User-centred design for type approval of AD(A)S

Roadmap towards a process audit

R-2022-16

SWOV

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Prevent crashes
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Report documentation

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Summary

Increasing numbers of vehicles (i.e., cars and trucks) are equipped with ADAS (Advanced Driver Assistance Systems) and ADS (Automated Driving Systems). Several risks relating to the use of AD(A)S have been described in the literature, including confusion about driving task responsibility, overreliance on the system, drivers being caught off guard by sudden transitions between vehicle automation levels, and inappropriate levels of attention to the driving context. Well-designed interaction and communication between the driver and the system may reduce these human factors risks However, clear specifications for a system that fulfils such requirements do not exist. This provides a challenge for type approval processes. In the absence of unambiguous system requirements for the interaction between an AD(A)S and its users, evaluating how a system was developed, could provide an alternative way of auditing safe system interaction.

The aim of this assignment was to draw up an advice on whether and how an audit on the application of *User-Centred Design processes* (UCD) in AD(A)S development regarding the user-system interaction could contribute to the approval of safe AD(A)S. The advice is based on collecting answers to two main research questions:

1. How is UCD currently implemented in the automotive industry?
2. How do stakeholders react to the implementation of UCD as part of the type approval process?

First, a literature study was done to establish a preliminary indication as to what a UCD approach for AD(A)S, based on human factors criteria, should consist of. Subsequently seven interviews with seven OEMs and two discussions with the Netherlands Vehicle Authority (RDW) were conducted to investigate the research questions.

› **Findings**

Application of UCD in practice
In general, it can be concluded that whereas the industry considers UCD a valuable approach in AD(A)S development, no indications were found that UCD principles were applied all the time, and – when they were applied – they seemed to focus more on customer satisfaction than on human factors in general.

Support for audit of UCD processes
All OEMs reacted critically to a product-based UCD audit. Two parties specifically questioned the added value. Considering the vast impact, they would like to see proof that applying UCD indeed yields better products before introducing such an audit. There was moderate support for periodic UCD certification on a company/department level, as opposed to a product-related audit. Such an audit is believed to take less time. But, for such an audit to be workable, important conditions were mentioned: the workload should not be increased and the prescribed processes must be beneficial to the own business processes.

RDW considers it a promising approach to place more responsibility on the industry to ensure that AD(A)S are safe to use for all drivers. However, RDW indicates that this requires clear and substantiated specifications of human factors criteria that have to be met.

› Recommendations

Substantiate added value
While the value of human factors in this context is undisputed, it is only an unsubstantiated assumption that UCD is an effective implementation method. Since support from the industry will most probably contribute to the quality of the prescribed approaches, it is important to substantiate the added value of a specific approach such as UCD.

Optimally combine flexibility and specificity
Seeing that specifications for safe driver-AD(A)S interactions are lacking and the industry does not want to be restricted, a prescribed approach should be flexible wherever possible. This requires proper consideration of parts that have to be strictly followed and parts that can be approached more flexible. Flexibility is also required since each system, operating under different conditions and in different situations, should fit within the approach.

Focus on human factors guidelines
Concerning the driver-AD(A)S interaction, it seems that more attention should be paid to human factors guidelines. Based on the interviews, it seems that the industry mainly focuses on customer demands, expectations and experiences, i.e., only a part of the user experience that represents compliance to human factors requirements.

Contents

1 Introduction

Increasing numbers of vehicles (i.e., cars and trucks) are equipped with ADAS (Advanced Driver Assistance Systems) and ADS (Automated Driving Systems), which involves automation of parts of the driving task (see definitions in *Box 1*). Several risks relating to the use of AD(A)S have been described in the literature (e.g., Carsten & Martens, 2018). Examples include confusion about driving task responsibility, overreliance on the system, drivers being caught off guard by sudden transitions between vehicle automation levels, and inappropriate levels of attention to the driving context. These risks may be reduced with well-designed interaction and communication, both of which are facilitated by the implementation of the Human Machine Interface (HMI) and the underlying system logic. Assuming that driver-vehicle interaction and communication affect safe vehicle operation, assessment of these qualities should become part of type approval processes. However, clear specifications for a system (e.g., HMI, underlying system logic) that fulfils aforementioned requirements do not exist, which provides a challenge for type approval processes. Knowledge of psychology and ergonomics (human factors) come into play since it is not possible to base the quality of the interaction between the vehicle and the driver on a mechanical approach (such as crash tests). This issue directly relates to the challenge raised in relation to ADAS by the Dutch Safety Board in their report on safety and automation in traffic (Dutch Safety Board, 2019). In the coming years, we find ourselves in a hybrid situation in which both the system and the driver can be in control, requiring increased interaction between the two. The Dutch Safety Board therefore recommends putting human factors on the UNECE agenda, supporting Euro NCAP initiatives to make human factors an integral part of vehicle safety assessment, and within the European Commission, specifying requirements relating to human factors and making manufacturers responsible for demonstrating that new ADAS improve safety.

Box 1 Definitions ADAS and ADS

Advanced Driver Assistance Systems (ADAS)

Advanced Driver Assistance Systems (ADAS) support the driver in performing the primary driving task. These systems observe their surroundings using sensors and can take over control of the speed and/or direction of the vehicle under the responsibility of the driver. Such systems can also alert the driver to situations that the system estimates to be dangerous. (Dutch Safety Board, 2019).

Automated Driving Systems

The hardware and software that are collectively capable of performing the entire DDT on a sustained basis, regardless of whether it is limited to a specific operational design domain (ODD) (SAE, 2021)

ISO standard 9241-210:2019 describes User-Centred Design (UCD) as a process in which, in each phase of system development, the needs and abilities of different types of users are taken into account. UCD is believed to increase chances of a safe system (Brinkley, 2021; Horberry et al., 2022): a system that different types of people, for example in terms of experience and capabilities, are willing and able to use. In the absence of unambiguous system requirements for the interaction between an AD(A)S and its users, evaluating the application of a UCD process could provide an

alternative way of auditing safe system interaction. However, to make such an approach feasible, it is important to know whether it is supported by the parties involved, i.e., the industry as well as vehicle approval authorities. Besides, it has to relate somehow to current daily practice. Therefore, one of the questions in this report is: how are systems currently developed within the industry and how do the suggested auditing processes fit in with current audit activities?

The Dutch Ministry of Infrastructure and Water Management has asked SWOV to investigate whether and how a UCD approach in AD(A)S development and vehicle type approval might be feasible, considering the level of support by the industry and current practice.

1.1 Aim and research questions

The aim of this assignment is to draw up an advice on whether and how an audit on UCD processes in AD(A)S development regarding the user-system interaction could contribute to the approval of safe AD(A)S. The advice has been based on collecting answers to two main research questions:

1. How is UCD currently implemented in the automotive industry?
2. How do stakeholders react to a potential audit of UCD implementation as part of the type approval process?

1.2 Assumption

For this project, we started from an assumption not further investigated within the current project, which is:
The application of a UCD procedure for AD(A)S development and design which is based on human factors increases chances of safe interactions between AD(A)S and its users.

1.3 Approach

First, a literature study was done to establish a preliminary indication as to what a UCD approach for AD(A)S based on human factors criteria should consist of. Subsequently, interviews were conducted to investigate the research questions described in *Section 1.1*. These methods provided qualitative results on which the advice on the implementation of a UCD process audit in relation to the driver-AD(A)S interaction is based.

1.4 Reading Guide

In *Chapter 2,* the elements of a UCD approach are described as well as human factors guidelines specifically related to safe AD(A)S. *Chapter 3* describes the approach, setup and results of the interviews with both the automotive industry and the Netherlands Vehicle Authority (RDW). Based on the forgoing results, *Chapter 4* describes an advice on whether and in what form an audit on UCD processes in AD(A)S development could be introduced. Besides, suggestions on next steps in the roadmap towards type approval that improve the quality and safety of driver-AD(A)S interactions are made.

2 Background

To examine how human factors guidelines relating to AD(A)S design and development are applied, it is first necessary to understand the status quo of human factors guidelines for AD(A)S (*Section 2.1*). Furthermore, to understand how UCD and human factors within UCD are applied by the automotive industry, a set of definitions and characteristics of UCD needs to be established (*Section 2.2*). Finally, this chapter provides an initial view on UCD application based on automotive literature (*Section 2.3*).

2.1 Human Factors guidelines for AD(A)S

Human factors is a scientific discipline concerned with the application of what we know about people, their abilities, characteristics, and limitations to the design of equipment they use, environments in which they function, and jobs they perform.[1] In the context of vehicle automation, examples of human factors issues are:

- Mode errors (e.g., not knowing which vehicle automation level is active and consequently how driving task responsibilities are distributed between driver and vehicle);
- Trust miscalibration (e.g., consciously or unconsciously trusting that vehicle automation performs outside its actual operational design domain);
- Automation surprises (e.g., due to sudden transitions from higher to lower vehicle automation levels, thereby increasing driving task responsibility for the driver);
- Inappropriate level of attention (e.g., engagement in non-driving related activities with a vehicle that takes care of longitudinal and lateral control when monitoring traffic is in fact still required).

2.1.1 Requirements and functional logic

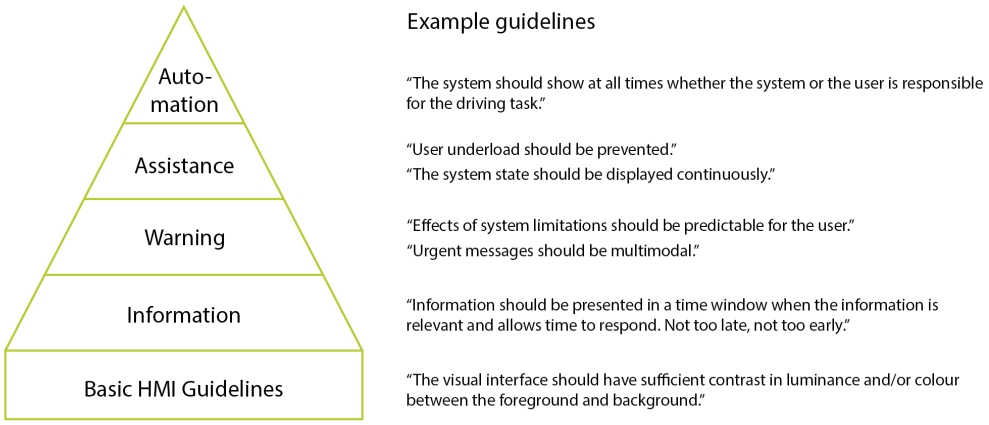
Based on an in-depth crash study of vehicles with ADAS, the Dutch Safety Board (2019) recommends introducing requirements relating to human factors in vehicle regulations. Furthermore, the board argues that eight generic safety principles for the introduction of new technology should be applied to the introduction and deployment of ADAS. Of particular interest for the present study is the guideline stating that *"legislation and regulations must be adapted to the maturity of the technology and the speed at which it is developing."* It is argued that mature technologies need to comply with **implementation-based requirements** (e.g., what the product should *be*), whereas developing technologies should adhere to **performance-based requirements** (e.g., what the product should *do*). Finally, rapidly changing technologies are more likely subjected to **process-based requirements** (e.g., *how* the product should be developed). According to Montalvo et al. (2020) human factors requirements for AD(A)S should not only focus on the Human Machine Interface of a vehicle (e.g., what the driver sees, hears, or feels through visual, auditory and tactile displays), but also on the underlying **functional logic** of the vehicle automation, to facilitate understanding of the system and thus to be able to anticipate how it operates in a given driving context.

1 https://www.hfes.org/About-HFES/What-is-Human-Factors-and-Ergonomics

2.1.2 Existing human factors guidelines

A literature review by Souman et al. (2021a) resulted in a set of 60 guidelines for AD(A)S, hierarchically categorised according to their functionality, that is: basic human-machine interaction (HMI) guidelines (13), supplemented with information functions (16), warning functions (15), assistance functions (12), and automation functions (4) (see *Figure 2.1* for examples of guidelines in each category). Guidelines applicable to lower levels are also applicable to higher levels, but not vice versa. The authors note that this hierarchical categorisation of guidelines is independent of the SAE levels of driving automation (SAE, 2021). Using an example of an ACC system, they argue that a system may interact at different functional levels with the driver: ACC may show its system state (e.g., the assistance function category in *Figure 2.1*), as well as providing warnings when its system limits are reached (e.g., the warning function category). The authors therefore conclude that the abovementioned hierarchical categorisation of human factors guidelines may be more fitting for designers of AD(A)S than a categorisation based on the SAE levels of driving automation. To test the validity of applying human factors guidelines, a study by Forster et al. (2020) compared two HMI designs for a vehicle with ADS, where the designs differed in the compliance with human factors guidelines. The design with high compliance yielded higher self-reported acceptance and usability, as well as faster reaction times, compared to the design with low compliance. [2]

Figure 2.1. The hierarchical levels of ADAS and ADS functionality in system-user interactions, including examples of guidelines. Source: Souman et al. (2021a). Reprinted with permission.



2.1.3 Ambiguity of human factors guidelines

Human factor guidelines may be ambiguously formulated. For example, the guideline that *"user underload should be prevented"* does not specify what underload is, how it should be measured, and which thresholds should be used to establish when underload comes into play. If human factors guidelines become part of an audit, they will need to be interpreted in the same way by all auditors and auditees. Therefore, ambiguous guidelines may need to be transformed into concrete evaluation criteria. For this reason, Souman et al. (2021b) developed a step-by-step methodology to operationalise human factors guidelines for AD(A)S. These steps involve defining the system, relevant system states, and evaluation measures; setting test criteria; and selecting evaluators. In addition, the report described a framework to develop test methods (e.g., standardisation of test procedures, test scenario selection, test execution). Accordingly, an initially ambiguous guideline "*System state changes of assistance systems should be communicated timely and effectively"* was operationalised into a concrete evaluation criterion: *"The lane-change state change from 'active' to 'stand-by' should be communicated at most 0.5 seconds after the system fails to detect line markings."* Knowledge is required to establish test criteria, such as the 0.5 second threshold in the aforementioned example. Thresholds may depend on specific

2. The study by Forster et al. (2020) serves as an example of validation of human factors guidelines for AD(A)S. Other studies may or may not provide additional support, e.g., using different HMI design and/or alternative (safety) performance indicators. However, an extensive literature study on the validity of human factors guidelines was not part of the project scope.

systems, specific users, and specific scenarios. Souman et al. (2021b) note that, in practice, it may be impossible to test all combinations of these factors comprehensively, but that the available knowledge base is insufficient to make selections and to translate the relevant constructs into measurable variables. The authors describe AD(A)S knowledge gaps relating to professional drivers, individual differences, user-accessible system descriptions, long- term effects, and development of mental models of AD(A)S. Therefore, we deduce that more research may be required (or made publicly available) to establish common, concrete criteria for similar systems, users, and scenarios (e.g., Van Grondelle et al., 2021).

2.2 User-Centred Design

2.2.1 UCD definitions

ISO standard 9241-210:2019 provides requirements and recommendations for human-centred design principles and activities for interactive systems. Human-centred design is defined as follows:

> *"Human-centred design is an approach to interactive systems development that aims to make systems usable and useful by focusing on the users, their needs and requirements, and by applying human factors/ergonomics, and usability knowledge and techniques. This approach enhances effectiveness and efficiency, improves human well-being, user satisfaction, accessibility and sustainability; and counteracts possible adverse effects of use on human health, safety and performance."*

Where interactive systems are defined as:

> *"[A] combination of hardware and/or software and/or services and/or people that users interact with in order to achieve specific goals."*

We view AD(A)S as interactive systems, seeing that drivers (users) interact with such vehicle technology through human machine interfaces (hardware) to achieve a variety of goals, ranging from comfort to safety. This view means that AD(A)S fall within the scope of ISO 9241-210:2019. In the standard, it is noted that the term 'human-centred design' (HCD) also addresses the impact on stakeholders other than the end user (e.g., other road users who may have to deal with the 'behaviour' of automated vehicle systems), as opposed to 'user-centred design' (UCD). It is also noted that the terms are often used synonymously. In the present report, we focus on the end user (i.e., the driver) and we view UCD and HCD as synonyms.

According to ISO 9241-220:2019, which covers UCD in more detail than ISO 9241-210:2019, UCD concentrates on the human-centred aspects of design. Other aspects of design, such as mechanical construction, are not part of the scope of UCD. Seeing that mechanical construction, amongst several other potential design processes, is part of AD(A)S design and development, it is reasonable to expect that within an OEM some departments may be involved with AD(A)S, but not necessarily in UCD.

2.2.2 UCD characteristics

According to ISO 9241-210:2019, UCD is characterised by the following six principles (hereafter: UCD principles):

- **UCD principle 1: Understanding of user context & requirements**

Interactive systems should be designed to take account of the people who will use them. The characteristics of the users (e.g., differences in experience, age, preferences), tasks (e.g., controlling the dynamic driving task, monitoring traffic) and environment (e.g., urban roads, highways) are called the context of use. User requirements are based on the context of use and include, amongst others, requirements arising from relevant ergonomics and user interface knowledge, standards and guidelines.

UCD principle 2: Active user involvement

Users (as identified in the context of use) should be involved throughout design and development. This involvement should be active, for example by participating in design, acting as a source of relevant data, or by evaluating design solutions.

UCD principle 3: Driven & refined by user-centred evaluation

User-centred evaluation of (preliminary) prototypes may yield feedback which can be used as input for subsequent design activities, resulting in a progressively refined interactive system. User-centred evaluation involves users directly (e.g., by using driving simulators), and/or concerns inspection-based evaluation (e.g., usability experts with human factors knowledge and prior experience of problems encountered by users).

UCD principle 4: Iterative process

Iterations are used to progressively arrive at a design that meets the user requirements. This not only implies that early prototypes may be revised based on user-centred evaluation, but also that such evaluations can be used to refine the context of use and user requirements (see *Figure 2.2*). For example, users may be better able to express their needs when faced with an early prototype.

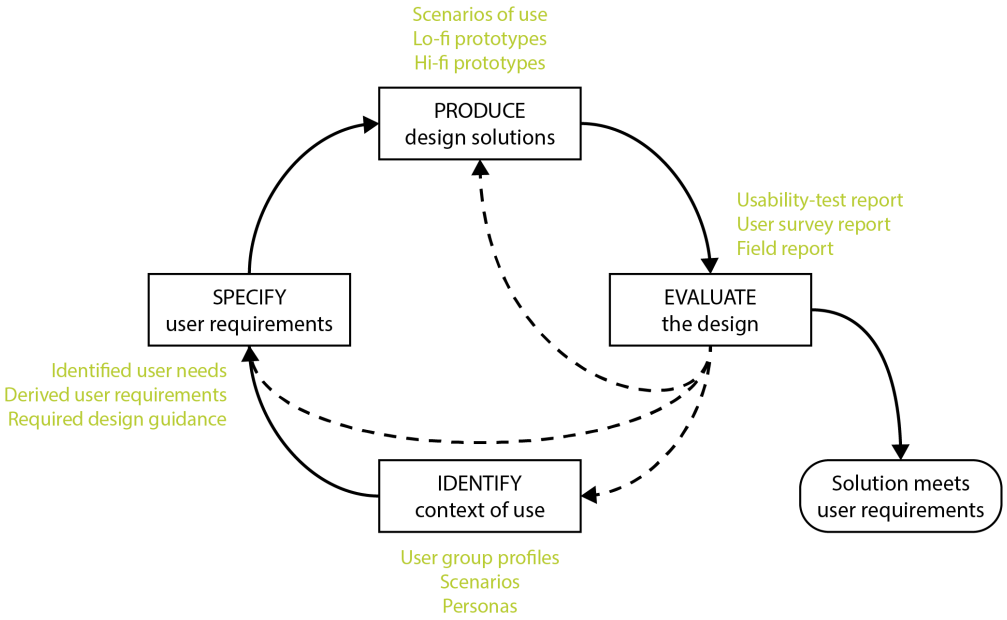


Figure 2.2. Iterative process of user-centred design activities (black) and examples of outcomes (green). Adapted from ISO 9241-210:2019.

UCD principle 5: Design addresses the whole user experience

User experience (UX) is defined as *"users' perceptions and responses that result from the use and/or anticipated use of a system, product or service"*, where *"users' perceptions and responses include users' emotions, beliefs, preferences, perceptions, comfort, behaviours, and accomplishments that occur before, during and after use."* Accordingly, users' strengths, limitations, preferences and expectations should be taken into account when specifying which activities are carried out by drivers and which functions are carried out by AD(A)S.

UCD principle 6: Multidisciplinary team

Various skill areas and viewpoints can be needed in a human-centred design and development team to address design and implementation trade-off decisions, such as: human factors and ergonomics, usability, users and other stakeholder groups, marketing, branding, sales, user interface design, business analysis, systems engineering, hardware and software engineering, programming, and human resources. A multidisciplinary approach fosters awareness of different perspectives among team members.

The previously observed lack of concrete human factors evaluation criteria for AD(A)S, the characteristics of UCD, and an analogy with product design methodology give rise to a hypothesis on using UCD as a means to operationalise human factors guidelines. Similar to the UCD loop described above, Roozenburg & Eekels (2001) describe the product design process as an iterative series of phases, involving problem analysis, synthesis, simulation, evaluation, and decision. The output of the analysis phase is a program of requirements, which is often not yet crystallised early in the design process. Here, iterations come into play: exploration of alternative solutions is often an effective approach to gain insight into the true nature of a design problem. As a consequence, ideas about what might be a good design solution mature in conjunction with the specification of the program of requirements. Therefore, in theory, following a UCD approach may help to iteratively operationalise ambiguous human factors guidelines into concrete evaluation criteria (i.e., a necessity described in *Section 2.1*), seeing that user requirements should specify relevant human factors guidelines (UCD principle 1), and that user requirements may be updated during the design and development process (UCD principle 4). This hypothetical process is illustrated in *Figure 2.3*, in which human factors guidelines in the user requirements become more and more specified (from dashed black lines to solid black lines), while simultaneously human factors issues are increasingly adequately addressed in the design (from dashed blue lines to solid blue lines). This hypothesis will be addressed in the interview analysis of *Chapter 3*.

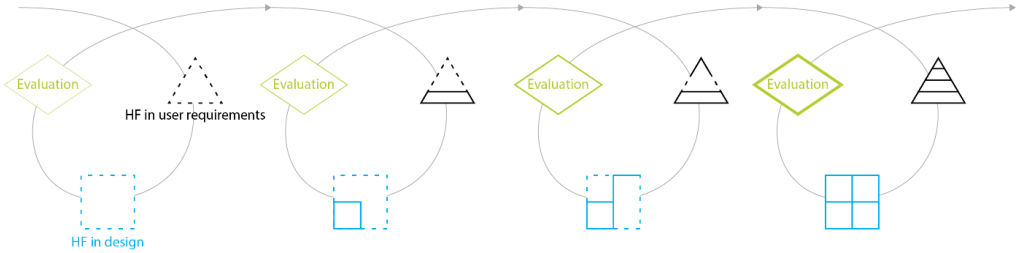


Figure 2.3. Hypothetical iterative process, in which the specification of human factors (HF) requirements matures in conjunction with the design.

2.3 Reports on User-Centred Design in automotive practice

In a literature survey and amongst network resources, a global scan was carried out to investigate if, how and to what extent application of User-Centered Design can be identified in automotive design processes. The scope of the automotive designs encompasses the organisational entities Exterior Design, Interior Design, Colour and Trim, and HMI in next vehicle development. The scan aims at both general UCD application and its application with respect to specific safety aspects. This global scan was performed by means of the following resources:

- Interviews and articles in Auto & Design[3], a bilingual (Italian and English) professional automotive design magazine. Issues of the last ten years were scanned. Additionally, the magazine's data base was scanned on keywords i.e., user-centered design and human centered design as well as abbreviations. Auto & Design publishes six issues per year.
- Interviews and articles in Car Design News (CDN)[4], an online international automotive design community regarding car design in all its aspects, from designs to careers to international auto shows and design competitions. Publication is continuous.
- Conference proceedings of automotive design conferences (predominantly organised by CDN).
- Interviews and articles in Interior Motives[5], a professional automotive interiors magazine which reports on concept cars and production cars.

3. https://autodesignmagazine.com
4. https://www.cardesignnews.com
5. https://www.cardesignnews.com/interiors/interior-motives-magazine

- Quick scan by means of interviews with designers in automotive consumer magazines (e.g., AutoVisie, Top Gear Magazine, Auto Motor und Sport).
- During the project term, two promising presentations were attended, one at TRA (Transport Research Arena) and one online seminar on vehicle approval audits.

The following findings were derived from the global scan:

- UCD (or HCD) are not specifically acknowledge as such. Nor is either of the terms commonly used, at least not in external publications and presentations such as our resources.
- UCD requisites or elements are often and frequently applied in automotive design processes, mostly in the form of clinics or similar meetings. In a clinic, concept cars are shared with (potential) customers to collect user data with respect to that specific design.
- The subject of clinics and similar meetings is virtually always user experience, generally phrased as customer experience. The perception of a concept car is investigated in terms of qualitative aspects (e.g., user experience and brand experience).
- Safety aspects have not been found as the aim of UCD processes.
- UCD is not embedded at an organisational level. However, organisational structures and design processes are evolving because, with electrification and autonomous technologies, responsibilities are shifting across departments (Hubik & Menzel, 2022).
- At TRA 2022 (Transport Research Arena)[6], the specific keywords of the global scan were not addressed. Interesting though is the development of a scenario data base for safety audits in autonomous vehicle approval. This common scenario data base contains all relevant operational design domains for autonomous driving, like unexpected lane changes. The intention is to continuously grow and update the data base. However, actual development of the data base has not started yet. The initiators are still researching how it should be created.
- The attended online seminar on vehicle approval audits for electric and autonomous vehicles (Kymal, 2022), did not turn out to be useful in relation to our project aim.

6. https://traconference.eu/

3 Interviews

A series of interviews were conducted with the aims 1) to explore if and how UCD is currently implemented in the automotive industry, and 2) to probe reactions to a potential audit on the implementation of UCD as part of the type approval process. This chapter presents the interview setup (*Section 3.1*), and a summary of the results (*Section 3.2* for OEM interviews, *Section 3.3* for interviews with the Dutch Road Authority), which forms the basis for a draft advice (see *Chapter 4*).

3.1 Method

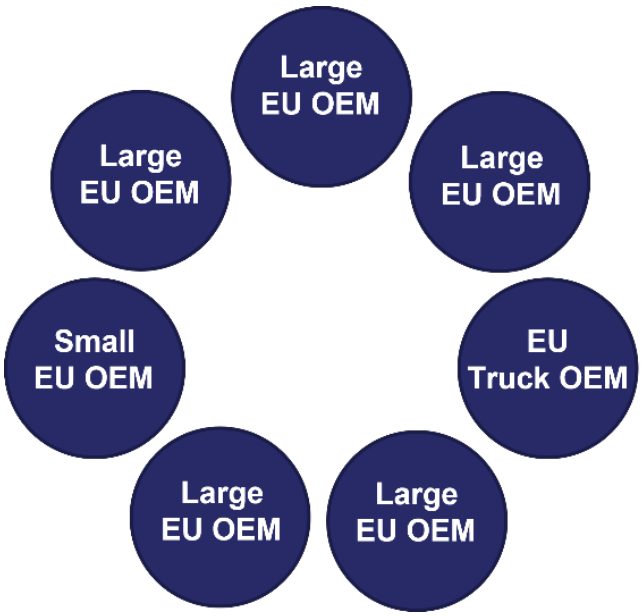
3.1.1 Sample description

Several OEMs in the network of the project members (i.e., the authors of this report) were contacted with the request to participate in an interview on UCD processes in AD(A)S development. The inquiry included the statement that the anonymised interview results would be used to formulate an advice on if and how UCD processes may be adopted or improved, and how these processes and results can be audited in relation to certification and type approval of (vehicles with) automated driving systems. To increase chances of positive replies, the inquiry also stated that the interview would contain questions on the type of outcomes and processes leading to certification and type approval, but that no concrete illustrations of actual outcomes meant for production would be required.

Following the inquiry, a total of seven interviews with OEMs were conducted in October and November 2022. Based in four European countries, the carefully constructed sample consisted of one small and multiple large OEMs, some of whom as a single brand and some with a brand portfolio. Next to six manufacturers of passenger vehicles, the sample included one truck manufacturer. Furthermore, the sample was spread in terms of participant roles and organisational level: interior designers, a director of design, HMI & human factors engineers, a senior executive, project leaders on AD(A)S engineering, and a driver behaviour specialist (see *Figure 3.1*).[7]

7. Detailed company and background descriptions have been anonymised at the request of the interviewees. The order in which the participating OEMs and interviewee backgrounds are listed has been randomised.

Figure 3.1. Overview of participating OEMs.



In addition to the interviews with OEMs, we interviewed the Netherlands Vehicle Authority (RDW) twice. The first interview took place at the start of the project to learn more about existing audit processes and about current challenges concerning AD(A)S. The second interview took place at the end of the project to reflect on a draft advice. As both interviews were unstructured, no further methods are described. The remainder of this section focuses on the setup of the interviews with the OEMs.

3.1.2 OEM interview questions & procedure

Four interviews took place face-to-face, and three interviews were held online using Microsoft Teams. Two of the three project members were involved in conducting the interviews. The semi-structured interview approach allowed interviewees to elaborate on topics if so desired. The interviews consisted of the following main parts and typically lasted between 1 and 1.5 hours (also see *Appendix A*).

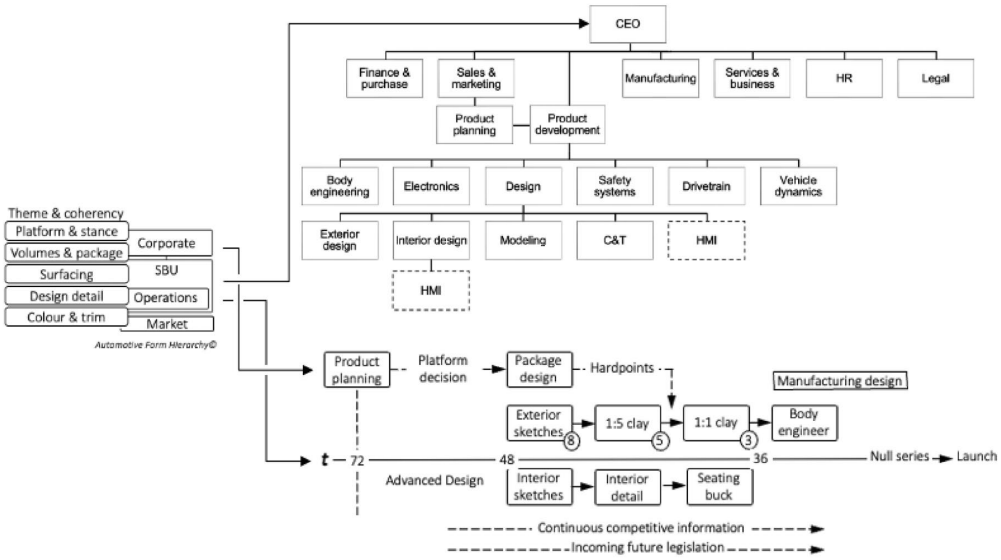
- **Introduction**

The project aim was explained, and terminology relating to UCD and AD(A)S was shared to establish a common ground. Interviewees were asked how they and their company should be referred to anonymously. Permission was asked to record the interview (e.g., with a telephone, or using Microsoft Teams in case of an online interview).

- **Structure of the organisation**

To guide and structure the interviews organisational diagrams were made of a generic company, or strategic business unit (SBU), and a generic automotive design process (see *Figure 3.2*). The relationship between the two is visualised by use of the Automotive Form Hierarchy (Van Grondelle & Van Dijk, 2004) that connects a structured automotive form analysis to decision levels within automotive corporations. The upper layer is the same for all involved, such that each department is represented in the board. HMI is depicted twice as it is sometimes part of interior design, but also often an independent entity. Research is not depicted here as it is not part of the specific vehicle development, and is generally at the corporate brand portfolio level (Strategic Business Units) in the diagram.

Figure 3.2. Generic company structure (top) and generic automotive design process (bottom), linked by Automotive Form Hierarchy (left)



Chapter 2 indicated that UCD-related activities may be part of one of several parallel processes. Therefore, interviewees were asked, by means of organisational diagrams, which departments are involved in AD(A)S development, which departments are involved in UCD-related activities, and how departments interact with each other.

› Application of User-Centred Design

Interview questions included how user requirements are established and/or refined, if and how ambiguously formulated human factors guidelines are operationalised into evaluation criteria, how drivers are involved in the research, design and development process, how many iterations are found in a typical design process, and how these iterations can be described. The questions were mostly targeted at the operational design process. Application of UCD at SBU level or at a corporate level, and potential differences between strategic units, were addressed in a separate set of questions.

› Audit

Interviewees were first asked about their opinion concerning the implementation of an UCD audit as part of vehicle type approval. The question was repeated, this time focusing on an audit for a periodic certificate (as opposed to an audit relating to individual vehicles).

› Wrap-up

Interviewees were provided with the opportunity to reconsider previous answers, and asked how they wished to be informed about the project outcomes.

3.1.3 OEM interview analysis

Interview notes were collected in an Excel file. Available recordings (3 interviews) were used to complete the Excel file where applicable. Participants occasionally provided such elaborate responses that parts of these responses were answers to other interview questions. These parts were relocated to the corresponding cells in the Excel sheet. At other times, elaborate responses to one question meant less time was available for other questions. Consequently, some cells in the Excel sheet remained blank. Relevant notes were identified for four main topics: organisational structure, UCD principles, addressing human factors issues, and responses to a tentative UCD process audit proposal.

- **Organisational structure**

A project member with a background in automotive strategy reviewed statements on organisational structures, to assess in which departments or divisions AD(A)S are typically developed and where UCD is applied according to the interviewees.

- **UCD principles**

For each OEM we explored if statements indicated whether or not any of the six UCD principles described in ISO 9241-210:2019 were applied. Due to time restrictions, the possibility to ask about individual UCD principles was limited. Consequentially, the project members who performed the interviews may have constructed an overarching view on whether UCD *as a whole* was applied. To minimise potential bias, a project member who did not attend the interviews identified, categorised, and initially assessed relevant statements, resulting in a 6 (UCD principles) by 7 (OEMs) table. For each cell in this table, a qualitative judgement was made on whether the statement(s) provided a strongly positive, moderately positive, moderately negative, or strongly negative indication of the application of the corresponding UCD principle. The difference between a strong and a moderate indication was based on the amount of evidence found for the corresponding UCD principle. For example, UCD principle 2 prescribes that users are actively involved throughout design and development. If a statement makes clear that users are involved throughout the entire process, and that involvement is indeed *active* (e.g., participating in design, acting as a source of relevant data, evaluating solutions), the statement was labelled as a *strong* positive indication. However, if it is clear that users are actively involved (as opposed to, e.g., solely expert-based testing), but unclear in which stage of the process, the statement was labelled as a *moderate* positive indication. Cells containing statements with positive and negative indications for the application of a UCD principle were labelled separately. It should be noted that if an interviewee does not provide any statements with a positive indication for the application of a particular UCD principle, one should not conclude that the UCD principle is not applied, but simply that information is lacking (this turned out to be the case for two OEMs in UCD principle 6, see *Section 3.2.2*).

- **Addressing human factors issues**

A project member with a background in human factors collected statements relating to addressing human factors issues. The main goal was to explore if the applied UCD approach could facilitate operationalisation of initially ambiguous human factors guidelines into concrete evaluation criteria (see *Chapter 2* for more information).

- **Reactions to audit proposal**

Responses to the proposed audits (e.g., per vehicle, periodic certificate) were categorised in positive and negative responses, including reasons for these responses.

3.2 OEM interview results

3.2.1 Organisational structure

If the organisational structure of an OEM corresponded with the diagram shown in *Figure 3.3*, interviewees generally indicate that the following departments are involved in AD(A)S development (marked in green): ‘legal’, ‘electronics’, ‘safety systems’, ‘vehicle dynamics’, ‘interior design’, and ‘HMI’. The HMI department is represented twice, because in some OEMs it falls under interior design, whereas in other OEMs it is a separate entity. The departments depicted in green are traditionally not actively connected but may need to be repositioned because of new (autonomous) technologies. Organisational redesign is underway at several OEMs and announced at others. Using the same diagram (see *Figure 3.4*), interviewees generally state that UCD-related activities take place in the departments ‘sales & marketing’, ‘exterior design’, ‘interior design’, and ‘HMI’. This implies that UCD is generally not applied by all

departments involved in AD(A)S design and development. There are deviations; one OEM stated that UCD activities (e.g., the loop shown in *Figure 2.2*) permeate the entire organisation:

> *"There are different entry points […] The UCD loop happens continuously and in several processes. The loop is distributed across the entire company in different stages of the process." (in Figure 2.2: a loop consisting of identifying the context of use, specifying user requirements, producing design solutions, and evaluating the design.)*

Figure 3.3. AD(A)S stakeholders in the current generic OEM structure (depicted in green).

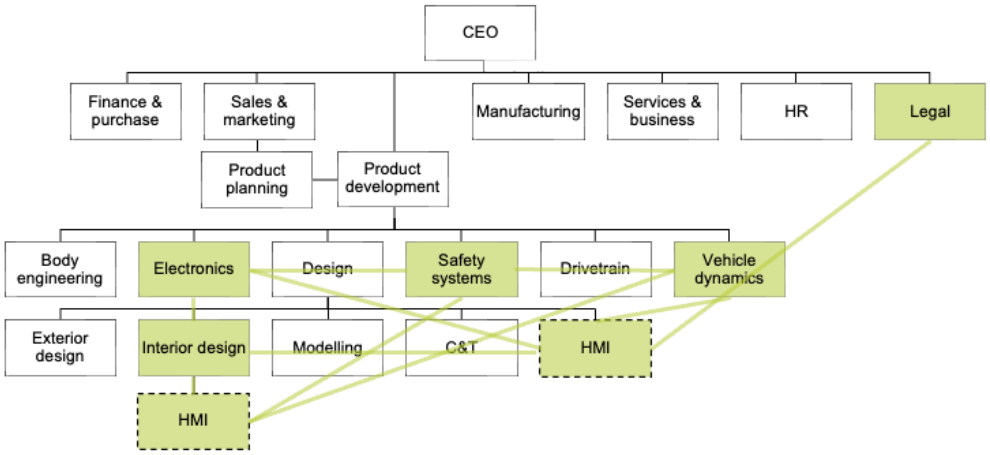
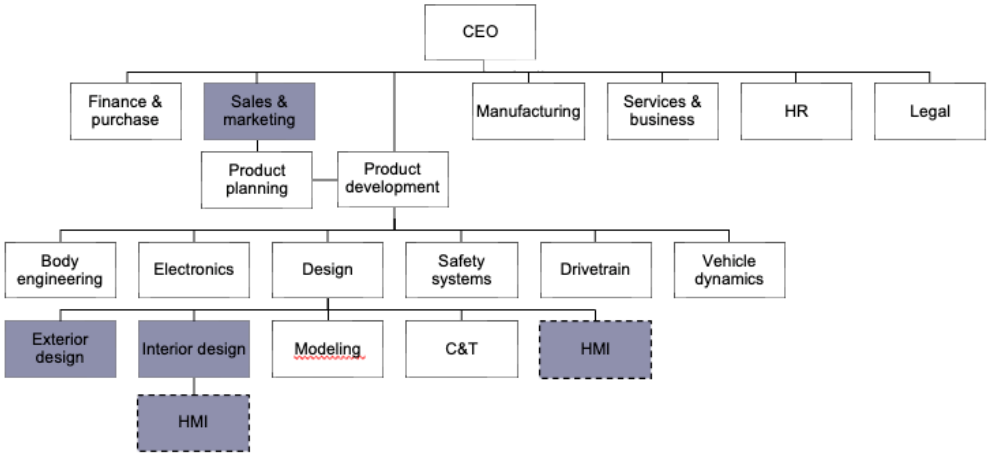


Figure 3.4. UCD application (depicted in blue) in the current generic OEM structure.



According to ISO 9241-220:2019, the degree at which human-centred quality objectives (e.g., avoidance of harm, usability, accessibility, user experience) are met depends, amongst others, on how potential conflicts between human-centred qualities and other quality attributes (e.g., security) are resolved. In this light, communication becomes more and more important when processes are distributed across departments. OEMs appear to differ in how communication between departments takes place. Some OEMs use relatively 'hierarchical' structures:

> *"Communication officially goes through bosses."*

> *"The ergonomics department sends specifications for physical measures to the design department. If the design department would like to deviate from these measures, they have to file a request. Often the answer is no."*

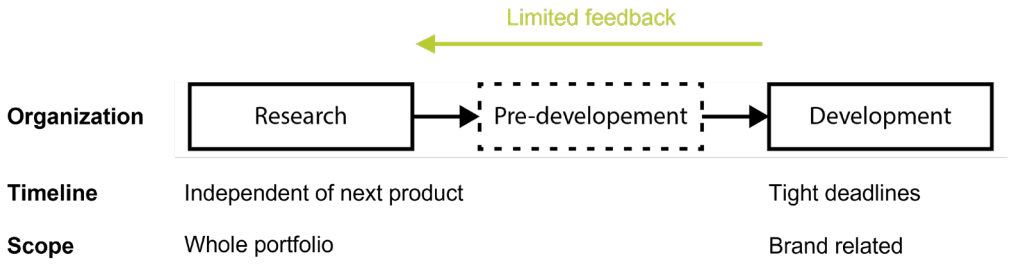
> *"We report to our own boss, not to upper management. […] You try to reach common goals, but also your own goals. In case of conflicts, we have to take into account potential deadlines. If we cannot sort it out directly amongst each other, we consult our direct boss, or ultimately upper management, but we try to avoid escalation. There are protocols for escalation."*

However, most OEMs appear to use relatively 'flat' structures, with direct communication between departments, e.g.:

> *"There is a direct communication between the different disciplines and departments."*
>
> *"There are no departmental boundaries."*
>
> *"There are meetings between relevant groups […] Conflicts happen all the time. Mitigation takes place at work level first, and management level second."*
>
> *"There is direct communication […] Conflicts are solved with peers. Product managers have an important role in this."*

Most OEMs appear to have a research department, operating for all strategic business units, i.e., brands in the brand portfolio (see *Figure 3.5*). Human factor challenges are typically investigated in the research department without tight deadlines, in contrast to the deadlines for specific vehicle development in the SBUs. In large corporations, findings from a centralised research department may constitute input for the development process of multiple brands. Some OEMs have a 'pre-development' department, involving members of both research and development.[8] Feedback from vehicle development to research seems limited: only one interviewee hinted at occasional, unstructured feedback.

Figure 3.5. Differences between research and development departments.



3.2.2 UCD principles

Overview of application UCD principles

Statements and notes relating to the UCD principles were collected for each OEM and were qualitatively assessed, see *Table 3.1*. In general, most OEMs show positive indications (e.g., green cells) for the majority of the UCD principles. Examples and additional observations per UCD principle are provided next.

Table 3.1. Qualitive evaluation of application of UCD principles. Colours denote the type of indications found. Dark green / red: strong positive / negative. Light green / red: moderate positive / negative. Gray: positive and negative. White: no indications.

UCD principle	OEM						
	I	II	III	IV	V	VI	VII
1 Understanding of user context & requirements							
2 Active user involvement							
3 Driven & refined by user-centred evaluation							
4 Iterative process							
5 Design addresses whole UX							
6 Multidisciplinary teams							

UCD principle 1: Understanding of user context & requirements

The following statement illustrates how one of the OEMs uses various techniques and perspectives to establish a set of user requirements:

8. After reading a draft version of this document, one interviewee noted some research does not end up in development and some development does not start with research.

"Future contexts are being developed […] User research must demonstrate why a specific ADS feature is needed. User requirements are balanced with price…"

These are positive indications for the application of UCD principle 1. According to ISO 9241-210:2019, relevant ergonomics and user interface knowledge, standards and guidelines should be part of the user requirements. No statements on addressing such human factors guidelines in relation to user requirements were identified for the OEM quoted above, which does not exclude the possibility that they are in fact addressed. For this reason, there is a moderate (e.g., not strong) positive indication that UCD principle 1 applies for this OEM. In contrast, a moderate negative indication is found at another OEM:

"Many requirements are decided upon by upper management. Such decisions are not always based on scientific research."

The above statement does not exclude the possibility of an explicit understanding of user context and requirements. However, it does indicate that human factors guidelines (derived from scientific research) may be overruled by decisions from upper management.

A general observation was that the interviewees rarely mentioned human factors guidelines or underlying issues (e.g., mode awareness, information overload), unless when prompted. Thus, it seems that an understanding of user context and requirements is driven more by customer experience than safety (also see section 3.2.5 on the apparent customer mindset).

- **UCD principle 2: Active user involvement**

ISO 9241-210:2019 states that users should be actively involved throughout design and development processes, where active involvement may take place by participating in design, acting as a source of relevant data, or evaluating solutions. The following statements provide strong positive indications that users are actively involved (e.g., evaluating solutions, source of relevant data) from the beginning of the design process (e.g., low fidelity prototypes) until the end (e.g., on-road tests):

"Around 10 years ago we started to apply UCD based on a training […]. We started to see how we can involve the end user in the development of our vehicles and systems instead of designing products based on customers' preferences. Involvement ranges from testing first ideas with low fidelity prototypes to on-road tests.[…] Functional logic of ADAS is [a] given when starting HMI design, but it is also evaluated with dedicated tests."

"Research department performs tests to explore how people use automated features. In the early development phase, expert judgment and customer surveys are used. In the late development phase, acceptance tests with various lo-fi and hi-fi prototypes are performed, including naive participants."

- **UCD principle 3: Driven & refined by user-centred evaluation**

When asked how designs are evaluated, all interviewees gave examples of evaluations with end users (including final acceptance tests), as well as evaluations with experts (e.g., professional drivers). The responses were all viewed as strong positive indicators of a design driven and refined by user-centred evaluation. Evaluations ranged from using low fidelity prototypes and driving simulators to on-road tests and customer feedback on existing models.

"For cognitive ergonomics, the ergonomics department uses user tests with driving simulators and eye-tracking, to evaluate where people are looking, how long their eyes are off-road, safety-related questions."

"The method depends on complexity, on features. We may use simulators, from laptop to large simulators. Simulators are less costly and repeatable. A new simulator was developed during COVID."

"We adjust the method to the question. Sometimes it's enough to use simple setups for initial testing, other times we do full-scale testing on tracks, on the open road, sometimes using fleet vehicles which are measured in daily use."

Prototype fidelity in evaluations is not only dependent on the development phase (full scale models are typically available only at the end), but also depends on test safety. Two interviewees stated that professional drivers are used when safety for naive drivers cannot be guaranteed:

"More advanced tests are done with both professional and naïve drivers. Depending on the test, this may be a specific sample or a generic sample. Open road tests whenever possible. Safety in testing is fundamental. When that is not allowed because of legal requirements we divert to simulators and VR testing."

"We do lots of on-road testing, especially if safety-related. For AEB we collected 1 million kilometres of data on emergency stops to test system sensitivity. For safety-sensitive systems we often do not use naive drivers in on-road tests, but engineers."

According to ISO 9241-210:2019, user-centered evaluation may involve end user as well as expert testing. The latter approach was mentioned by several OEMs, but never excluding tests with end users somewhere in the process. The choice between end user versus expert testing depends on, amongst others, efficiency and costs, as expressed in the following statement:

"We use a mix of naive participants and experts, depending on the design phase. Sometimes you can get really far with heuristics, and refine something before you put it in users' hands. That can be efficient because user testing is costly and time consuming. It is good to know whether we ask the right question before we bring in users."

Notably, one OEM mentioned that certain design features may not require evaluation if they are based on well-founded knowledge:

"We spent 10 years experimenting on designing good warnings, based on which we develop basic principles on which we do not need more research. Every two years, the actual developers are new; they either do what they think is best or someone else tells them what we already know. To protect the knowledge we already gained is as important as doing user testing in this area. We also should stay aware what the scientific state of the art is. We should not reinvent the wheel."

› UCD principle 4: Iterative process

Several positive indications of iterative design processes were found. In the first three statements below, it is not clear, however, which UCD activities are involved in the iterations. The fourth statement describes iterations during the development process, which appear to alternate between the UCD activities 'produce a design solution' and 'evaluate the design'. Seeing that none of the examples describe iterations involving UCD activities 'identify context of use' and 'specify user requirements', the statements were rated as moderate positive indications for UCD principle 4.

"Ideas are tested with end users. There are many iterations with low costs and fast results, up to 9 for interface design."

"Iterations continuously take place, when needed. There is no predefined number of iterations in the product development planning."

"Of course, there are feedbacks and loops. The number of iterations depends on the available time and the system. We end up with an adapted version which is the basis for continuation."

"Iterations in the development phase typically involve going into more and more detail. Each iteration may involve multiple departments negotiating on the use of space on the cluster, such as location and size."

One interviewee described an extensive project in which interaction with and acceptance of automated driving features were investigated. According to the interviewee such elaborate tests are only possible in the research department, which, in terms of risk mitigation, is reflected by the second statement of another interviewee. The second statement is not directly related to iterative processes:

> *"We used level 3 and level 4 prototypes to investigate how people use automated features, if they like and accept it, or if they would design it another way. We used prototypes on open roads with double consoles and trained safety drivers sitting in the passenger seat. There were 80 participants, and 3 drives each to test familiarisation, totalling up to 5 hours. It took one year to organise. We had observations of naive drivers with cameras and interviews after each ride to get insights in potential acceptance. This only possible in the research department. Then we potentially transfer results to [development][9], in which some light tests could still be done."*

> *"The program of requirements is initialised before the proof-of-concept. […] New things are typically investigated at the research department, separately from the regular design process. Next, pre-development may create a proof-of-concept, after which it may be planned in the regular design process. The risk is too high when you're implementing something of which you do not know yet if it will work."*

These statements suggest that research generally focuses on 'getting the right design', e.g., through explorations of new ideas, including studies aimed at a better understanding of context of use and user requirements. In contrast, development seems to focus on 'getting the design right', e.g., "going into more and more detail" (as commented earlier), based on a (fixed) list of requirements received from the research department. This apparent difference in content between iterative processes is illustrated in *Figure 3.6*.

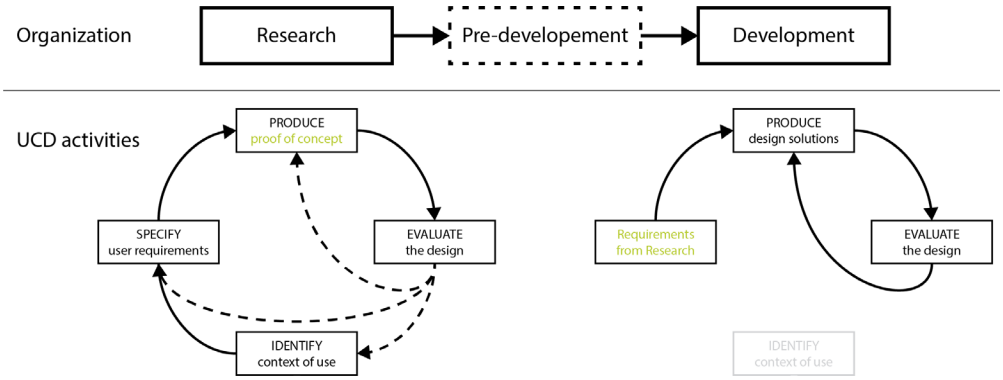


Figure 3.6. Iterative processes at research and development departments.

› UCD principle 5: Design addresses the whole user experience

ISO 9241-210:2019 defines user experience (UX) as *"users' perceptions and responses that result from the use and/or anticipated use of a system, product or service"*, where *"users' perceptions and responses include users' emotions, beliefs, preferences, perceptions, comfort, behaviours, and accomplishments that occur before, during and after use"*. All OEMs appear to address at least part of the aspects listed in the above definition. Typically, user-centred design and evaluation loops are focused on achieving a certain comfort level and meeting user expectations, and designs are sometimes based on experiences of previous models (e.g., through customer feedback).

9. The project team judged that the word used by the interviewee to describe the department was too specific. The generic word 'development' was chosen instead to avoid identification of the corresponding OEM.

"Systems are designed to meet criteria relating to understandability, avoiding confusion, comfort, and user expectations."

"What we try to do is to do things the way the customer is expecting to have the information. Even though we have information given to the driver, the driver may not perceive it if the eyes are on the road. Even more difficult is to combine what is in the cluster, in the navigation system, in the media system. You try not to distract the driver too much with information not related to driving. It is difficult to combine what the driver is expecting and which information is only accessible to ensure the driver is able to drive safely."

However, none of the OEMs made explicit that all aspects in the UX definition are addressed (i.e., the *whole* UX). Particularly, little or no mention was made of how a design yielded specific behavioural outcomes (such as safety performance indicators). Again, this does not exclude the possibility that these aspects are in fact addressed. Seeing that no negative indicators were observed, all OEMs were labelled with a moderate (i.e., not strong) positive indication for UCD principle 5.

› UCD principle 6: Multidisciplinary teams

ISO 9241-210:2019 lists several skill areas that should be present in a human-centred design team, such as human factors and ergonomics, users and stakeholder groups, application domain expertise, marketing and branding, user interface design, technical writing and training, business analysis, and systems engineering. The following statement highlights a multi-disciplinary approach and was viewed as a strong positive indication for UCD principle 6:

Driver interaction is the responsibility of a multifunctional user research team, involving driver interaction, electronics and dynamic interaction.

The various skill areas mentioned above are typically present in each OEM, but not necessarily within one team. Here it should be noted that ISO 9241-210:2019 does not specify or define what constitutes a team. According to the following statement, employees of different departments work together to the extent that their collaboration could lead to the perception that the employees are one large team. The statement was therefore labelled as a strong positive indication:

"There are no departmental boundaries, everybody works together all the time. HMI expert takes into account user and is present from the start."

However, an interviewee of another OEM explicitly mentioned gaps between departments (e.g., no team collaboration), despite the fact that all required expertise was present within the organisation as a whole. This statement was therefore labelled as a strong negative indication:

"Human factors are in research and feed into pre-development […] There is still a gap in the handover from research to pre-development."

One OEM reflected on the influence of human resources (HR) on team composition, and how user awareness influences HR decisions. Seeing that user awareness fluctuates over time, the statement has been labelled as both a positive and a negative indication for UCD principle 6:

"Safety, UX and design departments are closely linked. In a large organisation you cannot just add a layer of human factors experts; it has to be within each team. The challenge of UCD starts with human resources. […] What really goes up and down over time is user awareness. With high awareness the output of the circle is a user-friendly product. With low user awareness people want to get their function out of the door to meet tech requirements or due to time pressure."

3.2.3 Addressing human factors issues

› Operationalisation of human factors guidelines

Interviewees did not often speak of human factors issues and how they are addressed, unless when prompted. Notable exceptions are preventing cognitive overload and preventing false positives:

> *"It is important for us to not only work on technology, but on technology that [makes] sense to the final user. […] We also look at side effects, by making the HMI consistent with developments on different features. All departments (e.g., parking services, automation, connectivity, safety coaching) work together to make the HMI consistent and to prevent cognitive overload. The principal concern is to have the right signal in the right intensity at the right time."*

> *"In a lot of the tech stuff, if things break down, in a lot of the ADAS HMI stuff it does pop out in customer evaluation, because people never remember what the car has done to them in a real situation. In aircraft studies people were often not aware of the warning signal. The situation outside the car overrides everything else. If they have a bad experience with false positives, they do not want the car anymore."*

Interviewees were asked which steps are taken to operationalise ambiguously formulated human factors guidelines into concrete evaluation criteria. The response of one interviewee indicates that iterations as part of the UCD approach may help to clarify such ambiguity:

> *"Ambiguity is noted in feedback processes and iterates before sign-off, which is early in the process."*

Another interviewee stated that ambiguous human factors guidelines are not operationalised:

> *"The ADAS interface is tested by one test driver. Human factors guidelines are not operationalised. […] Human factors experts can be asked for advice."*

Yet another interviewee indicated that it was difficult to solve certain human factors issues (e.g., comprehensibility of a signal, confusion with other signals, information overload). Apparently, (ambiguous) human factors guidelines are consulted, but steps are not always taken to make them more concrete:

> *"[…] confusion, understandability, location, information overload, etc. What we try to do is to do things the way the customer is expecting to have the information. Even though we have [given] information […] to the driver, the driver may not perceive it if the eyes are on the road. Even more difficult is to combine what is in the cluster, in the navigation system, in the media system. You try not to distract the driver too much with information not related to driving. It is difficult to combine what the driver is expecting and which information is only accessible to ensure the driver is able to drive safely. […] We look at standard principles, some guidelines, but not very precise or detailed. We have our own principles, for example, we do not accept a menu that takes more than 5 or 6 seconds to process. In the cluster, some information should be visible using symbols instead of text. One of our rules is not to have too much information [in] the cluster."*

All in all, it seems that the iterative process that characterises UCD *can* be used to operationalise ambiguous human factors guidelines, but this is not done by most OEMs. Furthermore, none of the interviewees mentioned which human factors guidelines were consulted. [10, 11]

› Functional logic

The functional logic of AD(A)S underlies the way in which AD(A)S interact with the driver (Montalvo et al., 2020). The development of AD(A)S often involves multiple departments (e.g., electronics, safety systems, vehicle dynamics, interior design, HMI, see *Figure 3.2*), and consequentially handovers. Therefore, interviewees were asked whether HMI designers communicate design preferences regarding the functional logic when designing the HMI, or whether the functional logic is a given when starting the HMI design. Mixed responses were observed.

At two OEMs the functional logic of a system is a given prior to starting the HMI design. The second statement refers to the double diamond approach, an iterative process involving diverging (e.g., generating ideas) and converging (e.g., redefining the design problem, selecting solutions). [12] In one iteration, the internal logic is developed using relatively simple graphics, whereas in a subsequent iteration the final HMI design is developed based on the internal logic developed in the former iteration. The statement suggests that showing an HMI at a fidelity level that resembles a market-ready product may influence participants too much in their assessment of the underlying logic.

> *"The functional logic of a system is a given when starting the HMI design."*
>
> *"The latter [the functional logic is a given when starting the HMI design, red.]. The HMI used to be designed by an external company, according to the double diamond approach. From them we learned that the interaction model and visuals should be separated during development. Otherwise, the appreciation of the functions [is] too much influenced by what you see."*

Another OEM also uses the double diamond approach to develop the functional logic, but it could not be deduced at which stage in the process the functional logic is normally fixed:

> *"The ambition is always to have a tight dialogue and a tight loop between the technical requirements and what ends up on the display as communication to the customer. The way it works is the double diamond approach. We are converging on something we think is good, then there is divergence (discussions with engineers) and then we converge again with improvements. We have to balance a lot of attributes for each function. It is a give and take process. Sometimes we get challenged by the technical requirements, sometimes by the design solution (HMI), sometimes by new requirements, e.g., Euro NCAP protocols. We have dialogues not only on the here and now, but also on the longevity of it all."*

One interviewee stated that development of the functional logic involves a continuous iteration between engineers and HMI designers. Finally, at one OEM, the stage in the process at which development of the functional logic is fixed has not yet been decided, and the decision seems likely to be influenced by future purchase.

10. Interviewees were not prompted to specify which human factors guidelines were used. Possibly no spontaneous references to specific human factors guidelines were made because the interviewers mentioned "human factors guidelines for ADAS and ADS" (without specifying a publication) as part of one of the interview questions. The notion of the existence of these guidelines may have given interviewees with a background in human factors the impression that a common or joint understanding of the relevant guidelines already existed.
11. ISO 9241-210:2019 does not specify human factors or ergonomics guidelines for ADAS/ADS, likely because its scope is wider (e.g., interactive systems).
12. https://www.designcouncil.org.uk/our-work/skills-learning/tools-frameworks/framework-for-innovation-design-councils-evolved-double-diamond/

"No decision has been made yet, as to developing the full system in-house or find a purchase. User requirements are taken into account when deciding on a supplier."

3.2.4 Reactions to audit proposal

Opinions on UCD audit for type approval of individual vehicles

The general tendency in answering the question what the interviewees thought of a UCD audit for type approval was negative. Four OEMs mentioned that this would negatively influence their process:

*"I would consider implementing UCD in an audit as a **constraint**."*

*"More **rigidity** in processes is unwanted […] it would **slow down** work processes…"*

*"The people at legal would love to shoot at this, putting **creativity in chains**."*

*"It would **reduce flexibility** in the process. We like a certain level of freedom."*

Opinions on periodic certification

Two OEMs expressed moderate support for the proposal of periodic UCD certification independent of a specific vehicle, where the certificate would serve as prerequisite for subsequent type approval.

"That's an idea to think about."

"I do believe in certifying UCD, for sure in relation to safety. [This way,] a company can show […] that they will end up with safe products."

Scepticism

OEMs expressed scepticism regarding the validity of enforcing UCD. On the one hand, the validity of the outcome is questioned:

*"I wonder how prescribing a process would help to end up with better products. **Has it been validated**?"*

*"Support is expected to grow once the effect of applying UCD processes becomes **demonstrable**."*

On the other hand, OEMs questioned the validity of the audit process, in terms of the potential diversity of options to involve drivers, ambiguity about team composition and organisational scope, and the worry that applying UCD would result in redundant activities.

*"What would be the **ground truth**? […] And how do you compare a car company against your supposed ground truth?"*

"There are so many ways to evaluate driver-centric features. How would you audit the process?"

"It would be a very bold statement that UCD would not happen, if a team consists of only mechanical engineers and no human factors engineers. It would be hard to audit without having a clear preconceived notion about what constitutes a good design team that achieves UCD in the best way with some kind of people and process mix."

"It should not become a puppet show for the auditors […] We have many departments involved in the design. Where does the UCD end? What would you audit [in] a department with 7-8000 people?"

"Processes should be based on best practice, not dogma […] We should not end up with an endless [number] of iterations just because the process asks for it."

One OEM noted that the value of an audit may decrease when the underlying process model becomes more generic:

> *"If you follow the labels, we would be a UCD company. But there are ways to improve everywhere. Process-wise you could mould our approach into any generic process model for type approval processes. It's about the quality of the loops, not the loops themselves."*

Part of the scepticism originated from prior experience with driving simulator tests, indicating it is difficult to establish high external validity.

> *"What we ran into is that you cannot force people to work optimised. If you have a testing situation that is not immediately dangerous, then people will take their time. In a random group of participants, we may find 7 out of 10 test drives result in a fail. But when people are incentivised to do their best, they all passed. There is a huge variability in human capability and driving is not an optimisation activity. You have to do [well] enough to fit into traffic. How you have to measure what is successful design-wise in such a satisficing environment is a bit of a mystery. If you push them to perform, you take them out of normal driving. If spot testing a random set of users is the outcome of your project, we would not endorse that, as we have had bad experiences in the past."*

3.2.5 Miscellaneous findings

This section covers notable findings that were not part of the project scope.

› Drivers versus customers

When asked about the design process, interviewees often referred to the driver as the 'customer', as illustrated by the following statements:

> *"Customer department defines what **customers** experience as a gap."*
>
> *"What do our **customers** demand?"*
>
> *"Find technology that could be value for the **customer**."*
>
> *"…a study with naive participants to check if the technology fits with **customer** expectations."*
>
> *"What the **customer** wishes is most important…"*

Interviewees occasionally used the words 'driver' and 'participant', typically in the context of driving simulator studies and on-road tests.

› Influence of purchase on the process

Seeing that the Marketing & Sales department is involved in UCD (see *Figure 3.3*), interviewees were asked about the influence of purchase on the design process. Several interviewees described a balancing game between customer wishes and value propositions, as illustrated with the following statement:

> *"What the customer wishes is most important but there is always a continuous tension with what we can afford. […] We try to estimate a value for the client. We look at a list of applications which are feasible in terms of limited resources and regulations, and which give value to the customer. Value is wanting to buy and wanting to use."*

For one OEM, purchasing seems to play an important role in establishing the user requirements early in the process (e.g., in the research department, see *Figure 3.5*). It seems there is no explicit involvement of purchase in the actual design process, although it should be noted that purchase decisions embedded in the user requirements may implicitly influence the design process:

> *"Purchasing has no role in the design process. However, user research must demonstrate why a specific ADAS feature is needed. Key investors in the company though, may have influence on major investments. User requirements are balanced with price in the purchasing process."*

The role of purchase early in the process is also strong at another OEM, but this statement suggests that its role continues throughout the process:

> *"The role of purchasing is very strong. Pre-calculations for a full vehicle are started early on in the process."*

One interviewee did not expect that ADS will be integrated within the next 5-6 years, because it is too expensive for the customers of the brand, especially seeing that the operational design domain of systems with level 3 automation is limited:

> *"Customers do not wish to spend thousands of euros on a system that can only be used in specific circumstances."*

3.3 RDW interview results[13]

When introducing new (types) of audits, it is also important to take into account considerations and viewpoints of the (future) party that has to execute the audit. Therefore, we interviewed representatives of the Netherlands Vehicle Authority (RDW) to gain insight into their knowledge on existing audits as well as recommendations for a future audit. In this section the information from RDW's representatives is reported.

The representatives indicated that for traditional type approval, the OEM has to hand over their documentation providing all safety-related information. In addition, the approval authority conducts an audit to verify if reality corresponds with this documentation and to ensure that production will guarantee at least the same minimum level and compliance. For the introduction of AD(A)S, human factors will play an increasing role in this audit process. Moreover, for automated systems an additional element is introduced: in-use monitoring and reporting. This element obliges the OEM to provide proof from real-world performance that their systems remain safe and provide a safety benefit. This again also contains relevant information on human factors. The approval authority will not issue a type approval unless the OEM provided sufficient evidence for safety. Moreover, if in-use monitoring and reporting gives rise to software updates or recalls, this will be part of the process. Here, not only the approval authority but also the market surveillance authority has a role. Currently, relevant criteria for human factors are being developed to be used in the process of type approval (and surveillance). This development will also impact the knowledge and experience required for proper approval and surveillance.

RDW experts were also questioned on their opinion regarding a UCD approach in which also the design process itself is audited, as part of the audit of the processes for type approval. The experts consider this a promising approach. With the current type approval, responsibility already lies with the industry. It is expected that the suggested UCD approach, also auditing the design process, may help to get more confidence in the capability of the OEMs to properly address human factors aspects and to ensure that AD(A)S are safe to use for all drivers. Auditing the UCD can be added to the dedicated assessment of human factors requirements imposed by the regulation(s). However, they also indicate that this requires clear and substantiated specifications of human factors criteria that have to be met. Furthermore, the level of detail at which human factors criteria are specified influences the type and level of expertise (e.g., human factors, research methodology) required at the auditor's side.

13. Disclaimer: The text in this section does not represent the official RDW position, but it is based on opinions of RDW experts.

4 Advise UCD audit on AD(A)S

This chapter describes the conclusions and an advice on a UCD audit applied to AD(A)S, based on the results described in *Chapter 2* and *3*. The advice relates to whether and how an audit on UCD processes in AD(A)S development regarding the user-system interaction could contribute to the approval of safe AD(A)S.

The advice consists of recommendations as well as practical considerations for industry and vehicle approval authorities. Finally, suggestions are made on future steps in making the quality of AD(A)S-driver interaction part of an audit related to vehicle type approval.

In order to structure the outcomes, we started out with the following **preconditions** that have to be met to effectively introduce a UCD audit on AD(A)S-driver interactions.

- The UCD approach connects to industries' practice
- There is support from the industry for a UCD audit
- There is support from type approval authority (RDW) for a UCD audit

4.1 Connection UCD approach to industry practice

All OEMs we interviewed are familiar with the concept of UCD. All of them also indicated that they consider UCD as a valuable approach which they apply, to a certain extent, within their development of AD(A)S. However, only one OEM reported to have a fairly strict protocol in taking the user into account in the development and design of AD(A)S, which was reflected in a moderate or strong positive indication for all UCD principles.

Other OEMs indicated that for different products (mainly in terms of level of innovation), different procedures in relation to user involvement are being followed. Sometimes users are involved only in terms of expert-based knowledge, sometimes only part of the products are being developed based on active user involvement. Another finding is that UCD activities are scattered throughout the organisation. A reason might be that most interviewed companies were in the process of restructuring on account of new technologies.

All interviewed organisations indicated that their UCD practices are based on customer involvement. Almost never was the user referred to as a 'driver'. Although this does not imply that driver safety is not taken into account, it suggests a main focus on customer satisfaction within the UCD activities that were mentioned.

In general, we may conclude that whereas the industry considers UCD as a valuable approach in AD(A)S development, it was only applied part of the time, and with a seemingly stronger focus on customer satisfaction than on human factors in general.

4.1.1 Recommendations

Based on the above findings we present two recommendations:

1. Human factors should be explicitly stressed in AD(A)S user requirements. Irrespective of the type of process (here UCD is proposed) or criteria for safe AD(A)S interaction that an audit will require, a set of *specific* human factor guidelines relating to AD(A)S should be defined (see for example: Souman et al. (2021a)). These guidelines should be followed in design development. [14]
2. Since a large part of the OEMs is currently restructuring, it would be efficient if they could take new audit requirements into account when setting up new workflows. This, however, requires fast actions on the regulation level as well as support from the OEMs (see also *Section 4.2*)

4.2 Industry support for a UCD audit

During the interviews, a distinction was made between two types of audits: an audit that would be related to an individual product as part of vehicle type approval and a general periodic audit of UCD, not related to individual vehicles but as a prerequisite for type approval. Since support differed for both types of audits, a distinction between the two types is made in the paragraphs below.

4.2.1 Support product-based UCD audit

All OEMs reacted critically to a product-based UCD audit. Two parties specifically questioned the added value. They would like to see proof that applying UCD indeed yields better products before introducing such an audit. All feared extra workload without any quality improvement of AD(A)S development. An important reason for this fear is that product development lead times are short. Adding extra work increases time constraints. Besides, they greatly fear a reduced flexibility in development and design, which they relate to reduced innovation capacity.

4.2.2 Support for periodic general UCD audit

There was moderate support for general UCD certification on a company/department level, as opposed to a product-related audit. Such an audit is believed to take less time. But for such an audit to be workable, important conditions were mentioned: the workload should not be increased and the prescribed processes must be beneficial to the own business processes. One OEM mentioned as a possible advantage that a periodic audit may be beneficial for the positioning of human factors in the engineering culture of the company.

4.2.3 Recommendations

Based on the above results, we present three recommendations:

1. Explore whether a flexibly prescribed process is achievable, which at the same time limits extra workload.
2. Investigate how periodic UCD certification can be arranged.
3. Substantiate the relevance and possible added value of a to-be-prescribed UCD process.

14. ISO 9241-210:2019 prescribes that the specification of user requirements shall include, amongst others, requirements arising from relevant ergonomics and user interface knowledge. Seeing that ISO 9241-210:2019 is aimed at interactive systems in general, no references to specific human factors or ergonomics guidelines for AD(A)S are provided in the standard.

4.3 Support from type approval authority

The interviews with the Dutch Road Authority support the conclusion that clear and substantiated specifications of human factors criteria or guidelines are lacking. This does not imply that OEMs put no efforts in meeting these criteria, but whether and to what extent this is the case and how this is done remains unclear. An important step is to see under which conditions and to what extent OEMs are willing to share their knowledge and research on the assimilation of human factors criteria in their systems. This knowledge may not only contribute to the development of a useful and effective AD(A)S audit on the user-system interaction, it can also help to further specify human factors criteria. Something that is badly needed.

New audits relating to AD(A)S will be regulated on an EU level. Therefore, it would be valuable to investigate opinions on a European level, as was done for the OEMs. We recommend to investigate what European type approval authorities think about a process audit and how this fits in a roadmap towards guaranteeing the quality of the driver-system interaction within AD(A)S.

4.4 Practical considerations

Besides the results of the interviews on current practice and opinions, it is important to take some practical issues into account. First of all, the specificity of a prescribed process is inversely related to its flexibility: the less specific it is, the more flexible. On the one hand, the industry asks for flexible processes. On the other hand, when processes come with too few obligations, the added value of a regulation might be questioned. So, the challenge lies in prescribing the essential characteristics that have to be met in order to increase market chances of safe AD(A)S, and at the same time provide flexibility, where different approaches can all lead to good products. It also has to be kept in mind that the less detailed the prescribed procedure is, the more expertise is required from the auditor. When, for example, a guideline stating that ‘a system should not distract the driver from the driving task’ is not further specified, i.e. defined according to its different parameters, an auditor needs the expertise to assess whether the concept is operationalised in a meaningful and reliable way. This is the case with auditing processes instead of specifications anyway, but becomes even more true when parts of the process can be filled as one sees fit. Moreover, more flexibility requires more argumentation of the chosen approach by the audit applicant, which may inadvertently result in more workload for OEMs.

4.5 Feedback from interviewees

After data collection, we drafted an advice (see *Appendix B*) and sent it to all participants. In this paragraph, we describe the content of the comments per subject. The comments were (partly) taken into account in the recommendations as presented in the previous sections of this chapter. The first comment was made (in different terms) by three participants, all other comments were made by individual participants.

> *“Much scepsis exists on the idea that a UCD audit leads to better and safer products. Without solid proof that a real OEM product performs much better or is received more favourably in the market when developed under the prescribed UCD criteria, a very strong pushback is anticipated since no added value is perceived.”*

> *“The most important aspect for an OEM to apply UCD is that the customer is taken into account at an early stage without only using marketing research to investigate product acceptance before approving great investments.”*

"We produce products and services for customers. The customers' satisfaction is paramount in everything we make. The customer is therefore the first criterion for the evaluation of our behaviour in the company."

"There is not always a linear link between research and development. The picture in the report gives the impression that everything starts in research and ends in development. But it is more complex and diverse. Some researches do not end up in development and some development does not start with research."

"UCD should not bring additional workload."

4.6 Main conclusions and recommendations

4.6.1 Substantiate added value

Almost all the interviewed OEMs indicated that they want to know what the added value of a UCD audit would be. How does it contribute to safe AD(A)S and improved customer experiences of AD(A)S? They also indicate that if this 'proof' is not provided, it will be considered as one of many audits that increases workload but does not add quality to AD(A)S. Since support from the industry will most probably contribute to the quality of the prescribed approaches, it is important to substantiate the added value of a specific approach, and how such an approach may contribute to applicable knowledge that improves product experience.

4.6.2 Optimally combine flexibility and specificity

Seeing that specifications for safe driver-AD(A)S interactions are lacking and the industry does not want to be restricted, a prescribed approach should be flexible where possible. This requires proper consideration of parts that have to be strictly followed and parts that can be approached more flexibly. Flexibility is also required since each system, operating under different conditions and in different situations, should fit within the approach. Anyway, flexibility requires argumentation by the audit applicant as well as expertise of the auditor who has to evaluate the chosen approach and its argumentation.

4.6.3 Focus on human factors guidelines

Concerning the driver-AD(A)S interaction, it seems that more attention should be paid to human factors guidelines. Based on the interviews, it seems that the industry mainly focuses on customer desires, expectations and experiences, i.e., only a part of the user experience that assesses the compliance to human factors requirements. Customer evaluations of systems and its interactions are not always linked to the safety of interactions. Since drivers are not always aware of unsafe interactions (Twisk, 2019), system safety cannot be fully captured in stated preference studies. Based on the collected data, more objective behavioural measurements appear to be necessary to gain insight into these safety-related behaviours.

4.7 Future steps

Related to the recommendations as well as the practical considerations, some possible future steps are mentioned below.

4.7.1 Examine best practices

OEMs indicated that part of the required knowledge on the AD(A)S-driver interactions is already available within the company; a reason for not further addressing these aspects in specific product development. It would be very informative to see what can be learned from this existing knowledge for further specification of (human factors) guidelines. Moreover, existing AD(A)S might be examined for the AD(A)S-driver's interaction. The outcome may be used to demonstrate

good and bad practices. Besides, these findings can be used as input for audit procedures and prove the added value of specific approaches. It is hard to proceed in this matter without the industry sharing its knowledge, feedback and other data on AD(A)S and without more knowledge about the systems already in use. At this stage, it is hard to get access to this (confidential) information. But it seems important to see how governments, approval authorities and the industry can work together on this issue.

4.7.2 Investigate human factors guidelines

The end goal is to have AD(A)S that meet relevant human factors criteria. A prescribed approach, such as UCD, might be a helpful means to reach that goal; the user has to be taken into account, and requirements arising from relevant ergonomics and user interface knowledge, standards and guidelines should be part of the user requirements. As long as a system meets the relevant human factors criteria for all identified target users, the way this is done may actually be of less importance. Based on the current data, conforming to human factors guidelines seems not to be the most important consideration in the industry, and requires further investigation. Questions that should be answered are for example: how do current AD(A)S conform to the guidelines? How is conformance achieved and how is conformance determined? Would it be feasible to prescribe only the human factors guidelines systems have to meet (e.g., performance-based requirements), and not the way to get there (e.g., process-based requirements)? And how much knowledge among auditors and argumentation from auditees would this approach require?

4.7.3 Use audits to develop knowledge

Since knowledge about the requirements of safe system-user interaction is still scarce, the development of an effective and efficient audit requires flexibility, time, and good collaboration between the parties involved. In our view, that does not mean that an audit is not feasible before we have complete knowledge. It means that an audit may need to be set up in such a way that it can be easily updated in response to new knowledge and insights. This knowledge should be generated by the audit applications themselves and by field data after the implementation of a system. How the knowledge and data are shared and used should be anticipated before audit implementation.

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Appendix A Interview template

The following sections have been used as template for the semi-structured interviews. Questions are marked with the letter 'Q' and depicted in italics. Explanations to participants are preceded by a bullet.

A.1 Introduction

A.1.1 Personal

Q: Can you briefly tell a bit about yourself?

A.1.2 Purpose

- Explore if/how UCD could serve ADAS/ADS design;
- Explore if/how monitoring UCD processes could inform type approval.
- There are no wrong answers, we are just interested in your design process.

A.1.3 Legal

- Brand reference: [small/large] [manufacturer/OEM] of/for [vehicle type(s)] based in [country/region].
- Job title: e.g., lead designer responsible for human factors.

Q: How should we refer to you and to your company?

- No sharing of secrets is required.
- We may have questions on the type of outcomes (and processes leading there), but we do not need concrete illustrations of actual outcomes meant for production.
- If recording is allowed: only the project team will have access.
- Recordings will be deleted after the project is completed (expected in January 2023).

Q: Is recording okay under these conditions, or under additional conditions?

A.1.4 Terminology

A.1.4.1 User-Centred Design

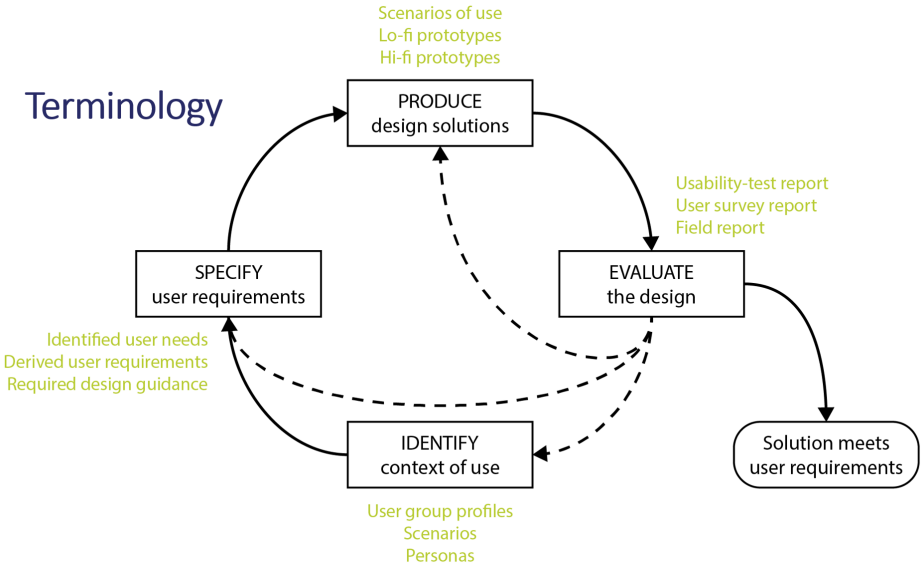
- Also known as 'Human-Centred Design'
- Show slide with terminology (*Figure A*.1).
- Show slide with terminology (*Figure A*.2).

Figure A.1. UCD definition and principles

Terminology

- Human-Centred Design is an approach to system design and development that aims to improve usability, accessibility and user experience and avoid harm from use, by focusing on the use of the system.
- Principles:
  - The design is based upon an explicit understanding of users, task and environments.
  - Users are involved throughout design and development.
  - The design is driven and refined by user-centred evaluation.
  - The process is iterative.
  - The design addresses the whole user experience.
  - The design team includes multidisciplinary skills and expertise.

Figure A.2. UCD loop



Q: Does this explanation fit with your perception of user-centred design processes? If not, how would you define UCD and/or its properties/principles?

A.1.4.2 ADAS & ADS

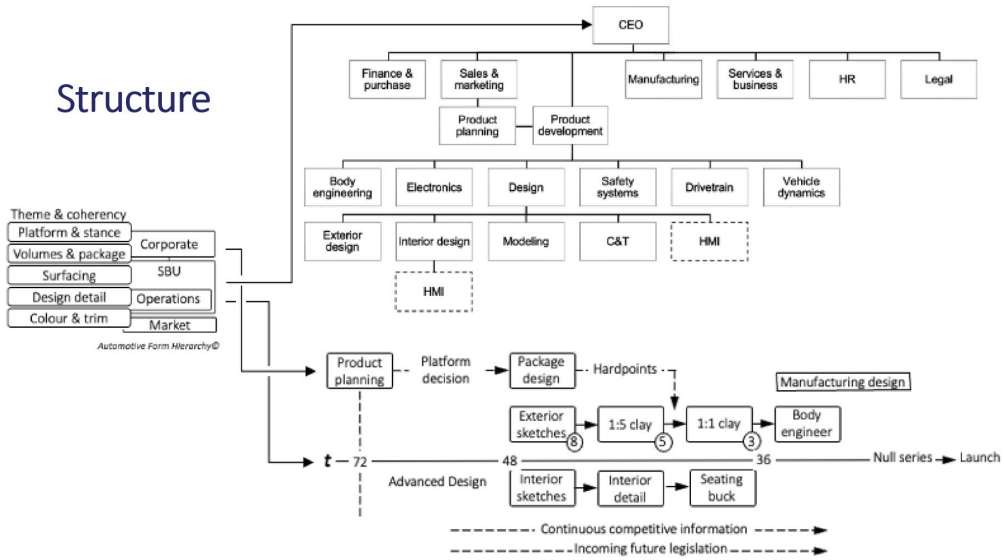
- Advanced Driver Assistance Systems (ADAS) support the driver in performing the primary driving task. These systems observe their surroundings using sensors and can take over control of the speed and/or direction of the vehicle under the responsibility of the driver. Such systems can also alert the driver to situations that the system estimates to be dangerous.
- Automated Driving Systems (ADS) means the hardware and software that are collectively capable of performing the entire dynamic driving task on a sustained basis.

Q: If your interpretation of ADAS/ADS differs, please explain how.

A.2 Structure of the organisation

- Show image of theoretical structure (*Figure A.3*)

Figure A.3. Theoretical organisational structure.



Q: Does this diagram adequately represent your organisation? If not, what are the main differences?

Q: In which department are you situated in this diagram?

Q: Which departments are involved in ADAS / ADS development in this diagram?

- Refer to previous image of iterative process, involving 'context of use', 'user requirements', 'design', and 'evaluation'.

Q: How are each of these departments involved in the four main UCD activities?

Q: How do these departments interact with other departments? (e.g., communication)

A.3 Application of User-Centred Design

Q: Can you briefly summarise your current involvement in ADAS/ADS development, within the department you are mainly working in?

- Please keep the activities & process you just described in mind in answering the following questions.

A.3.1 Operational design process

Q: How do context of use and user requirements (e.g., human factors guidelines, envisioned user experience) inform the design process?

Q: Are context of use and user requirements refined during the design process? If so, based on which insights?

Q: How do developers of AD(A)S technology communicate system limitations to the design team, and how do designers take these limitations into account when designing the HMI?

Q: The functional logic of AD(A)S underlies the way in which AD(A)S interact with the driver. Do HMI designers communicate preferences regarding the functional logic when designing the HMI, or is the functional logic a given when starting the HMI design?

Q: Human factor guidelines for ADAS/ADS can be formulated rather ambiguously (e.g., 'user overload should be prevented'). Which steps do you take to operationalise such guidelines specifically for the design you are working on?

Q: At which stage does automotive legislation (e.g., UN/ECE directives) enter the design process?

Q: How are designs evaluated and how do you choose the evaluation method?

Q: Do you use user tests as part of the evaluation? If so, how do you select the participants?

Q: Do you use expert opinion as part of the evaluation? If so, how do you select the experts?

Q: How do you use experiences gained from (user) tests/evaluations in previous design processes in your current design process?

Q: Do you plan UCD-related milestones, and if so, how are they integrated in a potentially overarching design process?

Q: How many iterations do you typically find in a design process, and can you briefly describe the nature of these iterations (e.g., what do you iterate between)?

Q: The purpose of UCD-related activities may be in conflict with the purpose of other design activities. Has this ever occurred and if so, did you use procedures to communicate and/or mitigate such conflicts?

Q: In your experience, are there enough resources available for a UCD process, e.g., to perform iterations, to process user feedback, to evaluate if the design meets the user requirements, and for communication with other departments not involved in UCD processes?

A.3.2 Strategic business unit design process

Q: Is UCD part of the organisational infrastructure (e.g., process management, guidelines, tools, qualified roles) and/or its strategy (e.g., vision, mission statement)?

Q: Where are UCD processes feasible, applicable, or unwanted?

A.3.3 Corporate design process

Q: Is UCD applied in corporate development processes?

A.4 Audit

Q: What if the implementation of a UCD process is going to be part of type approval for ADAS/ADS, does this change your perspective on UCD? How would you change your process to make it work for you?

Q: What if the UCD process is audited for a periodic certificate instead of type approval for individual vehicles. Does this change your perspective?

Q: How are designers currently involved in supplying documentation for audits (potentially on other parts of the design)?

A.5 Wrap-up

Q: Are there answers you like to get back to?

Q: After we finish the interviews on UCD processes, we will explore if/how monitoring UCD processes could inform type approval. Likely, we will first formulate a draft advice. Would you like to stay in the loop (e.g., a follow-up interview, a written reaction) before we submit such a final advice to the Dutch Ministry of Infrastructure and Water Management?

Appendix B Presentation draft advice

UCD: application & audits

Maartje de Goede, Reinier Jansen,
Elmer van Grondelle (TUDelft)

The Hague, November 30th 2022

1

- Dr. Maartje de Goede
  - Interaction (semi-)autonomous vehicles vs. other road users
  - Policy development light electric vehicles

- Dr. ir. Reinier J. Jansen
  - HMI design (semi-)autonomous vehicles
  - Human Factors risk inventories for field trials

- Elmer D. van Grondelle MBA Ba
  - Automotive designer and branding strategist
  - Automotive strategy at Industrial Design Engineering (TU Delft)

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Recap assignment

- Safety of AD(A)S dependent on interaction with driver
- Assumption: UCD approach to address human factors issues
- Based on theory & automotive design practice:
  - Explore if/how a UCD approach serves/could serve ADAS/ADS;
  - Explore if/how assessing UCD processes could inform type approval.

4

UCD background

5

Literature – UCD definition

- *"Human-centred design is an approach to system design and development that aims to improve usability, accessibility and user experience and avoid harm from use, by focusing on the use of the system."* (ISO 9241-220:2019)

6

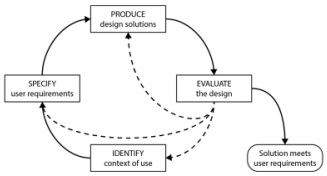
Literature – UCD principles

- 1. Explicit understanding of users/tasks/environment.
  - Including HF challenges
- 2. Active user involvement.
  - Participating in design, source of relevant data, evaluating solutions.
- 3. Design is driven and refined by user-centred evaluation.
- 4. Iterative process
- 5. Design addresses the whole user experience.
  - Users' perceptions and responses (emotions, preferences, comfort, behaviours…)
- 6. Multidisciplinary design team.

(ISO 9241-210:2019)

7

Literature – UCD activities



- UCD approach applied at distinct organizational levels / departments.
- UCD approach in parallel to other processes.

(ISO 9241-210:2019)

8

Literature – Human Factors guidelines

- Types of human factors guidelines
- Not based on automation levels
- Ambiguity at start of design process due to knowledge gaps

Figure 1. The hierarchical levels of ADAS and ADS functionality in system-user interactions

Souman et al. (2021) Human Factors Guidelines Report 4
Souman et al. (2021) Human Factors Guidelines Report 5: Test Criteria

9

Literature – UCD to operationalize HF guidelines?

- HF-related user requirements *may* be refined in conjunction with *that* design
- Requirement: all UCD activities take place

10

Interviews - Method

11

Approach

- Interviews to explore if/how UCD is applied and to probe audit reactions
- Duration: ~1-1,5h
- Run-through ISO checklists not feasible within interview
- Focus on UCD principles embedded at various departments

12

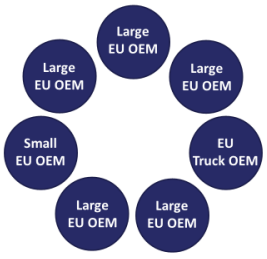
Interviews – OEM setup (~75min.)

- Introduction / purpose / terminology
- Structure of the organization
- Departments involved in AD(A)S research / development
- UCD principles, activities, planning
- Opinions on UCD process audit for AD(A)S

13

Participating OEMs

Based in four European countries



Interviewees

Interior designers
Director of design
HMI & human factors engineers
Senior executive
Project leader
Driver behaviour specialist
Project leader AD(A)S engineering

Descriptions have been anonimized at the request of the interviewees

14

Interviews - Results

15

*Customer department defines what **customers** experience as a gap.*

*Find technology that could be value for the **customer**.*

*...a study with naive participants to check if the technology fits with **customer** expectations.*

*What do our **customers** demand?*

Driver?
Customer

*What the **customer** wishes is most important...*

Occasionally 'driver' in context of simulator studies & on-road tests

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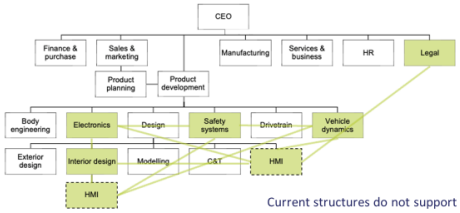
ADS stakeholders in current OEM structure



Current structures do not support ADS development
Large OEMs are restructuring or considering

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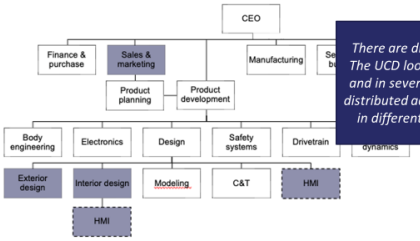
Organizational structure, UCD application

Dependency
Active communication versus hierarchy



There are different entry points [...] The UCD loop happens continuously and in several processes. The loop is distributed across the entire company in different stages of the process.

UCD application

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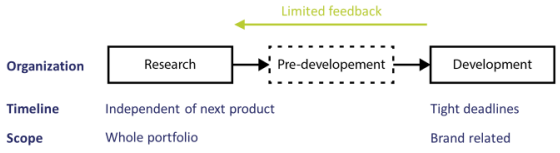
Interviews - Organizational structure



19

Interviews - UCD principles

- Qualitative indication: do principles apply and how?

Future contexts are being developed [...] User research must demonstrate why a specific ADS feature is needed. User requirements are balanced with price... [Note: no information on HF guidelines in user requirements]

UCD principle	OEM I	II	III	IV	V	VI	VII
1 Understanding of user context & requirements							

20

Interviews - UCD principles

- Qualitative indication: do principles apply and how?

Many requirements are decided upon by upper management. Such decisions are not always based on scientific research.

UCD principle	OEM I	II	III	IV	V	VI	VII
1 Understanding of user context & requirements							

21

Interviews - UCD principles

- Qualitative indication: do principles apply and how?

We started to see how we can involve the end-user in the development of our vehicles and systems instead of designing products based on customers' expectations [...] From testing first ideas to on-road tests.

UCD principle	OEM I	II	III	IV	V	VI	VII
1 Understanding of user context & requirements							
2 Active user involvement							

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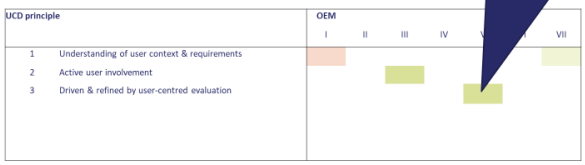
Interviews - UCD principles

- Qualitative indication: do principles apply and how?

Short loop: end-user tests with driving simulators and full scale tests.
Long loop: customer feedback existing models.
Research: principles based on 10 years of experimenting on designing good warnings.



23

Interviews - UCD principles

- Qualitative indication: do principles apply and how?

Ideas are tested with end users. There are many iterations with low costs and fast results, up to 9 for interface design.

[Note: unclear if iterations involve more than refining the design]

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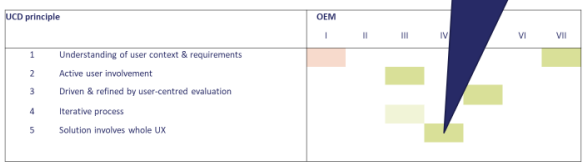
Interviews - UCD principles

- Qualitative indication: do principles apply and how?

Systems are designed to meet criteria relating to understandability, avoiding confusion, comfort, and user expectations.

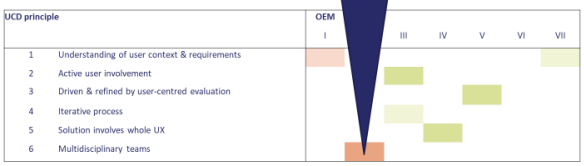


25

Interviews - UCD principles

- Qualitative indication: do principles apply and how?

Human Factors are in research and feed into pre-development [...] There is still a gap in the hand-over from research to pre-development.

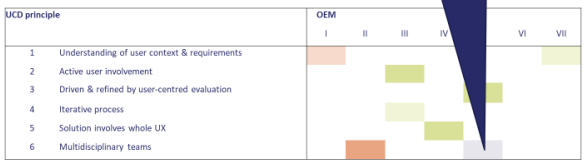


26

Interviews - UCD principles

- Qualitative indication: do principles apply and how?

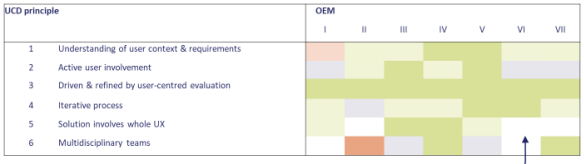
Safety, UX and design departments are closely linked. In a large organization you cannot just add a layer of HF experts; it has to be within each team. The challenge of UCD starts with HR.



27

Interviews - UCD principles

- Qualitative indication: do principles apply and how?



No information on principles *(no evidence of absence!)*

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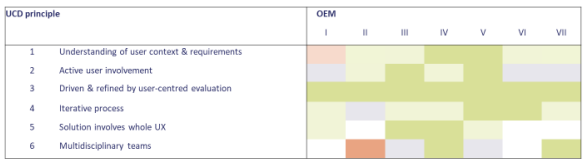
Interviews - UCD principles

- Qualitative indication: do principles apply and how?
- Most OEMs show positive indications on majority of UCD principles



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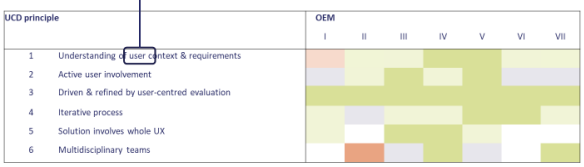
Interviews - UCD principles

Customer-based
Beta-users for trucks



30

Interviews - UCD principles

Not safety driven but customer experience

UCD principle		OEM
1	Understanding of user context & requirements	
2	Active user involvement	
3	Driven & refined by user-centred evaluation	
4	Iterative process	
5	Solution involves whole UX	
6	Multidisciplinary teams	

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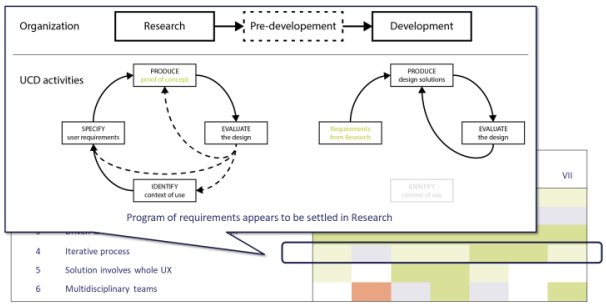
Interviews - UCD principles

- Δ Fidelity : Development process, safety issues
- Δ Method : End-users, experts
- Existing vehicles & research

UCD principle		OEM
1	Understanding of user context & requirements	
2	Active user involvement	
3	Driven & refined by user-centred evaluation	
4	Iterative process	
5	Solution involves whole UX	
6	Multidisciplinary teams	

32



UCD principle		OEM
4	Iterative process	
5	Solution involves whole UX	
6	Multidisciplinary teams	

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Interviews - UCD principles

- 5: Hard to evaluate without discussing product
- 6: Expertise present, but fragmented; especially in large organizations (HR challenge)

UCD principle		OEM
1	Understanding of user context & requirements	
2	Active user involvement	
3	Driven & refined by user-centred evaluation	
4	Iterative process	
5	Solution involves whole UX	
6	Multidisciplinary teams	

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Interviews - Human Factors guidelines

- From ambiguous guidelines to concrete criteria

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ADAS interface is tested by 1 testdriver. HF guidelines are not operationalized. […] HF experts can be asked for advice.

We look at standard principles, some guidelines, but not very precise or detailed […] We have our own principles. A menu on the cluster should take <5s to process.

Ambiguity is noted in feedback processes and iterates before sign-off, which is early in the process.

- Iterative operationalization *is* possible, but not used by most OEMs.
- Unclear which HF guidelines are involved.

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Interviews - UCD audit

*I would consider implementing UCD in an audit as a **constraint**.*

*The people at legal would love to shoot at this, putting **creativity in chains**.*

*More **rigidity** in processes is unwanted […] it would slow down work processes…*

*It would **reduce flexibility** in the process. We like a certain level of freedom.*

…on the upside it may help in the aforementioned culture change and in decision processes.

- Tendency: negative reactions

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Interviews - UCD audit

- Moderate support in case of periodic certification

That's an idea to think about

I do believe in certifying UCD, for sure in relation to safety. A company can show this way that they will end up with safe products.

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Interviews - UCD audit

- But also scepsis:

*I wonder how prescribing a process would help to end up with better products. **Has it been validated**?*

*What would be the **ground truth**? […] And how do you compare a car company against your supposed ground truth?*

If you push participants to perform, you take them out of normal driving. We would not endorse spot testing a random set of users.

*Support is expected to grow once the effect of applying UCD processes becomes **demonstrable**.*

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Interviews - UCD audit

- But also scepsis:

So many ways to evaluate driver-centric features. How would you audit the process?

It's about the quality of the loops, not the loops themselves.

It should not become a puppet show for the auditors […] We have many departments involved in the design. Where does the UCD end?

Process-wise you could mold our approach into any generic process model for type approval processes.

Processes should be based on best practice, not dogma […] We should not end up with an endless amount of iterations just because the process asks for it.

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Draft advice

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Assumptions and aims

Assumptions

- Requirements for safe AD(A)S are largely non-existent
- Following an UCD procedure results in safe AD(A)S (whether this is true is not a project goal)

Aims

- To determine whether there is support to make UCD part of an AD(A)S safety audit.
- Determine how UCD can be make part of a AD(A)S safety audit.

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Preconditions UCD audit

1. Prescribed UCD procedure provides valid results.
2. UCD procedure connects to the industries' practice.
3. Support from industry for UCD audit.
4. Support from type approval authority (RDW) for UCD audit.

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1. Prescribed UCD procedure provides valid results

- Interviewees indicated that they first would like to know whether and how a prescribed UCD process contributes to better and safer systems.
- We agree (but validation is not part of the assignment)

Recommendation: substantiate UCD validity for this objective

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2. Connection to the industries' practice

- All interviewed companies stated they consider it important to include the user in the design process. One company has a fairly strict protocol.
- In general, for different products different development procedures are being followed.
- Focus UCD practice seemingly more on customer satisfaction than on safety.
- UCD activities quite scattered throughout organizations.
- Most companies are in the process of restructuring in relation to new technologies.

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2. Connection to the industries' practice

Recommendations:

- Prescribing UCD process may improve the structural application but added value should be shown.
- In the restructuring of organizations, UCD implementation may be included.
- Inform industry: explicitly address HF in user requirements to meet UCD audit.

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3. Industry support for type approval related audit

- Industry is critical towards UCD audit
  - Reduction of process flexibility and innovation opportunities
  - Considered as extra workload
  - Proven added value is questioned

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3. Industry support for periodic UCD certification

- Moderate support for a general UCD certification on company / department level, as opposed to a product-related audit.
- Conditional:
  - No increased workload *
  - Must be beneficial for own processes
  - May be beneficial for HF positioning in engineering culture

**) OEMs are currently in the process of substantially reducing product development lead-times*

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3. Industry support – Preliminary recommendation

- Explore whether a flexible process is achievable which limits extra workload
- Investigate UCD certification on company/department level
- Demonstrate relevance (see #1)

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4. Support national type-approval authority (RDW)

- Interview RDW October 2022
- RDW indicates that they are already involved in auditing processes (in addition to type approval requirements). They consider it as a good approach to impose more responsibility on the industry.

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Considerations

A. Specificity relates to flexibility (innovation-capacity)
  - Less specificity of the prescribed procedure increases flexibility
  - The more flexible the process, the less added value of prescribing a process.
  - Process should be flexible, industry prefers periodic certification.

B. Specificity relates to required expertise of auditor
  - The less detailed the prescribed procedure, the more expertise is required from the auditor.

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General recommendation (preliminary)

- Flexible approach towards the UCD proces
- Stricter approach towards the applicable HF guidelines
- Thourough argumentation by the company

Considerations:
- *Diversity of products*
- *Diversty of situational approriate UCD methods*
- *Organisational structures (being redesigned)*

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Questions for interviewees

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Questions for interviewees

- Thank you once again for your participation. We would greatly appreciate if you could reply by e-mail to the following questions **before 10 December 2022**.
- Q1: Is it okay if we publicly report the overview of participants (slide #14) and the interview quotes of 'Results' section? (i.e., is the level of anonimization appropriate?)
- Q2: What is your opinion on our draft advice (slides #42-53)?

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Reduce injuries
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