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Assessment of the safe deployment of automated vehicles: human factors

**Human factors principles and procedures for automated
vehicle safety – DRAFT**

Submitted by Canada

This document proposes a set of key human factors principles for the safe design of automated vehicles and provides a set of human-centred design procedures to follow when developing and evaluating automated driving systems.

1. Introduction

At the 84th Session of WP1 (Sept 2021), Canada and the WP1 chair tabled a proposal to develop a framework of key principles for automated vehicle safety and human-centred needs. The following draft principles were developed to support dialogue among relevant UNECE bodies and industry stakeholders who have a role in supporting the safe operation of automated vehicles in road traffic.. The goal of the principles document is to promote human needs in the design of automated driving systems (ADS),and associated safety requirements and policy instruments adopted by relevant UNECE working parties. This document was drafted according to input from the expert contributions in the WP.1 Human Factors Panels (2022, 2023), HF-IRADS advisory group, human factors guidelines, and industry codes of practice.

This document proposes a set of key human factors principles for the safe design of automated vehicles including a set of human-centred design procedures to consider when designing, developing and evaluating automated driving systems. Following these principles and procedures will help to ensure the safety, usability, equity, and accessibility of automated driving systems that operate in road traffic.

These principles could be used to inform the development of a more formalized safety requirements and policy tools adopted by relevant UNECE bodies, where appropriate, to ensure that human-centred design (HCD) is consistently applied in the development of ADS-equipped vehicles intended for use in road traffic.

2. Preamble

Recalling the importance of enhancing road safety and recognizing the potential impact of road vehicle automation and other innovations on global road safety,

Emphasizing that achieving global road safety targets necessitates a multifaceted strategy beyond vehicle automation and warrants a safe systems approach,

Acknowledging that while vehicle automation holds the potential to enhance road safety, the technologies will not be flawless,

Affirming that road users' well-being and safety are paramount and that safety should not be compromised for the sake of innovation,

Appreciating the necessity of evidence-based safety in the development of road transportation technologies,

Acknowledging the importance of human factors in the development of vehicle automation to advance road safety objectives and promote the safety, usability, equity, and accessibility of road transportation systems,

Reiterating that the impact of technological innovations on road safety hinges on their alignment with user needs and capabilities,

Stressing that prioritizing the human experience through human-centred design is not only conducive to safety but also supports innovation and technological advancement,

Underscoring that "human error" should be viewed as an indication of system shortcomings rather than an inherent flaw in users,

Hereby adopts this guide to establish key human factors principles and procedures for automated vehicle safety and human-centred needs.

3. Scope and Definitions

The principles and procedures presented therein apply to vehicles intended for use on public roads with SAE Level 3 – Level 5 automated driving systems.

These principles apply to vehicles that can be driven manually, by automated driving systems as well as for vehicles that users can only interact with as passengers or other road users.

Automated Driving System (ADS) - The hardware and software that are collectively capable of performing the entire dynamic driving task on a sustained basis.

Human-Centred Design (HCD) - an approach to design that focuses on the users, their needs and requirements, by applying human factors knowledge and techniques.

Human Factors - Human factors is a multidisciplinary science that applies knowledge of human abilities and limitations to the design and evaluation of technology for improved safety and usability.

4. Human Factors principles

4.1 Manufactures should consider the following principles when designing vehicles equipped with ADS that permit manual driving

1. Clear and Intuitive Displays:
 - a. The ADS manufacturer should ensure information is presented on the user interface clearly, simply, and unambiguously.
 - b. The ADS manufacturer should ensure the automation mode and status information are continuously displayed when active or available.
2. User-Friendly Interaction:
 - a. The ADS manufacturer should ensure human interactions with the ADS are simple, discoverable, and easy-to-learn.
 - b. The ADS manufacturer should ensure the interfaces of the vehicle equipped with ADS are positioned to support safe and accessible interaction.
 - c. The ADS manufacturer should ensure the automation mode structure, settings, and transition types are simplified to minimize confusion.
3. Communicating Urgency:
 - a. The ADS manufacturer should ensure the vehicle equipped with ADS utilize combined visual, auditory or haptic cues effectively for alerts and warnings.
 - b. The ADS manufacturer should ensure messages convey their priority level clearly.
4. Smooth Transition of Control:
 - a. The ADS manufacturer should ensure unintentional activations and deactivations of the ADS are not possible.
 - b. The ADS manufacturer should ensure the vehicle equipped with ADS informs fallback users of their current role, if any, and signal any changes to that role.
 - c. The ADS manufacturer should develop clear, simple, and direct steps for transitioning control between the ADS and human drivers.
 - d. The ADS manufacturer should ensure the vehicle equipped with ADS provides Fallback users with sufficient time to safely re-engage in the driving task.
 - e. The ADS manufacturer should ensure the vehicle equipped with ADS monitors fallback users to verify they are available to safely resume manual driving.
 - f. The ADS manufacturer should ensure the vehicle equipped with ADS use multimodal displays and escalate warnings to engage fallback users.

5. Trust and Transparency
 - a. The ADS manufacturer should indicate clear user roles and responsibilities.
 - b. The ADS manufacturer should foster appropriate trust through transparent communication of how the automation works and its limitations.
 - c. The ADS manufacturer should ensure consistent interaction logic and driving behavior of the ADS.
 - d. The ADS manufacturer should ensure the ADS can clearly communicate intentions and actions at all times.
6. Training and Informing about Function Limits
 - a. The ADS manufacturer should provide accessible documentation and support to users for training and familiarization with safe use of the ADS.
 - b. The ADS manufacturer should provide information to the driver about their responsibilities and function limits that might require intervention.
 - c. The ADS manufacturer should avoid misleading terminology and exaggerated representations of ADS capabilities.
7. Detecting Failures and Alerts
 - a. The ADS manufacturer should ensure the ADS can detect failures and notify the user of any reduced capabilities.
 - b. The ADS manufacturer should ensure the ADS does not require immediate user intervention during ADS driving emergencies.
 - c. The ADS manufacturer should ensure the ADS enables automation override or switch-off in case of ADS malfunction.
 - d. The ADS manufacturer should ensure the ADS signals when it intends to put the vehicle in a minimal risk condition.
 - e. The ADS manufacturer should ensure the ADS is designed to gracefully handle unexpected situations and errors.
 - f. The ADS manufacturer should ensure the ADS provides clear instructions for user responses during system failures or emergencies.
8. Accessibility and Equity:
 - a. The ADS manufacturer should ensure that it designs the interface to accommodate a wide range of users, including those with disabilities or specific needs.
 - b. The ADS manufacturer should ensure that it avoids disadvantaging one group (e.g. non-users) over another (e.g. ADS users' safety).

4.2 Manufactures should consider the following principles when designing vehicles equipped with ADS that do not permit manual driving

9. Clear and Intuitive Interface:
 - a. The ADS manufacturer should ensure the vehicle's interface, whether physical or digital, is intuitive and user-friendly.
 - b. The ADS manufacturer should ensure vehicle interfaces provide clear information to the user about the vehicle's status, route, progress to destination, arrival time and any necessary actions.
10. Passenger-Controlled Stops:
 - a. The ADS manufacturer should ensure passengers are provided with a control to request stops at their convenience.

- b. The ADS manufacturer should ensure passengers have a control to command stops in emergency situations.
- 11. Accessibility for All Passengers:
 - The ADS manufacturer should ensure controls and displays are accessible to all passengers.
- 12. Effective Climate Control:
 - The ADS manufacturer should ensure the vehicle is equipped with effective climate control systems to ensure a comfortable environment inside the vehicle.
- 13. Prompt Human Assistance:
 - The ADS manufacturer should ensure a "help" button is provided for passengers to promptly obtain human assistance when necessary.
- 14. Transparent Information:
 - a. The ADS manufacturer should ensure information is made available to passengers to provide a clear understanding of vehicle activities.
 - b. The ADS manufacturer should ensure safety features and guidelines for safe interaction are clearly communicated.

4.3 Manufactures should consider the following principles when designing vehicles equipped with ADS that interact with other road users

- 15. Predictability and consistency:
 - a. The ADS manufacturer should ensure vehicle equipped with ADS behave predictably in various traffic situations, following established rules, norms, and conventions that other road users are familiar with, to help other road users anticipate the actions of the vehicle equipped with ADS.
 - b. The ADS manufacturer should ensure vehicle equipped with ADS avoid sudden or erratic behaviour that may confuse other road users and increase the risk of collisions.
- 16. Communication:
 - a. The ADS manufacturer should ensure vehicle equipped with ADS can clearly communicate intentions and actions to other road users at all times.
 - b. The ADS manufacturer should ensure vehicle equipped with ADS use standardized visual cues, signals and displays to indicate actions such as turning, stopping and yielding.
 - c. The ADS manufacturer should create mechanisms that enable an ADS-equipped vehicle to respond to communication (e.g., hand signals from pedestrians or gestures from cyclists) from other road users.
- 17. Share the road:
 - a. The ADS manufacturer should ensure vehicle equipped with ADS safely interact with vulnerable road users; and
 - b. The ADS manufacturer should ensure vehicle equipped with ADS detect and respond safely to road works, human traffic control and emergency vehicles.
- 18. Education and awareness
 - The ADS manufacturer should develop public awareness campaigns and educational initiatives to inform passengers, pedestrians, cyclists, and other drivers

about how to interact safely with automated vehicles, including their unique capabilities and limitations.

5. Human-centred design procedures

5.1 Specifications

19. Specify Intended Users and their Needs, Use Cases, and Interfaces:
 - a. The ADS manufacturer should follow established procedures to define the intended users, their needs, use cases, and interface requirements; and,
 - b. The ADS manufacturer should establish clear user roles and responsibilities.
20. Identify and Mitigate Use-Related Hazards:
 - a. The ADS manufacturer should identify potential use-related hazards and categorize critical tasks; and,
 - b. The ADS manufacturer should develop and implement risk mitigation or control measures to address these hazards.
21. Consult Relevant Guidelines and Standards:

-The ADS manufacturer should consult relevant bodies of knowledge, guidelines, and standards when defining, assessing, and validating the Human Machine Interface (HMI) concept.
22. Define Automated Driving Modes, Transitions and User Interaction:

-The ADS manufacturer should explicitly define all possible automated driving modes, the transitions between those modes, settings and outline how users interact with each.
23. Effective Communication of Active Driving Modes:

-The ADS manufacturer should identify effective modalities to communicate relevant active driving modes to users.
24. Identify Mistakes and Misuse Cases:

-The ADS manufacturer should identify foreseeable mistakes and misuse cases related to the HMI and the ADS.
25. Explicitly Define Operating Domain:

-The ADS manufacturer should clearly define the operating domain within which the vehicle and automation are expected to operate.
26. Design User Roles to Avoid Errors:

-The ADS manufacturer should ensure Users and the ADS have clearly defined roles and responsibilities, along with the corresponding authorities to execute these roles effectively and safely.
27. Consider User Diversity in Design:

-The ADS manufacturer should ensure the diverse needs of different user groups are carefully considered and accommodated during the design process.

5.2 Evaluation and testing

28. Comprehensive User Testing:
 - a. The ADS Manufacturer should validate the HMI design by conducting user testing with real users.

- b. The ADS manufacturer should assess the safety, usability, and user acceptance of the ADS through representative testing, accounting for relevant factors such as age and experience.
- 29. Monitor System Performance in the Field:
 - The ADS manufacturer should ensure performance of the system in real-world deployment scenarios is continuously monitored.
- 30. For vehicles with fallback users:
 - a. The ADS manufacturer should consider all relevant secondary tasks and assess their impact on the time required for users to take over control.
 - b. The ADS manufacturer should test that the driver monitoring systems can accurately and reliably detect safety-relevant driver conditions.
 - c. The ADS manufacturer should test the effectiveness of warnings interventions.
- 31. Use Realistic Testing Environments:
 - a. The ADS manufacturer should conduct testing in environments that closely mirror the actual operational design domain (ODD) of the vehicle.
 - b. The ADS manufacturer should test user response to normal and unplanned transitions, and minimal risk maneuvers.
 - c. The ADS manufacturer should include other road users in this testing when safe.
- 32. Document the Human-Centred Development and Testing Process:
 - The ADS manufacturer should thoroughly document the entire development and testing process to facilitate potential safety audits.

6. Conclusion

This list of human factors principles and procedures serves as a roadmap for designing safe and user-centred automated vehicles and associated safety requirements and policy instruments developed by applicable UNECE bodies. Adhering to these principles and following the outlined procedures should help to effectively address the multifaceted human factors challenges presented by ADS.

For vehicles equipped with ADS that provide for manual driving, the principles emphasize the importance of clear, observable, and intuitive interfaces that provide users with access to crucial information, mode transitions, and alerts. Additionally, the principles underscore the significance of maintaining control, ensuring smooth transitions of control, fostering trust and transparency, and accommodating a diverse user base. Through effective design, communication, and understanding of user roles, these principles aim to enhance user experience and overall safety. For vehicles equipped with ADS without manual driving capabilities, the principles emphasize accessibility for all passengers and transparency of information. Passengers' needs for assistance, control over stops, and emergency situations are addressed. Principles are also provided to support the safe interaction between vehicles equipped with ADS and other road users.

The human-centred design procedures further enhance the design process by providing actionable steps. These procedures cover user needs definition, risk mitigation, consultation of guidelines and standards, user testing, system monitoring, mode definition, communication strategies, mistake identification, impact assessment of secondary tasks, and documentation. Moreover, the procedures encourage comprehensive testing, diversity consideration, and the importance of clear documentation.

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