Towards Developing Socially Compliant Automated Vehicles - Survey

Hi! Thank you for your willingness to participate in this survey!

What is this survey about?

The deployment of Automated Vehicles with full automation will not happen overnight. There will be a transition period of mixed traffic during which automated vehicles with various automation levels will share the road with human-driven vehicles. Thus, making automated vehicles' driving strategies and behaviours socially compliant, understood, and accepted by human drivers is crucial for safe and efficient interactions in mixed traffic. By participating in this survey, you will contribute to this emerging research domain.

The questions will be presented in **seven** subsections and it will take approximately **15 minutes**. You can participate using your computer (suggested), tablet, or mobile phone.

Every successfully filled questionnaire will result in **a donation of 5 euros** to the United Nations Road Safety Fund.

All the information you provide will be used solely for research purposes and kept confidential. This survey is completely anonymous, participants will not be identified, and you may withdraw from further participation at any time.

For more information, questions, concerns or suggestions, please do not hesitate to contact Yonggi Dong: y.dong-4@tudelft.nl.

* Indicates required question

1. What is your gender? *

   Mark only one oval.

   - ◯ Male
   - ◯ Female
   - ◯ I would rather not answer this question.
   - ◯ Other: _____

2. Which is your country of residence? * Dropdown

Mark only one oval.

- Afghanistan
- Akrotiri
- Albania
- Algeria
- American Samoa
- Andorra
- Angola
- Anguilla
- Antarctica
- Antigua and Barbuda
- Argentina
- Armenia
- Aruba
- Ashmore and Cartier Islands
- Australia
- Austria
- Azerbaijan
- Bahamas, The
- Bahrain
- Bangladesh
- Barbados
- Bassas da India
- Belarus
- Belgium
- Belize
- Benin
- Bermuda
- Bhutan
- Bolivia
- Bosnia and Herzegovina
- Botswana
- Bouvet Island
- Brazil

- [ ] British Indian Ocean Territory
- [ ] British Virgin Islands
- [ ] Brunei
- [ ] Bulgaria
- [ ] Burkina Faso
- [ ] Burma
- [ ] Burundi
- [ ] Cambodia
- [ ] Cameroon
- [ ] Canada
- [ ] Cape Verde
- [ ] Cayman Islands
- [ ] Central African Republic
- [ ] Chad
- [ ] Chile
- [ ] China
- [ ] China (Hong Kong)
- [ ] China (Macau)
- [ ] Christmas Island
- [ ] Clipperton Island
- [ ] Cocos (Keeling) Islands
- [ ] Colombia
- [ ] Comoros
- [ ] Congo, Democratic Republic of the
- [ ] Congo, Republic of the
- [ ] Cook Islands
- [ ] Coral Sea Islands
- [ ] Costa Rica
- [ ] Cote d'Ivoire
- [ ] Croatia
- [ ] Cuba
- [ ] Cyprus
- [ ] Czech Republic
- [ ] Denmark
- [ ] Dhekelia
- [ ] Djibouti

- [ ] Dominica
- [ ] Dominican Republic
- [ ] Ecuador
- [ ] Egypt
- [ ] El Salvador
- [ ] Equatorial Guinea
- [ ] Eritrea
- [ ] Estonia
- [ ] Ethiopia
- [ ] Europa Island
- [ ] Falkland Islands (Islas Malvinas)
- [ ] Faroe Islands
- [ ] Fiji
- [ ] Finland
- [ ] France
- [ ] French Guiana
- [ ] French Polynesia
- [ ] French Southern and Antarctic Lands
- [ ] Gabon
- [ ] Gambia, The
- [ ] Gaza Strip
- [ ] Georgia
- [ ] Germany
- [ ] Ghana
- [ ] Gibraltar
- [ ] Glorioso Islands
- [ ] Greece
- [ ] Greenland
- [ ] Grenada
- [ ] Guadeloupe
- [ ] Guam
- [ ] Guatemala
- [ ] Guernsey
- [ ] Guinea
- [ ] Guinea-Bissau
- [ ] Guyana

- [ ] Haiti
- [ ] Heard Island and McDonald Islands
- [ ] Holy See (Vatican City)
- [ ] Honduras
- [ ] Hungary
- [ ] Iceland
- [ ] India
- [ ] Indonesia
- [ ] Iran
- [ ] Iraq
- [ ] Ireland
- [ ] Isle of Man
- [ ] Israel
- [ ] Italy
- [ ] Jamaica
- [ ] Jan Mayen
- [ ] Japan
- [ ] Jersey
- [ ] Jordan
- [ ] Juan de Nova Island
- [ ] Kazakhstan
- [ ] Kenya
- [ ] Kiribati
- [ ] Korea, North
- [ ] Korea, South
- [ ] Kuwait
- [ ] Kyrgyzstan
- [ ] Laos
- [ ] Latvia
- [ ] Lebanon
- [ ] Lesotho
- [ ] Liberia
- [ ] Libya
- [ ] Liechtenstein
- [ ] Lithuania
- [ ] Luxembourg

- [ ] Macedonia
- [ ] Madagascar
- [ ] Malawi
- [ ] Malaysia
- [ ] Maldives
- [ ] Mali
- [ ] Malta
- [ ] Marshall Islands
- [ ] Martinique
- [ ] Mauritania
- [ ] Mauritius
- [ ] Mayotte
- [ ] Mexico
- [ ] Micronesia, Federated States of
- [ ] Moldova
- [ ] Monaco
- [ ] Mongolia
- [ ] Montserrat
- [ ] Morocco
- [ ] Mozambique
- [ ] Namibia
- [ ] Nauru
- [ ] Navassa Island
- [ ] Nepal
- [ ] Netherlands
- [ ] Netherlands Antilles
- [ ] New Caledonia
- [ ] New Zealand
- [ ] Nicaragua
- [ ] Niger
- [ ] Nigeria
- [ ] Niue
- [ ] Norfolk Island
- [ ] Northern Mariana Islands
- [ ] Norway
- [ ] Oman

- [ ] Pakistan
- [ ] Palau
- [ ] Panama
- [ ] Papua New Guinea
- [ ] Paracel Islands
- [ ] Paraguay
- [ ] Peru
- [ ] Philippines
- [ ] Pitcairn Islands
- [ ] Poland
- [ ] Portugal
- [ ] Puerto Rico
- [ ] Qatar
- [ ] Reunion
- [ ] Romania
- [ ] Russia
- [ ] Rwanda
- [ ] Saint Helena
- [ ] Saint Kitts and Nevis
- [ ] Saint Lucia
- [ ] Saint Pierre and Miquelon
- [ ] Saint Vincent and the Grenadines
- [ ] Samoa
- [ ] San Marino
- [ ] Sao Tome and Principe
- [ ] Saudi Arabia
- [ ] Senegal
- [ ] Serbia and Montenegro
- [ ] Seychelles
- [ ] Sierra Leone
- [ ] Singapore
- [ ] Slovakia
- [ ] Slovenia
- [ ] Solomon Islands
- [ ] Somalia
- [ ] South Africa

- [ ] South Georgia and the South Sandwich Islands
- [ ] Spain
- [ ] Spratly Islands
- [ ] Sri Lanka
- [ ] Sudan
- [ ] Suriname
- [ ] Svalbard
- [ ] Swaziland
- [ ] Sweden
- [ ] Switzerland
- [ ] Syria
- [ ] Tajikistan
- [ ] Tanzania
- [ ] Thailand
- [ ] Timor-Leste
- [ ] Togo
- [ ] Tokelau
- [ ] Tonga
- [ ] Trinidad and Tobago
- [ ] Tromelin Island
- [ ] Tunisia
- [ ] Turkey
- [ ] Turkmenistan
- [ ] Turks and Caicos Islands
- [ ] Tuvalu
- [ ] Uganda
- [ ] Ukraine
- [ ] United Arab Emirates
- [ ] United Kingdom
- [ ] United States
- [ ] Uruguay
- [ ] Uzbekistan
- [ ] Vanuatu
- [ ] Venezuela
- [ ] Vietnam
- [ ] Virgin Islands

- [ ] Wake Island
- [ ] Wallis and Futuna
- [ ] West Bank
- [ ] Western Sahara
- [ ] Yemen
- [ ] Zambia
- [ ] Zimbabwe

3. What is your current professional role? Please choose the most suitable option from the list below. *

Mark only one oval.

- [ ] Student (undergraduate or master)
- [ ] Researcher at a university or research institute (including PhD students and Postdocs)
- [ ] Researcher at a company/ industry
- [ ] Developer at an OEM (e.g., a vehicle manufacture)
- [ ] Policy maker
- [ ] Consultant
- [ ] Technician
- [ ] Professional driver (taxi, truck, bus)
- [ ] Working in media industry (newspapers, televisions, etc.)
- [ ] Other: _____

4. Please tick all of those that apply to you in your employment? *

Tick all that apply.

- [ ] I am an employee of a vehicle manufacturer or supplier
- [ ] I work (research) in the development of automated vehicle functions
- [ ] I test automated vehicle functions
- [ ] I have a professional driving qualification
- [ ] I work as a driver transporting goods or people
- [ ] I am a qualified safety/test driver
- [ ] None of the above
- [ ] Other: _____

5. Do you have a valid driving license? *

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Other: _____

6. How often do you drive? *

Mark only one oval.

- ◯ (Nearly) Every day
- ◯ 3-5 days / week
- ◯ 1-2 days / week
- ◯ At least monthly
- ◯ Less often or never
- ◯ Other: _____

7. Approximately how many kilometres did you drive by a passenger car in the last 12 months? *

Mark only one oval.

- ◯ less than 2 000 km
- ◯ 2 000~5 000 km
- ◯ 5 000~10 000 km
- ◯ 10 000~15 000 km
- ◯ 15 000~20 000 km
- ◯ 20 000~50 000 km
- ◯ more than 50 000 km
- ◯ Other: _____

8. How familiar are you with the concept of automated vehicles? *

Mark only one oval.

- ◯ I have never heard of automated vehicles
- ◯ I have heard about automated vehicles once or twice
- ◯ I am fairly familiar with the idea of automated vehicles
- ◯ I follow the developments of automated vehicles
- ◯ I work in a field directly related to automated vehicles
- ◯ Other: _____

Socially compliant automated vehicles

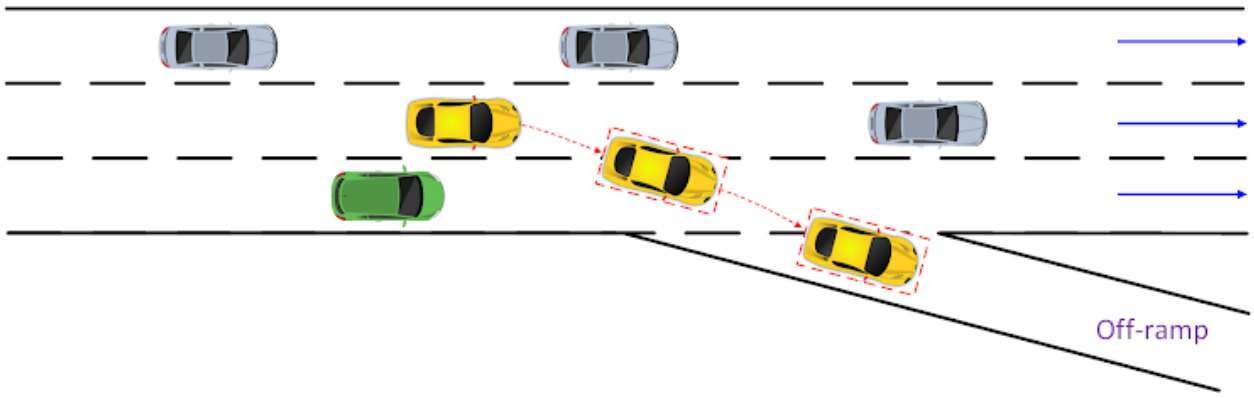
Please read the following definition before answering the questions

Socially compliant driving is defined as behaving **predictably** and **complying** with the **social expectations** (regarding cultures, norms, cues, formal and informal traffic rules) of human drivers and other surrounding road users and autonomous agents during their driving interactions (e.g., interactions at non-signalized intersections, roundabouts, on-ramp/off-ramp, or unprotected left turn).

Following is an example to better illustrate this definition.

Example: Motorway off-ramp driving manoeuvre

Suppose that the driver in the yellow car plans to take the off-ramp. Once the driver turns on the blinker, the green car on its right side anticipates the intention of the yellow car to exit the motorway. Normally, the driver in the green car will slow down to make room for the yellow car to exit the motorway. However, if the driver in the green car is aggressive, he/she will speed up to pass the yellow car. Thus, slowing down and speeding up indicate two different intents of the green car while both still **meeting the expectations** of the driver in the yellow car - making room for him/her to exit the motorway.



9. To what extent do you think socially compliant automated vehicles will influence the overall traffic safety? *

1: Strongly **worsen**;
4: Neutral/no influence;
7: Strongly **improve**

Mark only one oval.

	1	2	3	4	5	6	7	
Stro	◯	◯	◯	◯	◯	◯	◯	Strongly improve

10. (Optional) Explain briefly (using some key words) the reasons.

11. To what extent do you think socially compliant automated vehicles will influence the overall traffic **efficiency**? *

1: Strongly **worsen**;
4: Neutral/no influence;
7: Strongly **improve**

Mark only one oval.

	1	2	3	4	5	6	7	
Stro	◯	◯	◯	◯	◯	◯	◯	Strongly improve

12. (Optional) Explain briefly (using some key words) the reasons.

_____

_____

_____

_____

_____

Attitudes towards the development and deployment of socially compliant automated vehicles

13. What do you think about the development and deployment of socially compliant automated vehicles? Choose the option you most agree with. *

Mark only one oval.

- ◯ Easy to develop and easy to be deployed in real world
- ◯ Easy to develop but difficult to be deployed in real world
- ◯ Difficult to develop but easy to be deployed in real world
- ◯ Difficult to develop and difficult to be deployed in real world
- ◯ Difficult to develop and impossible to be deployed in real world
- ◯ It is impossible to develop socially compliant automated vehicles, neither will it be possible to deploy them in real world
- ◯ Other: _____

The development of socially compliant automated vehicles: **Properties and weights on different aspects.**

To what extent do you think that the socially compliant automated vehicles should have the following properties?

1: Least needed;

7: Strongly needed;

14. **Anticipation:** the socially compliant automated vehicles are capable of anticipating other road users' intended actions. *

Mark only one oval.

	1	2	3	4	5	6	7	
Leas	◯	◯	◯	◯	◯	◯	◯	Strongly needed

15. **eHMI:** The socially compliant automated vehicles are capable of conveying their intended actions via eHMI. *

External human-machine interface (eHMI)
eHMI is defined as "any interface perceivable from the exterior of a vehicle to communicate and/or interact with another human road user including conventional methods, such as honks or the turn indicator, but also novel concepts projecting images on the ground" or just simply as an "external human-machine interface positioned on the vehicle's exterior to communicate with surrounding traffic participants." (**interACT 2020**)

One example of eHMI on vehicle is shown in the figure below.

Mark only one oval.

	1	2	3	4	5	6	7	
Leas	◯	◯	◯	◯	◯	◯	◯	Strongly needed

16. The socially compliant automated vehicles are capable of aligning with local cultures, social norms and cues. *

Social norms *are shared standards of acceptable behavior by groups.*
Social cues *are verbal or non-verbal signals expressed through the face, body, voice,* ***motion*** *(and more) and guide social interactions by influencing our impressions of and responses to others (e.g., a slowing down in the previous off-ramp example).*

Mark only one oval.

	1	2	3	4	5	6	7	
Leas	◯	◯	◯	◯	◯	◯	◯	Strongly needed

17. The socially compliant automated vehicles are capable of considering the user acceptance of their drivers/passengers and the users in surrounding vehicles. *

Mark only one oval.

	1	2	3	4	5	6	7	
Leas	◯	◯	◯	◯	◯	◯	◯	Strongly needed

18. The socially compliant automated vehicles are capable of adjusting to different driving styles of surrounding human drivers (e.g., aggressive or defensive, pro-social or egoist). *

Mark only one oval.

	1	2	3	4	5	6	7	
Leas	◯	◯	◯	◯	◯	◯	◯	Strongly needed

19. The socially compliant automated vehicles are capable of bi-directional behavioural adaption. *

Explanation
The bidirectional behavioral adaption mean that during the deployment of (various levels and types of) automated vehicles (AVs), human drivers will adapt their driving behaviours (e.g., taking advantage of the very defensive AVs and always behave aggressively when interacting with such AVs); then to tackle the human drivers' behaviour adaption, the AVs should make corresponding adaption in return. Thus, ideally there is a bi-directional behavioural adaption going on iteratively.

Mark only one oval.

	1	2	3	4	5	6	7	
Leas	◯	◯	◯	◯	◯	◯	◯	Strongly needed

20. The socially compliant automated vehicles are capable of incorporating multi-objective optimization (e.g., safety, efficiency, energy consumption, environmental influence). *

Mark only one oval.

	1	2	3	4	5	6	7	
Leas	◯	◯	◯	◯	◯	◯	◯	Strongly needed

21. The socially compliant automated vehicles are capable of balancing the trade-offs between its own benefits and the benefits of surrounding traffic. *

Mark only one oval.

	1	2	3	4	5	6	7	
Leas	◯	◯	◯	◯	◯	◯	◯	Strongly needed

22. The socially compliant automated vehicles are capable of incorporating long/medium/short term spatial-temporal memory buffers to regularly update their driving strategies. *

Mark only one oval.

	1	2	3	4	5	6	7	
Leas	◯	◯	◯	◯	◯	◯	◯	Strongly needed

23. **Medium term development**

Suppose there are limited resources for developing socially compliant automated vehicles, what would be the most important aspects that should be tackled first in the **medium-term development** (coming 1-3 years).

Please choose the 3 most important aspects and rank them according to their importance for developing socially compliant automated vehicles.

"1st" for the most important aspect.

Mark only one oval per row.

	1st	2nd	3rd
Anticipation: the vehicles are capable of anticipating other road users' intended action	◯	◯	◯
eHMI to convey AVs' intended actions	◯	◯	◯
Compliant to local cultures, social norms and cues	◯	◯	◯
Considering different driving styles of the surrounding human drivers	◯	◯	◯
Incorporating multi-objective optimization (e.g., safety, efficiency, energy consumption, environmental influence)	◯	◯	◯

Balancing the trade-off between ego vehicle benefits and pro-social benefits			

24. **Long term development**

Suppose there are limited resources for developing socially compliant automated vehicles, what would be the most important aspects that should be tackled first in the **long-term development** (following 5-10 years).

Please chose the 2 most important aspects and rank them according to their importance for developing socially compliant automated vehicles.

"1st" for the most important aspect.

Mark only one oval per row.

	1st	2nd
Bidirectional behavioral adaption		
Compliant to local cultures, social norms and cues		
Incorporating long/medium/short term spatial-temporal memory buffers to regularly update the driving strategies		
Considering the user acceptance of driver/passenger in ego vehicle and surrounding vehicles		

25. When developing socially compliant automated vehicles, what other aspects should be considered?

_____

Possibility and applicability of mathematically modelling for different aspects

26. To what extent do you think that the **social factors (cultures, norms, cues)** can be mathematically modelled? *

Mark only one oval.

	1	2	3	4	5	6	7	
Not	◯	◯	◯	◯	◯	◯	◯	Highly possible

27. To what extent do you think that "**different driving styles**" can be mathematically modelled? *

Mark only one oval.

	1	2	3	4	5	6	7	
Not	◯	◯	◯	◯	◯	◯	◯	Highly possible

28. To what extent do you think that the "**bi-directional behavioural adaption**" can be mathematically modelled? *

Mark only one oval.

	1	2	3	4	5	6	7	
Not	◯	◯	◯	◯	◯	◯	◯	Highly possible

29. To what extent do you think that the "**multi-objective optimization**" can be mathematically modelled? *

Mark only one oval.

	1	2	3	4	5	6	7	
Not	◯	◯	◯	◯	◯	◯	◯	Highly possible

30. To what extent do you think that "**balancing the trade-offs between its own benefits and the benefits of surrounding traffic**" can be mathematically modelled? *

Mark only one oval.

	1	2	3	4	5	6	7	
Not	◯	◯	◯	◯	◯	◯	◯	Highly possible

31. To what extent do you think that "**long/medium/short term spatial-temporal memory buffers and regularly updating automated vehicles' driving strategies**" can be mathematically modelled? *

Mark only one oval.

	1	2	3	4	5	6	7	
Not	◯	◯	◯	◯	◯	◯	◯	Highly possible

Willingness to use Socially Compliant Automated Vehicle

32. Suppose you are about to buy a vehicle: to what extent and under which conditions will you consider buying a socially compliant automated vehicle (all other functions and brands are the same)? *

(Choose the most fitted one.)

Mark only one oval.

- ◯ I will definitely buy one even if it is much more expensive (within reasonable limit)
- ◯ I will buy one if it is only slightly expensive compared with other vehicles
- ◯ I will buy one if it is no expensive than other vehicles
- ◯ I will buy one if it is cheaper than other vehicles
- ◯ I will never buy one even if it is cheaper than other vehicles
- ◯ Other: _____

33. If socially compliant automated vehicles are available for on-demand mobility service (as robotaxis), to what extent, and under which conditions will you consider using one for your trip. *

(Choose the most fitted one.)

Mark only one oval.

- ◯ I will definitely use one for my trip even if it is much more expensive (within reasonable limit)
- ◯ I will use one if it is only slightly expensive compared with other vehicles
- ◯ I will use one if it is no expensive than other vehicles
- ◯ I will use one if it is cheaper than other vehicles
- ◯ I will never use it even if it is cheaper than other vehicles
- ◯ Other: _____

34. What else would you expect for the Socially Compliant Automated Vehicles? (You can type key words, phrases or full sentences)

_____

35. Do you have any further comments for better development of Socially Compliant Automated Vehicles? (You can type key words, phrases or full sentences)

_____

36. Do you see any potential cons of the Socially Compliant Automated Vehicles? (You can type key words, phrases or full sentences)

_____

37. How confident are you in answering all the aforementioned questions? *

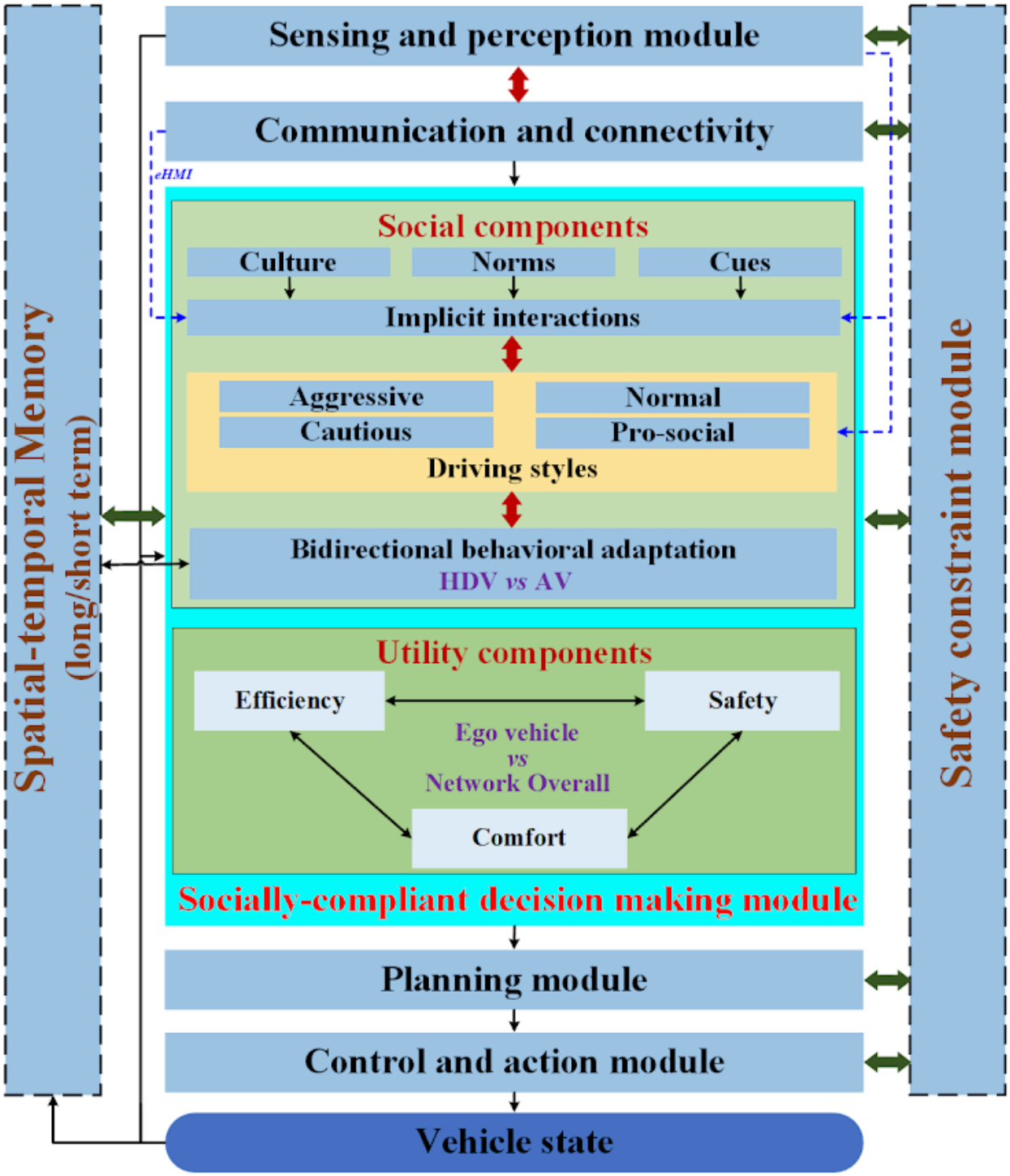
Mark only one oval.

- ◯ 5: (expert)
- ◯ 4: (high)
- ◯ 3: (medium)
- ◯ 2: (low)
- ◯ 1: (none)
- ◯ Other: _____

Proposed conceptual framework

The questions related to the development of socially-compliant automated vehicles are based upon the proposed conceptual framework shown in the picture below.

The proposed conceptual framework for developing socially compliant AVs



Brief introduction of the proposed conceptual framework

Overall this framework follows the standard module design for developing AVs which includes sensing and perception module, decision making module, planning module, and control action module.

The differences and added-values are:

The decision making module is replaced by the socially-compliant decision making module;

Safety constraint module is for always checking safety constraints to ensure the AVs behave within safety boundaries. (Although there are already safety metrics in the socially-compliant decision-making module, this is still crucial to ensure safety.)

The planning module includes both the high-level path and behaviours planning (lane change, merging) as well as the low-level motion (e.g., longitudinal and angular velocity and acceleration) planning.

For socially-compliant decision making module, social components (including culture, norms and cues), and different driving styles (e.g., aggressive, cautious, pro-social), together with the Bidirectional behavioural adaption are incorporated.

Furthermore, the benefits of ego vehicle regarding safety, comfort and efficiency need to be gamed with other road users and the corresponding trade-off between ego's benefits and the overall network-level benefits needs to be maintained at a certain level case by case.

Plus, the spatial-temporal memory module is for long/short term knowledge/rules upgradation, and behavioural adaption awareness. With the help of spatial-temporal memory module the driving strategies considering bidirectional behavioural adaption can be upgraded regularly.

38. Do you have any suggestions/comments regarding this conceptual framework?

39. Are you willing to share your email address for possible follow up and for sharing the results of this survey with you? If so, please leave your email below.

Thank you for your participation! This ends this survey.

Your participation will contribute to **Yongqi Dong**'s research on developing socially compliant automated vehicles which is part of the SAMEN project: 'Safe and efficient operation of AutoMated and human drivEN vehicles in mixed traffic', funded by the Dutch Research Council (NWO) and conducted at the Department of Transport and Planning, TU Delft.

If you want to stay tuned with relevant studies in socially compliant AVs you can follow our workshop and special session at **IV2023** https://sites.google.com/berkeley.edu/iv2023/. More relevant events are coming soon.

Reference

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