # - definition
  # - range
  # - error_codes
  # - quality
  # - offset
  # - enumeration_specification
  # - availability
  # - srid (for coordinates)
  # - time_zone (for time stamps)
  # - time_format (for time stamps)

  # Please note the following additions to the DSF:
  # - When dealing with coordinates, the SRID must be specified with the srid key.
  # - When dealing with times, the time zone must be specified with the timezone key.
  # - When dealing with dates or times, the format must be specified with the format key.

  Fields:

    sequence_number:
      description: The sequence number of this point within the file.
```

Data_precision: N/A
unit: N/A
sample_rate: 1hz
filter: N/A
origin: N/A
type: integer
range: 0-n
error_codes: N/A
quality: N/A
offset: N/A
enumeration_specification: N/A
availability: Unknown

timestamp_unix:
description: POSIX time, with decimals. Number of seconds since 1970.

Timezone: UTC
data_precision: 10
unit: s
sample_rate: 1hz
filter: N/A
origin: From the GNSS receiver in the OBU.
Type: float
range: 1686120000-1686140000
error_codes: N/A
quality: High
offset: N/A
enumeration_specification: N/A
availability: Unknown

timestamp_human:
description: timestamp_unix converted to a human readable timestamp in format yyyy-mm-dd hh:mm:ss.fff UTC.

Timezone: UTC
data_precision: 10
unit: s
sample_rate: 1hz
filter: N/A
origin: From the GNSS receiver in the OBU.
Type: string
range: 2022-02-07 – 2022-05-18
error_codes: N/A
quality: High
offset: N/A
enumeration_specification: N/A
availability: Unknown

obu_identifier:
description: The unique identifier of the OBU

data_precision: N/A
unit: N/A
sample_rate: N/A
filter: N/A
origin: Serial number from the OBU.
Type: string

```
   range: N/A
   error_codes: N/A
   quality: N/A
   offset: N/A
   enumeration_specification: N/A
   availability: Unknown

  event_type:
   description: |
    Record type for this row, describes the remaining data fields in the record.
    If SYSTEM_START or SYSTEM_STOP, no other columns will be present.
    If GPS, the GPS related columns will be present.
    If HMI, the hmi_type column will be present.
    If UPLOAD_FAILED or UPLOAD_SUCCESS, the info column will be present.

   Data_precision: N/A
   unit: N/A
   sample_rate: N/A
   filter: N/A
   origin: The data collection app on the OBU.
   Type: string
   range: N/A
   error_codes: N/A
   quality: N/A
   offset: N/A
   enumeration_specification: |
    SYSTEM_START
    SYSTEM_STOP
    GPS
    HMI,
    UPLOAD_SUCCESS
    UPLOAD_FAILED
   availability: Unknown

  longitude:
   description: The GNSS longitude from the GNSS receiver in the OBU (WGS84)

   srid: 4326
   data_precision: 8
   unit: degrees
   sample_rate: 1hz
   filter: N/A
   origin: The GNSS receiver in the OBU
   type: float
   range: 0-180
   error_codes: Repeated value from the previous row means that there was no new position for this row.
   Quality: Usually within 3 meters, described by the hdop field for each row.
   Offset: N/A
   enumeration_specification: N/A
   availability: Unknown

  latitude:
   description: The GNSS latitude from the GNSS receiver in the OBU (WGS84)

   srid: 4326
   data_precision: 8
   unit: degrees
```

sample_rate: 1hz
filter: N/A
origin: The GNSS receiver in the OBU
type: float
range: 0-180
error_codes: Repeated value from the previous row means that there was no new position for this row.
Quality: Usually within 3 meters, described by the hdop field for each row.
Offset: N/A
enumeration_specification: N/A
availability: Unknown

altitude:
description: The GNSS altitude from the GNSS receiver in the OBU (WGS84)

srid: 4326
data_precision: 8
unit: meters
sample_rate: 1hz
filter: N/A
origin: The GNSS receiver in the OBU
type: float
range: -40-300
error_codes: Repeated value from the previous row means that there was no new position for this row.
Quality: N/A
offset: N/A
enumeration_specification: N/A
availability: Unknown

bearing:
description: The GNSS bearing from the GNSS receiver in the OBU. Bearing 0 is straight North.

Data_precision: 8
unit: radians
sample_rate: 1hz
filter: N/A
origin: The GNSS receiver in the OBU
type: float
range: 0-2*PI
error_codes: N/A
quality: N/A
offset: N/A
enumeration_specification: N/A
availability: Unknown

speed:
description: Speed collected from the GNSS receiver of the OBU.

One of: time-history, time-segment, location, pi, video-annotation, self-reported, aggregated.
Corresponds to each of the tables in 5.3.1.
type: time-history

data_precision: 3
unit: km/h
sample_rate: 1hz
filter: N/A
origin: The GNSS receiver in the OBU
type: float

range: 0-130
error_codes: Empty cells are nulls. There are no known error codes in the data.
Quality: Unknown
offset: N/A
enumeration_specification: N/A
availability: Unknown

n_sats:
description: The number of GNSS satellites used in the position calculation.

Data_precision: 2
unit: N/A
sample_rate: 1hz
filter: N/A
origin: The GNSS receiver in the OBU
type: integer
range: 0-n
error_codes: N/A
quality: N/A
offset: N/A
enumeration_specification: N/A
availability: Unknown

fix_type:
description: The GNSS fix type.

Data_precision: 2
unit: N/A
sample_rate: 1hz
filter: N/A
origin: The GNSS receiver in the OBU
type: integer
range: 0-4
error_codes: N/A
quality: N/A
offset: N/A
enumeration_specification: |
GPS_TYPE_AUTONOMOUS = 0;
GPS_TYPE_EGNOS = 1;
GPS_TYPE_KINEMATIC_FLOAT = 2;
GPS_TYPE_KINEMATIC_FIXED = 3;
GPS_TYPE_DEAD_RECKONING_ONLY = 4;
availability: Unknown

hdop:
description: Horizontal dilution of precision from the GNSS receiver in the OBU.

Data_precision: 3
unit: N/A
sample_rate: 1hz
filter: N/A
origin: The GNSS receiver in the OBU
type: float
range: 0-500
error_codes: N/A
quality: N/A
offset: N/A

enumeration_specification: N/A
availability: Unknown

estimated_error:
description: The estimated horizontal error in the positions.

Data_precision: 5
unit: meters
sample_rate: 1hz
filter: N/A
origin: The GNSS receiver in the OBU
type: float
range: 0-500
error_codes: N/A
quality: N/A
offset: N/A
enumeration_specification: N/A
availability: Unknown

hmi_type:
description: Which information is shown in the human-machine interface.

Data_precision: N/A
unit: N/A
sample_rate: 1hz
filter: N/A
origin: The OBU
type: string
range: N/A
error_codes: N/A
quality: N/A
offset: N/A
enumeration_specification: |
MAP
TEXT
AUDIO
NONE
availability: Unknown

info:
description: Additional text information

data_precision: N/A
unit: N/A
sample_rate: 1hz
filter: N/A
origin: The OBU
type: string
range: N/A
error_codes: N/A
quality: N/A
offset: N/A
enumeration_specification: N/A
availability: Unknown

8 Appendix II: Descriptions of categories for data and metadata, and data acquisition methods

The following sub-sections present a brief description of the different categories of data and metadata, and different methods for data acquisition, based on the FESTA methodology. For a more comprehensive definition of the different data aspects, the reader is encouraged to see the FESTA handbook [1].

Data categories

- Context data: Indicate all the circumstances that surrounds a setting for a research study. This information is needed to fully understand the conditions in which the data was collected and to properly derive to conclusions. The context data can be directly collected (e.g., simultaneously with other type of data, such as weather sensors) or retrieved from external data sources (e.g., access to open weather data sources). It can also be already existent (e.g., regular and natural traffic conditions) or generated for the experimental aim (e.g., simulated and/or modified traffic conditions). Context data refer also to background information of, for example, people demographics (e.g., age, gender) and subjective attitudes towards a specific product, function, or service (e.g., people's subjective evaluations). As such, this data category can be used for either quantitative or qualitative data.
- Acquired and/or derived data: Acquired data are all the data that was purposely collected to directly address a study research question, i.e., for analyses purposes. Derived data are all data that have been under a transformation process from raw data to more usable data needed to evaluate, for example, KPIs. As an example within the MODI project, derived data would be the combination of the data for "perceived safety scale" and the data for "types of encounters with CCAM" to evaluate the indicator "Safe behaviour of users of confined area (occupational safety)" (see KPI-S02, Section 3.4.3). Acquired and/or derived data include data (not limited to):
  - Time-history data (measurements over time)
  - In-vehicle measures (such as vehicle dynamics, in-vehicle systems state, vehicle positioning and media (audio and/or video data))
  - Human behaviour measures
  - Roadside measures
  - Experimental conditions (as external factors that might impact people's behaviours)
  - Time and location segments (measurement during a delimited period of time)
- Aggregated data: Indicate that different kinds of reduced data (e.g., at a location segment) are used together to perform a smaller, more usable data analysis and interpretation.

Although derived data and aggregated data follow a similar principle (i.e., both combine different types of data), aggregated data is sought to be used for smaller analyses (e.g., one isolated situation), whereas derived data is sought to be used for larger analyses (e.g., to apply results to the whole project).

Metadata categories

- Descriptive metadata: Respond to the questions: *What is in the dataset?* And *How was each data item collected or calculated?* Descriptive data indicate the content of a dataset, by giving detailed information needed to understand the data. As such, it is probably the most useful type of metadata for data analysis. The descriptive metadata are used to describe context data, acquired or derived data, and aggregated data. For example, the metadata for some location segments in MODI (e.g., urban area in an UC) can indicate the measures needed to collect the data, and characteristics related to the location segment (e.g., number of exits or roundabouts, number of vehicles passing at a specific time and location segment, and/or average speed for such vehicles). The KPIs related to specific datasets should also be defined as descriptive metadata.

- Structural metadata: Respond to the question: *How is the dataset organised?* As the name indicates, structural metadata describes the structure of a data as a database schema design. For example, how data is organised in a dataset. This comprehends the definition of a database in which the system format is outlined, i.e., the data containers and formats. The database design, data container and content description are also part of the structural metadata. The storage and deposition of data for the MODI project is described in the project document D7.2 Data Management Plan.
- Administrative metadata: Respond to the question: *How is the dataset accessed and maintained?* The administrative metadata indicate the administrative information needed for the proper management of data storage, including topics such as access conditions, ownership, and preservation. The administrative metadata should be stored together with the datasets. Examples of types of administrative metadata are (but not limited to): version number, archiving date, access and rights information, contractual agreements, periodic backups, and end of data life. The creation of Digital Object Identifier (DOI) not only supports the creation for references and citations when the dataset has been used in a publication, but it also supports data management. For the MODI project, the creation of DOI will be used as a standard identification mechanism for the project's metadata (see D7.2 Data Management Plan).
- Execution documentation: Respond to the questions: *Why was the dataset collected?* This type of metadata provides an overall description of how the study was carried out, i.e., the study design, including the objectives and research questions. This is important for data analysis, as the documentation can provide information to project partners who were not a part of the data collection to properly interpret the data results, thus understanding how the data answer to specific research questions. This type of metadata also responds to the question: *How was the data collection executed?* The execution of a study should thus be documented, for example in a similar way as when it is reported in a research article. This means that the description of the study procedure should include e.g., RQs, experimental design/test plan, stimuli, monitoring equipment, study participants, description of test site/environment, sample selection criteria, and duration.

Data acquisition methods

- Background data acquisition: Includes details about drivers/users (e.g., demographic information, driving competence, specific task competences). The data can be collected using interviews or questionnaires, and due to its nature, the data usually need to be protected (due to privacy issues). As such, only parts of the data might be needed to be stored in the project's database.
- In-vehicle Data Acquisition Systems (In-vehicle DAS): Include systems (sensors) integrated in vehicles and systems attached or mounted on the vehicles, such as video cameras or data storage tools. The FESTA Handbook considers in-vehicle DAS as one acquisition method and "nomadic devices" as another acquisition method. Nomadic devices are defined as external objects purchased from the marked and installed in a vehicle. As such, these can be considered similar to the systems attached on the vehicles, as defined for the in-vehicle DAS. To avoid confusion between the terms, the nomadic devices are considered included in this category of in-vehicle DAS.
- Subjective data acquisition: Indicates all the data collected from study participants about for instance attitudes, personal evaluations, or opinions. Such data can thus be collected using interviews, questionnaires and/or focus groups, and usually need to be protected due to privacy issues.
- Real-time observations: Indicate all the data collected by one main observer either in real time or after an event has passed, e.g., using a recorded video. The data can be quantitative or qualitative (e.g., KPI-S06 which requires the observed behaviour of other road users). In both cases, i.e., either the data is quantitative or qualitative, the data should be saved as a digital format in the project's database.
- Infrastructure data acquisition: Includes devices or sensors that are usually placed close to a road (e.g., on a road in which the study will take place). On-road devices or sensors are often used to collect data about the weather conditions that could be complementary to the data collected from in-vehicles

sensors. In such cases, the FESTA Handbook recommends synchronising the data collection from both in-vehicle DAS and infrastructure data acquisition systems (e.g., using GPS time as recommended by FESTA).

9 Appendix III: Technological and physical objects needed as defined by the UCs

Use Case	Technological and physical objects needed
UC NL	• Add-on devices fitted to the trucks for communication and positioning. • Several communication units installed at the APM terminal. • Systems for detecting the position of trucks. • Manual driven non-connected trucks. • Positioning system at the terminal to support driving tasks. • Supporting system to support positioning of trailer when reversing. • Existing infrastructure. • Truck automation technology.
UC GE	• Vehicle fitted with L4 technology/CCAM connection • CCAM vehicle (VOLVO, DAF) • Positioning services with Global Navigation Satellite System (GNSS) correction • HD-maps and/or point clouds for navigation purposes (FHH-(LSBG&LGV) • C-ITS for V2X communication infrastructure • Services (FHH-(LSBG & HHVA & ITS Mobility)
UC SE	• CCAM vehicle and remote interface • On-board vehicle equipment • Gate access control solution (system opening the gate) • Mobile networks • Cloud systems • Web-services • Power grid provider • Remote interface • ERP-system • Connectivity systems • C-ITS solutions • Physical parking and gate areas • Referenced objects for CCAM vehicles (e.g., concrete blocks, light poles) • Physical objects (not exhaustive): Railway barriers/physical barriers, shark teeth, yield signs, line markings, traffic lights. • To be defined: Technical solution for automated charging, automated charging solution with its respective station, and solution for automated loading and unloading
UC NO	• CCAM vehicle • Remote interface • Positioning service with GNSS correction (e.g., SWEPOS/CPOS) • High density maps and/or point clouds for simulation / navigation purposes. • Cellular communication on both sides of the border • AutoPASS tag (needed for automated tolling on Norwegian roads) • C-ITS for V2X communication (e.g., traffic light SpaT/MAP messages) • C-ITS for V2X positioning (e.g., in GNSS denied areas as tunnels) • Automated gate at port (to access the port area) • Sea drone (to transport goods over the fjord) • Automated terminal tractors (to move goods on the port area)¨ • Digital declaration of goods

UC CCAM	• CCAM vehicle in ghost mode • Measurements vehicles • Operational logistic vehicles for continuous measurement • Connectivity measurement kit • Event triggers for registrations of challenges • Light Detection and Ranging (lidar) / camera for object detection • RTK availability measurement kit • Map / HD map data and availability • Geometry and inventory map data for corridor • Measurement of availability of C-ITS messages • Calculation resources for evaluation • Other dynamic data sources for context of measurements including weather and traffic information