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MOVE2CCAM

Methods and tools for comprehensive impact assessment of the CCAM solutions for passengers and goods

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D1.3 CCAM impact analysis roadmap

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Acronyms and definitions

Acronyms	Definitions
CCAM	Cooperative, Connected, and Automated Mobility
KPI	Key Performance Indicator

1. Introduction

Cooperative, Connected, and Automated Mobility (CCAM) is a new frontier for mobility. It allows vehicles to communicate with each other, the infrastructure, and other users of the transport network. CCAM opens new possibilities for both passenger and freight transport and could contribute to more efficient, equitable, and sustainable mobility systems. However, the potential impacts of this radical change are still not well understood. There is little knowledge on the many possible inter-relationships between the impacts of CCAM in different domains (for example, mobility, economy, environment), as well as on how these inter-relationships evolve across time.

The MOVE2CCAM project (https://move2ccam.eu) is exploring these inter-related impacts, aiming at delivering methods and tools for systems-wide assessments of CCAM solutions. This exploration is done with input from the project "Satellites", i.e., citizens and organizations in eight European countries, who are invited to participate in a series of co-creation activities throughout the projects. Citizens represent diverse groups in society and organizations represent a range of stakeholders with interest in CCAM solutions. This ensures that the methods and tools developed in the project acknowledge the wide diversity of perceptions, needs, objectives across and within the eight countries in this project (Cyprus, France, Germany, Greece, the Netherlands, Poland, Spain, and the United Kingdom) and are potentially transferable to the rest of Europe.

The first stage of the project consisted of a review of existing knowledge (reported in Deliverable 1.1) and activities where the Satellites co-created CCAM use cases, scenarios, business models, and Key Performance Indicators (KPIs) (Deliverable 1.2). The next stage of the project will assess the impact of the use cases, business models, and scenarios, on eight domains (Mobility, Safety, Public Health, Economy, Environment, Land use, Network Efficiency, and Equity), considering their mutual-reinforcing relationships.

Deliverable 1.3. consolidates and assesses the results of the first stage of the project and provides, based on that assessment, a series of roadmaps for the second stage of the project. These roadmaps define the requirements for different approaches to assess the systems-wide impact of CCAM solutions. The roadmaps include, for each approach:

- The rationale for using that approach
- Data to be collected
- Data collection methods
- Analysis methods and expected outcomes
- Recruitment strategy and ethics consideration (where particularly pertinent)

This deliverable also provides a roadmap to guide the modelling work required for the development of the impact assessment tool.

The rest of this deliverable consists of four sections:

- Section 2 consolidates and assesses the results from the literature review (Section 2.1) and the co-creation activities with the Satellites (2.2)
- Section 3 provides roadmaps for the impact assessment of CCAM solutions, which will be conducted with six different approaches: qualitative assessment (Section 3.2), detailed case studies (3.3), trial of a real-world autonomous vehicle (3.4), virtual reality (3.5), large-scale assessment via a pan-European survey (3.6), and social and environmental lifecycle analysis (3.7). The overall approach to triangulate the data from these approaches is presented in Section 3.1.
- Section 4 provides a roadmap for the development of the systems-wide impact assessment tool, including the modelling framework (Section 4.1), KPIs (4.2), and data needed (4.3).

2. Consolidation and assessment of MOVE2CCAM work

2.1 Literature review results

2.1.1 Autonomous vehicles use cases and business models

Table 1 and Table 2 show the types of autonomous vehicles and respective use cases found in the literature. Some types of vehicles are autonomous versions of vehicles that exist now, while others are new (delivery bots, platooning pods). Passenger use cases cover a range of travel destinations and trip purposes but tend to focus on short distances in urban areas. Freight use cases cover a range of products and delivery sites.

Table 1: Autonomous vehicles

Medium	Transport sector	Vehicle types
Land	Passenger	Cars, buses, pods
	Freight	Vans, delivery bots, platooning pods
Water	Passenger	Ferries, cruise ships
	Freight	Barges
Air	Passenger	Unmanned aircraft
	Freight	Drones

Table 2: Autonomous vehicle use cases

Passenger transport	Freight transport
• Private use (household) • Shuttles to access other modes (to stations or parking areas) • Express services in urban areas • Tourist shuttles • “Last mile” transport (station to home/workplace) • Transport within a site (park, airport) • Emergencies (ambulance)	• Private use (company) • “Last mile” deliveries from/to depots to a final customer • Specific deliveries in small areas • Delivery to remote areas • Emergency deliveries (medical products) • Express delivery of high-value products • Transport within a site (factory, port, airport) • Delivery from/to ships in ports

Table 3 lists the reviewed business models. Most of these models are being tested in small-scale pilot schemes around the world but concentrated in only a few countries (in North America, Europe, and China), and almost always in cities.

The review found that these business models are still in the early phases of development and have been insufficiently reported in the literature, even when they have already been implemented in pilot schemes. Examples of business models with scarce information include car-sharing or ride-hailing services using autonomous vehicles, on-demand autonomous shuttle bus services, and autonomous freight trucks. Information exists mainly on the technology used but not on the costs of implementing and operating the schemes, or on revenue streams. Business models developed for conventional vehicles do not necessarily apply to autonomous vehicles due to the different cost structures. The problems most frequently mentioned in the literature that apply to most business models include insufficient availability of appropriate infrastructure (road conditions, digital infrastructure) and regulatory challenges.

Table 3: Domains of business models

Passenger transport	Freight transport
• Privately-owned vehicles • Ride-hailing services • On-demand shuttle bus service • Car-sharing services • Bus fleet replacement • Mobility as a Service • Integrated multi-modal services • Scheduled airport shuttles • Smart parking	• Freight trucks • Delivery robots • Drone delivery

The box below suggests directions for the MOVE2CCAM systems-wide impact assessment in the second stage of the project, based on the conclusions of the review of use cases and business models.

Directions for MOVE2CCAM systems-wide impact assessment

- Include both passenger and freight use cases in the impact assessment.
- Pay special attention to the economic and equity aspects related to business models involving: 1) passenger transport shared solutions; and 2) public transport or freight solutions that require large investments from transport providers.

2.1.2 Perceptions and needs

A systematic literature review was conducted on the large body of academic work analysing the perceptions of citizens and organizations regarding autonomous vehicles. The review found that citizens tend to perceive passenger autonomous vehicles as useful because they release travel time and some of the stress associated with driving. However, citizens also have some concerns, as illustrated in Figure 1 below. Cost is the most frequently mentioned concern. Other concerns are related to the fact that fully autonomous vehicles do not have a human driver. This raises questions about safety (although users of autonomous vehicles in trials tend to report feeling safe) and personal security (i.e., safety from harassment or unwanted behaviour from other passengers). Other concerns are related to the fact that autonomous vehicles are driven by a computer, which raises questions about privacy, cyber security, and legal responsibility. There is little literature on how some of these concerns affect people's intentions to use autonomous vehicles, especially personal security.

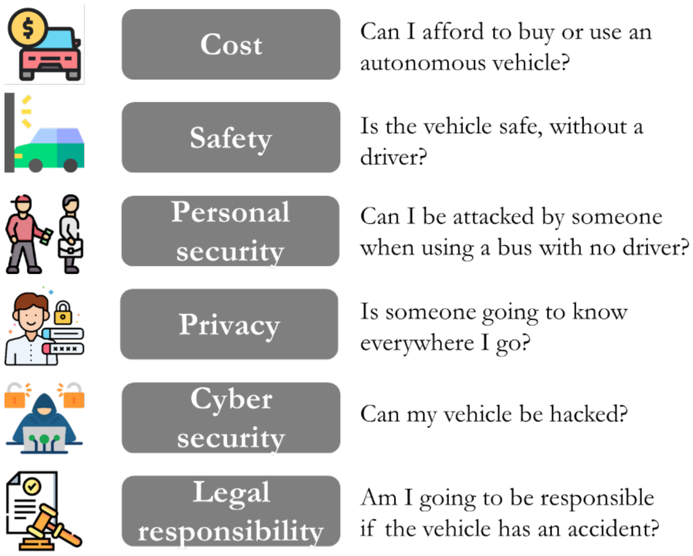

Figure 1: Main concerns with autonomous passenger vehicles

The review also found that parents with children are particularly concerned about personal security. Older people, and those with disabilities, tend to perceive autonomous vehicles as a potential enhancer of their mobility, but they also have additional concerns, such as the physical accessibility of the vehicles. In addition, there is much less evidence about perceptions and needs regarding autonomous freight distribution vehicles. Organisations have expressed concern with the cost-effectiveness of these vehicles, as well as the possible negative impact on employment. A few studies have analysed the case of autonomous airborne freight distribution, which has been identified by citizens as costly and with the potential to create congestion in air space.

Directions for MOVE2CCAM systems-wide impact assessment

- Assess the six main concerns found in the literature (Figure 1) and how they impact people's intentions to use autonomous vehicles
- Estimate willingness to pay for using different types of autonomous vehicles
- Pay special attention to personal security issues, a major gap in the literature: analyse reactions to possible public security issues in autonomous public transport vehicles and assess how personal security conditions the choice of (autonomous) travel mode.

2.1.3 Methods to collect and analyse autonomous vehicle user data

The project also reviewed methods to collect and analyse autonomous vehicle passenger user data. The usual methods of passenger data collection (i.e., surveys where users recollect their travel behaviour or state their perceptions, attitudes, and preferences) are insufficient in the case of autonomous vehicles. This is because most potential users have not yet experienced these vehicles and find it hard to imagine, understand, and assess the experience of using them. Solutions used in the literature include qualitative methods (focus groups, dialogues), general surveys, stated preference surveys, virtual reality, and the collection of physiological measures. Table 4 shows the main topics covered by these methods.

Table 4: Methods to collect and analyse autonomous vehicle user data

Method	The main topics analysed in the literature
Qualitative methods	Perceptions, attitudes, concerns, and intentions of citizens about passenger autonomous vehicles
Surveys	• Perceptions, attitudes, concerns, and intentions of citizens about passenger autonomous vehicles • Citizen views after using an autonomous vehicle (in trials or demonstration)

Stated preference surveys	Preferences towards attributes of passenger autonomous vehicles, including cost, time, and comfort
Virtual reality	Reactions to virtual trips in virtual autonomous vehicles
Collection of physiological measures	Reactions to real or virtual trips in autonomous vehicles

We conducted a systematic review on the use of two of these methods: virtual reality and the collection of physiological measures. Virtual reality studies involved participants using headsets showing a road, other vehicles, and the road surroundings. The interior of the vehicle was shown less often. Almost no studies showed participants engaging in in-vehicle activities while travelling. In some cases, the experiment used a motion simulator, to create the sensation that the virtual vehicle was moving.

Physiological measurement studies have measured heart rate, skin conductance, and electroencephalogram data (EEG), using sensors placed on fingers, headsets, or wearable devices, and analysed the data to capture mental states such as arousal, anxiety, discomfort, and cognitive workload.

Most of the studies found in the literature, analysed only the case of autonomous private cars, not shared vehicles, buses, or other types of public transport. In addition, most studies compared user reactions to fully autonomous vs. partially autonomous or conventional vehicles. Those who focused on fully autonomous vehicles found that the following factors were significant in determining user reactions: road and traffic conditions, types of messages provided by the vehicle to the passenger, vehicle interior configuration, driving style and events, time of day, and trip characteristics.

Both virtual reality and physiological measure collection methods have potential ethical issues, such as concerns about data privacy, apprehension or embarrassing related to using headsets, motion sickness, and possible negative reactions to some of the scenarios represented in virtual reality. However, most of the studies reviewed either do not mention these issues or give only perfunctory information about participants giving informed consent. The studies are also limited by the small samples used, and even more by using unbalanced samples, almost exclusively of younger participants (mostly students), and with a predominance of males.

Directions for MOVE2CCAM virtual reality and physiological measurement activities

- Compare the impacts of different types of fully autonomous vehicles
- Include experience of public transport in virtual reality study
- Show both the interior and exterior of the vehicle in virtual reality experiments
- Include in-vehicle activity in virtual reality scenarios.
- Include a comprehensive ethics assessment in study design and reporting
- Use a balanced sample in terms of age and gender in a virtual reality experiment
- Recruit participants likely to benefit from autonomous vehicles but less likely to participate in virtual reality experiments (for example, older people tend to be underrepresented in existing studies)

2.1.4 Key Performance Indicators (KPIs)

The project collected 250 KPIs from existing evaluation frameworks that could be applied to evaluate the impact of CCAM solutions. These KPIs have been classified according to the eight MOVE2CCAM domains (mobility, safety, public health, economy, environment, land use, network efficiency, and equity).

Directions for MOVE2CCAM systems-wide impact assessment

- Define the evaluation approach and select the relevant indicators to integrate into the systems-wide impact assessment tool
- Identify additional KPIs through impact assessment methods (qualitative assessment, Pan-European survey)
- Identify the required data to calculate the KPIs

2.2 MOVE2CCAM use cases and business models

2.2.1 Use cases

The MOVE2CCAM activities with the Satellites in the eight countries led to a set of co-created use cased for autonomous vehicles (Table 5). These use cases cover almost all use cases mentioned in the literature (compare with Table 2) but also include new variants, especially those involving the collective use of vehicles, by passengers and companies that have similar transport needs. Co-created use cases also provide more detail on the time of day in which the vehicle should run, locations served, energy source, and in-vehicle features.

Table 5: Co-created CCAM use cases

Passenger transport	Freight transport
• E-hailing pod • Demand-responsive bus • Taxi or mini van • Employee transport • On-campus hospital transport • Pod to hospital • Platooning pod • Private pod • Individual pod • Scheduled bus/shuttle • Cable car	• Delivery robot • Waste collection/street cleaning vehicle • Last-mile delivery with vans • Delivery drone • Manufacturing plant robot/drone • Farm and construction vehicle • Truck • Platooning trucks • Platooning gondolas • Military vehicle

These use cases were attached to different levels of importance according to the location of the Satellites. Citizens living in cities suggested a wide variety of different use cases, but those living in small towns, suburban, or rural suburban areas mainly suggested public transport use cases, such as taxis and buses. Delivery drones were also suggested frequently by participants in rural areas.

The Satellites identified challenges to the implementation of autonomous vehicles, such as collisions, initial investment required, and ethical and legal issues, as well as other issues widely mentioned in previous literature, as described in Section 2.1.2 of this report. Satellites also identified the key impacts that autonomous vehicles may have in their regions. The eight MOVE2CCAM domains were covered, across all participants. The main impacts participants identified were health and accessibility to jobs and facilities (mainly regarded as positive impacts), and road traffic volumes (with mixed opinions on whether traffic would increase or decrease.

Directions for MOVE2CCAM systems-wide impact assessment

- Include both passenger and freight use cases in the impact assessment.
- Split analyses according to spatial context (cities vs. other areas)
- Pay special attention to the health and accessibility to jobs aspects
- Develop strategies to identify the conditions under which road traffic will increase or decrease with the deployment of autonomous vehicles.

2.2.2 Business models

The MOVE2CCAM then co-created business models for 15 use cases. Participants specified the value proposition of these use cases, emphasizing the problems that autonomous vehicle technology would solve. The lack of a requirement for a driver in public transport vehicles means that more space is available in the vehicle, costs could decrease, and the frequency of the service could increase. For private passenger vehicles, the vehicle would not necessarily need to be parked. Freight delivery could also be faster and cheaper.

Revenue streams identified include standard pay-per-use schemes, but also schemes that are relatively rare in the case of uses of conventional vehicles, such as subscriptions (per month or year). These subscriptions were suggested not only for passenger transport but also for freight transport using autonomous vehicles.

Potential threats to these models were identified. These correspond mostly to the concerns of potential users (described in Sections 2.1.2 and 2.2.1 of this document). The cost of providing the service, the difficulty of capturing demand (due to people's concerns about privacy and safety), and regulatory challenges are the main threats.

Directions for MOVE2CCAM systems-wide impact assessment

- Include supply-side considerations in the evaluation of the economic impacts of CCAM solutions
- Estimate willingness to pay for using different types of autonomous vehicles
- Consider different future scenarios for the shift of demand from conventional to autonomous vehicles.

3. Roadmaps for CCAM Impact Analysis

3.1 Introduction

Section 3 provides roadmaps for the impact assessment of CCAM solutions, which will be conducted with six different approaches: qualitative assessment (Section 3.2), detailed case studies (3.3), trial of a real-world autonomous vehicle (3.4), virtual reality (3.5), large-scale assessment via a pan-European survey (3.6), and social and environmental lifecycle analysis (3.7). The data from these methods will be triangulated by identifying themes that are found across the different outcomes. In addition, the results of some assessments will inform the development of methods for subsequent assessments. For example, qualitative assessments will be used in the design of the virtual reality experiment and pan-European survey.

3.2 Qualitative assessment

3.2.1 Description and overall justification

The qualitative assessment will collect information about people's opinions about the potential role of autonomous vehicles in their lives and businesses. This will consolidate and build on the 15 co-created use cases mentioned previously, to develop impact models that reflect citizen and organisation expectations of autonomous vehicles. The use cases have been consolidated into 10 core use cases, which will be considered across the different regions, allowing for comparison between regions. In each region, between 30 and 40 members of the public and 30 to 40 organisations will consider 4 use cases each. Particular attention was paid to the relevance of use cases to the regions, based on the results of workshops organized to co-create business models. Activities will be organised to understand impacts in terms of the eight Move2CCAM domains (Move2CCAM Activities 4 and 5).

For organisations, the methodology consists of one two-hour workshop in person or online depending on the region. For citizens, the methodology also includes approximately one to two hours (depending on whether participants were involved in earlier activities or not) of online activities using the Recollective online engagement platform, to introduce citizens to use cases and gain initial feedback (building on earlier activities), as well as the two-hour workshop in person or online.

The objective of the engagement platform activities for citizens is to familiarise the participants with the use cases and domains ahead of the workshop discussion to allow for a maximum amount of time in the workshops to develop the impact maps. Organisations did not feel they needed this extra step. All participants will answer questions on three of the eight MOVE2CCAM domains, giving in-depth data across the whole sample while keeping the activity short enough to retain participant interest.

- All participants will answer questions on **mobility** – as the domain where individual behaviour is most influential.
- All participants will answer questions on **safety, economy, and environment** – the three domains which are easiest to engage with and where previous activities suggested citizens had the most developed views.
- All participants will answer questions on **health, network efficiency, land use and equity.**

The workshop is designed to elicit qualitative insight through relevant and focused discussion among participants to understand:

- Their view on the potential role of the selected use cases in their everyday lives/businesses

- What positive and negative impacts do they imagine will arise from the use cases proposed and which impacts are the most important to them?
- Where they are more or less certain about impacts and where there is agreement or disagreement about the impacts.

This will be done by orientating participants to a particular timeframe, ensuring consistency across the sample. The participants will then be split into smaller groups with each looking at four use cases in detail and working together with the moderator to develop the draft impact model for each domain (developed by using the engagement platform insight). Each smaller group's work will then be rotated and presented to another group, allowing a higher number of participants to review and input into each use case impact model.

3.2.2 Data to be collected

Table 6 shows the data to be collected. In this and other tables in the sections that follow, each dataset is assigned a code, to facilitate the project's data management and archiving processes. The table also shows the justification for collecting each dataset.

Table 6: Data to be collected from the qualitative assessment

Code	Data	Justification
QA1	Individual citizen views on the impacts of CCAM use cases	Citizens are key users of CCAM systems, and impacts are a key component of the MOVE2CCAM model. Understanding citizen views on impacts will challenge/validate the expert perspective and directly inform the development of a more accurate model.
QA2	Citizen and organisation views on the impacts of CCAM use cases	As above – both citizens and organisations may have different perspectives on the impacts of CCAM use cases. Understanding these perspectives will inform the development of the model.
QA3	Citizen and organisation views on the timeline for deployment of CCAM use cases.	These views are input to the scenarios used in the development of the MOVE2CCAM impact assessment tool, which will evaluate impacts for different time horizons

3.2.3 Data collection methods

Table 7 shows the data collection method. Each method is also assigned a code. The table shows the format of the data collection method, timing (concerning the engagement activities) and the data collected (of the data listed in the previous table).

Table 7: Data collection methods in qualitative assessment

Code	Method	Format	Timing	Data collected
QUAL1	Open text questions	Online platform – approx. 1 hour	Before workshop	QA1 (Citizen's baseline expectations of the impact of CCAM on the model domains in relation to use cases identified at activity 3)
QUAL2	Group discussion	Online and face-to-face	During workshop	QA2 (Citizen and organisations detailed

		workshops – 2 hours		expectations of the impact of CCAM on the model domains, validated in group discussions through a co-created impact map
QUAL3	Quantitative question	Online survey tool/ paper form	During workshop	QA3 (Citizen and organisation's perceptions of the timescale for deployment of CCAM use cases)

3.2.4 Analysis methods and expected outcomes

Table 8 shows the analysis methods and expected outcomes, for each dataset collected (identified by their code).

Table 8: Analysis methods and expected outcomes from qualitative assessment

Analysis method	Data	Expected outcome
Thematic analysis	QA1, QA2	Understanding of citizen and organisation views on the impacts of CCAM use cases, organised by the eight MOVE2CCAM domains, and by use case.
Comparative analysis	QA1, QA2	Indicative understanding of differences between countries in perceived impacts of use cases.
Descriptive statistical analysis	QA3	Understanding of citizens' and organisation's expectations about the deployment timeline for different CCAM use cases

3.3 Detailed case studies of organisations

3.3.1 Description and overall justification

In the second stage of the project, detailed case studies will be conducted with 10 organisations that are part of the project's Satellites network. This will derive more detailed insights, from each of these organisations, than those derived from their participation in the workshops described in Section 3.1.

3.3.2 Data to be collected

Table 9 lists the data to be collected from the case studies of organizations.

Table 9: Data to be collected from case studies

Code	Data	Justification
C1	**Views** about autonomous vehicle use cases and business models	Different types of organizations have different perspectives on use cases, business models, and impacts of autonomous vehicles, depending on the sector and other characteristics. The detailed case study will collect information about the reasons behind the organizations' views, with details that cannot be extracted in short workshops with many participants
C2	**Needs** and potential **impacts** of autonomous vehicles on the organization	
C2	**Perception** about the potential impact of autonomous vehicles in the 8 MOVE2CCAM domains	

3.3.3 Data collection methods

Table 10 suggests methods to collect the data listed above. The project partners in each country will interview representatives of the organizations (QUAL3), using a semi-structured approach, harmonized for all countries. This will be complemented with a review of any public documents released by the organizations relevant to CCAM (QUAL4).

Table 10: Data collection methods in case studies

Code	Method	Format	Data collected
QUAL3	Interview	Face-to-face or online	C1, C2. C3
QUAL4	Document review	Text	C1, C2. C3

3.3.4 Analysis methods and expected outcomes

Table 11 shows the method to analyse the data collected from the case studies.

Table 11: Analysis methods and expected outcomes from case studies

Analysis method	Data	Expected outcomes
Text analysis	QUAL3, QUAL4	A narrative account of the perspectives of the organizations (anonymised), identifying points in common and in contrast across organizations.

3.3.5 Approach to select organizations

The organisations will be selected from the ones that have participated in previous co-creation activities of the project. The aim is to select companies of different countries, sizes, and geographic reaches. The following criteria will be applied:

- At least one organization from each of the 8 countries in the project
- At least two small companies
- At least two organizations per geographic reach (local, national, international)
- Not more than one organization per type (considering the MOVE2CCAM Satellites typology: passenger transport operators, freight transport operators, transport infrastructure operators, fuel providers, CCAM developers and manufacturers, autonomous vehicle demonstration areas, authorities and regulatory bodies, research organizations, telecommunications and cybersecurity organizations, CCAM partnership and NGOs, health organizations.

Partners in the 8 countries will suggest two organizations that have been particularly engaged in previous co-creation activities. From these, organizations will be selected so that the overall set of 10 fulfils all the criteria above.

3.4 Demonstration of autonomous vehicles

3.4.1 Description and overall justification

A demonstration of autonomous vehicles will be organised by the MOVE2CCAM project in Helmond (Netherlands), one of the three “prototypical regions” of the project. A demonstration is a valuable approach to gathering data on people’s perceptions, as most people have not yet experienced using autonomous vehicles. Previous trials and demonstrations mainly featured a single vehicle, which is a limitation. The demonstration in Helmond could bring value to the literature by offering citizens the opportunity to try more than one type of autonomous passenger vehicle, as well as to observe an autonomous freight distribution vehicle. This will also allow the project to understand citizens’ opinions about the range of vehicles that will be using the roads in the future, and how citizens perceive the possible impact of those vehicles on their lives and the lives of others in their region.

Furthermore, autonomous passenger vehicles should be public transport vehicles, not private vehicles. This corresponds to the emphasis given by the Satellites in the co-creation activities, to use cases of collective use of vehicles, as reported in Section 2.2.1.

3.4.2 Data to be collected

Table 12 shows the data to be collected from the autonomous vehicle demonstration and respective justifications. In the table, “attitudes” mean how people think or feel about autonomous vehicles.

Table 12: Data to be collected from autonomous vehicle demonstration

Code	Data	Justification
DEM1	Initial **attitudes** towards autonomous vehicles (in general)	Provide a baseline to assess participants' attitudes towards autonomous vehicles
DEM2	**Attitudes** towards autonomous vehicles after passengers experience them (split by type of vehicle)	• As reported in the literature, people's attitudes might change after they experience a vehicle. • Previous demonstrations have featured only one type of vehicle, not allowing for comparison between attitudes towards different types of vehicles
DEM3	**Attitudes** towards freight autonomous vehicles after observing them (split by type of vehicle)	Almost no studies have reported how people perceive autonomous freight distribution vehicles, especially after experiencing them
DEM4	Participant **characteristics** (demographics, travel context, travel behaviour, general travel attitudes)	• In previous studies, attitudes have been shown to depend on individual characteristics • MOVE2CCAM wants to assess possible inequalities in how different groups will use autonomous vehicles and this depends on their attitudes (and their determinants)

3.4.3 Data collection methods

To collect the data outlined above, two instruments are needed (Table 13): a pre-questionnaire answered by participants before the day of the trial (Q1) and a post-demonstration questionnaire (Q2).

The pre-questionnaire (Q1) could be identical to the one already answered by citizens in previous co-creation activities of the project, as this questionnaire gathers the required information on attitudes towards autonomous vehicles (DEM1) and on participant characteristics (DEM4). As most of the participants in the demonstration will already have participated in those previous activities, they would not have to answer the same questionnaire again, reducing participants' burden.

The post-questionnaire (Q2) would gather attitudes towards the three types of vehicles that the participants experienced.

Table 13: Data collection methods in autonomous vehicle demonstration

Code	Method	Format	Timing	Data collected
Q1	Questionnaire	Online	Before the day of the trial	DEM1, DEM4
Q2	Questionnaire	Online or paper	Immediately after the trial	DEM2, DEM3

3.4.4 Analysis methods and expected outcomes

Table 14 shows the methods to analyse the data collected in the demonstration and the expected outcomes.

Table 14: Analysis of methods and expected outcomes from autonomous vehicle demonstration

Analysis methods	Data used	Expected outcomes
Comparison of attitudes after and before the trial	Dependent: DEM2, DEM3 vs. DEM1 Control: DEM4	Significant determinants of changes in attitudes towards autonomous vehicles
Comparison of attitudes towards two types of autonomous passenger vehicles	Dependent: DEM2, DEM3 Control: DEM4	Significant determinants of differences in attitudes towards different types of autonomous vehicles

3.4.5 Ethics

The demonstration involves participants interacting with a technology with which they are probably not familiar. Several ethical issues need to be considered, in this context. Table 15 details these considerations and strategies that need to be implemented to address them.

Table 15: Ethics considerations to include in the design of autonomous vehicle demonstration

Ethics issue	Strategy to address the issue
Safety of participants and researcher (risk of collision of the vehicle)	A driver should be present throughout the experiment and should take over the vehicle in case something goes wrong. Inform participants before the ride: • Autonomous vehicles have been tested widely in multiple contexts around the world and are considered as safe • They can opt out at any moment
Participants may feel uncomfortable when riding on autonomous vehicles, as for most of them it will be a new experience	Inform participants before the ride: • About the duration of the ride, route, and other details. • They can opt out at any moment

3.5 Virtual reality

3.5.1 Description and overall justification

MOVE2CCAM is planning virtual reality experiments with 30 participants in each of the three “prototypical regions”: Helmond (Netherlands), the GZM metropolitan area (Poland), and the North Aegean region (Greece).

Virtual reality provides an immersive experience that can realistically replicate realities that do not yet exist, such as a trip on a fully autonomous vehicle while introducing variations in the conditions of that trip. This method is relevant in a systems-wide assessment of CCAM solutions because most people have not yet experienced travelling in an autonomous vehicle, as these vehicles are not yet widely deployed on public roads. Most autonomous vehicles have been deployed in temporary trials in specific areas, or off-road demonstrations. Autonomous vehicles are not yet in use as the main mode of road transport and people may find it hard to imagine how they will operate, with only images or videos. The demonstration described in Section 3.4 helps people in that task, but it is done off-road, not accounting for the new types of infrastructure and the new travel environments that will exist in the future. Virtual reality can help people to experiment with these new infrastructures and environments realistically.

Before the activity, the virtual reality scenarios should be tested, for example with students. This is to test perceptions about the scenarios and possible discomforts or other issues with using virtual reality headsets. As mentioned in Section 2.1.3, most previous studies stopped here, i.e., analysed and reported only the results obtained with a sample exclusively of students. This is a shortcoming. MOVE2CCAM should go beyond this situation and use samples that are balanced in terms of age and occupation.

3.5.2 Scenarios to be designed

A virtual reality game of no more than 10 minutes should be designed. The literature shows that longer durations may induce boredom or even motion sickness among participants. Participants will wear a virtual reality headset and experience virtual scenarios. A suitable headset that has been identified after reviewing and testing different headsets, is Meta Quest Pro (https://www.meta.com/gb/quest/quest-pro).

The use of virtual reality in MOVE2CCAM should allow citizens to try different types of autonomous passenger vehicles, corresponding to different use cases. This will also allow the project to understand people's opinions about the use cases. Two simple use cases can then be tested: a small private vehicle and a bus, both used to travel along the same route (for example, from the city centre to home). These two use cases should be included in the experiment because:

- Previous activities led to the co-creation of use cases involving both private and public transport.
- Public transport use cases have been almost absent in previous studies using virtual reality to study autonomous vehicles.
- The demonstration described in Section 3.4 will not feature a private vehicle.

Two virtual reality scenarios should then be designed, a private and a public transport one, and integrated into a game where participants can initially choose between them. Furthermore, MOVE2CCAM should think ahead and devise situations that may not be possible on today's roads but will be feasible in the future. This includes the possibility of switching from an autonomous bus to an autonomous car mid-journey (for example at a bus stop). Therefore, the game should provide participants with the option to make that switch. In addition, the game could provide options for the use of travel time (read a book, browse a tablet computer, or just look around).

The scenarios should incorporate attributes that may potentially affect the choices described above. These attributes can assume different levels, which will change during the scenarios, possibly triggering a switch from/to car to/from bus, or physiological reactions. Table 16 shows a list of attributes that should be included and the respective justification.

Table 16: Attributes of the virtual reality scenarios

Attribute	Car	Bus	Justification
Land use (scenery outside the vehicle)	Yes	Yes	People do not have to drive so can enjoy the scenery, which becomes more important as a trip quality determinant

Time of day	Yes	Yes	Personal security concerns if the trip is made after dark
Congestion	Yes		• Travel time is a major determinant of travel mode choice and delays due to congestion increase stress • MOVE2CCAM should test scenarios where buses always move faster than cars, by using dedicated (and uncongested) lanes
Crowding		Yes	Related to three aspects of trip quality: discomfort, personal security concerns, and difficulty in seeing the scenario outside the bus
Supervision		Yes	• People are concerned with the risk of collision if no human is present to take over the vehicle if needed • People may not feel secure if no human supervisor is present to prevent harassment or other unwanted behaviour from other passengers.
The behaviour of other passengers		Yes	Personal security concern

As described in Section 1.3.1, personal security inside unsupervised public transport is one of the main concerns people have expressed about using autonomous vehicles. This will be one of the main foci of the experiments. Several attributes will test aspects that might influence the participants' sense of personal security in the public transport scenario. Levels of these attributes that might reduce perceived personal security are derelict industrial buildings (land use attribute), night-time, (time of day attribute), many people inside the bus (crowding attribute), no human supervisor (supervision attribute), and unsocial behaviour (other passengers' behaviour attribute).

Each part of the virtual scenario will be defined by a certain combination of attribute levels (for example "*city centre, daytime, uncrowded, human supervision, passengers minding their own business*"). A vector of variables VR0 will be defined, for each second of the game, representing the levels shown in that second.

3.5.3 Data to be collected

Table 17 shows the data to be collected from the experiment, based on the two virtual scenarios (private and public), and the respective justification.

Table 17: Data to be collected from virtual reality experiments

Code	Data	Justification
VR1	**Perceptions** of different aspects of travelling in self-driving private and public transport vehicles	Previous studies have featured only one type of vehicle, not allowing for comparison between attitudes towards different types of vehicles
VR2	**Physiological reactions** to different aspects of travelling in self-driving private and public transport vehicles	• Physiological data give insight into participants' mental states, which may be a determinant of choices • These mental states have an impact in itself, related to people's wellbeing using different modes.
VR3	**Preferences** between using self-driving private vs. public transport modes	The choice between private and public transport may have different determinants, if both vehicles are autonomous, compared with the case when both vehicles are human-driven

VR4	**Preferences** about different uses of time when travelling in a self-driving car or bus	Not having to drive opens possibilities for using travel time for other purposes, even in private cars. This may affect the choice between a car and a bus.
VR5	**Opinions** about the realism and other characteristics of virtual reality scenarios	Virtual reality is an underexplored research method in transport research. MOVE2CCAM is an opportunity to gather data on the effectiveness of the method for collecting passenger user data.
VR6	Participant **characteristics** (demographics, travel context, travel behaviour, general travel attitudes)	• Reactions to autonomous vehicles (and to virtual reality experiments) depend on individual characteristics • The project wants to assess possible inequalities in how different groups will use autonomous vehicles and this depends on how people perceive and react to these vehicles (and the determinants of these perceptions and reactions)

3.5.4 Data collection methods

Table 18 shows the methods that should be used to collect the data listed above. This includes:

- An initial online questionnaire (Q1). This is the same as the questionnaire described in Section 3.4.3. It will only be answered by participants who have not filled it out yet (before the autonomous vehicle demonstration or in previous activities of the project).
- Recording, by the virtual reality headset, of participants' choices during the virtual reality game (META1): initial choice of car or bus, if/when they change from one to another, and what they do during the trip.
- Recording, by the virtual reality headset, of eye movement (which parts of the virtual scenarios participants look at) (META2)
- Recording of physiological data (brain activity) through non-invasive Electroencephalography (EEG) earbuds (EMOTIV MN8 – see https://www.emotiv.com/mn8-eeg-headset-with-contour-app).
- A short post-experiment questionnaire (Q3) about participants' reasons for choices, perceptions of the scenarios, and opinions about the realism of the scenarios
- A qualitative stage (QUAL5), during which participants will finally watch 2D video versions of the scenarios and be asked about their opinions, generates a dataset with statements, linked to events in the videos.

Table 18: Data collection methods in virtual reality experiment

Code	Method	Format	Timing	Data collected
Q1	Questionnaire	Online	Before experiment	VR1, VR6
META1	Virtual reality headset participant input capture	Digital	During experiment	VR3, VR4
META2	Virtual reality headset eye movement capture	Digital	During experiment	VR2
EEG	EEG earbud data capture	Digital	During experiment	VR2
Q3	Questionnaire	Online or paper	Immediately after the experiment	VR1, VR5
QUAL5	Discussion	Notes	After Q3	VR1, VR5

3.5.5 Analysis methods and expected outcomes

The EEG raw data (VR2) will be processed to derive frequency bands, the strength of which will be used to estimate indicators of six emotional states. Methods used in a previous study (conducted by two MOVE2CCAM partners) will be used[1]

The participant choices (VR3 and VR4), eye movement (V2R), EEG data (VR2), and statements about the scenarios (VR5), and the scenario attributes shown in each second of the game (VR0) will be combined into one analysis dataset, based on time-stamp matching. Table 19 suggests methods to analyse this combined dataset and the expected outcomes.

Table 19: Analysis methods and expected outcomes from virtual reality experiments

Analysis methods	Data used	Expected outcomes
Choice modelling of in-game choices	• Dependent: VR3 and VR4 • Independent: V0, VR1, VR2 • Control: VR5	• Significant determinants of initial choices between autonomous car and bus • Significant determinants of real-time choices between autonomous car and bus • Significant determinants of use of time during autonomous car/bus travel
Statistical models of physiological data	• Dependent: VR2 • Independent: VR0, VR1, VR3, VR4 • Control: VR5	Significant determinants of participants' physiological reactions to scenario events
Analysis of participants' perceptions of scenarios	• VR5	Quantitative and qualitative assessments of the quality and effectiveness of the virtual reality scenarios

3.5.6 Recruitment

A sample of 30 for the virtual reality experiments in each region will balance the need to simplify planning and save costs (experiments with more than 30 participants will require several days). A sample of less than 90 (i.e., 30 in each region) would be insufficient for comparing data across gender and age groups. In Helmond, some participants should be the same as the ones participating in the autonomous vehicle demonstration described above, so differences can be analysed between participants who joined the demonstration first, then did the virtual reality game, and those who did the game first and then joined the demonstration.

A balance between different genders and ages is crucial, in each region, as previous studies have generally been limited by unbalanced samples, as mentioned in Section 1.1.3. All participants are to be adults who can be drivers today, i.e., 18+. Although we do not specify an upper age limit, in practice, previous studies in this field have found it difficult to recruit participants above 75 years of age. However, the project should aim at recruiting participants above 65 years of age so that they represent around a third of the sample.

3.5.7 Ethics

It is also crucial that the research aligns with ethics requirements, as the experiment involves participants wearing two devices, which they will probably be unfamiliar with. As mentioned in Section 1.1.3. this is an aspect that has been insufficiently covered in previous studies. Table 20 lists possible ethical issues and the strategies that should be implemented to address those issues.

[1] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1166513/great-self-driving-exploration-findings-from-eeg-study.pdf

Table 20: Ethics considerations to include in the design of virtual reality experiment

Ethics issue	Strategy to address the issue
General concerns of participants about what will happen and how data will be collected and treated	Participants should be provided with an information sheet and consent form before the event. Participants should only start the experiment if they have returned the signed form
Participants may feel uncomfortable or embarrassed wearing the virtual reality headset and the EEG earbuds	• Participants will be informed before the experiment that then can opt-out at any moment, before or after they start wearing the headset. • The virtual reality scenarios will display messages prompting participants to take off their headsets if they fell unease.
Motion sickness, headache, skin irritation, or other discomforts while using the virtual reality headset	
Uneasiness with some of the scenarios seen in the virtual reality game	
Red marks on the forehead for a few minutes after the experiment	Inform participants before the experiment
Risks of transmittable diseases through wearing equipment used by others before	Disinfect the virtual reality headset and the EEG earbuds after every use.
Participants may feel uncomfortable if a researcher of another gender helps them to wear the headset and EEG earbuds.	• Provide clear instructions on how participants can wear and calibrate the headset and wear the EEG earbud. • Have both male and female researchers present to guide the participants on how to wear the EEG headset, and to set this up for them.
Use of participants' time	Participants will receive a small compensation for their participation
Risks of fatigue	Provide food and drinks, and frequent breaks in the schedule.

3.6 Pan-European survey

3.6.1 Description and overall justification

MOVE2CCAM will implement an online survey with 8000 respondents (1000 in each of 8 countries: United Kingdom, Germany, France, Spain, Cyprus, Netherlands, Greece, and Poland) (Move2CCAM Activity 6). The questionnaire will be the same in all countries (but translated into the local language). A large survey such as this is needed because the demonstration and the virtual reality experiment have small samples, in just three regions, and focus on the specific experience of using given types of autonomous vehicles. A survey deployed widely across Europe is needed to capture other aspects such as attitudes towards autonomous vehicles, intention to use, possible changes in travel behaviour, and willingness to pay. A sample of 1000 per country is necessary to derive precise results and to ensure that the sample is representative of gender, age, and regions inside the country. We will first run a pilot survey with 100 participants in one of the countries (to be decided), to test the questions.

3.6.2 Stated preference choice scenarios to be designed

The survey should include a stated preference component, i.e., a set of questions where participants choose among options for travelling. This is important because it can provide insights into how people's choices are affected by the attributes of different travel options. MOVE2CCAM should compare choices among different travel modes, including conventional private cars and different types of autonomous vehicles (corresponding to different business models; for example, private cars, shared cars, and buses).

Table 21 suggests the attributes defining the options. These include ‘traditional’ attributes (cost, travel time), but also attributes related to the business models (flexibility, i.e., how often will the vehicle be available for a trip, in a given day), and attributes specific to public transport (the use of dedicated lanes, personal security, and crowding). The last column of the table justifies including these attributes. Prior estimates of the coefficients of these attributes will be derived from the pilot study.

Table 21: Attributes of the stated preference exercise

	Conventional	Autonomous			Justification
Attribute	Private Car	Private car	Shared car	Bus	
Cost per trip	x	x	x	x	The key determinant of travel mode choice
Travel time	x	x	x	x	The key determinant of travel mode choice
Travel time reliability	x	x	x	x	The key determinant of travel mode choice
Flexibility			x	x	One of the reasons why people do not choose public transport as a mode of transport
Dedicated lanes				x	The possible advantage of public transport, concerning car
Personal security (surveillance)			x	x	People may not feel secure if no human supervisor is present to prevent harassment or other unwanted behaviour from other passengers.
Crowding				x	One of the reasons why people do not choose public transport as a mode of transport

3.6.3 Data to be collected

Table 22 shows the data to be collected from this pan-European (PAN) survey.

Table 22: Data to be collected from the pan-European survey

Code	Data	Justification
PAN1	**Attitudes** towards autonomous vehicles (in general)	• Attitudes vary across countries and regions within the country • Attitudes explain perceptions about potential impact and preferences about travelling in a conventional vs. autonomous vehicle.
PAN2	**Perceptions** about the potential impact of autonomous vehicles on own life (time pressures, stress, work, shopping, social life, health)	To provide information to feed into the MOVE2CCAM Systems-Wide Impact Assessment Tool
PAN3	**Perceptions** about the potential impact of autonomous vehicles on the region (8 MOVE2CCAM domains: mobility, safety,	To provide information to feed into the MOVE2CCAM Systems-Wide Impact Assessment Tool

	public health, economy, environment, land use, network efficiency, equity)	
PAN4	**Preferences** among conventional vs. autonomous vehicles and among different types of autonomous vehicles.	The choice between private and public transport may have different determinants, if both vehicles are autonomous, compared with the case when both vehicles are human-driven
PAN5	Participant **characteristics** (country, demographics, travel context, travel behaviour, general travel attitudes)	• Perceptions and preferences depend on individual characteristics • The project wants to assess possible inequalities in how different groups will use and be impacted by autonomous vehicles

3.6.4 Data collection methods

The data will be collected through an online survey (Q4) (Table 23)

Table 23: Data collection methods in the Pan-European survey

Code	Method	Format	Data collected
Q4	Questionnaire, including stated preference component	Online	All data in Table 22

3.6.5 Analysis methods and expected outcomes

Table 24 lists the methods used to analyse the data from the survey. Choice modelling will be used to analyse the results of the stated preference data. Structural equation modelling will be used to analyse the inter-relationships between participant characteristics, attitudes, and the perceived personal and societal impacts. This will fulfil one of the main aims of the project (explore the multi-systems impact of CCAM).

Table 24: Analysis methods and expected outcomes from the Pan-European survey

Analysis methods	Data used	Expected outcomes
Choice modelling of stated preference data	PAN4	• Significant determinants of choices among conventional and different types of autonomous vehicles • Trade-off values between different attributes of using conventional and different types of autonomous vehicles • Willingness to pay for improvements in attributes of conventional and different types of autonomous vehicles
	PAN4 vs PAN1, 2, 3, 5	Determine the reasons why the values above vary with the characteristics, perceptions, and attitudes of the participant
Structural equation modelling	PAN1-3, PAN5	• Inter-relationships between participant characteristics (PAN5), attitudes about autonomous vehicles (PAN 1), perceived personal impacts (PAN2), and perceived societal impacts (PAN3)
		Same as above, split by country

3.6.6 Recruitment

Minimum quotas should be set so that the sample is representative of gender, age, and NUTS2 region in each country.

3.7 Social and environmental lifecycle analysis

This section presents the methodology to be developed in Task 3.7 of the project to calculate the environment and social impacts of CCAM solutions through a life cycle approach.

3.7.1 Environmental life cycle approach

Life Cycle Approach methodology will be applied to assess the environmental impacts of the deployment of CCAM solutions in the three prototypical European regions of the project considering the entire life cycle of vehicles introduced. This cradle-to-grave approach will allow us to evaluate the impacts on the environment of the extraction of raw material, manufacture of the vehicle and its components, fuel cycle, the use of the vehicle and its end of life (i.e., disposal/recycling).

Environmental footprint methodology will be used for the impact quantifications according to the categories considered below. Assumptions will be made regarding the type of fuel vehicles will be used.

Air quality

- Climate change
- Ozone depletion

Health

- Human toxicity, cancer
- Human toxicity, non-cancer
- Human health, ionising radiation
- Human health, photochemical ozone formation

Water

- Water scarcity
- Freshwater eutrophication
- Ecotoxicity freshwater
- Marine eutrophication
- Water acidification

Soil

- Land use
- Terrestrial eutrophication
- Soil acidification

Resources

- Resource use, mineral and metals
- Resource use, energy carriers

To assess the impacts of CCAM solutions in the MOVE2CCAM prototypical regions, it is required to collect the data identified in Table 25 which correspond with key features of the areas under evaluation.

Table 25: Data to be collected (key features of the regions)

Data	Strategy to collect this data
Population	Prototypical areas could provide this information, but also statistical sources can be used.
Motorization rate • Two-wheel motorised vehicles/1000 inhabitants • Four-wheel motorised vehicles/1000 inhabitants	

• Freight (light-duty and heavy-duty) vehicles/1000 inhabitants	
Fuel/energy source (petrol, oil, electricity, gas) of the vehicle fleet	
Vehicle fleet age	
Mobility statistics: trips per person, average distance travelled, use of public transport	

Additionally, it is required to define key parameters from the CCAM to evaluate and determine the baseline conditions (i.e., conventional vehicle to be replaced). The table below shows the data to collect and the strategy to apply.

Table 26: Data to be collected (additional data)

Data	Strategy to collect this data
Vehicle type	Use the scenarios co-created in WP2 activities
Individual/family or collective use	
Distance covered (km/trip, km/day, km/year)	
Frequency (trips/day, trips/year)	
Vehicle capacity (average) • Persons per trip (passengers' vehicles) • Weight per trip (freight vehicles)	
Maintenance service operations • Battery replacement frequency (years, km) • Tire replacement frequency (years, km)	Use data from the literature
Time life of vehicle (average): year	
Substitution rate: ratio at which the new mobility system will replace the current vehicle	To be decided

Ecoinvent® database, a Life Cycle Inventory database used to evaluate a large number of products from a diverse range of sectors on global and regional levels, will be used to collect other data required for the evaluation and evaluate the impacts from the whole vehicle chain.

3.7.2 Social life cycle approach

The social life cycle approach is a relatively newer and evolving methodology compared to the traditional environmental life cycle approach and standardization of social life cycle approach methodologies has not reached the level of maturity seen in the environmental life cycle approach. Currently, the methodology is described in guidelines and frameworks such as the UNEP/SETAC Life Cycle Initiative and the Social Hotspot Database. On the other hand, given the novelty of CCAM solutions, the approach to follow will be an adaptation of the existing approach.

Firstly, a materiality assessment will be done to determine the risks and opportunities associated with particular production activities or commodities by country without the full supply chain view. SHDB Risk Mapping Tool (Figure 2) will be used to visualize and communicate the social risks present in product supply chains. Several social categories: Human Rights, Labor Rights and Decent Work, Local Community, Governance and Health and Safety will be considered.

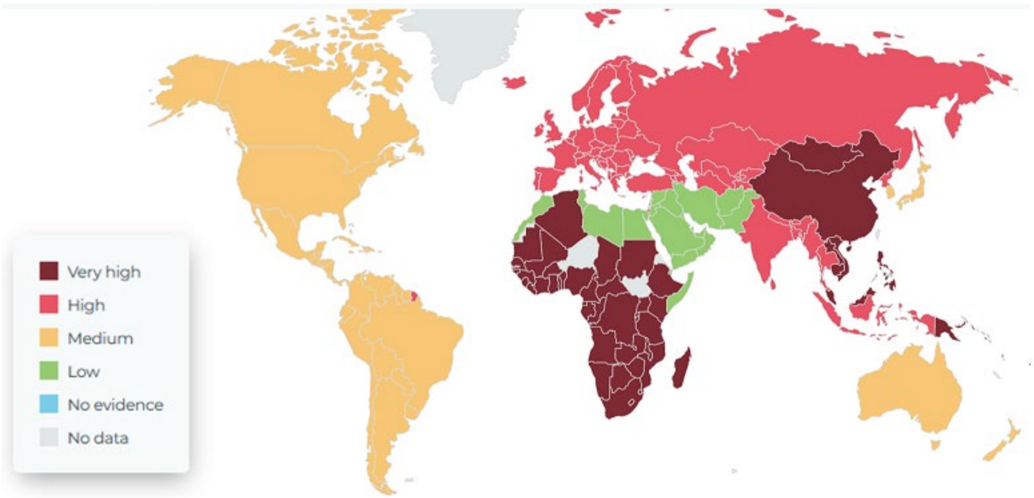

Figure 2. Risk assessment for motor vehicles and parts sector and health & safety category

Once the potential risks have been identified, as for the environmental life cycle approach, the risk assessment associated with each region and for each sector and impact category identified will be done. Social Hotspot Database provides the ability to use the risk information together with a supply chain model in a Life Cycle Assessment software (Sima Pro) to calculate the social footprint, measure positive impacts, and identify hotspots of CCAM solutions. The labour intensity information is used together with the social risk level to express social risks and opportunities in terms of medium risk hours equivalent, by sector and country for the main social impact categories.

At this point, the potential sectors that have been identified within the value chain of the use cases defined during co-creation activities include, among others:

- Oil, including extraction of crude petroleum, service activities incidental to oil and gas extraction excluding surveying.
- Manufacture of motor vehicles, trailers and semi-trailers.
- Electricity; steam and air conditioning supply.
- Land transport and transport via pipelines.

Other sectors will be identified during the second half of the project.

4. Roadmap for systems-wide impact assessment

4.1 Modelling framework

A system dynamics modelling approach can capture the complex and interconnected interrelationships within these domains adequately, providing a comprehensive understanding. System dynamics can enable the formulation and evaluation of feedback loops that include interactions between different domains which can yield impacts on system behaviour. MOVE2CCAM aims at developing a novel and practical system dynamics-based impact assessment tool that will enable the evaluation of CCAM interventions' impact on mobility, socio-economic, public health and environmental-related aspects considering diverse European region specifics and different actors' needs, objectives, and perceptions. This tool will empower the Satellites' stakeholders to configure, test, and evaluate the systems-wide impact of new CCAM interventions (either related to passenger and/or freight transport) besides a range of complementary policies. One of the main noteworthy contributions of the tool that sets it apart from solutions that aim to evaluate CCAM impacts is the fact that the modelling components that are integrated within the tool will be largely based on information retrieved and analysed as a result of co-creative activities (primary activities) with organizations and citizens during the lifespan of the project. Further, secondary data will be integrated to complement the analysis.

The backbone of the tool's modelling framework pivots on system dynamics modelling techniques that are widely acknowledged as a suitable approach for assessing system-wide impacts and are adopted herein to evaluate CCAM systems-wide impacts. The MOVE2CCAM systems-wide impact assessment tool includes 8 main components (domains), which are: i) mobility, ii) safety, iii) public health, iv) economy, v) environment, vi) land use, vii) network efficiency, and viii) equity.

Further, the MOVE2CCAM tool will be able to estimate the multidimensional impact of CCAM passenger and freight use case scenarios at a regional level. The 'Nomenclature of Territorial Units for Statistics' (NUTS) 2 classification system was selected, which is deemed as the appropriate level of analysis for policy-making, developing, and harmonizing European regional statistics that provides a balance between detail and comprehensiveness. Moreover, this level of analysis provides a standardization that provides a direct comparison and cross-country analysis that is also advantageous for policy analysis that also considers the emerging nature of CCAM solutions that are not yet widely implemented.

The MOVE2CCAM Systems-Wide Impact Assessment Modelling Tool (IAMT) also evaluates impacts for different time horizons (short, medium, and long term) using system dynamics approaches. In particular, all modelling components are estimated in the form of time series commencing in 2015 to 2050. The initial phase of the tool includes a comprehensive setup and fine-tuning that takes up an initial five years for initialization and calibration. Moving forward, the forecasting period spans from 2021 to 2050 and is classified into short-term impacts (up to 2026), medium-term impacts (up to 2035), and long-term impacts (up to 2050). The dynamic and evolving nature of CCAM services can also be captured by the system dynamics modelling aspect, as the tool can capture how changes in one modelling component of the system may influence other modelling components.

Understanding the temporal dynamics of impact variables within the tool is essential for evaluating the appropriateness of policy actions. The impact variables that can be illustrated in the form of time-profiles indicators can exhibit different patterns over time. An indicator may have a negative trend at the beginning of the analysis that can reflect the adverse effect of the evaluated policy. On the other hand, as time passes by, people may become more convinced towards the policy understanding their positive impact. Hence, the temporal aspect is important in policy analysis, even more so considering the dynamic behaviour of CCAM services.

Lastly, the tool will be developed, demonstrated, and tested for three prototypical regions (Helmond (NL), GZM (PL), and North Aegean Islands (GR)) throughout the project. These prototypical regions have different technological and infrastructural maturity and different population characteristics to ensure practical usefulness for a wide range of regions, which also enables a wide array of policy scenario analyses that are simulated within the tool by altering parameters and variables.

The figure below demonstrates the modelling framework of the tool which will initially collect primary and secondary data concerning the prototypical regions and which will be stored in the project's data warehouse. This collected information will be used in the systems dynamic model that will be able to estimate different KPIs concerning the 8 domains and finally provide an overview of the use case's short-, mid and long-term impacts.

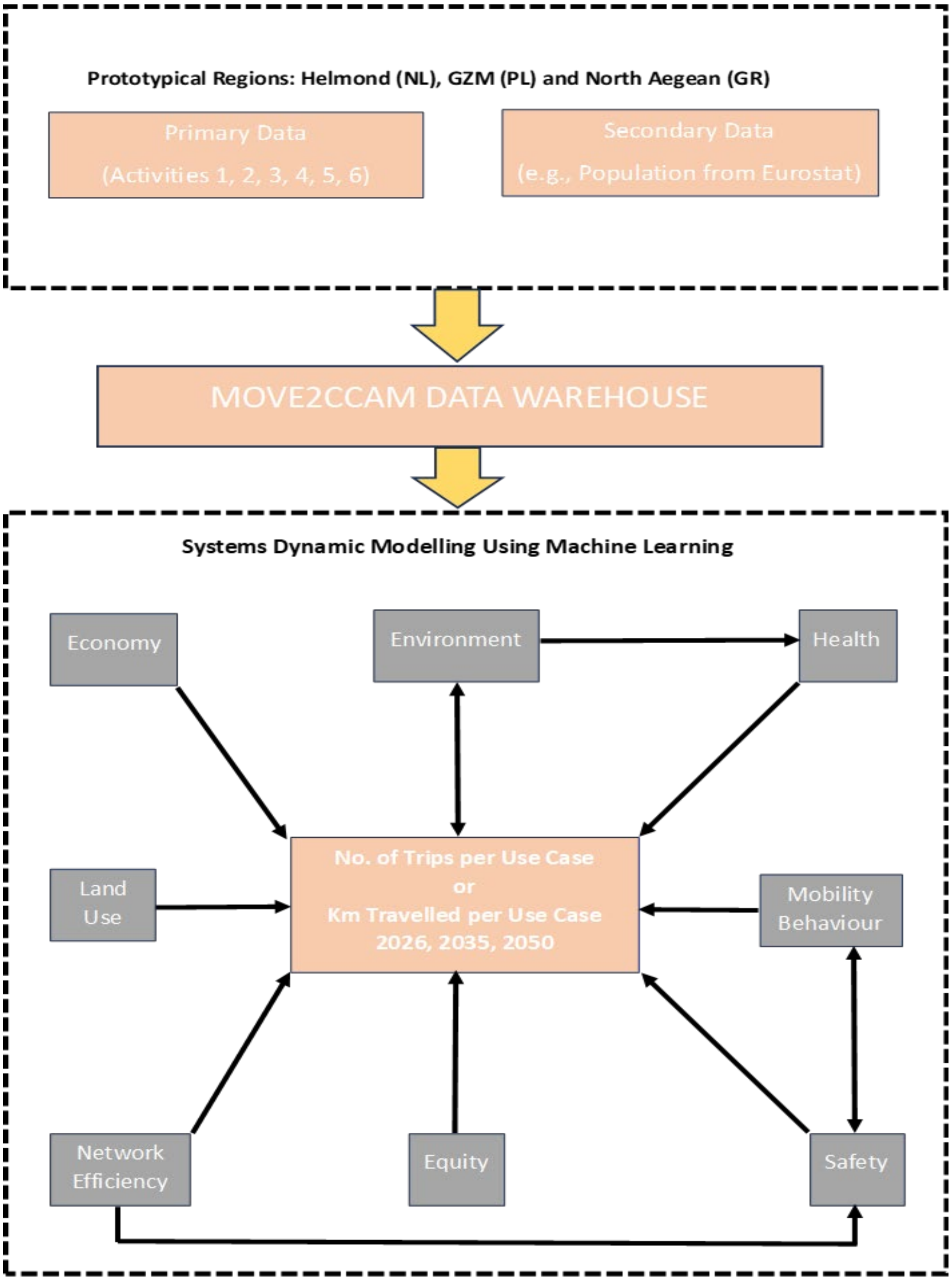

Figure 3: MOVE2CCAM Systems-Wide Impact Assessment Tool Modelling Framework

4.2 Key Performance Indicators

A main list of approximately 250 KPIs was created as part of the efforts of Task 1.2 from existing evaluation frameworks that could be applied to evaluate the impact of CCAM solutions. This list will serve as the foundation on which a visualization dashboard will be developed and hosted on the MOVE2CCAM Systems-Wide Impact Assessment Tool. The KPIs have been categorized into eight domains - i) mobility, ii) Safety, iii) public health, iv) economy, v) environment, vi) land use, vii) network efficiency, and viii) equity.

The rationale and the selection of the final list of the KPIs that will be included in the tool will be described in the subsequent work packages, primarily in Deliverables 3.3 and 3.4 and the final list will be included in Deliverables 4.1 and 4.2, as the definition of KPIs is anticipated as one of the main outcomes of the satellite co-creation activities that have not taken place yet (activities 4-7). An initial shortlist of the KPIs is included in the Appendix. Others will be added in the second half of the project.

4.3 Data needed

The data needed to inform the functioning of the MOVE2CCAM systems-wide impact assessment tool are classified into two categories (Table 6).

Table 27: Data to integrate into the MOVE2CCAM systems-wide impact assessment tool

Data	Source
Primary data	• Qualitative assessment (See Section 3.2 of this report) • Pan-European survey (See Section 3.6) • Feedback from the project satellites on the beta version of the tool
Secondary data	Sourced from external repositories and data sources outside the project

The first category includes primary data that are acquired through the co-creation activities held during the project. These activities are not only structured to foster collaborative input from various stakeholders, organizations, and citizens but also to achieve a user-centric approach for the modelling design of the tool which is deemed one of the major contributions of this project.

- Qualitative data collection, described in Section 3.2 of this report) will take place during October and November 2023, and will provide information on the interrelationships within different domains and within variables of each domain that will form the causal loop diagrams used in the MOVE2CCAM Systems-Wide Impact Assessment Tool.
- Additional information on the CCAM impacts is anticipated to be retrieved as part of the Pan-European citizens survey (Section 3.6 of this report). The survey is expected to be initiated in December 2023.
- Lastly, input will be received as part of further activities with the project satellites (Activity 8 - IAMT prototype demo and feedback), where participants will provide feedback on the beta version of the tool that is expected to take place in May 2024.

The second category includes secondary data that are sourced from external repositories and data sources outside of the project (Eurostat, national statistical repositories, completed CCAM-related research projects), which aim to provide supplementary insights and perspectives, while also enriching the analytical depth of the tool's impact assessment.

This approach integrates primary and secondary data providing a comprehensive foundation for meaningful analysis that will be hosted in the MOVE2CCAM data warehouse

5. Next steps

This deliverable consolidated and assessed the results of the first stage of the MOVE2CCAM project and provided roadmaps for the second stage of the project, defining the requirements for different approaches to assess the systems-wide impact of CCAM solutions.

This roadmap will be used as a guide to

- Update the data management plan, considering all the types of data that will be collected in the rest of the project, as laid out in this deliverable. The data management plan will be reported in Deliverable 3.2.
- Develop the materials for data collection in the various engagement activities that will be implemented in the project. These materials will be presented in Deliverable 3.3.
- Analyse the data collected in the activities, the results of which be presented in Deliverable 3.4.
- Design the social and environmental lifecycle analysis (Deliverable 3.5)
- Develop the systems-wide impact assessment tool beta version (Deliverable 4.1)

The roadmap presents guidelines that be applied in different ways, and possibly revised, following interactive discussions among partners, and results from pilot implementations of the various activities, analyses, and tools.

Appendix: Key Performance Indicators

	Field	Focus of the evaluation	KPIs
Environment	Air quality	Influence of autonomous vehicles in the concentration of pollutants	Nitrogen oxide emissions
			Fine particle matter emissions
			Ozone concentration
	Climate change	Influence of autonomous vehicles in the concentration of air emissions that produce climate change	Greenhouse emissions
	Energy consumption	Influence of autonomous vehicles in the amount of energy and energy source used to move vehicles	Energy consumption
			Fuel mix
			Renewable energy penetration
	Noise	Influence of autonomous vehicles in the exposition to noise above a certain threshold	Noise level
Mobility behaviour	Travel & Transport demand	Influence of autonomous vehicles in the number of movements carried out to meet daily needs as well as in the daily needs covered by transport	Distance travelled
			Daily trips
			Trip length
			Commuting distances to go to work
			Number of planned trips per hour
			Share of trips made during peak hours
			Travel & Transport purpose
	Travel time	Influence of autonomous vehicles in the timing and duration of travels	Timing of travel
			Average trip duration
			Peak period for travelling
	Transport mode	Influence of autonomous vehicles in the transport mode used to meet daily needs	Modal split / Transport mode share
			Number of multimodal trips
			Share of children walking or cycling to school
			Public transport use
			Number of users of public transport services
			Number of passengers with concession/subscription tickets in public transport
	Vehicle features	Influence of autonomous vehicles in the number of vehicles and features of these vehicles	Average age of vehicles
			Average vehicle occupancy
			Average vehicle speed
			Four-wheel motorised vehicles
			Two-wheel motorised vehicles
			Number of freight vehicles
Network efficiency	Network capacity and traffic flow	Effects of autonomous vehicles in the capacity of the network that cover the needs of movement	Travel/transport demand
			Punctuality of transport services
			Delays in transport system
			Average speed in the road
			Congestion
	Travel time		Timing of travel
			Peak hours

		Effects of autonomous vehicles in peak period travel time and the time used for travelling	Total journey time
			Wait time
			Connecting time
			Parking search duration
	Accessibility	Effects of autonomous vehicles on accessibility to different transport modes	Public transport stops
			Distance between transport modes
			Access to transport services at any time
	ICT extent	How ICT infrastructure will be extended in the transport sector due to autonomous vehicles	Road equipped with a real-time ICT-based system
			Traffic alerts at real time
Land use	Urban land	How the autonomous vehicles can influence in the urban structure of cities	Surface
			Population density
			Urban compactness
			Pedestrian areas
	Transport space	How the autonomous vehicles can influence in the space needed for transport	Space dedicated for motorised vehicles
			Space for the circulation of bicycles
			Space for parking
			Length of lines for public transport
Safety	Collision	How extent the autonomous vehicles can affect the frequency of traffic collisions	Traffic collisions ion roads
			Traffic collisions on city streets
	Security	How extent the autonomous vehicles can put in risk the use of electronic data by others	Cyber attacks
Health	Persons affected by traffic collisions	Influence of autonomous vehicles on the number and severity of collisions	Number of fatalities due to traffic collisions
			Number of injuries due to traffic collisions
	Access to healthcare	Influence of autonomous vehicles in the accessibility to key healthcare services	Time to reach the nearest health centre
			Travel costs to reach nearest health centre
	Access to services and leisure	Influence of autonomous vehicles in the accessibility to key services and leisure	Time to reach the nearest shopping centre/supermarket
			Travel costs to the nearest shopping centre/supermarket
			Time to reach the nearest library
	Air pollution exposure	Influence of autonomous vehicles in the unhealthy of persons caused by pollution	Days exceeding critical levels of emissions
			Population exposed to air pollution due to transport
	Quality of life	Influence of autonomous vehicles due to the replacement of traditional vehicles by autonomous vehicles	Number of older people feeling alone
			Time gained (avoided congestion, waiting time avoided, time liberated for use to work, entertainment)
Equity	Transport accessibility to vulnerable groups	How extent the autonomous vehicles can help people with problems of mobility (due to health and lack of driving licence)	Share of public transport adapted to mobility -impaired groups
			Driving licence possession
	Service distribution		Accessibility to public transport in low density areas

		How extent the autonomous vehicles can help people living in rural areas or suburban to cover the daily needs	Accessibility to public transport in suburban areas
	Affordability	Influence of autonomous vehicles in the affordability of citizens	Poverty share
			Fuel poverty
			Trip rates for disabled, older people, low income
			Share of the household budget required to hold public transport passes (unlimited monthly travel or equivalent) in the urban area of residence
Economy	Economic development	Effects of autonomous vehicles in the economy	Gross Domestic Product
			Growth of vehicle manufacture sector
			Growth of transport service sector
	Employment	Influence of autonomous vehicles in the creation and accessibility to jobs	Job creation
			Number of vanished/disappeared jobs
			Number of jobs accessible
	Investment	How extent the autonomous vehicles can influence in the cost of infrastructure for the sector of transport and in the purchase cost of a vehicle	Transport infrastructure cost (physical and digital)
			Purchase cost of vehicle
	Operating and maintenance costs (vehicle owner)	How extent the costs that must assume the owner of a vehicle can vary with the deployment of autonomous vehicles	Parking cost
			Fuel cost
			Annual maintenance cost
	Consumer expenditure	Costs of using shared vehicles	Travel cost (per trip for user, per distance, public transport single ticket price)
		Other costs	Consumer price index
	Societal benefit	Economic benefit for the administration due to the deployment of autonomous vehicles	Pollution costs avoided
			Expenses in health sector