Comparative Analysis of Liability Frameworks for Automated Vehicles: Legal Readiness in the EU, US and China

Julia Roussou[1*[0000-0003-3261-0156]], Armira Kontaxi[1[0000-0002-0935-0889]], Apostolos Ziakopoulos[1[0000-0001-6252-6743]] and George Yannis[1[0000-0002-2196-2335]]

[1] Department of Transportation Planning and Engineering, National Technical University of Athens, Greece
*jroussou@mail.ntua.gr
akontaxi@mail.ntua.gr
apziak@central.ntua.gr
geyannis@central.ntua.gr

Abstract. Automated Vehicles (AVs) are expected to have a plethora of benefits to road safety, traffic and society. With the rise of automation liability allocation is becoming a critical and unresolved legal challenge that will affect AVs adoption, price, road safety and traffic. This paper presents an analysis of AV liability frameworks comparing three major jurisdictions: the European Union, the United States and China. Each region has unique regulatory frameworks, legal structures, and implementation timelines, leading to different approaches in liability allocation and managing insurance claims in AV-involved incidents. This study used a structured legal analysis framework to evaluate the clarity, coherence, and adaptability of liability rules in each jurisdiction, focusing on key dimensions such as manufacturer liability, driver responsibility and treatment of automation (SAE Levels 3–5). The findings highlight significant legal fragmentation between the studied jurisdictions, which could pose risks for cross-border AV deployment and potentially hinder manufacturer compliance efforts and innovation development, creating uncertainty for insurers and users. A comparative matrix was developed to illustrate how liability standards vary across regions and identify best practices that could promote both innovation and accountability. The paper concludes with policy recommendations aimed at improving AV liability allocation regulations in the EU.

Keywords: Automated Vehicles, Comparative Analysis, Regulations.

1 Introduction

Automated vehicles (AVs) are expected to improve safety and produce important societal benefits, but are also set to expose unresolved issues about liability allocation in case of a crash [6]. Technical limitations (such as performance in bad weather conditions, data security and hacking risks) and complications in the understanding of the

urban environment can further complicate liability allocation, underscoring the need for clear regulations that apply to all AVs at SAE Levels 3–5 [3].

Furthermore, development of AV related regulations has not uniformly kept pace with the various technological advancements. Many national laws focus primarily on AV testing or require constant human supervision even for fully automated vehicle capabilities [10]. Given these critical gaps, the aim of this paper is to compare legal readiness across the European Union (EU), the United States (US), and China, focusing on the allocation of liability among drivers/users, vehicle users/owners, manufacturers and other actors, and on how each framework handles the distinct challenges of higher levels of AVs (i.e. L3–5).

2 Structure legal analysis framework

After identifying the regulations and policies related to AVs liability allocation for each jurisdiction and reviewing relevant literature, each jurisdiction regulations were evaluated based on three dimensions:

1. Clarity – whether the framework clearly identifies liable actors and allocates liability for various common crash scenarios (e.g., system in control vs. human in control), and whether supporting mechanisms (e.g., event data recorders) are required to establish who was driving.
2. Coherence – reviewing the extent of internal consistency across instruments (laws, directives, policies) and across regulatory levels (central, state/local), including the relation between ex ante "risk regulation" and ex post liability.
3. Adaptability – the extent to which regulations have evolved with technological advancements and accommodate all levels of automation, software updates, data governance and insurance market needs supporting cross-border applicability.

3 AVs liability allocation in the European Union

3.1 Baseline EU instruments: product liability, insurance, and AI risk regulation

At the EU level, there is no AV-specific civil liability regulation applied uniformly yet. The Product Liability Directive of 2024 (EU2024/2853 repealing PLD 85/374/EEC) attributes strict liability for defective products and is considered sufficient to apply to AVs without immediate amendment [2]. Similarly, the Motor Insurance Directive (MID 2009/103/EC) regime that compensates victims through compulsory motor insurance, allowing the insurer to subsequently turn to the manufacturer where appropriate, is considered applicable for AVs but requires harmonized definitions of "automated mode" and standardized data access to avoid litigation bottlenecks. The new EU Artificial Intelligence Act (Regulation (EU) 2024/1689) establishes risk-based ex-ante obligations for high-risk AI systems (including many vehicle AI components) to ensure

health, safety and human rights protection, aiming at the same time at the support of economy and innovation. Even though this regulation is primarily an ex-ante risk regulation, it interacts with civil liability rules and safety laws [1]. It is essential for risk regulation to be combined with liability to ensure victim compensation and optimal policies, especially for crashes where AVs SAE L3-4 are involved. Shifting primary responsibility from driver/insurer to manufacturer is still uneven across Europe. The Commission Implementing Regulation (EU) 2022/1426 is also an important guideline for AVs. Even though the purpose of EU 2022/1426 is to define the procedures and technical specifications for the type-approval of the automated driving system (ADS) of fully AVs, it could help to clearly distinguish driver assistance (L2) from automated driving (L3+) in order to avoid misallocation of liability.

3.2 Germany as an EU case study: L3-L4 operationalization

Germany amended its Road Traffic Act (StVG) in 2017 to address highly and fully automated driving. Through the definition of permitted operation modes, driver duties, and data recording requirements it is possible to determine who controlled the vehicle at the relevant time (system vs. human) [9]. These amendments increased liability limits for owners/users of AVs and maintained strict owner liability, with subsequent liability sharing towards manufacturers where appropriate. A dedicated provision of the Road Traffic Act (§63a StVG) mandates storage and disclosure of event data when mode switches or takeover requests occur, thus supporting evidentiary clarity. In 2021, Germany enacted the Autonomous Driving Act to enable Level 4 operation in defined areas under a technical supervisor model, accompanied by the Autonomous Vehicle Approval and Operation Ordinance (AFGBV) regulating permits, Operational Design Domain (ODD) approval, technical supervision, cybersecurity, and data storage. This structure improves adaptability by specifying technical and operational precautions and allocating responsibilities among owners, manufacturers, and the technical supervisor.

3.3 EU liability allocation framework assessment

The PLD that channels defect-based claims to manufacturers, together with the MID that secures victim compensation through compulsory insurance form a coherent baseline for ex-post rules on accountability and compensation, which is complemented by the AI Act, introducing the ex-ante risk rules. In parallel with PLD/MID and the AI Act, Implementing Regulation (EU) 2022/1426 provides the type-approval regulations for fully automated vehicles through defined use cases, ODD anchoring, and lifecycle safety/validation and in-service reporting. While not allocating civil liability, this system substantially improves legal clarity. However, civil liability is mainly regulated within the EU Member-States, thus national laws form the driver/owner side of the equation. At the same time, issues that remain unresolved, such as definitional gaps at AVs L3-4, hand-over liability windows, and standardized data-access rules, complicate cross-border deployment and proper liability allocation.

4 AVs liability allocation in the United States

The US AVs liability allocation regulations combine federal safety oversight with state-level liability and insurance rules. The Federal Automated Vehicles Policy of NHTSA (2016) outlines a Model State Policy and emphasizes the need to avoid inconsistency in state rules, while recognizing states' roles in allocating liability and determining insurance. States are prompted to consider how liability will be assigned among owners, operators, passengers, and manufacturers when a crash occurs. NHTSA also highlights its enforcement authority over safety defects, including those arising from fully AV technologies. During the transition phase where AVs of all levels and conventional vehicles will share the roads, conventional liability doctrines will continue to be applied [5].

In tort practice, AV harms tend to be resolved by existing product-liability and negligence frameworks. Plaintiffs typically plead strict products liability and negligence. It is essential to highlight that if AVs are statistically safer overall but fail in distinctive ways, juries might still deem those failures "defects," leading to legal exposure that discourages companies from advancing AV technology, unless liability is calibrated to relative safety and proper warnings [8]. At L3–L4, duty to supervise is central; misuse/misunderstanding or overtrust triggers shared liability debates. States rarely legislate distinct L3 vs. L4 liability triggers, this legal indeterminacy is a major source of uncertainty at L3 [4].

4.1 US liability allocation framework assessment

The US approach is characterized by coherence at the federal level regarding safety oversight and by adaptability through state experimentation. Clarity of AV liability regulations can vary for end-users across states because of the decentralized allocation of liability and insurance responsibilities. Robust tort tools exist, but state-by-state divergence and AVs L3 hand-over ambiguities reduce clarity. Appropriate harmonization is essential to avoid deployment risk and insurance uncertainty. U.S. legislative debates spotlight definitional gaps (what counts as a "driver"), data ownership/Event Data Recorder (EDR) access, and insurance design as important barriers to achieving clear and coherent AV liability allocation regulations.

5 AVs liability allocation in China

China's central regime is transitioning from policy encouragement to legislative preparation, with key road-testing and pilot guidelines in place but without uniform liability rules at the national level [12]. Local regulations have established various liability assignment models: Shenzhen (2022) distinguishes "human liability" vs. "vehicle liability" and thus for L3–L4 AVs the driver is responsible for compensation if the vehicle is at fault; for L5, the owner/manager is held liable, with the possibility of post-payment recourse against the manufacturer in case of defects. Beijing establishes liability allocation on whether the automated system was activated, reflecting attempts to link

liability to the functional status of the AVs. Other jurisdictions (e.g., Shanghai Pudong, Wuhan) tend toward enterprise liability for unmanned operation, again with possible recourse to other entities [5]. Recent analyses urge codifying AV-specific liability allocation (owner/manager pays first with recourse to manufacturers) in order to increase safety and specially to accelerate national legislation beyond local pilots [9].

5.1 China liability allocation framework assessment

China's AV liability framework is characterized by local and regional divergence. Many regions are mainly aiming on deploying AV pilots, without developing clear and coherent AVs regulations. Key gaps identified in the AV liability allocation regulations include the uncertainty of the attention obligations for AVs L3 drivers, the high local divergence in the hierarchy between human and product liability, the unclear definition of manufacturer's continuing obligations (software updates, data retention) and the absence of nationwide unified crash data-recording rule.

6 Comparative matrix across the three regions

Table 1 presents a comparison of the three considered regions across various critical aspects. Across the three jurisdictions AV liability allocation diverges in various ways. In the EU product liability and compulsory insurance together with the increasing ex-ante safety regulations (AI Act, 2022/1426 type-approval) offer a strong victim protection framework, but the AV driver/owner liability allocation regulations are defined by the Member States creating uncertainty. In the US, safety oversight is centralized at a federal level, leaving tort and insurance to the States, leading to uneven clarity for end-users. China local pilots support progress, but lead to fragmented liability allocation regulations in the absence of mature nationwide AV legislation.

Diverse liability allocation regulations (e.g., driver vs. owner vs. manufacturer) can create uncertainty for cross-border deployment, complicating compliance as well as insurance pricing. The present comparative analysis showed that Europe is more coherent on product and motor insurance baselines than the US, but still relies on Member-State liability allocation.

L3 human-machine handover generates the most ambiguity, particularly around attention duties and activation status. This unclear area underlines the need for explicit, uniform standards and evidence mechanisms (EDR) [13]. Germany's StVG is a strong model; in contrast, Chinese local frameworks and many US states lack comparable uniformity. Ex-ante AI risk rules (EU AI Act) should be complemented by liability regulations that allocate crash responsibility and motivate precaution; especially for mixed-control scenarios.

Reliable, accessible, and standardized operational data (mode, takeover request, compliance) is essential to resolve causation and lead to fair liability allocation. Across all frameworks, compulsory insurance remains central to victim protection; it is essential to emphasize in the use of insurance to deliver prompt compensation while preserving the possibility to turn towards the manufacturer where defects exist.

Table 1. Comparative matrix

Aspect	European Union	United States	China
Core legal framework	EU-wide PLD strict product liability. MID compulsory motor insurance Member States retain road-traffic liability rules.	NHTSA federal safety oversight & defect enforcement. Liability and insurance are primarily based on state law.	Central policy with various local ordinances (e.g., Shenzhen) on liability allocation.
Manufacturer liability	Strict via PLD for defects.	Product liability and negligence doctrines apply.	Many local rules hold owner/manager primarily liable, with recourse to manufacturers.
Driver/user liability	Member-State traffic law determines owner/driver duties. MID ensures victim compensation.	Defined by state law. Driver definition and responsibilities vary across states.	Different local regulations.
Treatment of L3	No EU-wide L3 attention standard. National laws address handover and monitoring unevenly.	No uniform federal L3 duty. Studies define no-fault handover windows and computer-driver duties.	L3 with driver: driver often bears compensation where vehicle "at fault".
Treatment of L4-5	EU allows national L4 frameworks. MID covers victims. L5 liability regulations are not yet codified.	State pilots and deployments. Federal safety action on defects. Liability remains state-based.	Shenzhen model: owner/manager primary for driverless. Recourse to manufacturer after proof of defect.
Insurance approach	MID mandates coverage and victim compensation. No need for AV specific amendment due to tech-neutral regulations.	States set insurance obligations. Federal policy recognizes impact of liability/insurance on deployment.	Mostly "pay-first, recover-later" insurance to protect victims in AVs crashes, then regress upstream.
Data	EU-wide liability-focused EDR not mandated.	No uniform AV-EDR mandate for liability. Evidence rules evolve case-by-case.	No unified EDR mandate; "black box" gaps hinder proof.

7 Policy recommendations for the EU

Based on the comparative analysis the following policy recommendations could assist the development of clear and coherent AV liability regulations in the EU. It is essential to clearly separate driver assistance (L2) from automated driving (L3+) and define when the AV is "driving itself." After making these status signals machine-readable (engaged, ODD-compliant, transition demand active, MRM in progress) it will be easier to tie liability requirements to them.

AVs L3 should have minimum HMI/transition-demand standards and safe reaction period during which fault doesn't shift to the human while the ADS keeps the vehicle safe/legal. After that window, responsibility can migrate if the human fails to take over. This could help improve liability allocation understanding and enhance trust to AVs. The legal procedure could be accelerated by creating a fast pathway for access to a minimum evidence dossier which would include all necessary liability-focused data namely ODD status, transition demands, MRM, health sensor, etc.

The MID could be strengthened by the introduction of a harmonized recourse package, so that victims could be compensated fast by the motor insurers and then insurers will be able to seek recovery by the manufacturers in case of defect. To accelerate cross-border recovery procedures a contractual protocol setting deadlines, data formats, and escalation paths could be developed.

8 Conclusions

Across the EU, US, and China, AV liability law is converging on a few pillars, such as manufacturer responsibility for defects, human vigilance duties when required, and motor-insurance as the first compensation layer. Nonetheless, details are considerably different, especially at SAE L3, where shared control renders responsibility hard to assign and evidentiary demands are highest. The comparative analysis of the present work suggests the application of control-based liability allocation rules, insurance-first compensation with structured recourse, and trustworthy data infrastructure. Implementing these regulations along all member states would reduce fragmentation risk, support innovation, and improve accountability for automated mobility. In conclusion, while the legal debate on AV liability has advanced significantly, the dynamic relationship between liability allocation and traffic remains insufficiently addressed. Closing this gap is critical not only for legal clarity and public trust, but for realizing the full safety and efficiency benefits promised by automated mobility.

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