Competent and Careful human driver performance model

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Transmitted by experts of Japan
Agenda

• Background
• Basis for each parameter
  1. Risk perceive situation
     *What is 0.375m?*
  2. Human delay
     *What are 0.72m and 0.75sec*
  3. Max Decerebration G and
     *What is 0.774G/0.6sec w/ AEB*
BACKGROUND
- 97% of the accidents were related to the human factors of driver. (of which 60% was due to delay in perception caused by lack of attentiveness)
- 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 related to human factors: 97%

- Delay in perception (inattention to the forward roadway (external)) 27%
- Misjudgment (inattention to the movement) 25%
- Delay in perception (safety check insufficient) 19%
- Delay in perception (inattention to the forward roadway (internal)) 14%
- Operation mistake 10%
- Misjudgment (wrong assumption) 6%
- Special cases 4%

Accidents due to low level of attentiveness: 85%

- Delay in perception (inattention to the forward roadway (external))
- Delay in perception (safety check insufficient)
- Misjudgment (inattention to the movement)
- Operation mistake
- Unknown
**Driver Model Structure**

<table>
<thead>
<tr>
<th>Risk Perceive Situation</th>
<th>Human reaction delay</th>
<th>Deceleration degree and Max. G-force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition of a situation that is perceived as a risk that requires evasive action in response to the behavior of surrounding vehicles.</td>
<td>The time it takes to perceive the behavior of surrounding vehicles as dangerous</td>
<td>Definition of time and maximum G until deceleration rises to a given G + AEB assist</td>
</tr>
<tr>
<td>Risk Perceived delay</td>
<td>Braking delay</td>
<td></td>
</tr>
<tr>
<td>The time between recognizing the risk, determining avoidance action, and changing from the accelerator pedal to the brake pedal.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
BASIS FOR EACH PARAMETER
1. Risk perceive Situation

- Risk Perceive Situation
- Human reaction delay
- Deceleration degree and Max. G-force
- Risk Perceived delay
- Braking delay

Cut-in

Delay in releasing accelerator pedal
Delay in pressing brake pedal
Brake pedal

Brake pedal

![Image of a car cut-in situation with arrows indicating the flow of events: from risk perception to human reaction delay, then to deceleration degree and maximum G-force, followed by risk perceived delay and braking delay.]}
When the other vehicle is wandering within its own lane, it is unlikely that the ego-vehicle perceives the possibility of cut-in.

Define the cut-in perceived boundary based on the lateral movement range of other vehicle wandering within its own lane.

Risk Perceived Boundary by Lateral Movement

One side of wandering width

\[ 0.75 \text{m} / 2 = 0.375 \text{m} \]

50%tile: 0.75 m
95%tile: 1.59 m
99%tile: 2.02 m

Lane width = 3.5 m

n = 5244
Based on the UNR guidelines on warning signals, define **Time To Collision (TTC) of 2.0 seconds** as the boundary of emergency braking area.

(a) Low-level: driver prepares action or decision within 10 seconds to 2 minutes; may escalate to a higher level if not acted upon;

(b) Mid-level: requires action or decision within around 2 to 10 seconds; may escalate to high-level warning if not acted upon;

(c) **High-level: warning** requires the driver to take immediate action or decision (0 to around 2 seconds) to avoid a potential crash that could result in serious injuries or fatalities.

**Risk Perceived Boundary by Longitudinal Distance**

![Emergency braking area (TTC <= 2 sec)](image)

- ADAS detects conflict
- System indicates conflict is imminent
- ADAS issues warning signal

High-priority warning: around 2 seconds prior to crash event

Warning 2.0 seconds prior to crash event

Unsuccessful

Successful

Perception-Response Sequence:
- Detection: Driver attention
- Identification: Understanding
- Decision: Choosing response
- Response: Taking action
2. Human reaction Delay

Risk Perceive Situation → Human reaction delay → Deceleration degree and Max. G-force

Risk Perceived delay → Braking delay

Cut-in

Delay in releasing accelerator pedal
Delay in pressing brake pedal

Brake pedal
Brake pedal
Braking delay 0.75sec is the value commonly used to calculate the stopping distance among the police and the courts in Japan.

Stopping Distance against velocity

Velocity / Stopping Distance = Braking Delay ÷ 0.75


※This value has been in use since about 1967.
Analysis of Risk Perception Time by DS Test

Analyze DS test data of driver reaction time against cut-in by other vehicle

- Measure risk perception time (time to react and avoid) of drivers against cut-in by other vehicle with 11 test participants

DS test summary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane width</td>
<td>3.5 m</td>
</tr>
<tr>
<td>Ego-vehicle target velocity $V_e$</td>
<td>100 km/h</td>
</tr>
<tr>
<td>Platoon velocity traveling in parallel forward $V_o$</td>
<td>70 km/h</td>
</tr>
<tr>
<td>Max. lateral velocity of cut-in vehicle $V_{oL}$</td>
<td>1.8 m/s</td>
</tr>
<tr>
<td>TTC at cut-in start</td>
<td>3.0 s</td>
</tr>
</tbody>
</table>

Test group details

<table>
<thead>
<tr>
<th>No. of participants</th>
<th>Description</th>
<th>Composition of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Having 5 years or more driving experience on regular basis, drives on highway at least once a month</td>
<td>- 6 Males, 5 Females - Avg. age: 38.7</td>
</tr>
</tbody>
</table>
Average time of risk perception was 0.8 sec in the first trial, and 0.4 sec in the second and subsequent trials.

Total delay of driver's reaction to cut-in by other vehicle:

- **<1st trial>**
  - Risk Perceived Situation
  - Risk Perceived Delay

- **<2nd and subseq. trials>**
  - Risk Perceived Situation
  - Risk Perceived Delay

**Braking delay=0.75s**
## Risk Perception Time Against Cut-in by Other Vehicle

Average time of risk perception was 0.8 sec in the first trial, and 0.4 sec in the second and subsequent trials.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Accelerator release time</th>
<th>Foot transfer time</th>
<th>Time from risk perception to maneuver initiation</th>
<th>Subtract 0.75 sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-1</td>
<td>1</td>
<td>1.40</td>
<td>0.47</td>
<td>1.12</td>
</tr>
<tr>
<td>1-2</td>
<td>1</td>
<td>1.18</td>
<td>0.42</td>
<td>0.85</td>
</tr>
<tr>
<td>1-3</td>
<td>1</td>
<td>1.12</td>
<td>0.20</td>
<td>0.57</td>
</tr>
<tr>
<td>1-4</td>
<td>1</td>
<td>1.53</td>
<td>0.17</td>
<td>0.95</td>
</tr>
<tr>
<td>2nd and subseq.</td>
<td>2 1.15 0.32</td>
<td>0.75</td>
<td>0.72</td>
<td></td>
</tr>
<tr>
<td>2-1</td>
<td>2</td>
<td>1.13</td>
<td>0.20</td>
<td>0.58</td>
</tr>
<tr>
<td>2-2</td>
<td>2</td>
<td>0.77</td>
<td>0.17</td>
<td>0.18</td>
</tr>
<tr>
<td>2-4</td>
<td>2</td>
<td>0.90</td>
<td>0.23</td>
<td>0.38</td>
</tr>
<tr>
<td>Avg.</td>
<td></td>
<td>1.27</td>
<td>0.29</td>
<td>0.87</td>
</tr>
<tr>
<td>2nd and subseq. Avg.</td>
<td>0.96 0.26</td>
<td>0.47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ratio</td>
<td></td>
<td>0.75</td>
<td>0.92</td>
<td>0.53</td>
</tr>
</tbody>
</table>

- **1st trial**: Approx. 0.9 sec.
- **2nd and subseq. trials**: Approx. 0.5 sec.

※The collected data are results of same TTC and brake avoidance with the same cut-in timing.
In the 2nd trial, the driver has learned the protocol in the 1st trial and will expect the cut in just after starting the lateral movement of the vehicle in adjacent lane.

**<1st trial>**

In the 1st trial, the driver observes a cut-in while braking, with an average reaction time of 0.8 seconds. This reaction time includes the perception time and the lateral movement of the vehicle in adjacent lane.

**<2nd and subsequent trials>**

In subsequent trials, the driver expects the cut-in just after starting the lateral movement, resulting in an average reaction time of 0.4 seconds. This reaction time also includes the perception time and the lateral movement.
When the lateral velocity is slower than the risk perception time becomes longer. So the quicker risk perception time, which is more demanding to AD, is adapted as assumption.
3. Deceleration degree and Max. G-force
Deceleration Degree and Max. G-force

Reference Driver

Max. Deceleration G: 0.774 G (tentative)

Delay in time = 0.75 sec

Deceleration degree: 0.6 sec (tentative)

Entered emergency braking area

AEB

TTC at the timing of AEB activated: \( \text{TTC}_{\text{AEB}} \)

Max Deceleration G
0.85G

Jerk_time
0.1s

TTC

Relative Speed [km/h]

Center of lane

Cut-in Perceived Boundary

Emergency braking area

TTC: 2.0 sec

Entered emergency braking area

Ego-vehicle deceleration
Max. deceleration G-force

Trained drivers’ **Max. deceleration G-force: 0.774G**

=> Define the driver model with **skilled drivers** who have **driving skills superior** to regular drivers

**[JP]**

A study example of emergency braking characteristics of driving trainees in Japan
- Regular drivers : 0.689 G
- Trained drivers* : 0.774 G

*Trained drivers: Trainees of Japan Safe Driving Center (JSDC) Central Training Academy for Safe Driving

0.774

Trained drivers  ·  N = 245

Regular drivers  ·  N = 36

(Makisita et al., 2001)  *Dry road surface

**[US]**

Near-Crash median (0.74 G)
Incident median (0.5 G)

*100-car naturalistic driving study
*Age group: 18-20(15%), 21-24(20%), 25-34(17%), 35-44(18%), 45-54(18%), 55+(12%)
Achieving Time to max G

Trained drivers’ time to reach Max. deceleration: 0.6 second

- Acceleration waveforms of trained drivers

- 183 Trained drivers, (JP, 21~65 years old)

Achieved steady deceleration state of 0.9 G within 0.6 second

(Based on the graph)

(Makisita et al., 2001)
**Competent and Careful human driver performance model**

<table>
<thead>
<tr>
<th>Risk Evaluation and Decision</th>
<th>Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk evaluation</td>
<td>Delay in decision</td>
</tr>
<tr>
<td>Next car started interrupt to me</td>
<td>How to avoid?</td>
</tr>
<tr>
<td>Danger!</td>
<td></td>
</tr>
<tr>
<td>Braking!</td>
<td></td>
</tr>
</tbody>
</table>

**Breaking Delay: 0.75 sec**

**Situation Perception**

- Accelerator pedal
- 0.375m
- Behavior Start
- Cut-in Perceive

**Risk Perceived Delay**

- 0.72m
- Risk Perceived

**Risk Perceived Delay**

- Delay in decision
- Decision on braking
- Accelerator pedal completely released
- Start Deceleration

**Deceleration degree:** 0.6 sec (tentative)

**Max. Deceleration G:** 0.774 G (tentative)

**Ego-vehicle deceleration**

- Delay in time = 0.75 sec
- Deceleration degree: 0.6 sec (tentative)

**Entered emergency braking area**

**Max Deceleration G**

- 0.85G
- TTC at the timing of AEB activated: TTC_{AEB}
- TTC_{AEB} [sec]
- Relative Speed [km/h]
- Jerk time
- 0.1s