Policy Brief

ROADVIEW
Robust Automated Driving in Extreme Weather

Automated Vehicles for Safer, Smarter, and Sustainable Mobility – Overcoming Harsh Weather Challenges.

Executive Summary: Connected and Automated Vehicles (CAVs) are expected to play a crucial role in advancing safer, smarter, and more sustainable mobility across Europe, supporting the European Union (EU)'s Vision Zero strategies. However, the technology currently available on the market remains limited in its operational scope, with harsh weather conditions still presenting a significant challenge to their reliable functioning.

The ROADVIEW project has been at the forefront of developing innovative solutions to address weather-relevant challenges, offering technologies that can partially or fully mitigate the impact of adverse weather on CAV performance. Despite their potential, the successful commercialisation and deployment of these innovations could be constrained by regulatory and policy-related barriers.

To fully unlock the benefits of CAV technology, the EU and its Member States must work together to align regulatory frameworks, foster cross-border cooperation, and support investment in critical infrastructure. A coordinated approach will not only accelerate the deployment of weather-resilient automated vehicles but also strengthen Europe's position as a leader in smart mobility solutions.

Below is an overview of the key needs identified in the ROADVIEW analysis. For more information, refer to the subsequent pages of this brief.

KEY POLICY NEEDS RESULTING FROM ROADVIEW

01 A harmonised **European framework** is needed **to address fragmented CAV testing regulations** and enable cross-border validation, particularly under harsh weather conditions. Legal constraints, combined with unpredictable weather, make comprehensive testing across scenarios even more challenging.

02 Need for a harmonised **CAV liability framework to clarify responsibility in accidents**, especially when following Vehicle-2-Everything (V2X) driving advice in harsh weather. Inconsistent regulations across EU Member States create legal uncertainties that could hinder commercialisation of weather-robust technologies across the European single market.

03 **Balancing privacy and security** in CAV data collection is needed. ROADVIEW technologies enhance CAV reliability in adverse weather through the use of cameras. Yet, this may conflict with GDPR. Addressing this trade-off is essential for enabling effective data sharing within the CCAM ecosystem while ensuring compliance and road safety.

04 Need for clear EU **best practices and guidelines for AI use in CAVs** to ensure transparent, effective, and compliant decision-making under the AI Act. ROADVIEW innovations may be classified as high-risk, requiring significant efforts to meet regulatory requirements, potentially impacting development and deployment.

05 An EU-wide regulatory **hybrid methodology for CAV testing and approval** is required, with policymakers considering the metrics and test methodologies developed by ROADVIEW. Integrating these into regulations could enhance simulation credibility especially in harsh weather and accelerate CAV deployment.

06 Need for **mandatory EU/United Nations (UN) regulations following V2X communication standards** for adverse weather to ensure safety, interoperability, and large-scale adoption. Policymakers should consider ROADVIEW's contributions within ETSI to strengthen regulatory frameworks and drive industry-wide compliance.

Introduction:
The Challenge of Bad Weather

Automated driving solutions are bringing significant benefits to our society, including fewer traffic accidents and fatalities, improved traffic management, reduced congestion, and lower CO2 emissions. The increasing implementation of Advanced Driver-Assistance Systems (ADAS) and Connected and Automated Vehicles (CAVs) as mobility solutions plays a crucial role in the EU's Smart and Sustainable Mobility Strategy and the Towards Vision Zero strategy.

The Vision Zero initiative, which aims to eliminate road fatalities by 2050, emphasises that human error remains the leading cause of accidents. By reducing reliance on human drivers and leveraging automation, CAVs contribute to safer roads by minimising accidents caused by distraction, fatigue, or misjudgement.

In addition to improving safety, automated mobility also contributes to traffic efficiency and congestion reduction. The EU's Smart and Sustainable Mobility Strategy highlights the need for seamless, intelligent, and connected transport systems, where digitalisation plays a key role in optimising traffic flow. CAVs, through real-time data exchange and adaptive driving behaviour, improve traffic flows, reduce bottlenecks, and enhance overall transport network efficiency, also producing a positive effect on the environment by reducing the overall CO2 emissions.

Figure 1. ROADVIEW partner (VTT) vehicle testing in harsh weather.

Nonetheless, bad weather and complex traffic conditions affect the safety and operations of CAVs. Weather affects not only the vehicle performance but also the roadway infrastructure, thereby increasing the risk of collision and traffic scenario variations. So far, most automated vehicles have been primarily trained and tested under optimal weather and road conditions with clear visibility. Yet, to see widespread adaption and the fulfilment of the EU policy objectives, CAV systems will have to prove to be equally reliable under any weather and road condition (See Figure 1). The challenges caused by harsh weather conditions, such as rain, fog, and snow, are substantial as they affect the functioning of key technologies of which CAVs are reliant on, as illustrated below.

Challenges of CAV technology in harsh wather

Sensors
Sensors may be obstructed by snow, ice, water, or mud, affecting measurements and altering noise levels.

Detection
Snow on the road may be mistaken for markings, water drops detected as objects, and traffic signs obscured by snow or rain.

Control
Friction on the road may change rapidly, for example, on icy roads, or due to aquaplaning.

System testing
Testing is difficult, as (extreme) harsh weather is not as abundant and hardly reproducible.

ROADVIEW approach:
Developing Weather-robust CAVs

To address these challenges, the ROADVIEW project is developing complex in-vehicle perception and decision-making systems able to perform advanced traffic recognition and prediction under severe weather conditions, such as snow, fog, and rain. Based on a cost-efficient multisensory setup, the revolutionary systems can independently perceive the environmental conditions and make decisions based on their enhanced sensing, localisation, and improved object and person classification. The project takes a holistic approach to addressing these challenges, which can be summarised as follows:

» **Early filtering of sensor noise** to enhance object and vulnerable road user detection.
» **Adaptive sensor data fusion** that dynamically selects the most suitable sensor inputs based on environmental conditions.
» **Collaborative perception** between CCAM vehicles to improve detection robustness.
» Mathematically grounded **sensor noise modelling** to simulate realistic variations in harsh weather conditions.
» **Faster testing** through simulation-assisted methods, including CAV validation that integrates virtual and real-world testing.

Innovations resulting from ROADVIEW

As part of the development of the ROADVIEW final technology, several groundbreaking innovations have emerged, offering potential for both commercial and non-commercial applications. The key innovations are listed below.

Harsh weather visibility estimator for safe automated driving

Weather-conditional velocity controller for safe automated driving in harsh weather conditions

Fast and Accurate Multi-sensor Fusion for Joint Multitask Learning

A fast and memory efficient outlier detector for 3D LiDAR point clouds

A fast free space detector using LiDAR point clouds

Semantics-aware pseudo point cloud-based 3D object detector

A real-time multimodal weather type detector for autonomous vehicles

Infrastructure-based perception system including weather conditions for collaborative perception solution using V2X

Weather-aware infrastructure-based manoeuvre cooperation for vehicle control and decision-making system using V2X

Data quality level indications for autonomous driving

Tyre and vehicle dynamics model on snow and ice

Metrics for assessing performance of motion planning

XiL test environment for automated driving and credibility evaluation methodology

Automatic and real-time detection of weather conditions from roadside cameras

Environment-aware high-definition mapping method for real-time positioning of an autonomous vehicle on the map

Optical measurement of road grip and road surface conditions in front of the vehicle

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ROADVIEW findings: Policy Challenges for CAVs in Bad Weather

The commercialisation of ROADVIEW technologies has encountered legal and regulatory barriers that could hinder the future use of project results unless action is taken to address them. Before examining the specific challenges faced by the ROADVIEW project, it is essential to understand the broader regulatory framework governing CAVs in the EU. Currently, CAV regulations in Europe remain fragmented, with responsibilities divided between the EU and its individual Member States. The regulatory landscape consists of three key dimensions:[1]

- **Vehicle design & technical specifications:** This legal dimension sets standards for safety, efficiency, and operational performance. These aspects fall under the regulatory competence of the EU and the UN, ensuring harmonisation across different jurisdictions.
- **Traffic rules:** This dimesion governs the movement of vehicles, pedestrians, and cyclists on roads to ensure safety and maintain order. These rules are determined at the national level, though they are often influenced by international agreements and conferences.
- **Vehicle liability:** This last dimension defines responsibility when an automated system violates legal requirements. As liability laws are established at the national level, their interpretation varies across Member States, adding complexity to the legal landscape.

[1] Jenny Lundahl. RiSE Research Institutes of Sweden AB. (2024, December 4). ROADVIEW - Network AD Regulations Project. Online/Teams.

At the **national level,** challenges often emerge due to the absence of a unified European approach to CAV regulations. National challenges were analysed within the ROADVIEW framework and grouped into two core categories:

1. **Data collection and testing:** Data collection and testing are essential for CAVs as they validate and refine prediction, perception, and decision-making, enhancing safety, reliability, and the adaptability of machine learning/AI models to real-world conditions. However, in the European context, there is no unified approach to CAV data collection and testing. Each EU Member State sets its own regulations for obtaining permits to test CAVs on open roads, creating significant barriers to EU-wide testing and data collection. This challenge is further amplified when testing CAVs in harsh weather conditions, as such conditions can only be predicted, not guaranteed. A harmonised and simplified European framework could facilitate more efficient cross-border CAV testing, ultimately accelerating technological progress and deployment.
2. **Liability of CAVs:** In the event of an accident, liability for human-driven vehicles rests with the driver. However, for CAVs, it remains unclear who would be responsible if a CAV were to follow Vehicle-to-Everything (V2X) driving advice from an infrastructure system and cause an accident. Furthermore, liability regulations and their interpretations can vary significantly across EU Member States. The lack of harmonisation and EU-wide definition of liability are expected to slow down the commercialisation of the ROADVIEW V2X Manoeuvre Coordination Services across the European single market.

Focusing on the **EU and UN dimensions,** the ROADVIEW consortium has identified potential barriers that could hinder the large-scale adoption of the proposed results:

1. **Privacy and data sharing:** In Europe, the General Data Protection Regulation (GDPR – EU 2016/679) governs the collection, processing, storage, and sharing of personal data within the EU and the European Economic Area (EEA), imposing obligations on organisations to protect data security and transparency of users. Several ROADVIEW technologies rely on image acquisition through light and thermal cameras to guide CAVs safely and effectively, particularly in harsh weather conditions. These technologies collect personal data, such as licence plate numbers and images of road users, which are then shared within the CCAM ecosystem to enhance collective awareness of CAVs. Although various anonymisation software solutions exist, achieving full compliance with GDPR is not necessarily guaranteed, posing potential legal and ethical challenges. While ROADVIEW's technology enhances CAV safety and efficiency especially in harsh weather conditions, ensuring GDPR compliance remains a critical challenge.
2. **AI classification:** Artificial Intelligence (AI) is essential for CAVs as it enables real-time perception, decision-making, and control, allowing vehicles to navigate safely without human intervention. AI is used to process sensor data, predict the behaviour of other road users, and optimise routes. In Europe, the AI Act – (EU) 2024/1689 – governs the development, deployment, and use of AI systems by categorising them based on risk levels – unacceptable, high, limited, and minimal risk – to ensure safety, transparency, and compliance with fundamental rights while fostering innovation. Under the AI Act, innovations from the ROADVIEW project may be classified as high-risk, requiring technology manufacturers to make significant additional efforts to meet requirements for AI risk management, transparency, robustness, human oversight, and continuous monitoring. While AI is increasingly integrated into ADAS and CAV technologies, clear EU best practices and guidelines for ensuring efficient, transparent, and effective AI-driven decision-making and data management within CAV ecosystems are still lacking.
3. **Hybrid validation methodology for CAV testing and approval:** Validation methodologies are structured approaches used to assess and ensure the safety, reliability, and performance of CAVs before they enter the market. In Europe, these methodologies are regulated by the (EU) 2022/1426 and the UNECE Regulation 157. ROADVIEW developed a combination of virtual and real-world environments – a hybrid environment – to simulate CAVs' behaviour, using an XiL testing environment to accelerate the deployment of safe and robust automated driving functions, especially in harsh weather conditions. However, despite various norms and regulators emphasising the benefits of this type of simulation environment, there is no clear EU-wide regulatory methodology for validating the credibility of these simulations, inevitably delaying the time-to-market of innovations.
4. **EU & UN adoption of V2X communication standards for adverse weather:** Communication standards provide essential guidelines and specifications to ensure the safety, interoperability, and performance consistency of V2X communication across vehicle systems and infrastructure. These standards enhance collective awareness within the broader CCAM ecosystem. ROADVIEW is actively contributing to the development of V2X communication standards for adverse weather conditions within the European Telecommunication Standards Institute (ETSI). While establishing such standards within the CAV industry marks progress towards Europe-wide implementation, compliance remains voluntary, as no mandatory EU or UN regulations currently enforce them, inevitably affecting their pathway to a large-scale adoption.

Conclusion:
A reflection on the future of CAVs

In conclusion, while CAVs offer significant potential for safer, smarter, and more sustainable mobility, their large-scale deployment is still hindered by challenges posed by harsh weather conditions. The innovations introduced by the ROADVIEW project provide a promising opportunity to address these weather-related issues. However, overcoming regulatory barriers remains crucial for their widespread adoption.

This analysis highlighted the need for a harmonised European approach to tackle fragmented CAV regulations, ensure legal clarity on liability, and establish standardised testing methodologies. Additionally, clear guidelines on AI transparency, data privacy, and V2X communication standards are essential to facilitate large-scale adoption while maintaining public trust and compliance with EU regulations.

To fully realise the benefits of ROADVIEW's innovations, policymakers must actively promote cross-border collaboration, invest in resilient transnational data-sharing infrastructure, and streamline regulatory frameworks. By taking these steps, Europe can reinforce its leadership in automated mobility and enable the successful deployment of weather-resilient CAVs – ultimately supporting the EU's Vision Zero and Smart and Sustainable Mobility Strategies.

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