BASt 11 December 2018

F4s – 2.1 AVSR

Comments by the Federal Highway Research Institute (BASt) appraising the current state of knowledge and the need for standardization with regard to the external communication of automated vehicles.

- Decree StV 22/7347.3/10 of 12 November 2018
- Specifically: Paper by the BASt (Division F4) from the perspective of human-machine interaction

In 2018, UN-ECE WP.29/GRE established the "Autonomous Vehicle Signalling Requirements" (AVSR) Task Force. This was prompted by the desire of the "International Automotive Lighting and Light Signalling Expert Group" (GTB) to include the subject of external signalling equipment on automated vehicles as a new field of work. The AVSR Task Force is chaired by Germany (Federal Ministry of Transport and Digital Infrastructure (BMVI)).

The introduction of new lighting equipment as external communication systems on automated vehicles is an issue where the BMVI, BASt plus numerous national and international experts are in agreement that restraint still needs to be exercised. It is likely that the findings of ongoing national and international research projects will make a contribution to the further discussion of the need for standardization and regulation.

The BASt (Division F4) was requested by the BMVI to appraise the existing findings regarding research and standardization activities, thereby making a contribution to the estimation of the current need for regulation in the AVSR Task Force. The comments are organized into the following sections:

1. Findings from selected national and international research projects
2. Status of work and discussion in ISO TC22 SC39 WG 8 HMI, "External communication for AV" Task Force

3. Presentation given at the PIRE Symposium in Washington, October 2018

1. Findings from selected national and international research projects

- Communication between road users by means of actions and signals, for instance a hand signal between a passenger car driver and a pedestrian, play a major role in assessing and predicting how other road users are going to behave in present-day road traffic (without automated vehicles). Its purpose is so compensate for errors, and it thus promotes road safety and supports the flow of traffic (Färber, 2015).

  What is currently known about non-verbal communication in road traffic refers predominantly to a vehicle operated by a human driver and the latter's interaction with other road users, including pedestrians, pedal cyclists, other drivers, etc.

- When automated vehicles are introduced, there is likely to be, for a lengthy period of time, mixed traffic comprising non-automated road users and automated vehicles that enter into communication with one another. From automation level 3 (conditional) upwards, the driver of the automated vehicle is not available, or only available to a significantly lesser extent, for external communication with other road users. This raises questions as to the impact of automation on communication between road users. There are two main questions are. What are the needs for communication between automated and non-automated road users? What requirements result from them for the shape to be taken by external communication and associated technical communication systems.

- In the sphere of public research, there have so far been only a few projects addressing issues of external communication between automated vehicles and non-automated road users. The findings described in the research literature exhibit differing trends. Reference is made to both positive and negative effects of the additional communication equipment – which was the object of the studies – installed on the vehicle. The conclusions drawn so far in the research literature indicate that the current

state of knowledge is considered to be still too low for a comprehensive estimate of the need for and the shape to be taken by technical solutions for the external communication of automated vehicles.

- Numerous research projects are currently underway for which no findings are yet available or for which only preliminary findings are available. Discussions with experts from the HMI research community in Germany back up the view that it would be best to wait until the findings of these projects are available before standardizing proposed solutions or reaching agreement on their licensing.

- On the basis of C2X terminology, an increasing number of solutions to the new communication needs between automated vehicles and, among others, vulnerable road users have been identified in recent years. Here, too, numerous questions are still unanswered, and this will require further research efforts, for instance into suitability for specific situations, market spread. It is, however, likely that C2X solutions will be able to meet only part of the communication needs that have arisen in connection with automated driving. Nothing is yet known about which of the remaining communication needs would have to be performed by visual/auditory communication equipment on the automated vehicle.

- With regard to the question as to the extent to which infrastructure measures could support communication between non-automated road users and automated vehicles, solutions are conceivable, especially in the urban environment. There is a need for research into possible use cases and associated solutions, among other things. Another unanswered question is how communication is to be distributed to the two information channels (in-vehicle, infrastructure-based). Initial research approaches are emerging, which makes it likely that further research projects studying infrastructure-based communication will shortly commence.

There follows a list of research projects addressing issues of external communication by automated vehicles of which the BASt has been apprised and which provide a partial overview of the status of research and ongoing research activities.

URBAN (DE), "Humans in Traffic" sub-project

Objectives, terms of reference:	Human-machine interaction appropriate for the urban environment. Predicting behaviour and identifying intentions
Commissioned by:	Federal Ministry for Economic Affairs and Energy (BMWi)
Project duration:	Completed (2016)
Project coordinator:	Munich University of Technology
Source:	http://urban-online.org/de/urban.html
Abstract of findings:	To research human behaviour, new methods and systems were developed that help to identify in a timely manner the intentions of the driver and vulnerable road users, for instance on the basis of their head movement. With the help of the new systems, vehicles can now respond appropriately to the intentions of other road users. Various driving simulators were interlinked and augmented by pedestrian, pedal cycle and motorcycle simulators. This makes it possible to analyse, in a risk-free and standardized manner, the interaction between several road users, for instance an assisted driver and a pedestrian.

Safe interaction between cyclists, pedestrians and automated vehicles (NL)

Objectives, terms of reference:	Provide an overview of current knowledge about the interaction of pedestrians and cyclists with (partly) automated vehicles. Identify what we need to know in order to ensure that a (partly) automated driving system does not compromise the safety of pedestrians and cyclists.
Commissioned by:	SWOV
Project duration:	Completed (2016)
Project coordinator:	Delft University of Technology

Source:	Vissers, L. et al. (2016). Safe interaction between cyclists, pedestrians and automated vehicles: What do we know and what do we need to know? The Hague: SWOV, Report R-2016-16. https://www.swov.nl.
Abstract of findings:	It appears very difficult to predict behavioural intentions of pedestrians and cyclists by current technology of automated vehicles. It cannot be excluded that pedestrians and cyclists will respond differently to (partly) automated vehicles than to manually-driven vehicles. Pedestrians and cyclists are fairly cautious when interacting with an automated vehicle and not per definition confident of its 'skills'. They seem to appreciate messages and/or signals from the car indicating whether the car has detected them and what it intends to do. However, which exact messages need to be brought about and the method of communicating them are not yet settled and this requires further study.

Communicating Intent of Automated Vehicles to Pedestrians (SE)

Objectives, terms of reference:	Study how the interaction between pedestrians and AVs might look like in the future and how the interaction might be affected if AVs were to communicate their intent to pedestrians
Commissioned by:	SAFER et al.
Project duration:	Concluded
Project coordinator/ contractor:	RISE Research Institutes of Sweden, Volvo, Autoliv, Scania

Source:	Habibovic A. et al. (2018). Communicating Intent of Automated Vehicles to Pedestrians. Front. Psychol. 9:1336. doi: 10.3389/fpsyg.2018.01336
Abstract of findings:	Pedestrians may need support to experience safe interactions with AVs. A minimalistic external interface is suggested that communicates to pedestrians whether or not an AV is in the automated mode and what the vehicle intends to do next. The studies imply that communicating the mode and intent of AVs via simple external interfaces could be sufficient to improve interactions between pedestrians and AVs by creating a higher perceived safety for pedestrians. Further investigations in more dynamic traffic situations and involving a larger number of pedestrians to validate this conclusion and to determine how it relates to vehicle motion patterns are suggested.

Testing the self-driving intent interface (US)

Objectives, terms of reference:	Testing of three different lighting scenarios, as well as a baseline condition where the lights were off, to observe how pedestrians and other road users responded to the vehicle signaling its intent
Commissioned by:	Ford (USA)
Project duration:	Completed (2017)
Contractor:	VTTI

Source: https://media.ford.com/content/fordmedia/fma/me/en/news/2018/10/07/seeing-the-light--fords-call-for-a-standard-self-driving-car-lan.html

Abstract of findings:	The light signal interface did not encourage any unsafe behavior by other road users. The results prove there is a baseline to build from in terms of the potential to improve acceptance of self-driving vehicles and trust in the technology. It took about two exposures for participants to

	learn what a single signal meant and between five and 10 exposures to understand the meaning of all three lighting patterns (a) yielding, b) active driving mode, c) start-to-go).

External Communication Pilot study (JP)

Objectives, terms of reference:	Identify possible negative outcomes of external communication of external HMI at an unsignalized crosswalk
Commissioned by:	? (Japan)
Project duration:	Concluded
Contractor/ project coordinator:	? (Japan)
Source:	Presentation at ISO Meeting in Milan on 18 October 2018
Abstract of findings:	The external HMI negatively influenced 14 subjects (pedestrians) out of 56.The negative influence was defined as reduced number of checking for approaching vehicles before making a decision to cross.

Rear-end external HMI for AV (FR)

Objectives, terms of reference:	Evaluate a rear-end external HMI which signals different speed levels, gap acceptance, minimal risk manoeuvre. Compare with traditional indicator signaling.
Commissioned by:	? (France)
Project duration:	Concluded
Contractor:	LAB (France)
Source:	Presentation at ISO Meeting in Milan on 18 October 2018
Abstract of findings:	Benefits of the considered external HMI could be shown: the external HMI allows faster understanding of emergency situation and faster reaction; a positive subjective assessment of the external HMI by drivers of following cars could be shown.

Interact (EU)

Objectives, terms of reference:	Analyze today's human-human interaction strategies. Implement and evaluate solutions for safe, cooperative, and intuitive interactions between AVs and both their on-board driver and other traffic participants.
Commissioned by:	EU
Project duration:	Ongoing (until 2021)
Project coordinator:	DLR
Source:	https://www.interact-roadautomation.eu/ https://www.interact-roadautomation.eu/about-interact/
Abstract of findings:	So far, only interim findings are available. Explicit communication (e.g. gesturing, flashing lights etc.) happens rarely. Most interaction-demanding situations are resolved before they actually arise. Communication and interaction btw human RU takes place at low speeds, usually below 20 km/h. At higher speed pedestrians use vehicle behavior for their decision, e.g. large enough inter-vehicle gaps to cross the road. Conclusion: The use of "external Human Machine Interfaces" seems to be only relevant in ambiguous situations, when explicit communication is necessary above and beyond kinematic cues. It is still unclear, whether external interfaces can enhance acceptance, safety, and traffic flow by communicating to other RU earlier.

InMotion (DE)

Objectives, terms of reference:	Develop light-based communication strategies between automated vehicles and other road users

Commissioned by:	BMVI
Project duration:	Ongoing (until 2020)
Contractor/ project coordinator:	Chemnitz University of Technology
Source:	https://www.tu-chemnitz.de/hsw/psychologie/professuren/allpsy1/verkehr/InMotion.php
Abstract of findings:	The BASt has not so far received any findings.

Fundamentals of communication between automated motor vehicles and road users, FE 82.0701/2017 (DE)

Objectives, terms of reference:	Analyse relevant forms of communication that occur today in various traffic constellations. Develop fundamental knowledge regarding the needs, requirements and strategies for communication between automated and non-automated road users in mixed traffic.
Commissioned by:	BASt
Project duration:	Ongoing (until 2020)
Contractor:	Rapp Trans; Dresden University of Technology
Source:	Contract specifications (see annex)
Abstract of findings:	No findings have so far been published.

Automated Vehicle Communication and Intent with Shared Road Users (US)

Objectives, terms of reference:	Identify key pieces of information for the AV to communicate to shared road users. Identify ways to measure communication effectiveness between the AV and shared road users. Provide research to inform human factors guidance regarding communication of AV intent
Commissioned by:	NHTSA
Project duration:	Ongoing (until 2019)

Contractor:	UMTRI/Westat
Source:	https://www.nhtsa.gov/sites/ nhtsa.dot.gov/files/documents/
Abstract of findings:	The BASt has not so far received any findings.

Analysis of pedestrians-vehicle interaction in simulated urban environments (PT)

Objectives, terms of reference:	Describe pedestrian and vehicle interaction at un-signalized crossings (no traffic lights), based on the analyses of the behavior of those agents (cars/pedestrians) at specific situations
Commissioned by:	? (Portugal)
Project duration:	Ongoing
Project coordinator:/ contractor:	Uni Minho, Uni Porto, Centro de Computacao Grafica (Portugal)
Source:	Presentation at ISO Meeting in Milan on 18 October 2018
Abstract of findings:	Simulation tool with models for describing pedestrian-vehicle accident risks

2. Status of work and discussion in ISO TC22 SC39 WG 8 HMI, "External communication for AV" Task Force

Following an initiative by the ISO and the American ANSI, work commenced in early 2017 on standardization on the new issue of "external communication between automated vehicles and non-automated road users". The importance of and need for such standardization with regard to the introduction of automated driving is not disputed by any of the stakeholders.

However, there have been heated debates regarding the approach to be adopted and the time frame. The US side pushed ahead with the standardization of specific design recommendations and solutions, especially with regard to additional lighting equipment for visual communication. On the other hand, the European and Japanese sides point out the numerous as yet unresolved

research issues, and they believe that developing technical standards on specific design recommendations at the present point in time is premature.

The first standardization document of this Task Force was published in September 2018. It is Technical Report ISO/TR 23049 (Road Vehicles - Ergonomic aspects of external visual communication from automated vehicles to other road users): The aim of this document is to provide recommendations for action to developers of external communication systems and visual signals on automated vehicles. The document is not designed to describe specific functional or technical elements of external communication systems. Rather, it sets out general principles of interaction between automated and non-automated road users and derives from them recommendations for non-verbal (visual) communication. The German side (NA-052-00-39-08-AK MMI) was not involved in preparing this document.

In 2018, SO TC22 SC39 WG8 has discussed possible future standardization activities by the Task Force in this thematic field. The issues discussed were a) experimental evaluation of external communication and b) compilation of general design recommendations. The German side (NA-052-00-39-08-AK MMI) put forward the following standpoints:

- The available research findings regarding design and deployment are not yet sufficient for the standardization of technical communication solutions to "external HMI (eHMI).
- Provisional research findings indicate that eHMI could be required for certain traffic situations but that eHMI alone will in no way be sufficient. - Methods for the assessment of eHMI should be speedily standardized.

The new package of work entitled ISO/NP TR 23720 (Road Vehicles - Methods for evaluating other road user behavior in the presence of automated vehicle external communication), which was formally tabled regarding issue a), was confirmed in November 2018 in the coordination at international level. It is planned that the German side (NA-052-00-39-08-AK MMI) will be involved.

On the other hand, the package of work entitled ISO/NP TR 23735 (Road Vehicles - Ergonomic design guidance for external visual communication from automated vehicles to other road users), which was tabled regarding issue b), was deemed premature and rejected in the

coordination at international level in November 2018.The following list provides an overview of the aforementioned ISO activities and their status:

ISO/TR 23049:2018

Road Vehicles - Ergonomic aspects of external visual communication from automated vehicles to other road users

Purpose of the document:

- to propose how automated vehicles (AV) equipped with automated driving systems could communicate with other road users via an external communication system,
- to discuss the interaction between humans and AVs within roadway environments
- does not address functionality elements of the AV external visual communication system itself.

Status of the document: published, Sept 2018.

ISO/NP TR 23720

Road Vehicles - Methods for evaluating other road user behavior in the presence of automated vehicle external communication

Purpose of the document:

- to provide a common set of terms and variables that can be used when evaluating AV external communication

Status of the document: New Work Item Proposal, approved Nov 2018.

ISO/NP TR 23735

Road Vehicles - Ergonomic design guidance for external visual communication from automated vehicles to other road users

Purpose of the document:

- to provide guidance such that there is common implementation across the automotive industry; existing regulations will provide the model for this guidance.

Status of the document: Abandoned NWIP. Proposal was disapproved, Nov 2018

3. Presentation given at the PIRE Symposium in Washington, October 2018

Within the scope of the German-American collaborative project entitled "Science of Design for Societal Scale Cyber-Physical Systems", a joint symposium was held in Washington on 30 and 31 October.

In his presentation entitled "Communication and Interaction between AV and other Road Users", Prof. Bengler (Munich University of Technology) provided an overview of the status of research. The conclusions he presented essentially reflected the position already adopted by ISO TC22 SC39 WG 8, including:

- There is currently a dilemma regarding the coherence of the external HMI solutions currently being discussed (and proposed for introduction in the near future) and the existing state of knowledge regarding their design and application.

- Implicit communication (i.e. message derived from behaviour) plays a dominant role for interaction between road users.

- No clear indications can currently be given regarding explicit communication (i.e. message conveyed by signals and signalling equipment). F4s – 2.1 AVSR