Safety Criteria Study on Innovative Safety Validation Methods of Automated Driving System

Oct 16-17, 2019

Transmitted by experts of Japan
Within ODD, AD shall not cause **rationally foreseeable** and **preventable** accident resulting injury or death.

**Foreseeable**: It is important to cover the events occurring in the actual traffic situation. =>Specify the foreseeable range based on the actual traffic data in line with the scenario structure.

**Preventable**: Socially acceptable criteria for AD needs to be defined through further discussion.

As for the rational boundary conditions, we think it is appropriate to set the ability of ADS at general public understand as attentive skilled human driver level without any human errors as a first step.
- 97% of the accidents were related to the human factors of driver. (of which 60% was due to delay in perception)
- Most of the accidents can be prevented if the driver’s level of attentiveness is high.

Data collection criteria:
Accidents occurred on highways in Japan in which the primary responsible party was a vehicle (automobile/motorcycle) (2017)
Accidents on the Highways

70% of the accidents were car-to-car on the highways, and in 90% of which, the primary responsible party did not perform lane change.

<table>
<thead>
<tr>
<th>Road geometry</th>
<th>Ego-vehicle Behavior</th>
<th># of Accidents</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main roadway</td>
<td>Lane keep</td>
<td>5,435件</td>
<td>6,051件</td>
</tr>
<tr>
<td>Merge Branch</td>
<td>Lane keep</td>
<td>13件</td>
<td>31件</td>
</tr>
<tr>
<td></td>
<td>Lane change</td>
<td>18件</td>
<td></td>
</tr>
<tr>
<td>Ramp</td>
<td>Lane keep</td>
<td>42件</td>
<td>57件</td>
</tr>
<tr>
<td></td>
<td>Lane change</td>
<td>15件</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>Lane keep</td>
<td>5,490件</td>
<td>6,139件</td>
</tr>
<tr>
<td></td>
<td>Lane change</td>
<td>649件</td>
<td></td>
</tr>
</tbody>
</table>

Emergency avoidance by braking is Key.
In low-speed ALKS scenario, the avoidance capability required for the driver model is braking control only. This driver model is separated into the following three segments: “Risk perceive situation”, “Delay in time”, and “Deceleration degree and Max. G-force”
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**Concept of “Cut In Risk Perceive Situation”**

Separately define Risk perceive situation for Emergency braking and Normal braking area.

**A1** Normal braking area

- **A1-a** Risk perceive area in longitudinal direction
- **A1-b** Risk perceive start timing in lateral direction

- **Time Headway (THW)**
- **Distance from ego-vehicle’s lane marking**

**A2** Emergency braking area

- **A2-a** Risk perceive area in longitudinal direction
- **A2-b** Risk perceive start timing in lateral direction

- **Time To Collision (TTC)**
- **lateral movement of Side vehicle**

\[
\begin{align*}
\text{Time Headway (THW)}^1 & = \frac{\text{Headway (L)}}{\text{Ego-vehicle velocity (V)}} \\
\text{Time To Collision (TTC)}^2 & = \frac{\text{Headway (L)}}{\text{Relative Velocity (ΔV)}}
\end{align*}
\]
In low-speed ALKS scenario, the avoidance capability required for the driver model is braking control only. This driver model is separated into the following three segments: “Risk perceive situation”, “Delay in time”, and “Deceleration degree and Max. G-force”
“Delay in time” occurs in each driving process of human: “Perception-Decision-Reaction”
Define total delay in time from occurrence of dangerous event to occurrence of deceleration

<table>
<thead>
<tr>
<th>Dangerous event occurred</th>
<th>Decision</th>
<th>Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other vehicle starts lateral movement</td>
<td>Perceive cut-in</td>
<td>Decide how to avoid</td>
</tr>
<tr>
<td>Cut-in</td>
<td>Decide emergency braking is required</td>
<td>Release accelerator pedal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transfer foot</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Apply brake</td>
</tr>
</tbody>
</table>

Other vehicle starts lateral movement
Cut-in
Perceive cut-in
Driver
Danger!

Decide emergency braking is required
Release accelerator pedal
Transfer foot
Apply brake

Delay in decision
Accelerator release time
Foot transfer time
C: Deceleration degree and Max. G
Deceleration occurs
Time
Deceleration

Pedal angle
Accelerator pedal
Side vehicle starts lateral movement
Cut-in Perceive
Risk evaluation

B-a
B-b
B-c
B-d

B: Delay in Decision/Reaction

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In low-speed ALKS scenario, the avoidance capability required for the driver model is braking control only. This driver model is separated into the following three segments: “Risk perceive situation”, “Delay in time”, and “Deceleration degree and Max. G-force”
Required braking force (deceleration degree and max. g-force) varies between the normal braking and emergency braking

=> Separately specify the driver model for the normal braking and emergency braking
1. Please let us know your comment regarding attentive skilled human driver model based on the consideration in each country.

2. Please propose quantitative parameters of Emergency braking area (B-a, B-b, …) with rationale like experimental data.

3. Safety evaluation scenarios using numerical model for low-speed ALKS will be presented at the next VMAD meeting.
APPENDIX
Scenario based approach process

It is recommended to harmonize the scenario DB within the necessary range according to the process shown below to verify the differences of traffic environment in each country.

Driving Database

- Real world data
- Trajectory data w/Road structure

Quality Requirement
- a) Required accuracy
- b) Amount of data

Parametric data

- Statistical distribution of trajectories' parameters
- Parameter Selection
- Analysis
- Scenario Category Sufficiency Check

Criteria for certification

- Parameter range of scenarios
- Safety Philosophy

Scenario Structure

- Scenario DB
- Test Scenario Catalog
- Scenario based approach proposed in VMAD

Foreseeable scenario
- Preventable scenario

Certification test scenario allocation to test environment

- Real-traffic tests
- Proving ground tests
- Audit (Virtual tests)

Red: Would be shared among industry
Green: NO need to be shared
Orange: Need harmonization
Scenario based approach process

Further discussions toward the harmonization of the following topics are required between the representatives from each member state.

Would be shared among industry
- Statistical method for trajectory parameters
- Definition and range of required data amount
- Definition of correlation

Real world data
Extract

Trajectory data w/ Road structure

Extract

Statistical distribution of trajectories' parameters

Parameter Selection

Scenario Category Sufficiency Check

Criteria for certification

Scenario Structure

Scenario DB

Scenario based approach proposed in VMAD

Parametric data

Safety Philosophy

Scenario

Need harmonization
- High-accuracy image data extraction method
- Definition of data cut-out method (Start-End, etc)
- Data format

Need harmonization
- Definition of trajectory parameter items
- Scenario modeling
* If any new scenario extracted during this step, add it to the scenario structure

Quality Requirement
a) Required accuracy
b) Amount of data

Safety criteria concept considering the social acceptance

Further discussions toward the harmonization of the following topics are required between the representatives from each member state.