Additional research of False Reaction scenarios
- Measurement data of driving behavior by normal drivers -

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1. Background and Purpose

- Japan studied eight draft scenarios as the false reaction scenarios in a wider view point, and system behavior in each scenario was validated by several test vehicles (AEBS-10-03).
- In some scenarios, some conditions such as vehicle speed and approaching situation to the related objects (TTC) should be considered based on data of driving behavior of normal drivers.
- In this research, some experiments were carried out in order to collect data of driving behavior of normal drivers in some scenarios.
- Based on the results of the experiment in some scenarios, modification of some conditions is proposed.
- It is considered that the False Reaction scenarios shall be used as the tool in order to share technical information which clarifies behaviour and the safety concept of the system between the Technical Service and the vehicle manufacturer.
2. Draft scenarios proposed in AEBS-10-03

**Draft Scenario 1**
Start point of steering input for right turn

- 3.9m/5.7m
- 20km/h
- Stationary

**Draft Scenario 2**
Start timing of left turn
TTC=4s, 5s, 6s

- 30km/h and 40km/h
- 10km/h
- Test vehicle
- Related vehicle

Remind from AEBS-10-03
Draft Scenario 3

Test vehicle  Related vehicle

20km/h  20km/h

Curve radius: approximately 19m

Remind from AEBS-10-03

Draft Scenario 4

Test vehicle  Related vehicle  Pedestrian target

20km/h and 30km/h

Stationary

Curve radius: approximately 25m

Guard pipe

20km/h and 30km/h

Stationary

Curve radius: approximately 25m

Guard pipe
Draft Scenario 5

approximately 80cm

approximately 5km/h

Guard pipes

30km/h

Draft Scenario 6

Start timing of steering input
TTC=0.8s, 1.4s, 2.0s

Signboard of notifying to reduce the lane

30km/h and 40km/h

Test vehicle

Remind from AEBS-10-03
Draft Scenario 7

Just when the related vehicle approaches the lane marking most, approximately TTC=1s, 0s

30km/h and 40km/h

2~3km/h

Test vehicle Related vehicle

Draft Scenario 8

with Pedestrian target*

stationary

Guard pipes

30km/h

Test vehicle Pedestrian target

*The condition of "without Pedestrian target" is also carried out.
3. Scenarios for data measurement of driving behavior by normal drivers

- Data measurement was carried out in the following four scenarios.

**Scenario A (Based on draft Scenario 1)**

- The test vehicle drives the straight section at the speed of about 30km/h.
- The test vehicle starts to flash the turn signal indicator, and decelerate itself.
- The test vehicle turns right at the intersection.*
- The experiment of one time is finished at when the test vehicle completes turning right.

*During turning right at the intersection, the speed and the trajectory depend on driving behavior of the experimental participants.
Scenario B (Based on draft Scenario 2)

The test vehicle follows the related vehicle and drives the straight section at the speed of about 40km/h. *

The related vehicle starts to flash the turn signal indicator about 30m before the point of turning left.

The related vehicle decelerates the speed from about 40km/h to about 10km/h in the decelerating section.

The related vehicle turns left with the speed of about 10km/h.

The test vehicle decelerates itself in order to avoid a collision with the related vehicle, and then, drives itself straight and accelerates.

The experiment of one time is finished at when the speed of the test vehicle is recovered to about 40km/h.

*During following the related vehicle at the speed of about 40km/h, the distance between the two vehicles depends on driving behavior of the experimental participants.
Scenario C (Based on draft Scenario)

- The test vehicle drives the straight section at the speed of about 30km/h.
- The test vehicle enters the curved section.*
- The test vehicle passes through the curved section.
- The experiment of one time is finished at when the test vehicle moves to the straight section.

*During driving the curved section, the speed and trajectory within the lane depend on driving behavior of the experimental participants.
Scenario D (Based on draft Scenario 6)

- The test vehicle drives the straight section at the speed of about 40km/h.
- The test vehicle changes the lane in front of the signboard which notifies reducing the lane.*
- The experiment of one time is finished at when the test vehicle moves to the right side lane.

*Start timing of changing the lane depend on driving behavior of the experimental participants.
Examples of the pictures during the experiments

Scenario A
- Test vehicle
- Related vehicle
- Test vehicle
- Related vehicle

Scenario B
- Test vehicle
- Related vehicle

Scenario C
- Test vehicle
- Related vehicle
- Pedestrian target

Scenario D
- Sighboard
- Test vehicle
4. Profile of the experiment participants and procedure

- Ten normal drivers who drive car in their daily life participated the experiments.

<table>
<thead>
<tr>
<th>ID</th>
<th>Sex</th>
<th>Age</th>
<th>Driving career</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Female</td>
<td>20</td>
<td>about 1 year</td>
</tr>
<tr>
<td>2</td>
<td>Female</td>
<td>35</td>
<td>about 15 years</td>
</tr>
<tr>
<td>3</td>
<td>Male</td>
<td>38</td>
<td>about 16 years</td>
</tr>
<tr>
<td>4</td>
<td>Male</td>
<td>56</td>
<td>about 38 years</td>
</tr>
<tr>
<td>5</td>
<td>Male</td>
<td>52</td>
<td>about 30 years</td>
</tr>
<tr>
<td>6</td>
<td>Male</td>
<td>44</td>
<td>about 25 years</td>
</tr>
<tr>
<td>7</td>
<td>Female</td>
<td>54</td>
<td>about 35 years</td>
</tr>
<tr>
<td>8</td>
<td>Female</td>
<td>28</td>
<td>about 10 years</td>
</tr>
<tr>
<td>9</td>
<td>Female</td>
<td>48</td>
<td>about 30 years</td>
</tr>
<tr>
<td>10</td>
<td>Female</td>
<td>29</td>
<td>about 12 years</td>
</tr>
</tbody>
</table>
4. Profile of the experiment participants and procedure

• The experiments were carried out based on the rule of ethic applied to experiments carried out to human being in NTSEL.
• Informed consent was confirmed.
• Outline of each scenario was explained to the experiment participants.
• Before start of the experiment, practice driving to experience the test vehicle well was carried out (ex. acceleration, deceleration, turning, keeping appropriate distance to the related vehicle). And practice driving in each scenario was also carried out approximately two times.
• The number of experiments in each scenario to one experiment participant was three times.
5. Test vehicle and Related vehicle

<Test vehicle>
• A passenger car made by a Japanese manufacturer was used.
• During the experiments, AEBS and LDWS were deactivated (switched off).

<Related vehicle>
• A passenger car made by a German manufacturer was used.
6. Result of the experiments

Scenario A

1) At the timing of beginning to steer for right turn at the intersection

- A lot of data of the test vehicle speed exists between 12km/h and 20km/h.
- A lot of data of TTC to the related vehicle exists between 2.3 sec. and 3.0 sec.
  ⇒ It is larger than TTC at the same timing of draft scenario 1.
- Brake pedal operation is observed in all data.
2) At the timing of becoming 0% of wrap ratio to the related vehicle

- A lot of data of the test vehicle speed exists between 7km/h and 13km/h.
- A lot of data of TTC to the related vehicle exists between 1.4 sec. and 2.0sec..

⇒ It is larger than TTC of the cases of AEBS activating in draft scenario 1.
- No brake pedal operation is observed in 73% of data.

[Reference]
Result of draft Scenario 1 (cases of AEBS activating)
Scenario B

1) At the timing when the related vehicle begins left turn*

- A lot of data of the test vehicle speed exists between 22km/h and 29km/h.
- A lot of data of TTC to the related vehicle exists between 3.6 sec. and 5.4 sec.
  ⇒ It is approximate to TTC at the timing of beginning to steer to in draft scenario 2.
- Brake pedal operation is observed in 97% of data.

[Reference]
The timing when the related vehicle begins to steer in draft scenario 2
**Scenario B**

2) At the timing of becoming 50\% of wrap ratio to the related vehicle

- A lot of data of the test vehicle speed exists between 16km/h and 24km/h.
- A lot of data of TTC to the related vehicle exists between 2.3 sec. and 4.1sec.
  \[ \Rightarrow \text{2.3 sec. is approximate to TTC of the cases of AEBS activating in draft scenario 2.} \]
- No Brake pedal operation is observed in 80\% of data.

![Graphs showing speed and TTC distribution](image-url)
**Scenario B**

3) **At the timing of becoming 0% of wrap ratio to the related vehicle**

- A lot of data of the test vehicle speed exists between 16km/h and 23km/h.
- A lot of data of TTC to the related vehicle exists between 1.6 sec. and 3.2 sec.
  \( \Rightarrow \) 1.6 sec. is approximate to TTC of the case of AEBS activating in draft scenario 2.
- No Brake pedal operation is observed in all of data.

![Speed vs. TTC](image)

[Test vehicle speed vs. TTC](image)
1) At the timing of beginning to turn right*

- A lot of data of the test vehicle speed exists between 19km/h and 24km/h.
- A lot of data of TTC to the related vehicle exists between 1.6 sec. and 1.9 sec..
  ⇒ It is larger than TTC of the cases of AEBS activating in draft scenario 4.
- Brake pedal operation is observed in 87% of data.

[Reference]
Result of draft Scenario 4 (Stationary vehicle) (cases of AEBS activating)
Scenario C (Stationary vehicle)

2) At the timing of becoming 50% of wrap ratio to the stationary vehicle
   • A lot of data of the test vehicle speed exists between 18km/h and 23km/h.
   • A lot of data of TTC to the related vehicle exists between 1.4 sec. and 1.7sec..
   \[\Rightarrow\] It is larger than TTC of the cases of AEBS activating in draft scenario 4.
   • Brake pedal operation is observed in 77% of data.
3) At the timing of becoming 0% of wrap ratio to the stationary vehicle

- A lot of data of the test vehicle speed exists between 17km/h and 23km/h.
- A lot of data of TTC to the related vehicle exists between 0.9 sec. and 1.2sec..

⇒ It is approximate to TTC of the cases of AEBS activating in draft scenario 4.

- No Brake pedal operation is observed in 47% (80% in case of above 20km/h) of data.

[Reference]
Result of draft Scenario 4 (Stationary vehicle) (cases of AEBS activating)
3) **Maximum lateral acceleration during turning right**

- A lot of data of the maximum lateral acceleration exists between 1.1m/s² and 1.9m/s².

⇒ It is approximate to the maximum lateral acceleration of the condition of the speed of test vehicle 20km/h in draft scenario 4.
Scenario C (Pedestrian target) *The timing when the yaw angle of the test vehicle exceeds 2 deg.

1) At the timing of beginning to turn right*
   - A lot of data of the test vehicle speed exists between 19km/h and 24km/h.
   - A lot of data of TTC to the related vehicle exists between 1.5 sec. and 1.7sec..
     ⇒ It is larger than TTC of the cases of AEBS activating in draft scenario 4.
   - Brake pedal operation is observed in 97% of data.

[Reference]
Result of draft Scenario 4 (Pedestrian target) (cases of AEBS activating)
2) At the timing of becoming -100% of offset ratio to the pedestrian target

- A lot of data of the test vehicle speed exists between 18km/h and 23km/h.
- A lot of data of TTC to the related vehicle exists between 1.0 sec. and 1.3 sec.
  ⇒ It is larger than TTC of the cases of AEBS activating in draft scenario 4.
- No Brake pedal operation is observed in 43% (50% in case of above 20km/h) of data.
3) Maximum lateral acceleration during turning right

- A lot of data of the maximum lateral acceleration exists between 1.2m/s² and 1.8m/s².
  ⇒ It is approximate to the maximum lateral acceleration of the condition of the speed of test vehicle 20km/h in draft scenario 4.
**Scenario D**

1) **At the timing of beginning to steer for changing the lane**
   - A lot of data of the test vehicle speed exists between 37km/h and 41km/h.
   - A lot of data of TTC to the related vehicle exists between 3.7 sec. and 4.7 sec.
   - ⇒ It is larger than TTC of the cases of AEBS activating in draft scenario 6.
   - No Brake pedal operation is observed in 79% of data.
Scenario D

2) At the timing of becoming -100% of offset ratio to the signboard

- A lot of data of the test vehicle speed exists between 35 km/h and 41 km/h.
- A lot of data of TTC to the related vehicle exists between 3.0 sec. and 3.7 sec.
  ⇒ It is larger than TTC of the cases of AEBS activating in draft scenario 6.
- No Brake pedal operation is observed in 75% of data.
### 7. Summary of the results of the experiments

<table>
<thead>
<tr>
<th>Scenario</th>
<th>The point of data extraction</th>
<th>Driving behavior of normal drivers (experiment participants)</th>
<th>Speed (25%ile - 75%ile)</th>
<th>TTC (25%ile - 75%ile)</th>
<th>Brake pedal operation</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Beginning to steer for right turn</td>
<td></td>
<td>12～20km/h</td>
<td>2.3～3.0 sec.</td>
<td>Observed (all of data)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wrap ratio 0%</td>
<td></td>
<td>7～13km/h</td>
<td>1.4～2.0 sec.</td>
<td>Not observed (73% of data)</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Beginning of left turn (related vehicle)</td>
<td></td>
<td>22～29km/h</td>
<td>3.6～5.4 sec.</td>
<td>Observed (97% of data)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wrap ratio 50%</td>
<td></td>
<td>16～24km/h</td>
<td>2.3～4.1 sec.</td>
<td>Not observed (80% of data)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wrap ratio 0%</td>
<td></td>
<td>16～23km/h</td>
<td>1.6～2.3 sec.</td>
<td>Not observed (all of data)</td>
<td></td>
</tr>
</tbody>
</table>
7. Summary of the results of the experiments

<table>
<thead>
<tr>
<th>Scenario</th>
<th>The point of data extraction</th>
<th>Driving behavior of normal drivers (experiment participants)</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Speed (25%ile - 75%ile)</td>
<td>TTC (25%ile - 75%ile)</td>
</tr>
<tr>
<td>C (Stationary vehicle)</td>
<td>Beginning to turn right</td>
<td>19～24km/h</td>
<td>1.6～1.9 sec.</td>
</tr>
<tr>
<td></td>
<td>Wrap ratio 50%</td>
<td>18～23km/h</td>
<td>1.4～1.7 sec.</td>
</tr>
<tr>
<td></td>
<td>Wrap ratio 0%</td>
<td>17～23km/h</td>
<td>0.9～1.2 sec.</td>
</tr>
<tr>
<td>C (Pedestrian target)</td>
<td>Beginning to turn right</td>
<td>19～24km/h</td>
<td>1.5～1.7 sec.</td>
</tr>
<tr>
<td></td>
<td>Offset ratio -100%</td>
<td>18～23km/h</td>
<td>1.0～1.3 sec.</td>
</tr>
<tr>
<td>D</td>
<td>Beginning to steer for changing a lane</td>
<td>37～41km/h</td>
<td>3.7～4.7 sec.</td>
</tr>
<tr>
<td></td>
<td>Offset ratio -100%</td>
<td>35～41km/h</td>
<td>3.0～3.7 sec.</td>
</tr>
</tbody>
</table>
8. Proposal of modification in the draft scenarios

Based on the experiment results of measuring driving behavior of normal drivers, some modification is proposed in the draft scenario 1, 2, 4 and 6.

**Draft Scenario 1**

<table>
<thead>
<tr>
<th>Driving condition</th>
<th>New proposal</th>
<th>Original proposal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Straight section</strong></td>
<td>Speed 30km/h</td>
<td>20km/h</td>
</tr>
<tr>
<td><strong>Beginning to steer for right turn</strong></td>
<td>Speed Decelerating to not less than 20km/h by braking</td>
<td>20km/h (constant) Without braking</td>
</tr>
<tr>
<td>TTC to the related vehicle</td>
<td>not more than 2.3 sec.</td>
<td>about 0.7 sec. and about 1.0 sec.</td>
</tr>
<tr>
<td><strong>During right turn</strong></td>
<td>Speed Decelerating to about 13km/h by braking, and then keeping constant speed</td>
<td>20km/h (constant) Without braking</td>
</tr>
<tr>
<td>TTC to the related vehicle</td>
<td>not more than 1.4 sec. (timing of wrap ratio 0%)</td>
<td>Not prescribed</td>
</tr>
<tr>
<td>Driving condition</td>
<td>Speed</td>
<td>Test vehicle</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------------</td>
<td>-------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>During following the related vehicle</td>
<td>Speed</td>
<td>Test vehicle</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Related vehicle</td>
</tr>
<tr>
<td>During decelerating before left turn</td>
<td>Speed</td>
<td>Test vehicle</td>
</tr>
<tr>
<td>(related vehicle)</td>
<td></td>
<td>Related vehicle</td>
</tr>
<tr>
<td>Beginning of left turn</td>
<td>Speed</td>
<td>Test vehicle</td>
</tr>
<tr>
<td>(related vehicle)</td>
<td></td>
<td>Related vehicle</td>
</tr>
<tr>
<td>TTC to the related vehicle</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Draft Scenario 2

<table>
<thead>
<tr>
<th>Driving condition</th>
<th>New proposal</th>
<th>Original proposal</th>
</tr>
</thead>
<tbody>
<tr>
<td>During left turn (related vehicle)</td>
<td>Speed</td>
<td></td>
</tr>
<tr>
<td>Test vehicle</td>
<td>Decelerating to not less than 21km/h by braking, and then keeping constant speed</td>
<td>30km/h (constant) and 40km/h (constant)</td>
</tr>
<tr>
<td>Related vehicle</td>
<td>10km/h (constant)</td>
<td>10km/h (constant)</td>
</tr>
<tr>
<td>TTC to the related vehicle</td>
<td>not more than 1.6 sec. (timing of wrap ratio 0%)</td>
<td>Not prescribed</td>
</tr>
</tbody>
</table>
### Draft Scenario 4*

*Same modification is proposed in the two types of the objects (a stationary vehicle and a pedestrian target).

<table>
<thead>
<tr>
<th>Driving condition</th>
<th>New proposal</th>
<th>Original proposal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Straight section</strong></td>
<td>Speed</td>
<td>30km/h (constant)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20km/h (constant) and 30km/h (constant)</td>
</tr>
<tr>
<td><strong>Beginning to turn right</strong></td>
<td>Speed</td>
<td>Decelerating to not less than 24km/h by braking</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20km/h (constant) and 30km/h (constant)</td>
</tr>
<tr>
<td></td>
<td><strong>TTC to the object</strong></td>
<td>not more than 1.5 sec.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not prescribed</td>
</tr>
<tr>
<td><strong>During turning right</strong></td>
<td>Speed</td>
<td>not less than 24km/h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Without braking</td>
</tr>
<tr>
<td></td>
<td><strong>TTC to the object</strong></td>
<td>not more than 1.0 sec. (timing of wrap ratio 0% to the stationary vehicle or offset ratio -100% to the pedestrian target)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not prescribed</td>
</tr>
<tr>
<td></td>
<td><strong>Lateral acceleration</strong></td>
<td>equal or less than about 2m/s²</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not prescribed</td>
</tr>
</tbody>
</table>
## Draft Scenario 6

<table>
<thead>
<tr>
<th>Driving condition</th>
<th>New proposal</th>
<th>Original proposal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight section</td>
<td>Speed</td>
<td>40km/h (constant)</td>
</tr>
<tr>
<td>Beginning to steer for changing a</td>
<td>Speed</td>
<td>40km/h (constant) Without braking</td>
</tr>
<tr>
<td>lane</td>
<td>TTC to the object</td>
<td>not more than 3.7 sec.</td>
</tr>
<tr>
<td>During changing a lane</td>
<td>Speed</td>
<td>40km/h (constant) Without braking</td>
</tr>
<tr>
<td></td>
<td>TTC to the object</td>
<td>not more than 3.0 sec. (timing of offset ratio - 100% to the signboard)</td>
</tr>
</tbody>
</table>