WeCARe: Workshop on Inclusive Communication between Automated Vehicles and Vulnerable Road Users

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ABSTRACT

Automated vehicles are expected to become a part of the road traffic in the near future. This upcoming change raises concerns on how human road users, e.g., cyclists or pedestrians, would interact with them to ensure safe communication on the road. Previous work focused primarily on the scenario in which a young adult without impairments crosses a street in front of an automated vehicle. Several road user groups, such as children, seniors, or people with special needs, in roles of pedestrians and cyclists, are not considered in this scenario. On top of this, cultural differences are rarely considered. To ensure that future traffic is safe and accessible for all citizens, we aim to address inclusive communication between automated vehicles and vulnerable road users. In this workshop, we will discuss and exchange methods, tools, and scenarios applicable for inclusive communication, identify the most relevant research gaps, and connect people for future collaborations.

CCS CONCEPTS

• **Human-centered computing** → **Accessibility**; *Human computer interaction (HCI)*; • **Computer systems organization** → *External interfaces for robotics.*

KEYWORDS

Workshop; vulnerable road users; automated vehicles; inclusiveness; human-machine interaction; external human-machine interfaces

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1 BACKGROUND

Social cues play an essential role in resolving road situations between car drivers and vulnerable road users. However, this interaction might be more challenging in the presence of automated vehicles [13]. We will be using these definitions for automated vehicles and vulnerable road users in the following:

Automated Vehicles (AVs) Vehicles that provide some level of automation, thereby reducing the effort of the human driver for the primary driving task. In this workshop, we focus on AVs that do not need an attentive driver at all times, thus SAE Levels 3 and above.

Vulnerable Road Users (VRUs) Non-motorized road users, such as pedestrians and cyclists, motor-cyclists, and persons with disabilities, reduced mobility, or reduced orientation [8]. This workshop specifically focuses on VRUs like children, older adults or people with impairments.

Previous works focused on addressing the challenge of interacting between VRUs and AVs using external Human-Machine Interfaces (eHMIs, see Figure 1) [7, 22] or by simulating social interactions via eye contact or gestures [36]. Such approaches primarily focus on visual stimuli (e.g., [16, 30]) and do not comply with Universal Design principles (see [9]), which excludes people with visual limitations [7]. In general, several groups, such as children, blind people, or older adults, are underrepresented in empirical evaluations of eHMI concepts for interaction between AVs and VRUs. We aim to develop inclusive solutions with the help of this workshop to make the traffic accessible for them. Moreover, these groups are not limited to the example groups discussed below and may also include people with hearing loss, wheelchair users, or skateboarders.

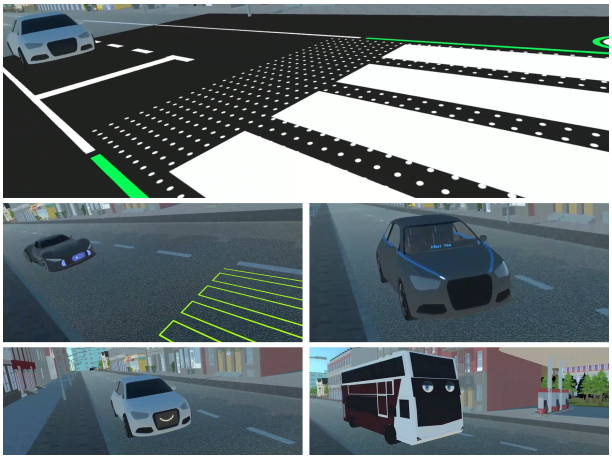

Figure 1: Example eHMIs from a VRU's perspective as discussed in [22]

Children between six and thirteen are the most vulnerable subgroup among cyclists, due to the still-developing motor and perceptual-motor skills [1, 12]. About 1.98 billion people are children (age 0 - 14) [28]. Road traffic injuries are the primary cause of death for children and adults aged 5-29 years [37]. Previous work tried to address the safety issue for child cyclists by augmenting bicycles and helmets to represent warnings [25], navigation [27], and lane-keeping cues [26]. Still, Deb et al. [10] identified children as underrepresented participants in studies with eHMIs. They revealed different behavior compared to the adult counterparts and identified a more risky behavior among children. Thus, we find it particularly important to explore the design space for children as VRUs like cyclists or pedestrians.

Another group of underrepresented VRUs is **people with visual limitations**. About 1.3 billion people have some, and 217 million people moderate to severe, vision impairments. 36 million people are blind [4, 31]. 466 million people have disabling hearing loss [32]. Colley et al. [7] showed that current concepts mostly focus on visual stimuli. Design spaces in external communication of AVs [5, 24] acknowledge that other stimuli are feasible, but previous research did not adequately address them. Colley et al. also discussed existing auditory concepts with experts on accessibility [6]: recent concepts were rated as unusable. Thus, they introduced the "omniscient narrator", an approach where one AV communicates for all relevant AVs.

Older adults are an important group of traffic participants. The world's population of age 65 and above has been increasing [14, 34]. The number of older adults is projected to increase with "persons over age 65 being the fastest-growing age group" [29]. By 2050, one in six persons is projected to be aged 65 or over [29]. Thus, Human-Computer Interaction (HCI) research increasingly takes into account the additional user needs that come with aging [15]. For example, Dickinson et al. [11] provide an overview of methods for HCI research with older people. It has been shown that age plays a vital role in making crossing decisions [33]. Also, older adults seem to have different expectations for automated driving than younger adults [23]. It has also been shown that older adults take longer to adapt to new technology [2] and have different requirements [21].

Table 1: A draft for the workshop's schedule.

WeCARe Schedule	
09:00	Opening
09:15	Overview on eHMIs
09:30	Paper Presentations
10:30	Morning Break
10:50	World Café
11:50	Presentations
12:35	Research Challenges
12:50	Lunch Break
13:50	Discussion
14:10	Prototyping
15:00	Presentations
15:30	Afternoon Break
15:50	Results
16:05	Plenum Discussion
16:30	Wrap-Up
17:00	End.

2 GOALS OF THE WORKSHOP

We intend to achieve the following goals with this workshop:

(1) Provide an overview of the current state of the research for interaction between AVs and VRUs.
(2) Identify the research gap and raise awareness for lowering the barriers to traffic participation.
(3) Hands-on experience and live feedback in designing inclusive interfaces.
(4) Establish communication with workshop attendees for future (international) collaborations.

3 AUDIENCE

This workshop welcomes researchers and practitioners with interest in accessible technology, interactive technologies for children, seniors, or people with impairments, or automotive user interfaces. Specifically, we want to reach those developing mobile interfaces for traffic participants (e.g., pedestrians, or cyclists), inclusive interfaces (addressing, e.g., visually impaired people), or external human-machine interfaces for AVs. We will promote this workshop using a dedicated website with information about it. We will reach out to the community via social media channels (e.g., Twitter, Facebook, or LinkedIn), mailing lists (e.g., GI, or ACM SIGCHI), and at the AutomotiveUI conference. We expect to have 15 to 20 attendees.

4 WORKSHOP ORGANIZATION

This workshop invites people from different cultures, backgrounds, and affiliations to explore the interplay of automated vehicles and other road users. The workshop emphasizes cultural differences, diversity, and inclusive design solutions for the interaction of AVs and VRUs. To this end, there are presentations, hands-on activities, and group discussions planned. The organizers will be available

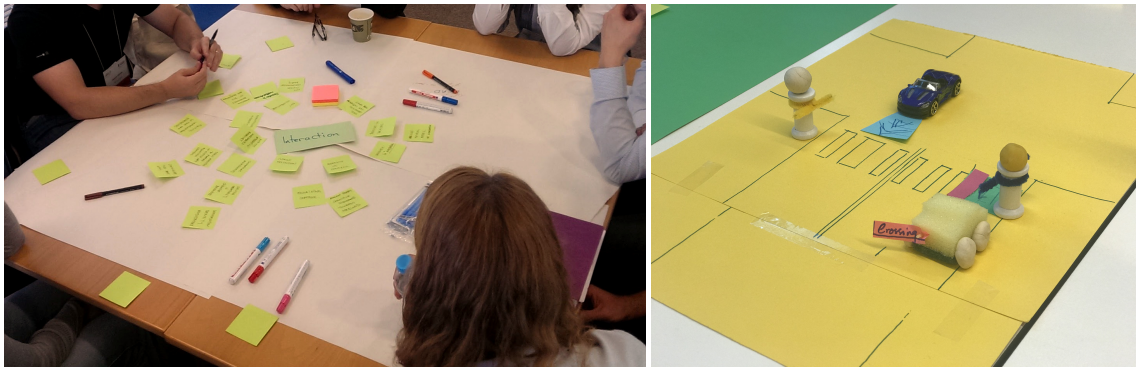

Figure 2: Images from previous workshops. Left: A snapshot of a table during a World Café. Right: A prototyped traffic scenario.

throughout the sessions to support participants during the activities. An overview of the schedule is presented in Table 1.

We will distribute a call for participation before the workshop. Participants are required to submit position papers between two and four pages, not counting references, in the SIGCHI Extended Abstract template. Each paper will be reviewed by at least two organizers of this workshop with regard to its contribution to the workshop.

We begin with a round of introduction (*Opening*), a brief presentation of the current state of research regarding automated vehicles and vulnerable road user interaction (*Overview on eHMIs*), and 4 minutes Pecha-Kucha style [3] presentations of the position papers by participants (*Paper Presentations*).

Between the first break and lunch, we want to establish a common understanding of the key challenges in current AV-VRU research. We will revise open questions from submitted workshop papers to derive topics for a *World Café* (see Figure 2, left). Thus, groups of participants discuss a topic for twenty minutes before switching to another table. Possible subjects might be: "technology for AV-VRU communication including mobile devices", "identification of cultural differences in traffic", or "inclusive interfaces for impaired people". After 60 minutes, each group presents the outcome of the table they are sitting at in about 15 minutes, including a 5 minutes discussion (*Presentation*). Afterward, the participants will be asked to write down their most important research challenges, and the workshop organizers will collect and cluster the presented findings (*Research Challenges*).

In the first 20 minutes after lunch, we will discuss identified challenges based on the World Café results (*Discussion*). Afterward, participants are split into groups of four people to prototype matching interaction techniques, methods, or scenarios, using the "Quick and Dirty Prototyping" technique (*Prototyping*, see Figure 2, right). After 50 minutes, each group has 10 minutes to present their prototype(s) before the afternoon break (*Presentations*).

In the last part, we want to focus on the results of the workshop and the next steps (*Results*). The composed challenges and solutions are split into clusters and become revisited in groups for 15 minutes. Afterward, the relevance of each research opportunity / challenge is discussed in a plenum (*Plenum Discussion*). The goal is to reach a common understanding of research gaps and opportunities as well as requirements for inclusive AV-VRU interaction. The last 30 minutes are dedicated to wrapping up the workshop's outcomes, plan the next steps, and discuss where to publish possible results (*Wrap Up*). Furthermore, we aim to agree on a platform for future exchanges of workshop participants, e.g., a Slack team.

5 PLANNED OUTCOMES

The primary goal of this workshop is to bring together people from different areas to discuss how to develop inclusive communication concepts for automated vehicles that need to interact with human traffic participants. We plan to make the outcomes of the workshop accessible for the research community. Accepted position papers will be published on the workshop's website. We will summarize the presented works, discussions, and results of the workshop into an article that can be published. As this topic is under-reported, we have the ambition to make a special issue, given there is enough interest from the workshop participants.

We also plan to maintain future communication with the workshop participants. We believe that inclusive solutions for traffic participation can only be developed if the involved developers incorporate diverse ideas and requirements from several perspectives while also looking at the requirements for different cultures [35].

6 ORGANIZERS

Andreas Löcken (main contact) is a postdoctoral researcher in the HCI group at the Technische Hochschule Ingolstadt (THI). His research focuses on Human-Computer Interfaces in socio-technical safety-critical systems in general, and specifically the interaction between VRUs and AVs.

Mark Colley is a PhD candidate at the University of Ulm. His research looks into communication possibilities between AVs and VRUs such as pedestrians and cyclists.

Andrii Matviienko is a postdoctoral researcher at Technical University of Darmstadt. His research focus lies on designing multimodal assistance systems for child cyclists, educational technology for children and people with special needs.

Kai Holländer is a PhD candidate at the LMU Munich. His research offers a pedestrian perspective on automated driving, primarily regarding the design of future interaction strategies between pedestrians and automated vehicles.

Debargha Dey is a PhD candidate at Eindhoven University of Technology and his research focus is the human factors of automated driving, particularly the interaction between automated vehicles and other road users.

Azra Habibovic is senior researcher at RISE Research Institutes of Sweden and research area director for road user behaviour at research center SAFER. Her research focuses on traffic safety, with emphasis on interactions between automated vehicles and other road users.

Andrew Kun is professor of Electrical & Computer Engineering at the University of New Hampshire. His research focus is HCI in vehicles [20] and specifically for automated vehicles [17–19]. He is the steering committee co-chair of AutomotiveUI.

Susanne Boll is professor for Media Informatics and Multimedia Systems at the University in Oldenburg. In her research she addresses the interaction technologies for elderly people and and interaction of traffic participants with automated vehicles.

Andreas Riener is professor for Human Machine Interface and Virtual Reality at Technische Hochschule Ingolstadt (THI) with co-appointment at the CARISSMA research center. His research interests include driving ergonomics, driver state assessment from physiological measures and trust, acceptance, and ethics in automated driving.

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REFERENCES

[1] Andrés Aparicio, Laura Sanz, Gary Burnett, Hans Stoll, Maxim Arbitmann, Martin Kunert, Fabian Flohr, Patrick Seiniger, and Dariu Gavrila. 2017. Advancing active safety towards the protection of vulnerable road users: the PROSPECT project. In *25th International Technical Conference on the Enhanced Safety of Vehicles (ESV) National Highway Traffic Safety Administration.*

[2] Felix Becker and Kay W Axhausen. 2017. Literature review on surveys investigating the acceptance of automated vehicles. *Transportation* 44, 6 (2017), 1293–1306.

[3] Alisa Miller Beyer. 2011. Improving student presentations: Pecha Kucha and just plain PowerPoint. *Teaching of Psychology* 38, 2 (2011), 122–126.

[4] Rupert RA Bourne, Seth R Flaxman, Tasanee Braithwaite, Maria V Cicinelli, Aditi Das, Jost B Jonas, Jill Keeffe, John H Kempen, Janet Leasher, Hans Limburg, et al. 2017. Magnitude, temporal trends, and projections of the global prevalence of blindness and distance and near vision impairment: a systematic review and meta-analysis. *The Lancet Global Health* 5, 9 (2017), e888–e897.

[5] Mark Colley and Rukzio Rukzio. 2020. Towards a Design Space for External Communication of Autonomous Vehicles. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems* (Honolulu, Hawaii USA) *(CHI '20)*. ACM, Association for Computing Machinery, New York, NY, USA. https://doi.org/10.1145/3334480.3382844 Accepted.

[6] Mark Colley, Marcel Walch, Jan Gugenheimer, Ali Askari, and Rukzio Rukzio. 2020. Towards Inclusive External Communication of Autonomous Vehicles for Pedestrians with Vision Impairments. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (Honolulu, Hawaii USA) *(CHI '20)*. ACM, Association for Computing Machinery, New York, NY, USA. https://doi.org/10.1145/3313831.3376472 Accepted.

[7] Mark Colley, Marcel Walch, Jan Gugenheimer, and Enrico Rukzio. 2019. Including People with Impairments from the Start: External Communication of Autonomous Vehicles. In *Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications: Adjunct Proceedings* (Utrecht, Netherlands) *(AutomotiveUI '19)*. Association for Computing Machinery, New York, NY, USA, 307–314. https://doi.org/10.1145/3349263.3351521

[8] European Commission. 2020. ITS & Vulnerable Road Users. https://ec.europa.eu/transport/themes/its/road/action_plan/its_and_vulnerable_road_users_en. [Online; accessed: 04-MARCH-2020].

[9] BR Connell, M Jones, R Mace, J Mueller, A Mullick, E Ostroff, J Sanford, E Steinfeld, M Story, and G Vanderheiden. 1997. The principles of universal design, Version 2.0, Raleigh, NC. *Center for Universal Design, North Carolina State University* (1997).

[10] Shuchisnigdha Deb, Daniel W Carruth, Muztaba Fuad, Laura M Stanley, and Darren Frey. 2019. Comparison of Child and Adult Pedestrian Perspectives of External Features on Autonomous Vehicles Using Virtual Reality Experiment. In *International Conference on Applied Human Factors and Ergonomics*. Springer, 145–156.

[11] Anna Dickinson, John Arnott, and Suzanne Prior. 2007. Methods for human–computer interaction research with older people. *Behaviour & Information Technology* 26, 4 (2007), 343–352.

[12] Jenny Ellis and LLC JEBE Consulting. 2014. *Bicycle safety education for children from a developmental and learning perspective.* Technical Report. United States. National Highway Traffic Safety Administration.

[13] Daniel J Fagnant and Kara Kockelman. 2015. Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations. *Transportation Research Part A: Policy and Practice* 77 (2015), 167–181.

[14] Office for National Statistics. 2019. National population projections: 2018-based.

[15] James L Fozard and Sandra Gordon-Salant. 2001. Changes in vision and hearing with aging. (2001).

[16] Kai Holländer, Ashley Colley, Christian Mai, Jonna Häkkilä, Florian Alt, and Bastian Pfleging. 2019. Investigating the Influence of External Car Displays on Pedestrians' Crossing Behavior in Virtual Reality. In *Proceedings of the 21st International Conference on Human-Computer Interaction with Mobile Devices and Services* (Taipei, Taiwan) *(MobileHCI 2019)*. ACM, New York, NY, USA, 11. https://doi.org/10.1145/3338286.3340138

[17] Christian P. Janssen, Linda Ng Boyle, Andrew L. Kun, Wendy Ju, and Lewis L. Chuang. 2019. A Hidden Markov Framework to Capture Human–Machine Interaction in Automated Vehicles. *International Journal of Human-Computer Interaction* 35, 11 (2019), 947–955. https://doi.org/10.1080/10447318.2018.1561789

[18] Christian P Janssen, Stella F Donker, Duncan P Brumby, and Andrew L Kun. 2019. History and future of human-automation interaction. *International Journal of Human-Computer Studies* 131 (2019), 99–107.

[19] Christian P. Janssen, Shamsi T. Iqbal, Andrew L. Kun, and Stella F. Donker. 2019. Interrupted by my car? Implications of interruption and interleaving research for automated vehicles. *International Journal of Human-Computer Studies* 130 (2019), 221–233. https://doi.org/10.1016/j.ijhcs.2019.07.004

[20] Andrew L. Kun. 2018. Human-Machine Interaction for Vehicles: Review and Outlook. *Foundations and Trends® in Human-Computer Interaction* 11, 4 (2018), 201–293. https://doi.org/10.1561/1100000069

[21] Shuo Li, Phil Blythe, Weihong Guo, and Anil Namdeo. 2019. Investigation of older drivers' requirements of the human-machine interaction in highly automated vehicles. *Transportation research part F: traffic psychology and behaviour* 62 (2019), 546–563.

[22] Andreas Löcken, Carmen Golling, and Andreas Riener. 2019. How Should Automated Vehicles Interact with Pedestrians? A Comparative Analysis of Interaction Concepts in Virtual Reality. In *Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications* (Utrecht, Netherlands) *(AutomotiveUI '19)*. Association for Computing Machinery, New York, NY, USA, 262–274. https://doi.org/10.1145/3342197.3344544

[23] A. Löcken, P. Wintersberger, A. Frison, and A. Riener. 2019. Investigating User Requirements for Communication Between Automated Vehicles and Vulnerable Road Users. In *2019 IEEE Intelligent Vehicles Symposium (IV)*. 879–884. https://doi.org/10.1109/IVS.2019.8814027

[24] Karthik Mahadevan, Sowmya Somanath, and Ehud Sharlin. 2018. Communicating awareness and intent in autonomous vehicle-pedestrian interaction. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, 429.

[25] Andrii Matviienko, Swamy Ananthanarayan, Shadan Sadeghian Borojeni, Yannick Feld, Wilko Heuten, and Susanne Boll. 2018. Augmenting Bicycles and Helmets with Multimodal Warnings for Children. In *Proceedings of the 20th International Conference on Human-Computer Interaction with Mobile Devices and Services* (Barcelona, Spain) *(MobileHCI '18)*. Association for Computing Machinery, New York, NY, USA, Article 15, 13 pages. https://doi.org/10.1145/3229434.3229479

[26] Andrii Matviienko, Swamy Ananthanarayan, Stephen Brewster, Wilko Heuten, and Susanne Boll. 2019. Comparing Unimodal Lane Keeping Cues for Child Cyclists. In *Proceedings of the 18th International Conference on Mobile and Ubiquitous Multimedia* (Pisa, Italy) *(MUM '19)*. Association for Computing Machinery, New

York, NY, USA, Article 14, 11 pages. https://doi.org/10.1145/3365610.3365632

[27] Andrii Matviienko, Swamy Ananthanarayan, Abdallah El Ali, Wilko Heuten, and Susanne Boll. 2019. NaviBike: Comparing Unimodal Navigation Cues for Child Cyclists. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow, Scotland Uk) *(CHI '19)*. Association for Computing Machinery, New York, NY, USA, Article 620, 12 pages. https://doi.org/10.1145/3290605.3300850

[28] United Nations. 2019. World Population Prospects: The 2019 Revision. https://www.statista.com/statistics/678737/total-number-of-children-worldwide/. [Online; accessed: 04-MARCH-2020].

[29] United Nations. 2019. World Population Prospects: The 2019 Revision 10 Key Findings. https://population.un.org/wpp/Publications/Files/WPP2019_10KeyFindings.pdf. [Online; accessed: 04-MARCH-2020].

[30] Trung Thanh Nguyen, Kai Holländer, Marius Hoggenmueller, Callum Parker, and Martin Tomitsch. 2019. Designing for Projection-based Communication between Autonomous Vehicles and Pedestrians. In *Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications* (Utrecht, Netherlands) *(AutomotiveUI '19)*. ACM, New York, NY, USA. https://doi.org/10.1145/3342197.3344543

[31] World Health Organization. 2018. Blindness and vision impairment. https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment. [Online; accessed: 07-JUNE-2019].

[32] World Health Organization. 2019. Deafness and hearing loss. https://www.who.int/news-room/fact-sheets/detail/deafness-and-hearing-loss. [Online; accessed: 07-SEPTEMBER-2019].

[33] Jennifer A Oxley, Elfriede Ihsen, Brian N Fildes, Judith L Charlton, and Ross H Day. 2005. Crossing roads safely: an experimental study of age differences in gap selection by pedestrians. *Accident Analysis & Prevention* 37, 5 (2005), 962–971.

[34] Jeffrey S Passel and D D'Vera Cohn. 2008. *US population projections, 2005-2050*. Pew Research Center Washington, DC.

[35] Champika Ranasinghe, Stefan Schneegass, Kai Holländer, Rebecca Currano, David Sirkin, Dylan Moore, and Wendy Ju. 2020. Autonomous Vehicle-Pedestrian Interaction Across Cultures: Towards Designing Better External Human Machine Interfaces (eHMIs). In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems* (Honolulu, Hawaii USA) *(CHI '20)*. ACM, Association for Computing Machinery, New York, NY, USA. https://doi.org/10.1145/3334480.3382957 Accepted.

[36] Amir Rasouli, Iuliia Kotseruba, and John K Tsotsos. 2017. Understanding pedestrian behavior in complex traffic scenes. *IEEE Transactions on Intelligent Vehicles* 3, 1 (2017), 61–70.

[37] WHO/NMH/NVI/18.20. 2018. *Global status report on road safety 2018: Summary*. Status Report. World Health Organization, Geneva. https://www.who.int/violence_injury_prevention/road_safety_status/2018/en/.