

**PRE-
LARGE-SCALE
DEMONSTRATION
PROJECT**

Barriers to Large-Scale Deployment of CCAM in Europe and Priority Evaluation Topics for Future Demonstration Projects



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Executive summary

This report provides a survey-based insight into the key barriers to the large-scale deployment of cooperative, connected and automated mobility (CCAM) technologies in Europe and identifies the high-priority evaluation topics that future large-scale demonstration projects could address to help overcome these barriers.

This work was carried out as part of the Pre-Large-Scale Demonstration (Pre-LSDemo) project. The team gathered evidence through two online surveys: an internal survey of project partners and a survey of external experts and stakeholders from the CCAM community. The Pre-LSDemo project team then harmonised the responses and combined the external and internal survey results. The team then reviewed the results in a dedicated Pre-LSDemo expert workshop, where participants refined the presentation of the results, including moderation of the ranking order of the top barriers and evaluation topics.

The study identified twelve high-priority barrier themes and thirteen priority evaluation topics. These form an indicative, evidence-informed shortlist rather than a statistically representative ranking. The outcome of this workshop informed the recommendations presented in this report. The clearest overall finding was that large-scale deployment should be considered a holistic challenge with multiple dimensions; vehicles, infrastructure, digital systems, operators, regulators, public authorities, users, and business models all need to be ready at the same time.

1 Introduction

Europe is entering a decisive phase in the development of Connected, Cooperative and Automated Mobility (CCAM). While numerous pilots exist, large-scale deployment requires a unified approach that integrates technical, societal, regulatory, infrastructural, and operational dimensions.

The Pre-Large-Scale Demonstration (Pre-LSDemo) project prepares the essential groundwork for Europe's future Large-Scale CCAM demonstrations. The project gathers the most promising and mature CCAM use cases across individual mobility, shared/public transport and logistics, creating a coordinated and cross-domain foundation for real-world demonstration projects planned for 2027-2030 and beyond.

Through stakeholder engagement, it also explores the readiness of key enabling technologies, including sensors, V2X communication, digital services, human-machine interaction, and artificial intelligence, which is becoming a pervasive element of CCAM solutions.

The objectives include:

- Pre-LSDemo develops a harmonised, integrated demonstration plan for CCAM across Europe.
- It embeds societal readiness as a core pillar of future demonstration activities.
- The project consolidates evaluation methodologies, test procedures, enabling technologies, and readiness criteria.
- A multi-stakeholder forum ensures co-creation across industry, authorities, research, operators, and civil society.

To achieve the third objective, Pre-LSDemo reviews and consolidates relevant existing CCAM test and evaluation methodologies into a toolkit for a large-scale demonstration project. To this end, priority topics for evaluation are identified considering all three CCAM domains. These priority topics are then mapped to the most suitable methodologies, and potential gaps are identified. Then, the related data needs for the evaluations are defined. Finally, a standardised, user-friendly toolkit is developed for demonstration planners and site managers, supporting the implementation of different types of demonstrations (FOTs, Technology Pilots, Living Labs).

This report focuses on the priority evaluation topics, which form the basis for the other methodological tasks in the project.

2 Methodology

To identify priority evaluation topics for large-scale demonstrations, input was collected from internal and external experts on the barriers, challenges, concerns, and expectations associated with the large-scale deployment of CCAM in Europe, as well as the areas where dedicated evaluation would be beneficial. The surveys were conducted early in the project, in May and June 2026, so that the results could inform the prioritisation of evaluation topics for subsequent project tasks.

The study gathered input through two online questionnaires: an internal survey of project partners and an external survey of experts and stakeholders from the wider CCAM community. Respondents could submit up to five barriers and related evaluation topics in each response and were invited to complete the questionnaire again if they wished to suggest additional input. They were also encouraged to provide input across all CCAM domains. The two datasets were then harmonised and combined into a single dataset for the subsequent analysis.

The survey responses were reviewed and harmonised to ensure clear and consistent wording, allowing similar issues expressed in different ways to be compared and grouped by respondent background, barrier type, and CCAM domain. Entries were then prioritised for further analysis based on how often they recurred, whether they were raised by both internal and external respondents, their relevance across CCAM domains (e.g., personal mobility, public/shared transport, and logistics), their significance as barriers to deployment, and their potential to be addressed through a concrete evaluation activity. This process produced an initial shortlist of barrier themes and evaluation topics.

The Pre-LSDemo project team then reviewed the survey-based recommendations in a dedicated expert workshop. Participants discussed the descriptions and relevance of the identified barriers and evaluation topics, with collaborative large-scale demonstration projects specifically in mind. This resulted in refined descriptions of the barriers and evaluation topics and adjustments to their relative priorities.

3 Results

This section provides an overview of the key insights on the main barriers to large-scale CCAM deployment identified in this study. The key findings of this study are summarised in Table 1 and Table 2.

Table 1 summarises the top barriers to the large-scale deployment of CCAM in Europe. The ‘Rank’ column highlights the four barriers the study identified as top priorities, but all the barriers in the table are highly relevant according to the surveys. For reference, each barrier is assigned an ID shown in the ‘Barrier ID’ column (B1 to B12). The table also includes the ‘Barrier Theme’, a harmonised description of a group of related survey responses grouped under a single statement. The ‘Canonical Category’ indicates the dominant nature of the barrier, whether technical, regulatory, societal, operational, infrastructure-related, economic, transport system integration, or cross-cutting. Where a barrier spans more than one of these categories, all relevant categories are listed, reflecting the fact that most barriers do not sit neatly in a single domain. The final column, titled ‘Why it matters for deployment’, explains the practical impact of the barrier, that is, how it would constrain or delay large-scale deployment in practice.

Table 2 shows the high-priority evaluation topics related to the barriers in Table 1 that future large-scale demonstration projects are recommended to address. As in Table 1, each topic has an ID (E1 to E13) and an ‘Evaluation Topic Theme’ summarising the area to be evaluated. The ‘Barrier(s) addressed’ column links the topic back to the Barrier IDs in Table 1 and briefly restates the specific aspects of those barriers that the topic targets, making the traceability between the two tables explicit. The ‘Core Question(s)’ column expresses the topic as the evaluation question a demonstration would seek to answer, which is the form most directly usable when defining evaluation objectives. The final column, ‘Examples of Subjects’, lists illustrative aspects that could be examined under the topic.

Overall, the insights from this study indicate that CCAM deployment is hindered by a combination of technical, regulatory, societal, operational, infrastructure, integration, and economic barriers. The clear overall message is that large-scale deployment cannot be achieved through vehicle testing alone; the problems across vehicles, infrastructure, digital systems, operators, regulations, public authority approvals, user acceptance, and business model requirements must be considered together. Experts most frequently raised technical, societal, and regulatory barriers. Many barriers also cut across several categories. For example, an issue that is primarily technical, such as safety validation, can also affect approval processes, liability, public trust, procurement, and long-term business viability.

The tables represent a Pre-LSDemo recommendation rather than mandated priorities for individual large-scale CCAM demonstration projects. To this end, it should be emphasised that the specific priorities of any large-scale demonstration project will ultimately depend on its objectives, demonstration contexts, partner input, and implementation considerations.

Table 1: Main barriers to large-scale deployment of CCAM technologies identified in this study and their indicative ranking.

Rank	Barrier ID	Barrier theme	Canonical Category	Why it matters for deployment
Top	B1	Safety validation, ODD specification and safety-case credibility	Technical / Regulatory	Without accepted evidence that systems are safe in real operating conditions, deployment remains limited to pilots or highly constrained permits.
	B8	Business models, cost-benefit evidence, procurement and scalability	Economic / Business; Operational / Service-related	A service that works technically may still fail if it cannot be funded, procured, insured and operated at scale.
	B2	Technical ADF robustness, edge cases and real-world ODD expansion	Technical	Weak ADF robustness narrows the ODD, reduces service availability and makes scaling to diverse European contexts difficult.
	B3	Regulatory uncertainty, approval pathways, liability and cross-border harmonisation	Regulatory	Fragmented approval processes for homologation / series approval create delay, duplication and uncertainty, limiting transfer of solutions across Europe.
Other main barriers	B5	Public trust, user acceptance, perceived safety and behavioural adaptation	Societal	Technical success alone is insufficient if citizens, users, operators or affected groups do not consider the services safe, useful and legitimate.
	B4	Infrastructure, connectivity and road-environment readiness	Infrastructure-related / Technical	Even mature vehicles may fail to scale if the operational environment, digital services and support infrastructure are not ready or interoperable.
	B6	Operational feasibility, service quality, remote supervision and fleet readiness	Operational / Service-related	Large-scale services must operate reliably as everyday services, not only as technically successful demonstrations.

Rank	Barrier ID	Barrier theme	Canonical Category	Why it matters for deployment
	B7	Integration with public transport, multimodal systems, traffic management and logistics chains	Transport System Integration	Isolated automated services may add complexity or congestion unless they improve the wider transport system and integrate with existing operations.
	B11	Inclusion, accessibility, affordability and wider social effects	Societal / Operational / Economic	Large-scale deployment should provide public value and avoid creating exclusion, unaffordable services or unmanaged labour impacts.
	B10	Lack of robust evidence for EU policy, standards, investment or proposal development	Cross-cutting / Multi-domain; Technical; Regulatory	Common European evaluation methodology, comparable KPIs and baseline evidence are needed to support this.
	B9	Data governance, cybersecurity, privacy and interoperability	Technical / Regulatory / Cross-cutting	Connected automated mobility depends on trusted information exchange across vehicles, infrastructure, operators and authorities.
	B12	Stakeholder coordination, authority readiness and value-chain governance	Cross-cutting / Regulatory / Operational	A CCAM service can only scale when authorities, operators, OEMs, infrastructure managers, cities, users and affected groups have clear roles and commitment.

Table 2: Recommended high-priority evaluation topics and their indicative ranking.

Rank	Topic ID	Evaluation topic theme	Barrier(s) addressed	Core question(s)	Examples of subjects
Top	E1	Real-world safety and ODD	Barrier IDs B1, B3 — safety validation, ODD specification, safety-case credibility and regulatory approval pathways beyond testing permits.	Can the CCAM system operate safely within its ODD limits under real-world European deployment conditions? What are applicable estimators and approaches for safe real-world operation of CCAM systems and services?	Safety-critical events, disengagements/interventions, minimum-risk manoeuvres, ODD boundary events, VRU interaction quality, safe driving behaviour.
	E13	System-level traffic, environmental and societal impact assessment	Barrier IDs B7, B11 — unclear effects on congestion, energy use, emissions, safety, accessibility, modal shift and non-user impacts.	What are the direct effects and wider impacts of CCAM on the transport system and society when scaled?	Traffic flow efficiency, road capacity, emissions, energy demand, modal shift, accessibility, crash rate, impact on non-users.
	E2	ADS robustness under adverse weather, low visibility, mixed traffic and edge cases	Barrier ID B2 — perception limitations, sensor vulnerabilities, AI/ML robustness, localisation weaknesses, and complex traffic behaviour.	Which environmental, traffic and infrastructure conditions affect performance, and how can the ODD be extended?	Object detection performance, localisation error, sensor degradation, false positives/negatives, edge-case handling, service availability by condition.
	E7	Public trust, user acceptance, HMI and behavioural adaptation	Barrier ID B5 — low trust, perceived safety concerns, unclear vehicle intent, limited exposure, acceptance of takeovers and passenger reassurance.	To what extent do different users, non-users and other road users trust, accept and safely interact with CCAM?	Willingness to use, perceived safety, comfort, trust over time, observed behaviour over time, HMI comprehension, acceptance by user segment.
	E8	Accessibility, inclusion,	Barrier ID B11 — Risk of excluding elderly, rural, low-income or	To what extent do CCAM services create inclusive, affordable and	Accessibility of booking/boarding/payment,

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Rank	Topic ID	Evaluation topic theme	Barrier(s) addressed	Core question(s)	Examples of subjects
		affordability and public-value assessment	reduced-mobility users; unclear benefits for non-users and public authorities.	measurable public value compared with existing options?	service coverage, affordability, use by vulnerable groups, public-value benefits, non-user impacts.
Other priority topics	E3	Scenario-based testing, simulation-to-real-gap evidence and edge-case libraries	Barrier IDs B1, B2 — limited scalability of physical testing, uncertainty about simulation validity and lack of safety-critical scenario corpora.	Which combinations of real-world, virtual and hybrid evidence deliver trustworthy and transferable results to real-world operation?	Scenario coverage, simulation-to-real deviation, edge-case discovery rate, KPI comparability, test repeatability, evidence traceability.
	E10	Public transport and multimodal integration	Barrier ID B7 — weak fit with legacy public transport, ticketing, trip planning, service concepts, modal balance and urban mobility goals.	To what extent can CCAM complement existing public transport and shared-mobility services?	Transfer quality, journey time, reliability, passenger accessibility, ticketing/planning integration, modal shift.
	E12	Business model, procurement, cost-benefit and economic sustainability	Barrier ID B8 — high capital and operating costs, weak revenues, procurement limits, investment responsibility and uncertain long-term viability.	To what extent can different funding models provide financially viable CCAM services?	Total Cost of Ownership, cost per passenger-km/tonne-km, revenue assumptions, public subsidy need, Return on Investment, procurement barriers, funding model robustness, financial risk allocation.
	E4	Infrastructure, V2X/C-ITS and connectivity readiness	Barrier ID B4 — physical and digital infrastructure gaps, unreliable connectivity, road-readiness differences, charging/depot requirements and corridor constraints.	What is the minimum physical, digital and energy infrastructure needed for reliable CCAM operations in different contexts? What are the effects of PDI characteristics on CCAM performance?	V2X latency/availability, connectivity coverage, map quality, road marking/signage suitability, charging/depot capacity, tunnel/cross-border continuity.

Rank	Topic ID	Evaluation topic theme	Barrier(s) addressed	Core question(s)	Examples of subjects
	E6	Liability, insurance and responsibility allocation	Barrier IDs B3, B12 — unclear responsibilities between OEMs, operators, logistics actors, infrastructure managers, public authorities, users and insurers.	What are the current practices and gaps in responsibility allocation during incidents, service failures, remote interventions and automated logistics operations?	Role-allocation matrices, incident responsibility pathways, insurance requirements, contractual gaps, claims-handling scenarios.
	E9	Operational service feasibility, fleet management and remote supervision	Barrier ID B6 — service continuity, incident handling, maintenance, remote monitoring, driverless passenger support and business-as-usual operation.	To what extent can different service models operate reliably and efficiently as a scalable service?	Service uptime, fleet utilisation, remote operation and incident response time, remote-supervision workload, maintenance events, passenger support events, operating cost per service hour.
	E5	Regulatory sandbox, approval pathway and certification evidence	Barrier ID B3 — fragmented permits, unclear homologation/type approval, local operating-area approvals and cross-border deployment delays.	What are the current practices and gaps in procedures and authority coordination that support moving from pilot permission to scalable deployment approval?	Approval steps, time-to-permit, duplicated requirements, authority interfaces, certification evidence gaps, mutual-recognition opportunities.
	E11	Logistics corridors, depot, terminal and supply-chain integration	Barrier IDs B7, B8 — cross-border corridors, freight terminals, loading/unloading, eFTI, data exchange, operations in legacy logistics systems and ROI.	To what extent can CCAM integrate with logistics operations while improving efficiency and predictability?	Vehicle utilisation, energy use, delivery reliability, travel time, loading/unloading time, terminal interface performance, eFTI compliance, cost per shipment, end-to-end operation.

4 Summary and Outlook

This study identified and prioritised the main barriers to the large-scale deployment of CCAM technologies in Europe, as well as the evaluation topics that the Pre-LSDemo project recommends for future European large-scale CCAM demonstration projects. The recommendations are based on combined input from an internal and external expert survey, as well as a subsequent expert workshop reviewing the survey results.

Safety validation and ODD/safety-case credibility was identified as the highest-priority barrier, while real-world safety/ODD validation was identified as the highest-priority evaluation topic in this study.

Pre-LSDemo recommends considering the main barriers and high-priority evaluation topics identified in this study when planning relevant activities in future large-scale demonstration projects. However, the final selection should be made for each project once the specific demonstrations, use cases, and deployment contexts are defined. Relevant areas include safety validation, technical robustness, business models, infrastructure readiness, public trust, regulatory approval pathways, real-world safety validation, scenario-based testing, and system-level impact assessment.

List of abbreviations and acronyms

Abbreviation	Meaning
ADS / ADF	Automated Driving System / Automated Driving Function
AI/ML	Artificial Intelligence / Machine Learning
CCAM	Cooperative, Connected and Automated Mobility
C-ITS	Cooperative Intelligent Transport Systems
eFTI	Electronic Freight Transport Information
HMI	Human–Machine Interface
KPI	Key Performance Indicator
ODD	Operational Design Domain
OEM	Original Equipment Manufacturer
PDI	Physical and digital infrastructure
Pre-LSDemo	Pre-Large-Scale Demonstration (project)
ROI	Return on Investment
V2X	Vehicle-to-Everything (communication)
VRU	Vulnerable Road User