

## Proposal for amendments to

### **ECE/TRANS/WP.29/2020/81 complemented by ECE/TRANS/WP.29/GRVA/2020/32 and ECE/TRANS/WP.29/GRVA/2020/33**

The text reproduced below was prepared by the experts from the EC. The proposal is aimed at modifying the text of document ECE/TRANS/WP.29/2020/81 (Regulation 157 on ALKS) as amended by ECE/TRANS/WP.29/GRVA/2020/32 and ECE/TRANS/WP.29/GRVA/2020/33. All modifications to ECE/TRANS/WP.29/GRVA/2020/32 and ECE/TRANS/WP.29/GRVA/2020/33 are given in **red** text. Modifications to the original text of ECE/TRANS/WP.29/2020/81 (Regulation 157 on ALKS) are given in **bold**. Deletions are indicated by ~~red strikethrough~~ text.

## I. Proposal

*Paragraph 5.2.1.*, amend to read:

- 2.6. "Imminent collision risk" describes a situation or an event which leads to a collision of the vehicle with another road user or an obstacle which cannot be avoided by a braking demand with **an acceleration** lower than 5 m/s<sup>2</sup>.

*Paragraphs 2.21 to 2.25.*, insert to read:

- 2.21. "**Starting lane**" is the lane out of which the ALKS vehicle intends to manoeuvre.
- 2.22. "**Target lane**" is the lane into which the ALKS vehicle intends to manoeuvre. The target lane can be a regular lane of travel, an enter lane, an exit lane or a hard shoulder.
- 2.24. A "**Lane Change Procedure (LCP)**" starts when the direction indicator lamps are activated and ends when the direction indicator lamps are deactivated by the system. It comprises the following operations:
- (a) **Activation of the direction indicator lamps;**
  - (b) **Temporary suspension of the mandatory lane keeping functionality of the ALKS;**
  - (c) **Lateral movement of the vehicle towards the lane boundary;**
  - (d) **Lane Change Manoeuvre;**
  - (e) **Resumption of the mandatory lane keeping function of the ALKS;**
  - (f) **Deactivation of direction indicator lamps.**
- 2.25. A "**Lane Change Manoeuvre (LCM)**" is part of the LCP and
- (a) **Starts when the outside edge of the tyre tread of the vehicle's front wheel closest to the lane markings crosses the outside edge of the lane marking to which the vehicle is being manoeuvred and**
  - (b) **Ends when the rear wheels of the vehicle have fully crossed the lane marking.**

2.26. “*Stability of vehicle and driver system*” is the ability of the system composed by the vehicle and the driver, either human or non-human, to recover the initial safe motion after a disturbance.

2.27 “*String stability*” is the capability of the ALKS vehicle to react to a perturbation in the speed profile of the vehicle in front, whose speed profile directly affects the speed profile of the ALKS vehicle, with a perturbation in its speed profile of lower or equal absolute magnitude.

Paragraph 5.2.1., amend to read:

5.2.1. The activated system shall keep the vehicle inside its lane of travel and ensure that the vehicle does not cross any lane marking (outer edge of the front tyre to outer edge of the lane marking). The system shall aim to keep the vehicle in a stable lateral ~~position~~ motion inside the lane of travel to avoid confusing other road users.

Paragraph 5.2.3.3., amend to read:

5.2.3.3. The activated system shall detect the distance to the next vehicle in front as defined in paragraph 7.1.1. and shall adapt the vehicle speed in order to avoid a collision.

~~While the ALKS vehicle is not at standstill, the system shall adapt the speed to adjust the distance to a vehicle in front in the same lane to be equal or greater than the minimum following distance.~~

In case ~~this the minimum time gap~~ cannot be respected temporarily because of other road users (e.g. vehicle is cutting in, decelerating lead vehicle, etc.), the vehicle shall readjust the ~~minimum~~ following distance at the next available opportunity without any harsh braking unless an emergency manoeuvre would become necessary.

~~The minimum following distance shall be calculated using the formula:~~

~~$$d_{\min} = v_{\text{ALKS}} * t_{\text{front}}$$~~

~~Where:~~

~~$d_{\min}$  = the minimum following distance~~

~~$v_{\text{ALKS}}$  = the present speed of the ALKS vehicle in m/s~~

~~$t_{\text{front}}$  = minimum time gap in seconds between the ALKS vehicle and a leading vehicle in front as per the table below:~~

<i>Present speed of the ALKS vehicle</i>		<i>Minimum time gap</i>	<i>Minimum following distance</i>
<i>(km/h)</i>	<i>(m/s)</i>	<i>(s)</i>	<i>(m)</i>
7.2	2.0	1.0	2.0
10	2.78	1.1	3.1
20	5.56	1.2	6.7
30	8.33	1.3	10.8
40	11.11	1.4	15.6
50	13.89	1.5	20.8
60	16.67	1.6	26.7
70	19.44	1.7	33.1
80	22.22	1.8	40.0
90	25.00	1.9	47.5

<i>Present speed of the ALKS vehicle</i>	<i>Minimum time gap</i>	<i>Minimum following distance</i>
<b>100</b>	<b>27.78</b>	<b>2.0</b>
<b>110</b>	<b>30.56</b>	<b>2.0</b>
<b>120</b>	<b>33.33</b>	<b>2.0</b>
<b>130</b>	<b>36.11</b>	<b>2.0</b>

~~For speed values not mentioned in the table, linear interpolation shall be applied.~~

~~Notwithstanding the result of the formula above for present speeds below 2 m/s the minimum following distance shall never be less than 2 m.~~

**The requirements of this paragraph are without prejudice to other requirements in this Regulation, most notably paragraphs 5.2.4. and 5.2.5. with subparagraphs.“**

**Paragraph 5.2, amend to read**

5.2. Dynamic Driving Task

**The fulfilment of the provisions of this paragraph shall be demonstrated by the manufacturer to the technical service during the inspection of the safety approach as part of the assessment to Annex 4 (in particular for conditions not tested under Annex 5) and according to the relevant tests in Annex 5.**

*Paragraph 5.2.4., amend to read:*

- 5.2.4. The activated system shall be able to **handle in a safe way the presence in the same lane of** ~~bring the vehicle to a complete stop behind~~ a stationary vehicle, a ~~stationary~~ road user, **a passable or unpassable obstacle [debris, lost cargo, etc.]**, or a blocked lane of travel to avoid a collision. This shall be ensured up to the maximum operational speed of the system.

*Paragraph 5.2.5. and its subparagraphs, amend to read:*

- 5.2.5. The activated system shall detect the risk of collision in particular with another road user ahead or beside the vehicle, due to a decelerating lead vehicle, a cutting in vehicle, **a vehicle proceeding in the opposite direction** or a suddenly appearing obstacle and shall automatically perform appropriate manoeuvres to minimize risks to safety of the vehicle occupants and other road users.

~~For conditions not specified in paragraphs 5.2.4., 5.2.5. or its subparagraphs, this shall be ensured at least to the level at which a competent and careful human driver could minimize the risks. This shall be demonstrated the assessment carried out under Annex 4 and by taking guidance from Appendix 3 to Annex 4.~~

- 5.2.5.1. The activated system shall avoid a collision with a leading vehicle which decelerates up to its full braking performance provided that there was no undercut **by another vehicle** ~~of the minimum following distance the ALKS vehicle would adjust to a leading vehicle at the present speed due to a cut in manoeuvre of this lead vehicle. This shall be demonstrated in accordance with the test specifications defined in Annex 5.~~
- 5.2.5.2. The activated system shall avoid a collision with a cutting in vehicle **at least for the conditions for which a competent and attentive human driver supported by state-of-the-art driving assistance or automation systems would also be able to avoid a collision. This shall be demonstrated in accordance with the test specifications defined in Annex 5 of this Regulation and with the performance model defined in Appendix 3 to Annex 4.**

- ~~(a) — Provided the cutting in vehicle maintains its longitudinal speed which is lower than the longitudinal speed of the ALKS vehicle and~~
- ~~(b) — Provided that the lateral movement of the cutting in vehicle has been visible for a time of at least 0.72 seconds before the reference point for *TTCLaneIntrusion* is reached;~~
- ~~(c) — When the distance between the vehicle's front and the cutting in vehicle's rear corresponds to a TTC calculated by the following equation:~~

$$\text{TTCLaneIntrusion} > v_{rel}/(2 \cdot 6\text{m/s}^2) + 0.35\text{s}$$

~~Where:~~

~~$v_{rel}$  — relative velocity between both vehicles, positive for vehicle being faster than the cutting in vehicle~~

~~*TTCLaneIntrusion* — The TTC value, when the outside of the tyre of the intruding vehicle's front wheel closest to the lane markings crosses a line 0.3 m beyond the outside edge of the visible lane marking to which the intruding vehicle is being drifted.~~

- 5.2.5.3. The activated system shall avoid a collision with an unobstructed crossing pedestrian in front of the vehicle.

In a scenario with an unobstructed pedestrian crossing with a lateral speed component of not more than 5 km/h where the anticipated impact point is displaced by not more than 0.2 m compared to the vehicle longitudinal center plane, the activated ALKS shall avoid a collision up to ~~the maximum operational speed of the system~~ **60 km/h**.

- 5.2.5.4. It is recognised that the fulfilment of the requirement in paragraph 5.2.5. may not be fully achieved in other conditions than those described above. However, the system shall not deactivate or unreasonably switch the control strategy in these other conditions. This shall be demonstrated in accordance with Annex 4 of this Regulation.

*Paragraph 5.2.6. and subparagraphs, insert to read:*

#### **5.2.6. Lane Change Procedure**

The requirements of this paragraph and its subparagraphs apply to the system, if **additionally** fitted to perform a LCP.

The fulfilment of the provisions of this paragraph and its subparagraphs shall be demonstrated by the manufacturer to the satisfaction of the technical services during the assessment of Annex 4 and according to the relevant tests in Annex 5.

- 5.2.6.1. A LCP shall not cause a risk to safety of the vehicle occupants and other road users.

- 5.2.6.2. The activated system shall only undertake a LCP if the following requirements are fulfilled:

- a) The vehicle is equipped with a sensing system capable of fulfilling the rearward detection range requirements as defined in paragraph 7.1. and subparagraph 7.1.3.;
- b) The system self-check as defined in paragraph 5.1.6. is positively confirmed;
- c) The assessment of the target lane as defined in paragraph 5.2.6.6. and its subparagraphs is positively confirmed;

- d) The LCP is anticipated to be completed before the ALKS vehicle comes to standstill (i.e. in order to avoid coming to standstill while in the middle of two regular lanes due to stopped traffic ahead). In case the ALKS vehicle becomes stationary between two regular lanes during the LCM **nonetheless** (e.g. due to the surrounding traffic), it should at the next available opportunity either complete the LCP or return to its original lane.

5.2.6.3. In compliance with paragraph 5.1.2. **in particular**, the activated system may undertake a LCP if:

- a) Operation cannot be continued in the current lane (e.g. due to a blocked lane ahead, ending lane ahead), for the purpose of overtaking a slower moving vehicle or to prevent violation of the obligation to drive in the slowest lane when possible;
- b) A gap allowing a LCM is already present or expected to open up shortly.

5.2.6.4. A LCP shall be completed without undue delay.

The system shall generate the signal to activate and deactivate the direction indicator signal. The direction indicator shall remain active throughout the whole period of the LCP and shall be deactivated by the system in a timely manner once the lane keeping functionality is resumed.

5.2.6.5. Specific requirements for LCM

The lateral movement to approach the lane marking in the starting lane and the lateral movement necessary to complete the LCM shall aim to be one continuous movement.

The LCM shall not be initiated before a period of 3.0 seconds and not later than 7.0 seconds after activation of the direction indicator lamps.

The LCM may be terminated before being completed if the situation requires it. In this case the ALKS vehicle has to be steered back into the starting lane.

The ALKS vehicle shall be in a single lane of travel at the end of the LCM.

5.2.6.6. Assessment of the target lane

A LCP shall only be initiated if **the ALKS vehicle would be able to keep a safe distance from a lead vehicle or any other obstacle in the target lane according with the provisions of paragraph 5.2.3.3. and if an approaching vehicle in the target lane is not forced to unmanageably decelerate due to the lane change of the ALKS vehicle.**

5.2.6.6.1. **An approaching vehicle in the target lane should always have a TTC to the ALKS vehicle of at least [4] seconds at the end of the LCM. ~~not have to decelerate at a higher level than A m/s<sup>2</sup>, B seconds after the ALKS vehicle starts crossing a lane marking, to ensure the distance between the two vehicles is never less than that which the lane change vehicle travels in C seconds.~~**

**With:**

- ~~A equal to 3 m/s<sup>2</sup>.~~

- ~~B equal to:~~

- a) ~~0.4 seconds after the ALKS vehicle has crossed the lane marking, provided there was at least 1.0 s lateral movement of the ALKS vehicle within the starting lane in principle visible to an approaching vehicle from the rear without an obstruction before the LCM starts or~~

- b) ~~1.4 seconds after the ALKS vehicle has crossed the lane marking, provided there was not at least 1.0 s lateral movement of the ALKS vehicle within the starting lane in principle visible to an approaching vehicle from the rear before the LCM starts.~~

- ~~C equal to 1 second.~~

5.2.6.6.2. ~~If no approaching vehicle is detected by the system in the target lane, the conditions laid down in paragraph 5.2.6.6.1 minimal gap to the rear shall be assessed calculated~~ under the assumption that

- a) ~~the approaching vehicle in the target lane is at a distance from the ALKS vehicle equal to rearward detection distance and~~

- b) ~~the an approaching vehicle in the on a target lane intended for faster traffic (including enter lanes) is travelling with the allowed or the advised maximum speed whichever is lower higher or~~

- b) ~~an approaching vehicle on a target lane intended for slower traffic (including exit lanes and shoulders temporarily opened for regular traffic) is travelling with a maximum speed difference of 20 km/h at the beginning of the LCM while not exceeding the allowed or advised maximum speed.~~

5.2.6.7. ~~At the beginning of the LCM, ¶the distance between the rear of the ALKS vehicle and the front of to a vehicle following behind in the target lane at equal or lower longitudinal speed shall never be less than the speed which the following vehicle in target lane travels in 1 second.”~~

Paragraph 5.2.7., insert to read:

**5.2.7** ~~The stability of the vehicle and driver system is a necessary condition that must be always met, provided that effects of unplanned events disturbing the safe motion are within reasonable limits. This shall be demonstrated in the assessment of the tests carried out in accordance with Annex 4 and 5 of this Regulation~~

Paragraph 5.2.8., insert to read:

**5.2.8** ~~While following another vehicle the ALKS vehicle shall be string stable. This shall be demonstrated in accordance with Annex 5 of this Regulation.~~

Paragraph 5.3.2., amend to read:

5.3.2 This manoeuvre shall decelerate the vehicle up to its full braking performance if necessary and/or may perform an automatic evasive manoeuvre, when appropriate.

If failures are affecting the braking or steering performance of the system, the manoeuvre shall be carried out with consideration for the remaining performance.

During the evasive manoeuvre the ALKS vehicle shall not cross the lane marking (outer edge of the front tyre to outer edge of the lane marking).

After the evasive manoeuvre the vehicle shall aim at resuming a stable ~~position~~ **motion**.

Annex 4 Appendix 3, amend to read

## 1. General

1. This document clarifies derivation process to define conditions under which ~~Automated Lane Keeping Systems (the~~ ALKS) ~~vehicle~~ shall avoid a collision. Conditions under which ALKS shall avoid a collision are determined by ~~a general simulation program with following attentive human driver~~ the performance model and<sup>1</sup> related parameters in the traffic critical disturbance scenarios.

## 2. Traffic critical scenarios

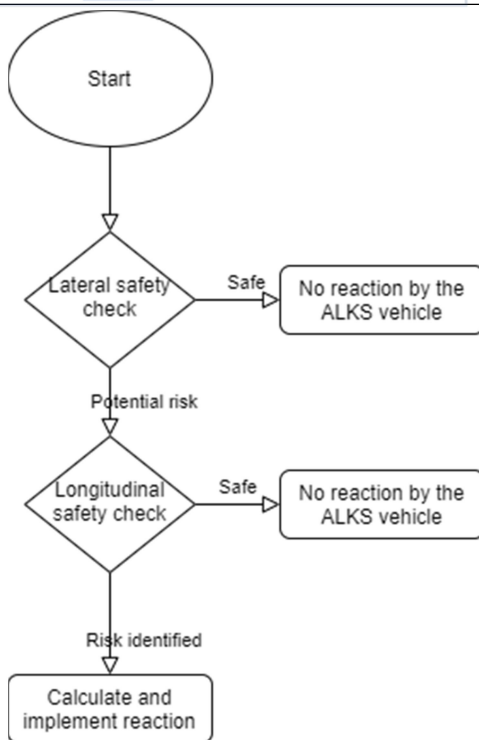
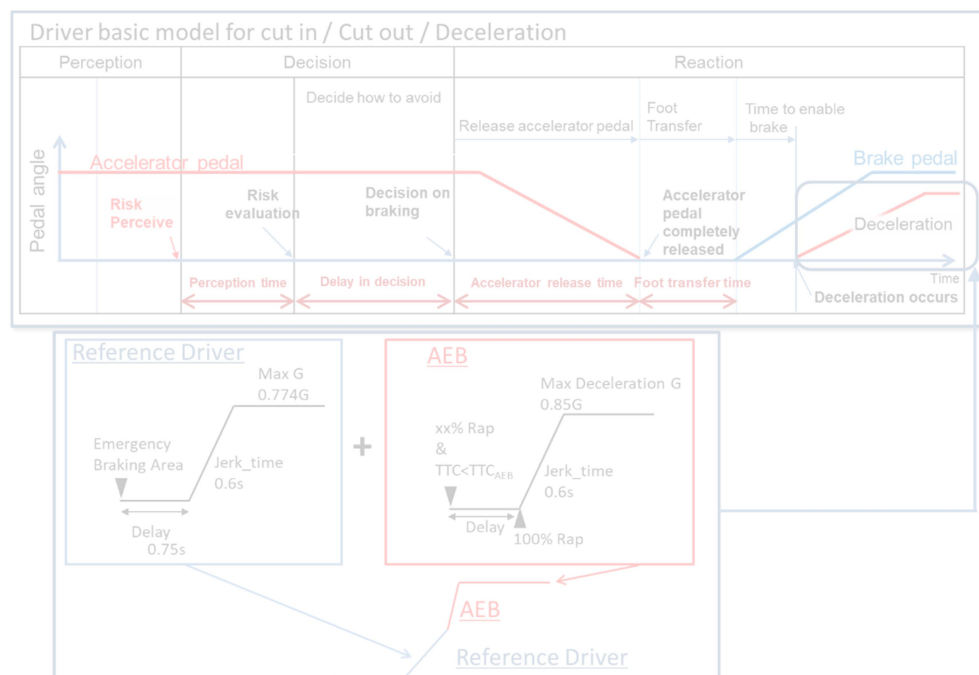
- 2.1. Traffic disturbance critical scenarios are those which have conditions under which ~~the~~ ALKS ~~vehicle~~ may not be able to avoid a collision.
- 2.2. ~~The F~~following ~~three are~~ traffic critical scenarios ~~is considered for the case of the ALKS vehicle~~:
  - (a) Cut-in: the 'other vehicle' suddenly merges in front of the ~~'ego-ALKS vehicle'~~<sup>2</sup>
  - ~~(b) — Cut-out: the 'other vehicle' suddenly exits the lane of the 'ego vehicle'~~<sup>2</sup>
  - ~~(c) — Deceleration: the 'other vehicle' suddenly decelerates in front of the 'ego vehicle'~~<sup>2</sup>
- 2.3. ~~Each of these~~ **This** traffic critical scenarios can be created using the following parameters/elements:
  - (a) Road geometry
  - (b) Other vehicles' behavior/maneuver

## 3. Performance model of ALKS for the cut-in scenario

- 3.1. Traffic critical scenarios of ALKS are divided into preventable and unpreventable scenarios. The threshold for preventable/unpreventable is based on the simulated performance of a ~~skilled competent~~ and attentive human driver ~~supported by state-of-the-art driving assistance or automation systems~~. It is expected that some of the "unpreventable" scenarios by human standards may actually be preventable by the ALKS system.
- 3.2. ~~In a low speed ALKS scenario, the avoidance capability of the driver model is assumed to be only by braking.~~ The driver model is separated into the following three ~~steps segments~~: "~~Pereception~~ **Lateral Safety Check**"; "~~Longitudinal Safety Check Decision~~"; and, "Reaction". **A Reaction is implemented only if the Lateral and Longitudinal Safety Checks identify a risk of imminent collision.** The following diagram is a visual representation of these ~~three steps segments~~:



Figure 1

**Flow-chart of the ALKS Skilled-human performance model**

**3.2.1 The Lateral Safety Check identifies a potential risk of collision if the following conditions hold true:**

- the rear of the 'other vehicle' is ahead of the front of the ALKS vehicle along the longitudinal direction of motion;
- the 'other vehicle' is moving towards the ALKS vehicle
- the longitudinal speed of the ALKS vehicle is greater than the longitudinal speed of the 'other vehicle'
- the following equation is satisfied

$$\frac{dist_{lat}}{u_{cut-in,lat}} < \frac{dist_{lon} + length_{ego} + leng_{cut-in}}{u_{ego,lon} - u_{cut-in,lon}} + 0.1$$

Where

$dist_{lat}$	instantaneous lateral distance between the two vehicles
$dist_{lon}$	instantaneous longitudinal distance between the two vehicles
$len_{ego}$	length of the ALKS vehicle
$lengt_{cut-in}$	length of the ‘other vehicle’
$u_{cut-in,lat}$	instantaneous lateral speed of the ‘other vehicle’
$u_{ego,lon}$ vehicle	instantaneous longitudinal speed of the ALKS vehicle
$u_{cut-in,lon}$	instantaneous longitudinal speed of the ‘other’ vehicle.

3.2.2 The Longitudinal Safety Check requires the assessment of two Fuzzy Surrogate Safety Metrics, the Proactive Fuzzy Surrogate Safety Metric (PFS), and the Critical Fuzzy Surrogate Safety Metric (CFS).

3.2.2.1. The PFS is defined by the following equation:

$$PFS(dist_{lon}) = \begin{cases} 1 & \text{if } 0 < dist_{lon} < d_{unsafe} \\ 0 & \text{if } dist_{lon} > d_{safe} \\ \frac{dist_{lon} - d_{safe} - d_1}{d_{unsafe} - d_{safe}} & \text{if } d_{unsafe} < dist_{lon} < d_{safe} \end{cases}$$

where

$d_1$  is the safety distance when the two vehicles reach complete stop

$$d_{safe} = u_{ego,lon}\tau + \frac{u_{ego,lon}^2}{2b_{ego,comf}} - \frac{u_{cut-in,lon}^2}{2b_{ego,max}} + d_1$$

$$d_{unsafe} = u_{ego,lon}\tau + \frac{u_{ego,lon}^2}{2b_{ego,max}} - \frac{u_{cut-in,lon}^2}{2b_{cut-in,max}}$$

with

$\tau$  the reaction time of the ALKS vehicle defined as the total time from the moment in which the need for a reaction is identified until it starts to be implemented

$b_{ego,comf}$  the comfortable deceleration of the ALKS vehicle

$b_{ego,max}$  the maximum deceleration of the ALKS vehicle

$b_{cut-in,max}$  the maximum deceleration of the ‘other vehicle’

3.2.2.2 The CFS is defined by the following equation:

$$CFS(dist_{lon}) = \begin{cases} 1 & \text{if } 0 < dist_{lon} < d_{unsafe} \\ 0 & \text{if } dist_{lon} > d_{safe} \\ \frac{dist_{lon} - d_{safe}}{d_{unsafe} - d_{safe}} & \text{if } d_{unsafe} < dist_{lon} < d_{safe} \end{cases}$$

Where

$$d_{safe} = \begin{cases} \frac{(u_{ego,lon} - u_{cut-in,lon})^2}{2a'_{ego}} & \text{if } u_{ego,lon,NEXT} \leq u_{cut-in,lon} \\ d_{new} + \frac{(u_{ego,lon,NEXT} - u_{cut-in,lon})^2}{2b_{ego,comf}} & \text{if } u_{ego,lon,NEXT} > u_{cut-in,lon} \end{cases}$$

$$d_{unsafe} = \begin{cases} \frac{(u_{ego,lon} - u_{cut-in,lon})^2}{2a'_{ego}} & \text{if } u_{ego,lon,NEXT} \leq u_{cut-in,lon} \\ d_{new} + \frac{(u_{ego,lon,NEXT} - u_{cut-in,lon})^2}{2b_{ego,max}} & \text{if } u_{ego,lon,NEXT} > u_{cut-in,lon} \end{cases}$$

in which

$$a'_{ego} = \max(a_{ego}, -b_{ego,comf})$$

$$u_{ego,lon,NEXT} = u_{ego,lon} + a'_{ego}\tau$$

$$d_{new} = \left( \frac{(u_{ego,lon} + u_{ego,lon,NEXT})}{2} - u_{cut-in,lon} \right) \tau$$

where

$a_{ego}$  the instantaneous longitudinal acceleration of the ALKS vehicle

$a'_{ego}$  a modified instantaneous acceleration which assume that ALKS vehicle cannot decelerate by more than  $b_{ego,comf}$

$u_{ego,lon,NEXT}$  the expected longitudinal speed of the ALKS vehicle after the reaction time assuming constant acceleration

$d_{new}$  the expected longitudinal distance between the ALKS vehicle and the 'other vehicle' after the reaction time

3.2.2.3. The Longitudinal Safety Check identifies a potential risk if either PFS or CFS are greater than 0.

3.2.3. If a risk is identified the ALKS vehicle is assumed to plan and implement a reaction by decelerating according to the following equation:

$$b_{reaction} = \begin{cases} CFS \cdot (b_{ego,max} - b_{ego,comf}) + b_{ego,comf} & \text{if } CFS > 0 \\ PFS \cdot b_{ego,comf} & \text{if } CFS = 0 \end{cases}$$

3.3.2.1 The deceleration is implemented after a time equal to  $\tau$  when it starts to increase with a constant rate equal to the maximum jerk.

3.2.4. In the case the reaction is not able to prevent the vehicle to collide with the cutting-in vehicle, the scenario is classified as unpreventable, otherwise it is classified as preventable.

3.3. To determine conditions under which ~~the Automated Lane Keeping Systems (ALKS) vehicle~~ shall avoid a collision, ~~the following~~ performance model factors ~~for these three segments in the following table should be used as the performance model of ALKS considering attentive human drivers' behavior with ADAS shall be used.~~

Table 1  
Performance model factors for vehicles

		Factors
Risk perception point	<del>Lane change (cutting in, cutting out)</del>	<del>Deviation of the center of a vehicle over 0.375m from the center of the driving lane (derived from research by Japan)</del> <b>The time when either PFS or CFS value is not any longer 0</b>
	<del>Deceleration</del>	<del>Deceleration ratio of preceding vehicle and following distance of ego vehicle</del>

Risk evaluation time	0.4 seconds (from research by Japan)
Time duration from having finished perception until starting deceleration	0.75 seconds (common data in Japan)
Reaction time of the ALKS vehicle	$\tau = 0.75$ seconds
Jerking time to full deceleration (road friction 1.0)	0.6 seconds to 0.774Gg (from experiments by NHTSA and Japan)
Jerking time to full deceleration (after full wrap of ego vehicle and cut in vehicle, road friction 1.0)	0.6 seconds to 0.85Gg (derived from UN Regulation No. 152 on AEBs)
Safety distance when the two vehicles reach complete stop	$d_1 = 2$ meters
Comfortable deceleration of the ALKS vehicle	$b_{ego,comf} = 4 \text{ m/s}^2$
Maximum deceleration of the ALKS vehicle	$b_{ego,max} = 6 \text{ m/s}^2$
Maximum deceleration of the 'other vehicle'	$b_{cut-in,max} = 7 \text{ m/s}^2$

3.4. Driver model for the three ALKS scenarios:

3.4.1. For Cut in scenario:

The lateral wandering distance the vehicle will normally wander within the lane is 0.375m.

The perceived boundary for cut in occurs when the vehicle exceeds the normal lateral wandering distance (possibly prior to actual lane change)

The distance  $a$  is the perception distance based on the perception time  $[a]$ . It defines the lateral distance required to perceive that a vehicle is executing a cut in manoeuvre  $a$  is obtained from the following formula;

$a = \text{lateral movement speed} \times \text{Risk perception time } [a] (0.4\text{sec})$

The risk perception time begins when the leading vehicle exceeds the cut in boundary threshold.

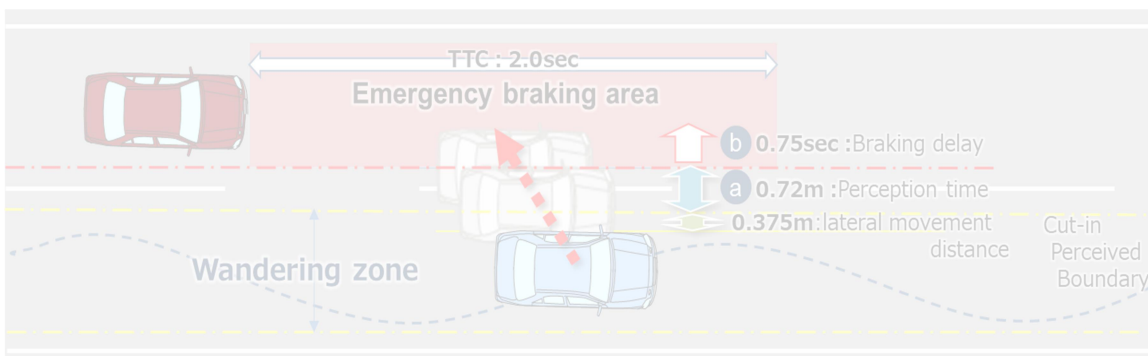
Max lateral movement speed is real world data in Japan.

Risk perception time  $[a]$  is driving simulator data in Japan.

2sec\* is specified as the maximum Time To Collision (TTC) below which it was concluded that there is a danger of collision in the longitudinal direction.

Note:  $TTC = 2.0\text{sec}$  is chosen based on the UN Regulation guidelines on warning signals.

Figure 2  
Driver model for the cut-in scenario



3.4.2. For Cut out scenario:

The lateral wandering distance the vehicle will normally wander within the lane is 0.375m.

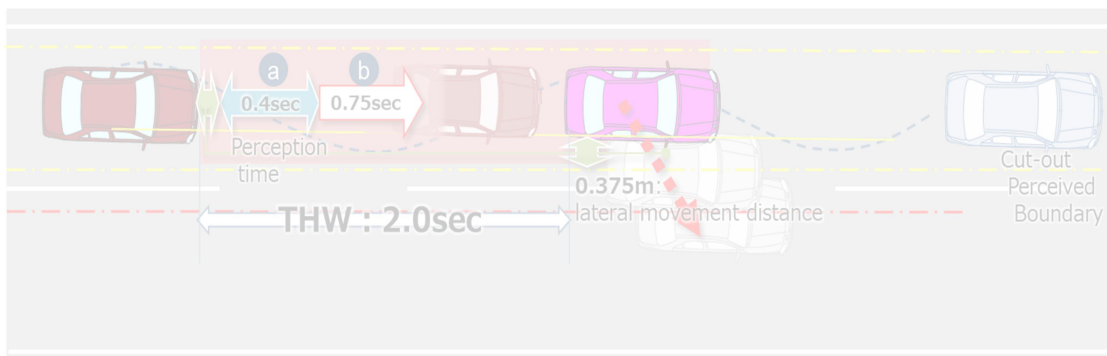
The perceived boundary for cut out occurs when the vehicle exceeds the normal lateral wandering distance (possibly prior to actual lane change)

The risk perception time [a] is 0.4 seconds and begins when the leading vehicle exceeds the cut-out boundary threshold.

The time 2 sec is specified as the maximum Time Head Way (THW) for which it was concluded that there is a danger in longitudinal direction.

Note: THW = 2.0sec is chosen according to other countries' regulations and guidelines.

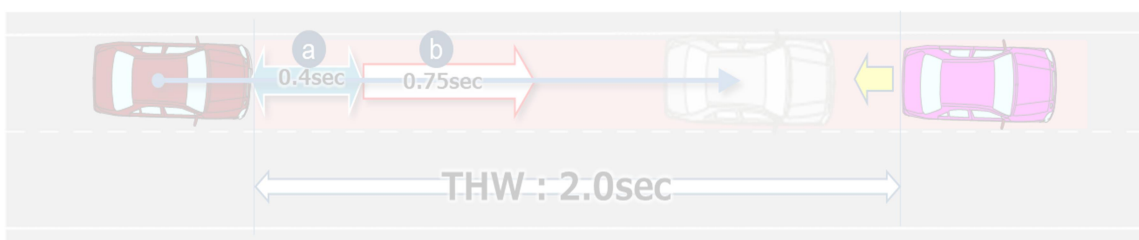
Figure 3  
Cut in scenario



3.4.3. For Deceleration scenario:

The risk perception time [a] is 0.4 seconds. The risk perception time [a] begins when the leading vehicle exceeds a deceleration threshold  $5m/s^2$ .

Figure 4  
Deceleration scenario



## 4. Parameters

- 4.1. Parameters below are essential when describing the pattern of the traffic critical scenarios in section 2.1.
- 4.2. Additional parameters could be added according to the operating environment (e.g. friction rate of the road, road curvature, lighting conditions).

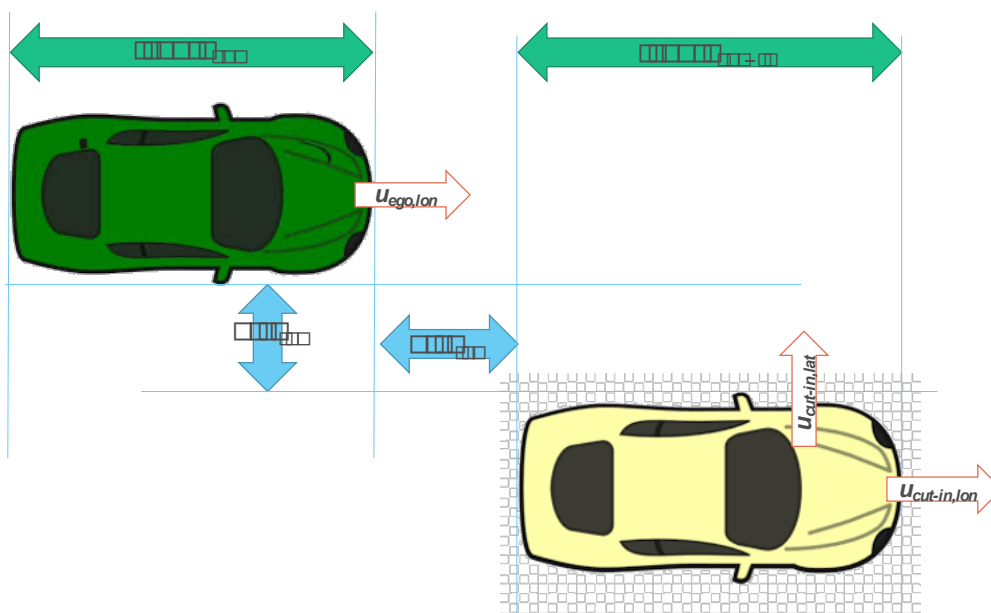
Table 2  
Additional parameters

Operating conditions	Roadway	<p><b>Number of lanes</b> = The number of parallel and adjacent lanes in the same direction of travel</p> <p><b>Lane Width</b> = The width of each lane</p> <p><b>Roadway grade</b> = The grade of the roadway in the area of test</p> <p><b>Roadway condition</b> = the condition of the roadway (dry, wet, icy, snow, new, worn) including coefficient of friction</p> <p><b>Lane markings</b> = the type, colour, width, visibility of lane markings</p>
	Environmental conditions	<p><b>Lighting conditions</b> = The amount of light and direction (ie, day, night, sunny, cloudy)</p> <p><b>Weather conditions</b> = The amount, type and intensity of wind, rain, snow etc.</p>
Initial condition	Initial velocity	<del><math>v_{e0} u_{ego,lon}</math></del> = <del>ALKS vehicle</del>
		<del><math>v_{e0} u_{cut-in,lon}</math></del> = <del>Leading 'Other vehicle' vehicle in lane or in adjacent lane</del>
		<del><math>v_{f0}</math></del> = <del>Vehicle in front of leading vehicle in lane</del>
	Initial distance	<del><math>dx_0 dist_{lon}</math></del> = <del>Distance in Longitudinal direction between the front end of the ego vehicle and the rear end of the leading vehicle 'other vehicle' in ego vehicle's lane or in adjacent lane</del>
		<del><math>dy_0 dist_{lat}</math></del> = <del>Inside Lateral distance between outside edge line of ego vehicle in parallel to the vehicle's median longitudinal plane within lanes and outside edge line of leading vehicle 'other vehicle' in parallel to the vehicle's median longitudinal plane in adjacent lines.</del>
		<del><math>dx_0_f</math></del> = <del>Inside Lateral distance between outside edge line of leading vehicle in parallel to the vehicle's median longitudinal plane within lanes and outside edge line of vehicle in front of the leading vehicle in parallel to the vehicle's median longitudinal plane in adjacent lines.</del>
		<del><math>dx_0_f</math></del> = <del>Distance in longitudinal direction between front end of leading vehicle and rear end of vehicle in front of leading vehicle</del>
		<del><math>dfy</math></del> = <del>Width of vehicle in front of leading vehicle</del>
<del><math>doy</math></del> = <del>Width of leading vehicle</del>		
<del><math>dox length_{cut-in}</math></del> = <del>Length of the leading 'other vehicle'</del>		

		$length_{ego}$ = Length of the ALKS vehicle
Vehicle motion	Lateral motion	$Vy$ $u_{cut-in,lat}$ = leading-vehicle 'Other vehicle' lateral velocity
	Deceleration	$Gx\_max$ = Maximum deceleration of the leading vehicle in G
		$dG/dt$ = Deceleration rate (Jerk) of the leading vehicle

4.3. Following are the visual representations of parameters for the three types of cut in scenarios

Figure 5  
Visualisation of the cut-in scenario



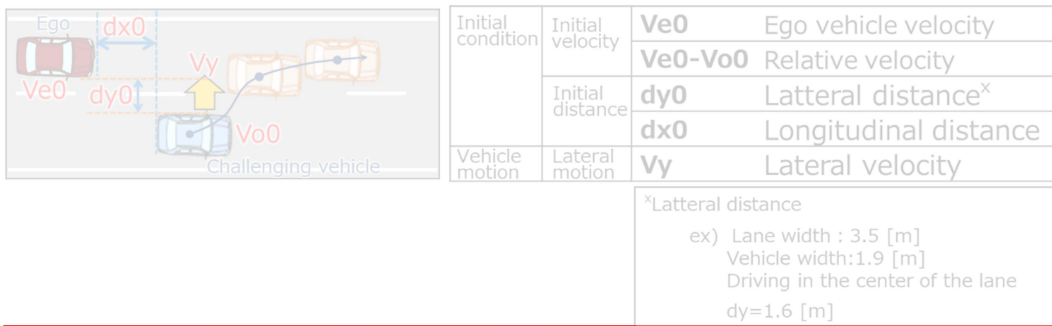
Cut-in	
Cut-out	
Deceleration	

## 5. Reference

Following data sheets are pictorial examples of simulations which determines conditions under which ALKS shall avoid a collision, taking into account the combination of every parameter, at and below the maximum permitted ALKS vehicle speed.

### 5.1. Cut in

Figure 6  
Parameters



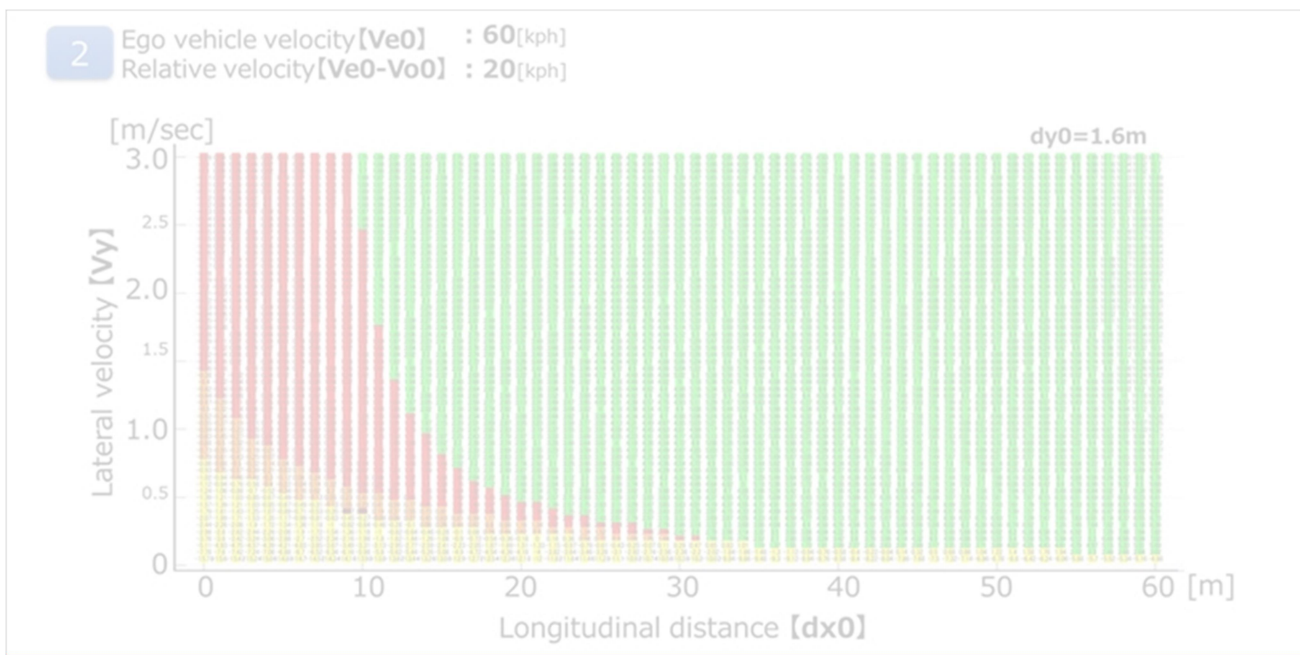
(Data sheets image)

Figure 7  
Overview





Figure 8  
For  $V_{e0} = 60$  kph



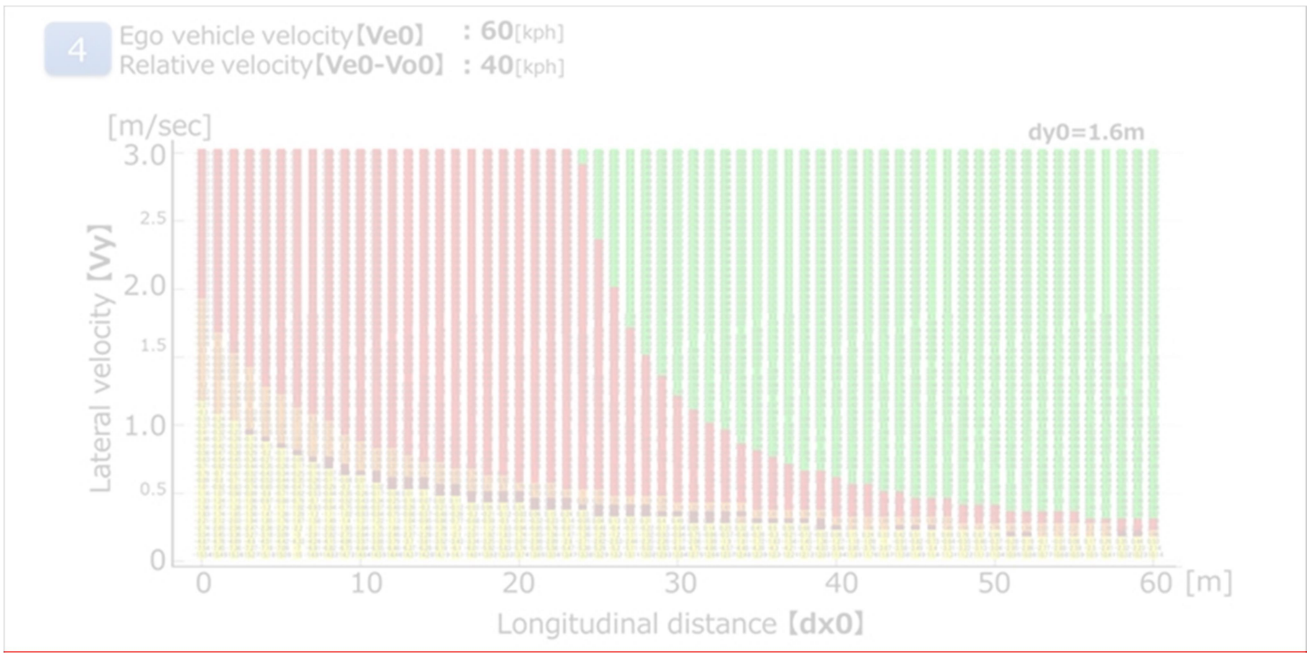
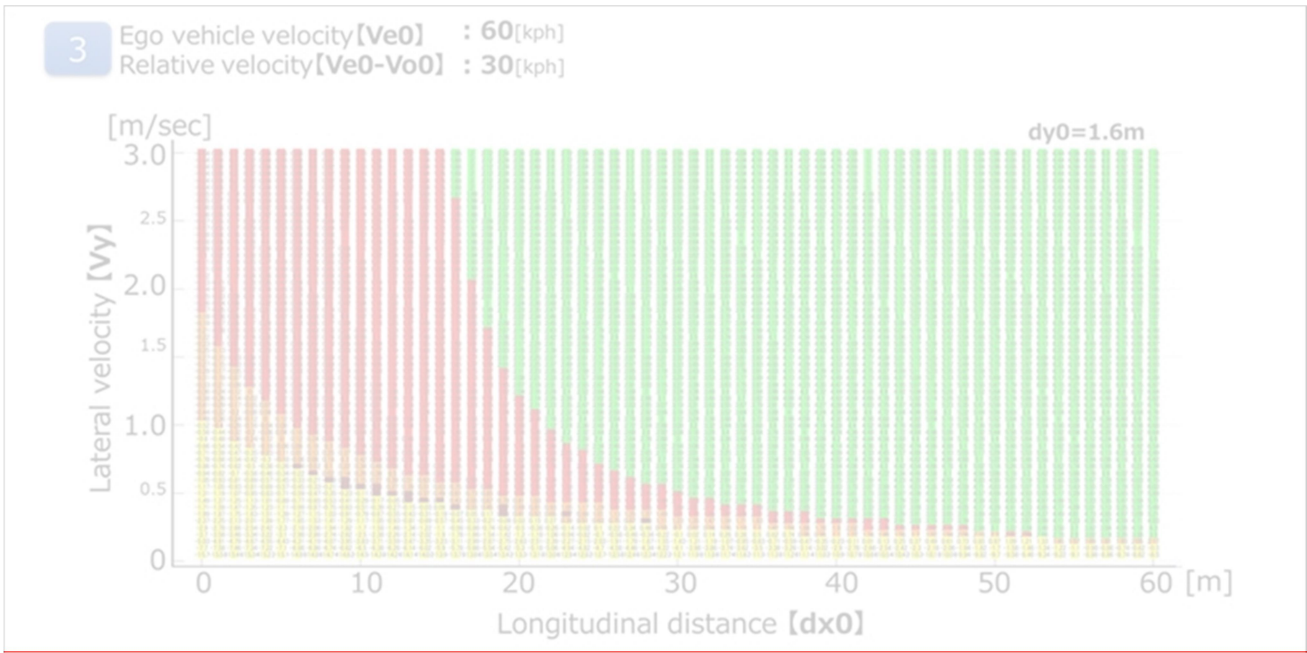
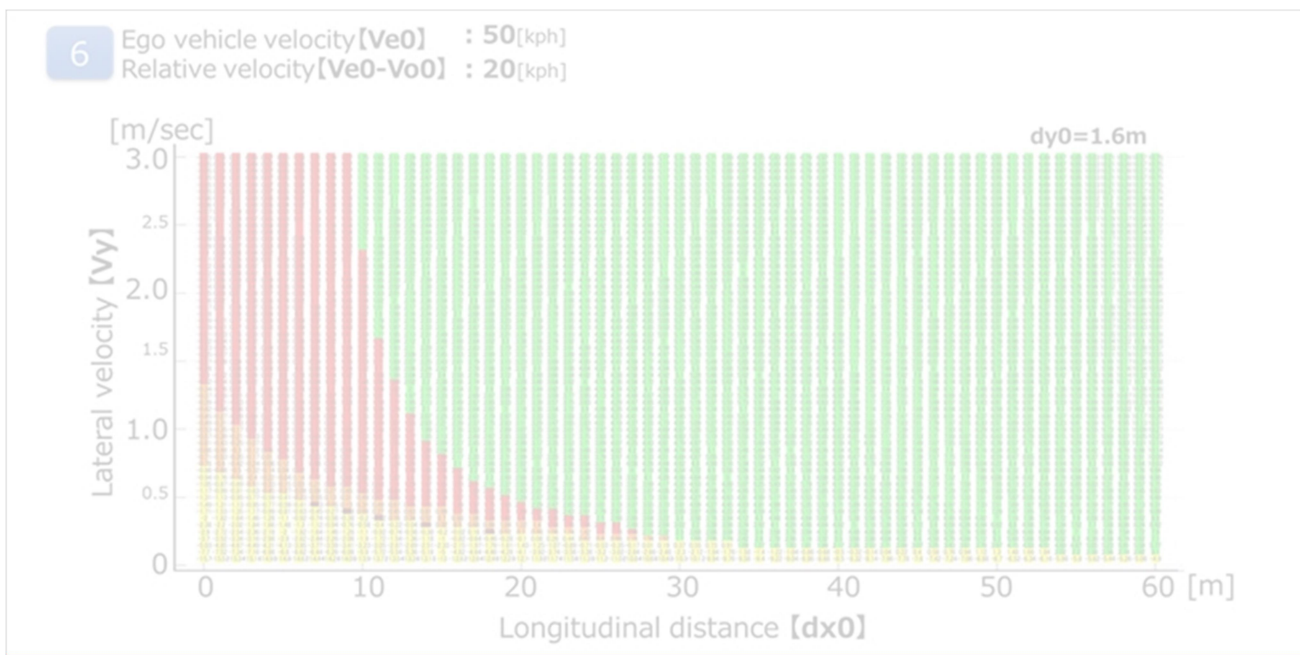
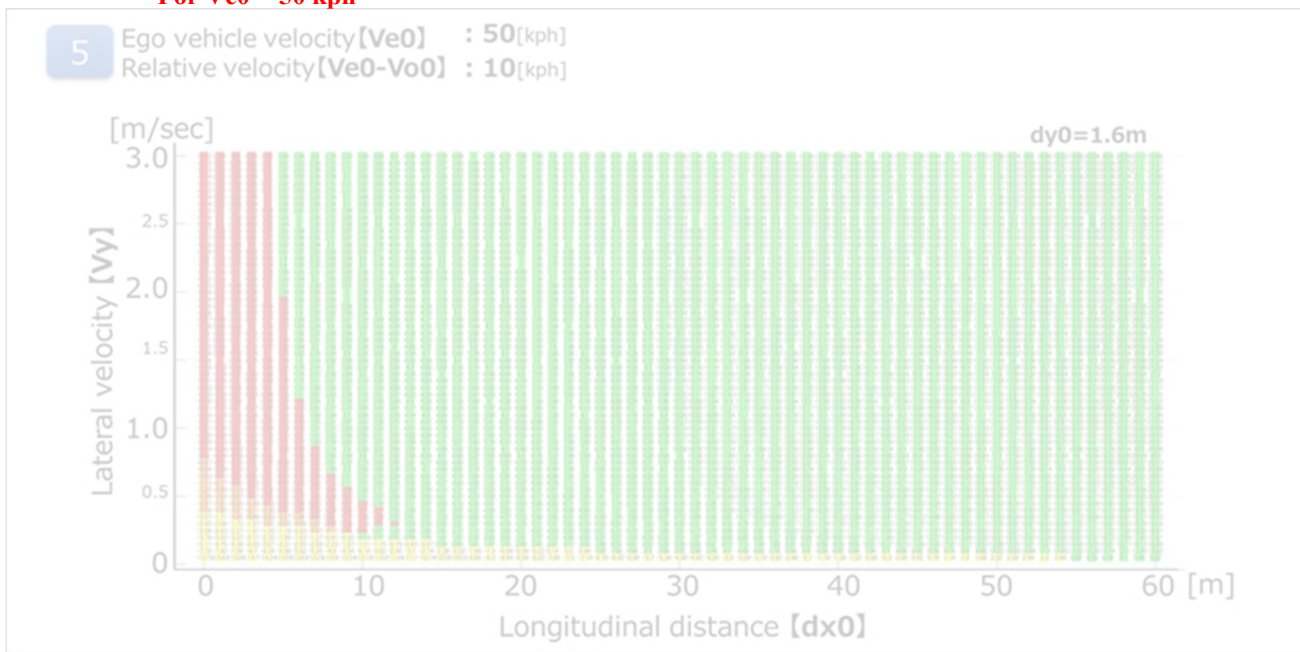


Figure 9  
 For  $V_{e0} = 50$  kph



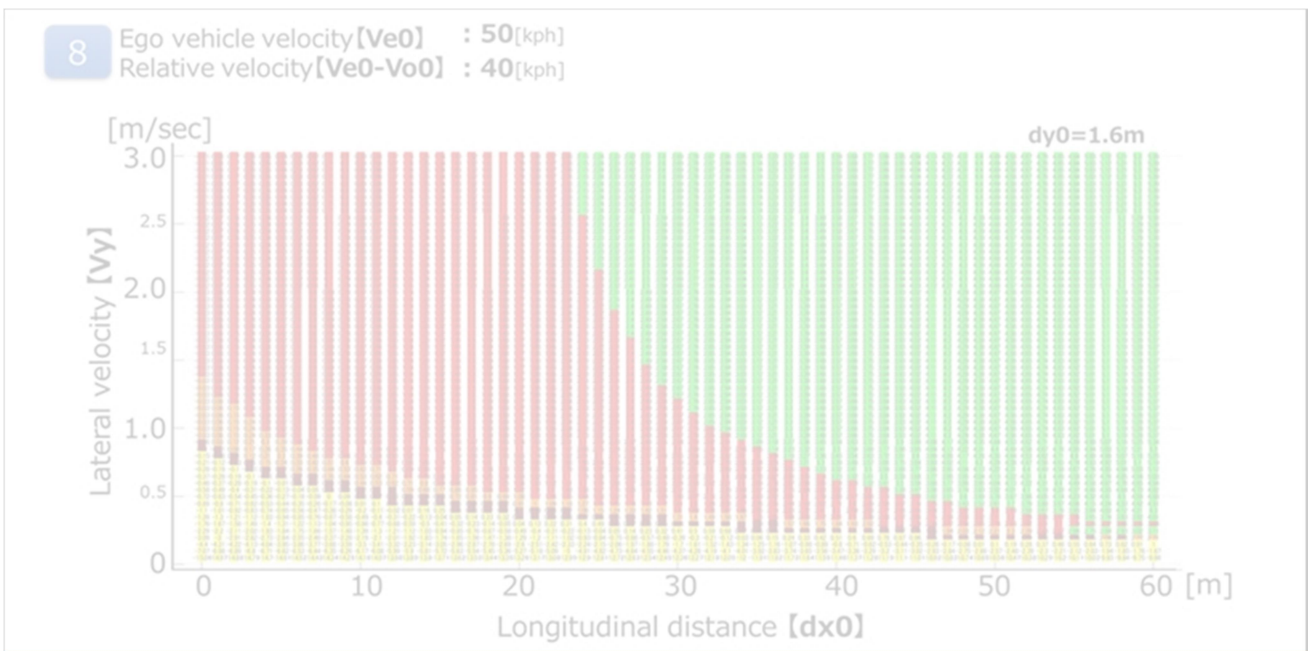
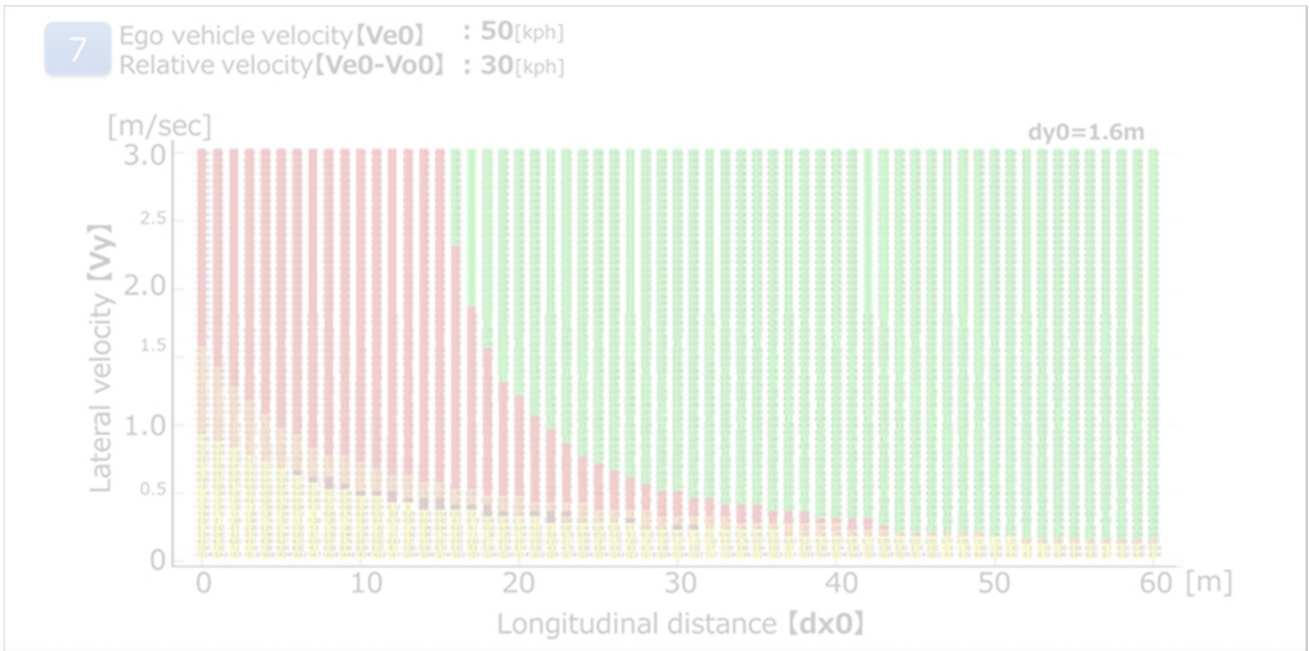
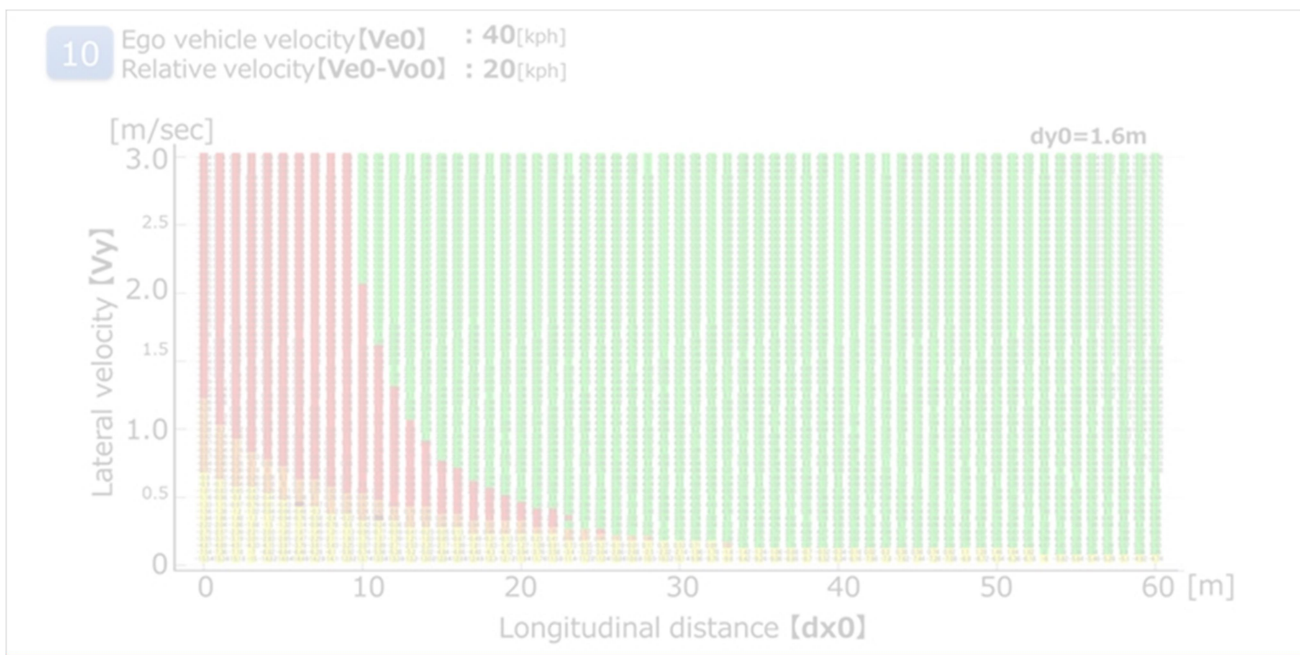
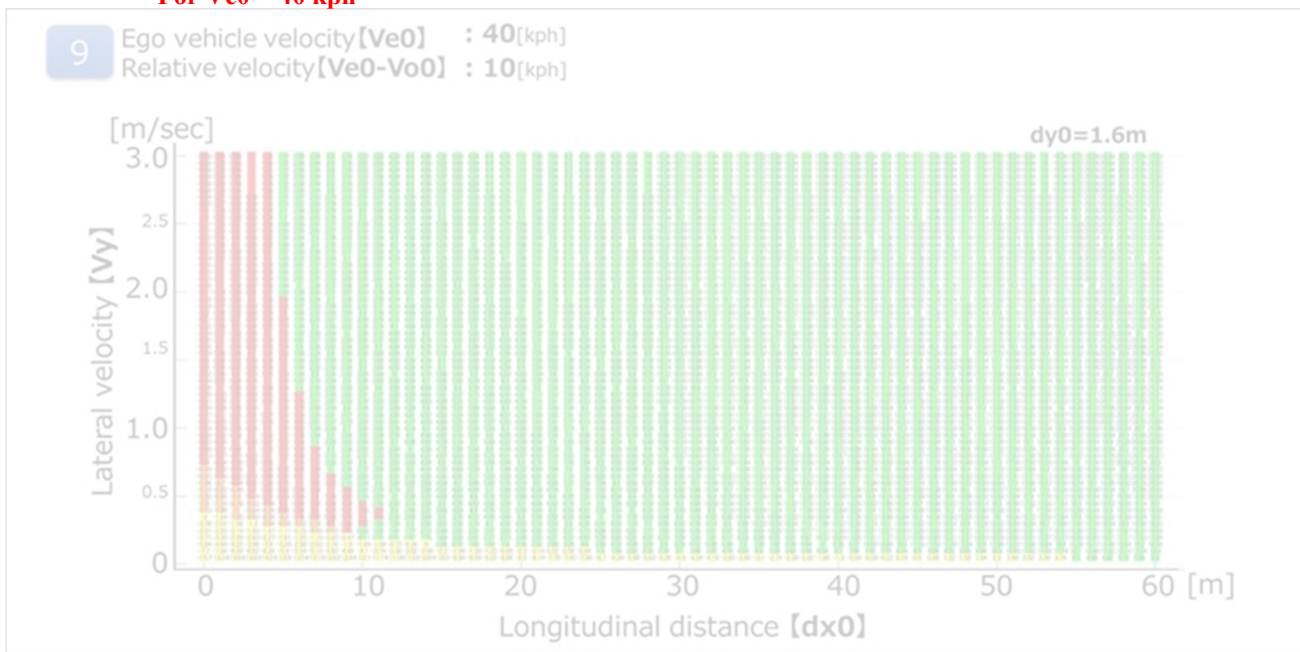


Figure 10  
 For  $V_{e0} = 40$  kph



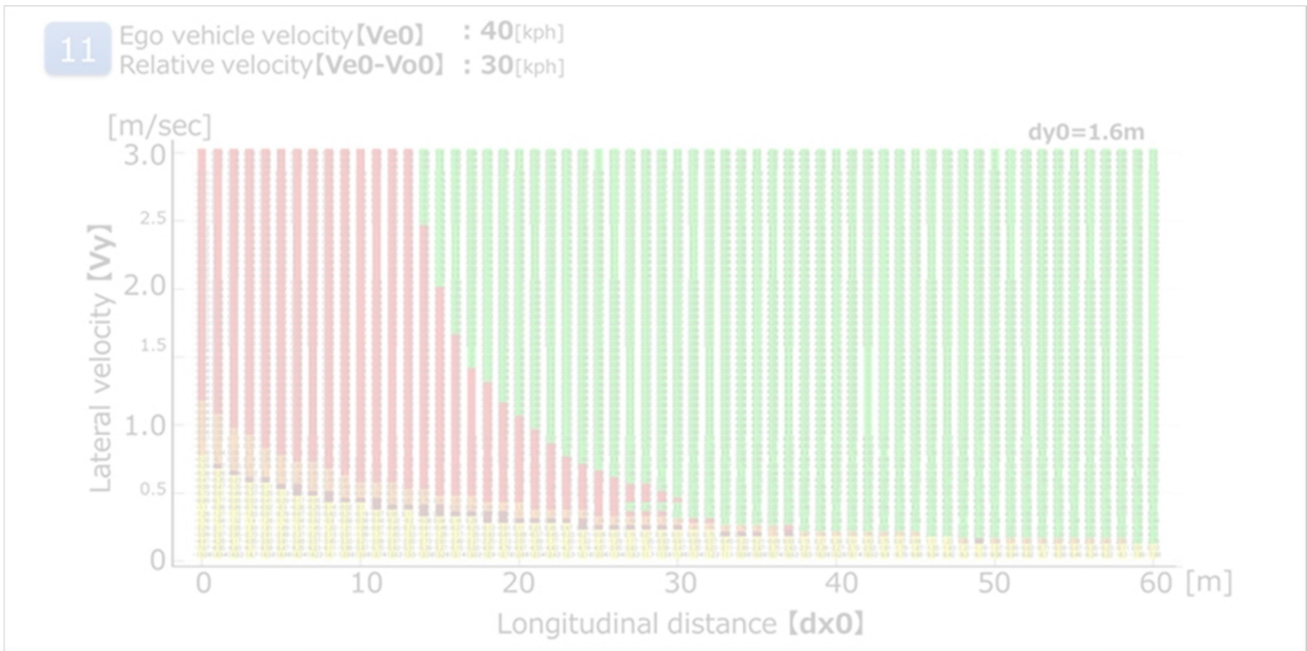
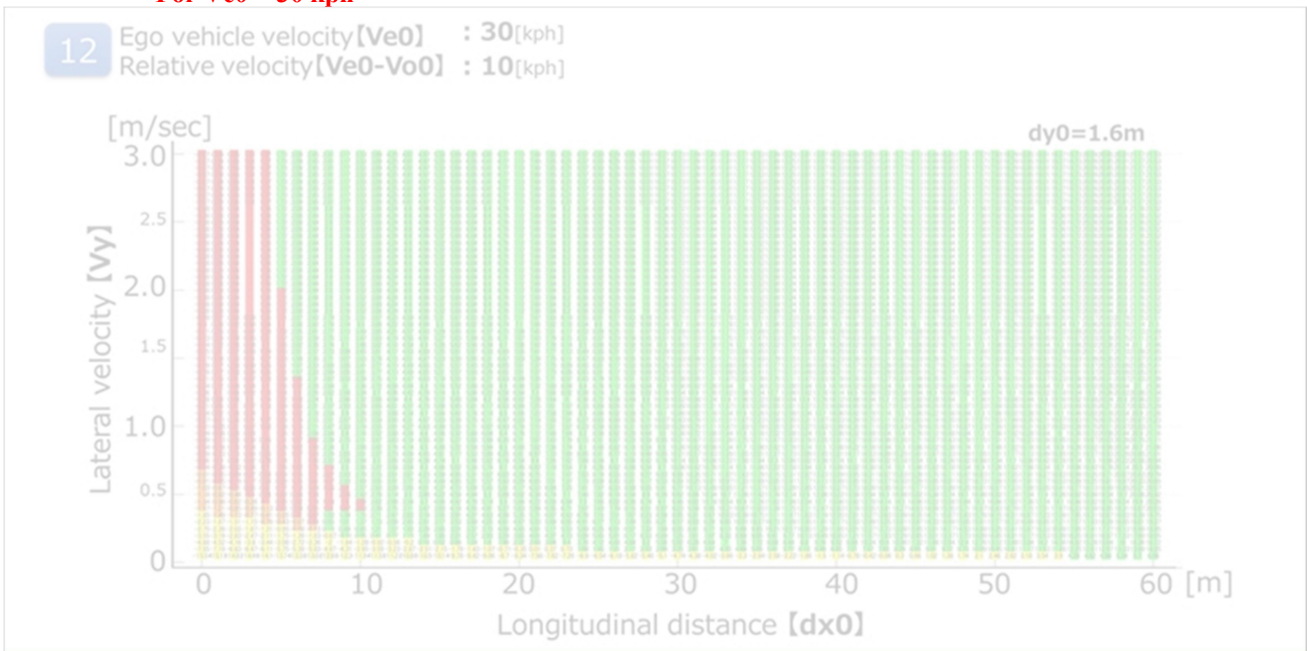


Figure 11  
For  $V_{e0} = 30$  kph



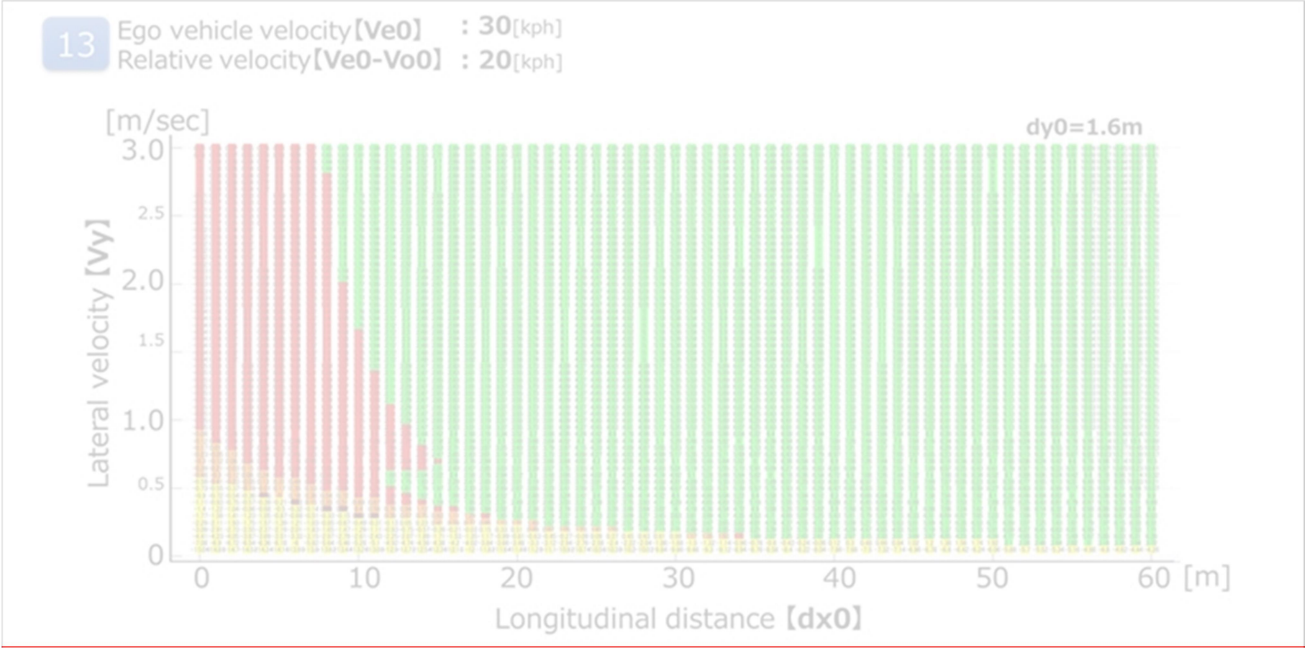
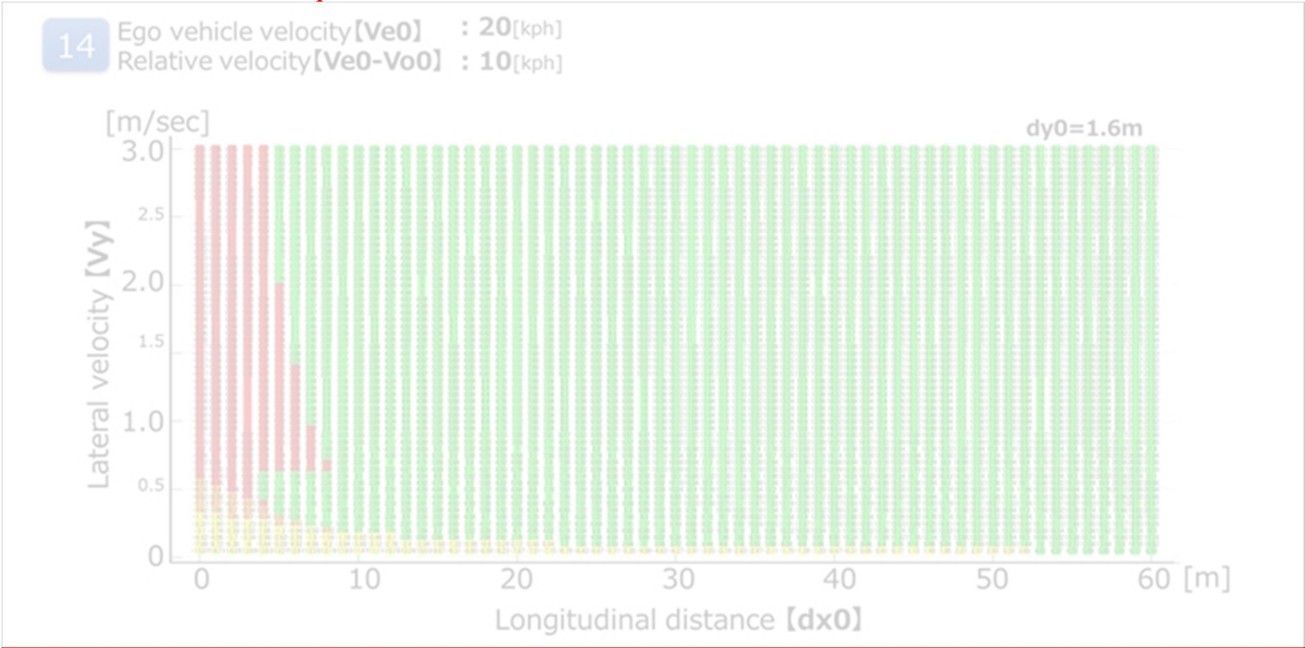


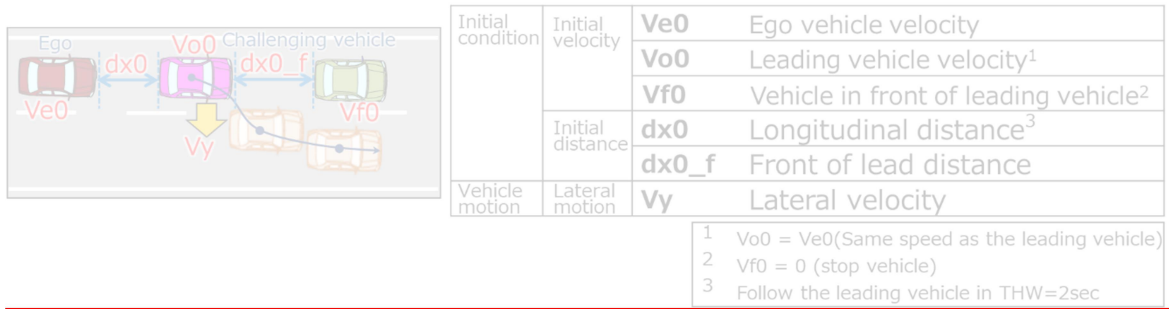
Figure 12  
For Ve0=20 kph



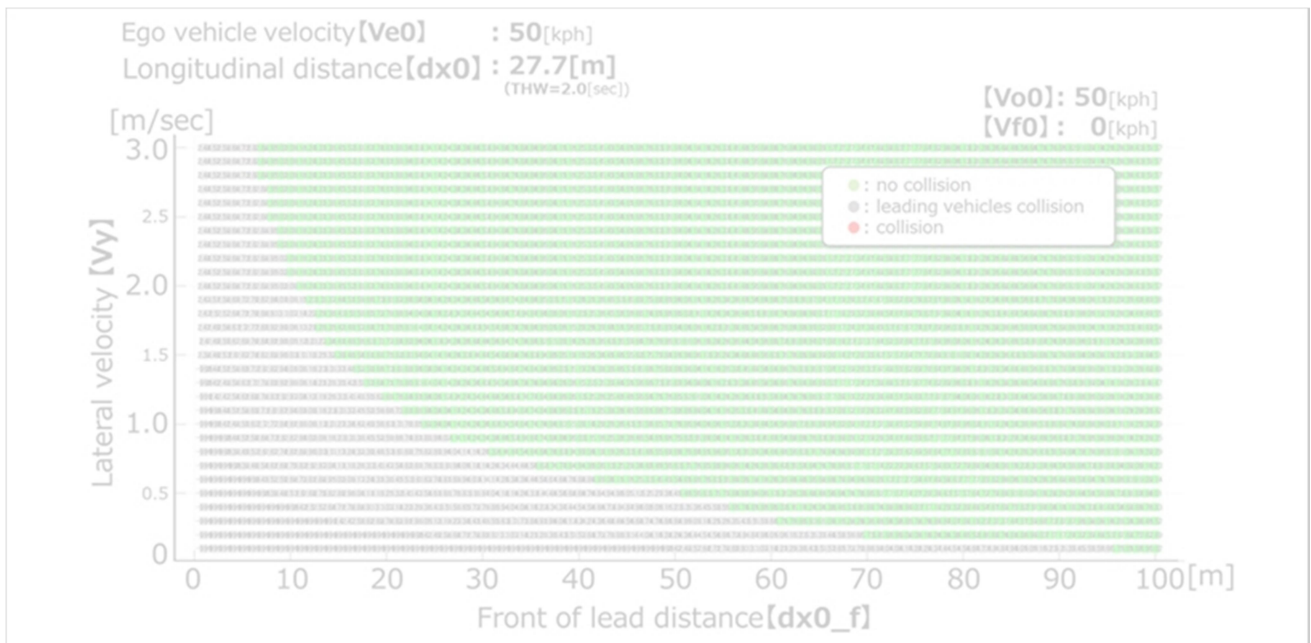
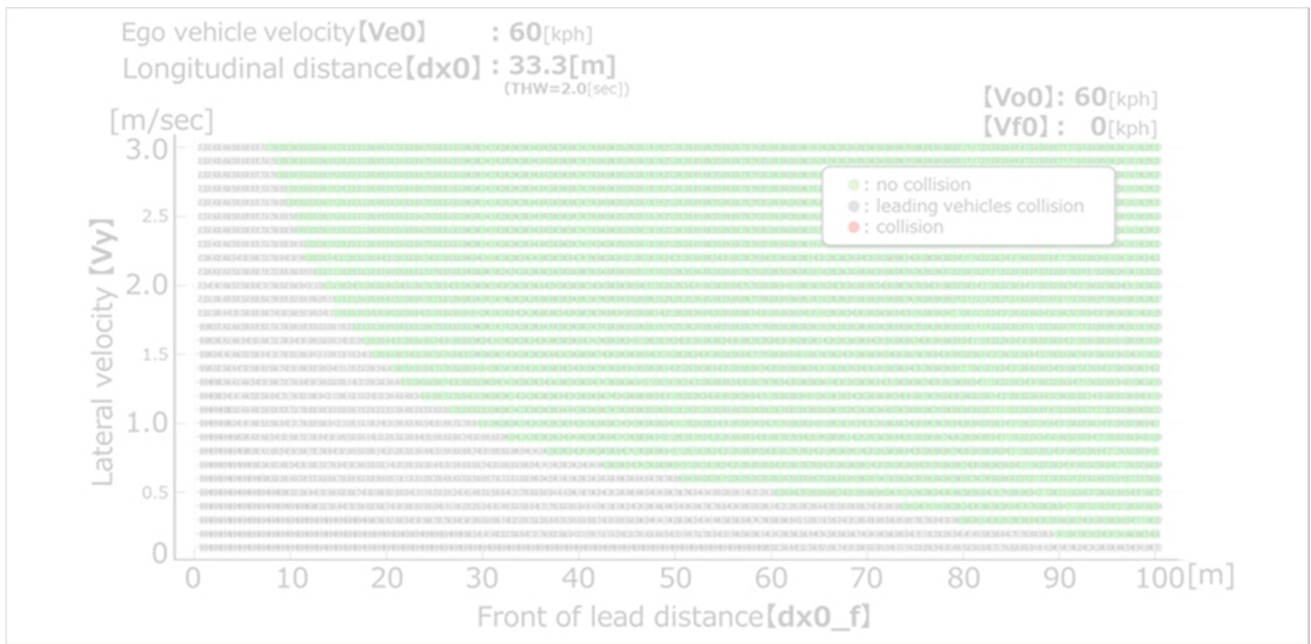
5.2. Cut-out

It is possible to avoid all the deceleration (stop) vehicles ahead of the preceding vehicle cut-out in the following running condition at THW 2.0 sec.

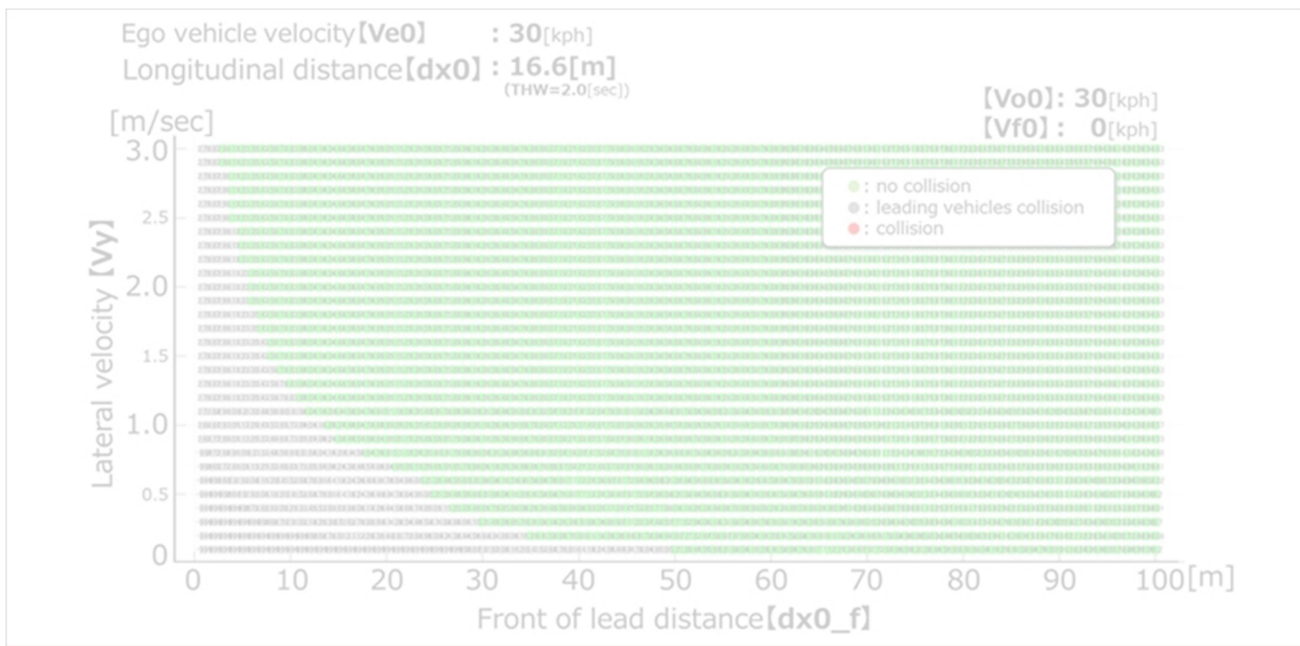
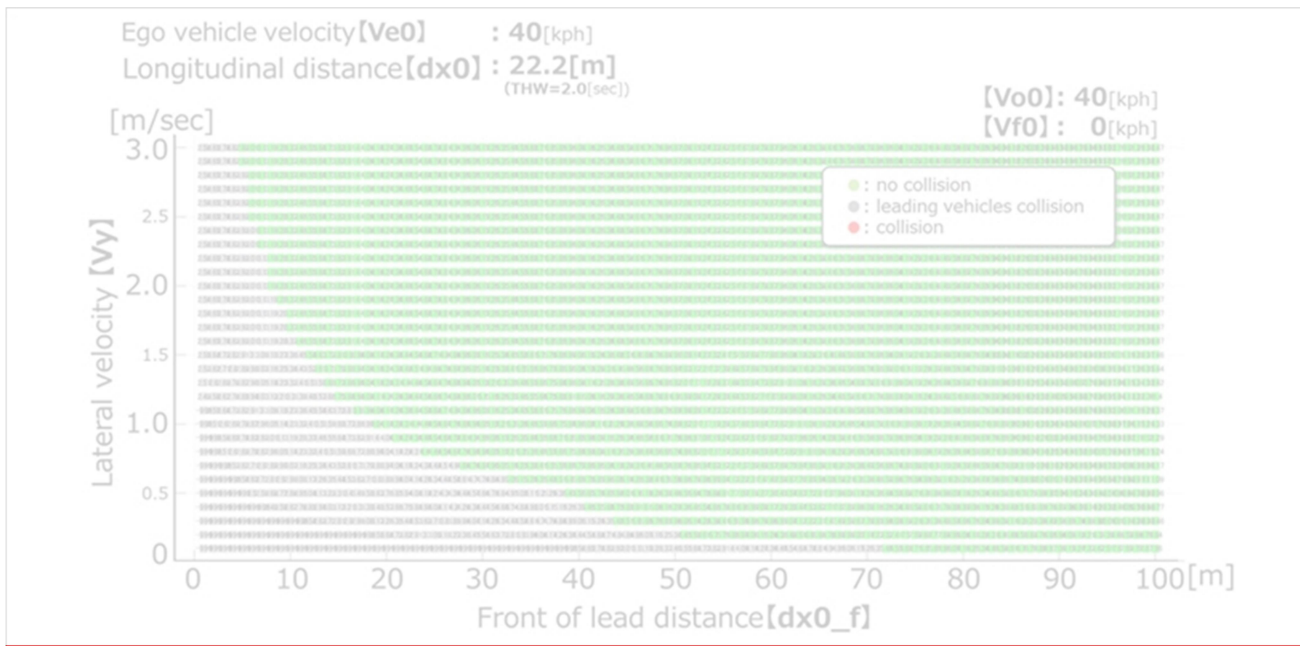
Figure 12  
Parameters

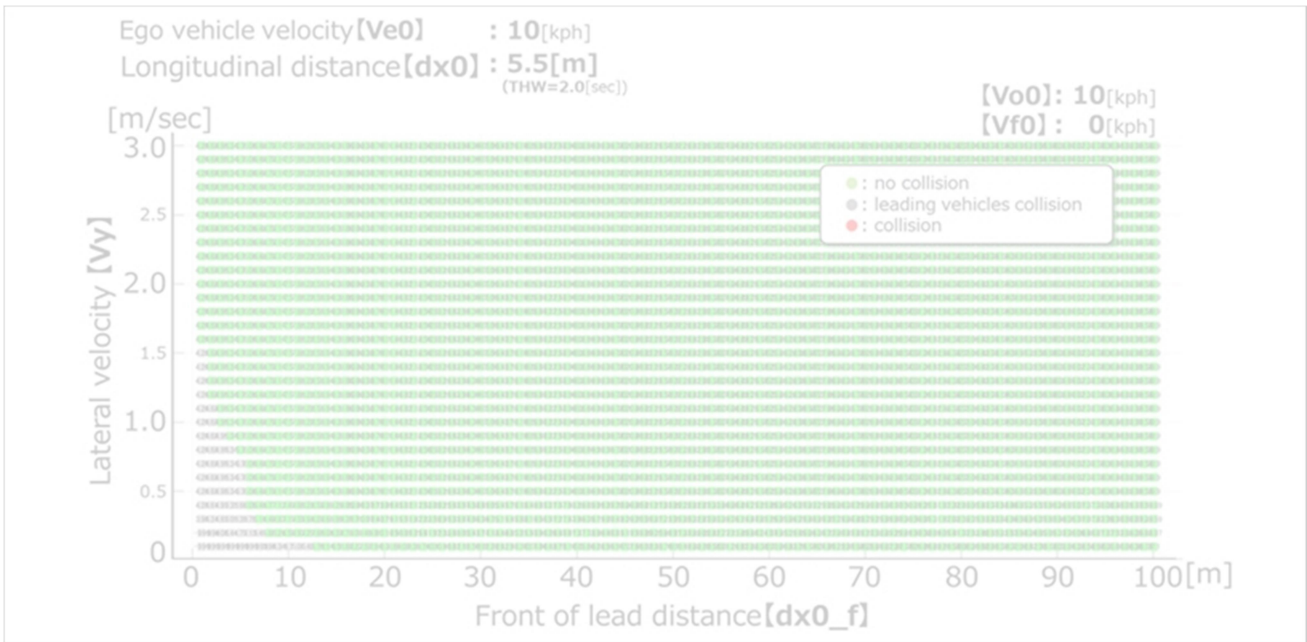
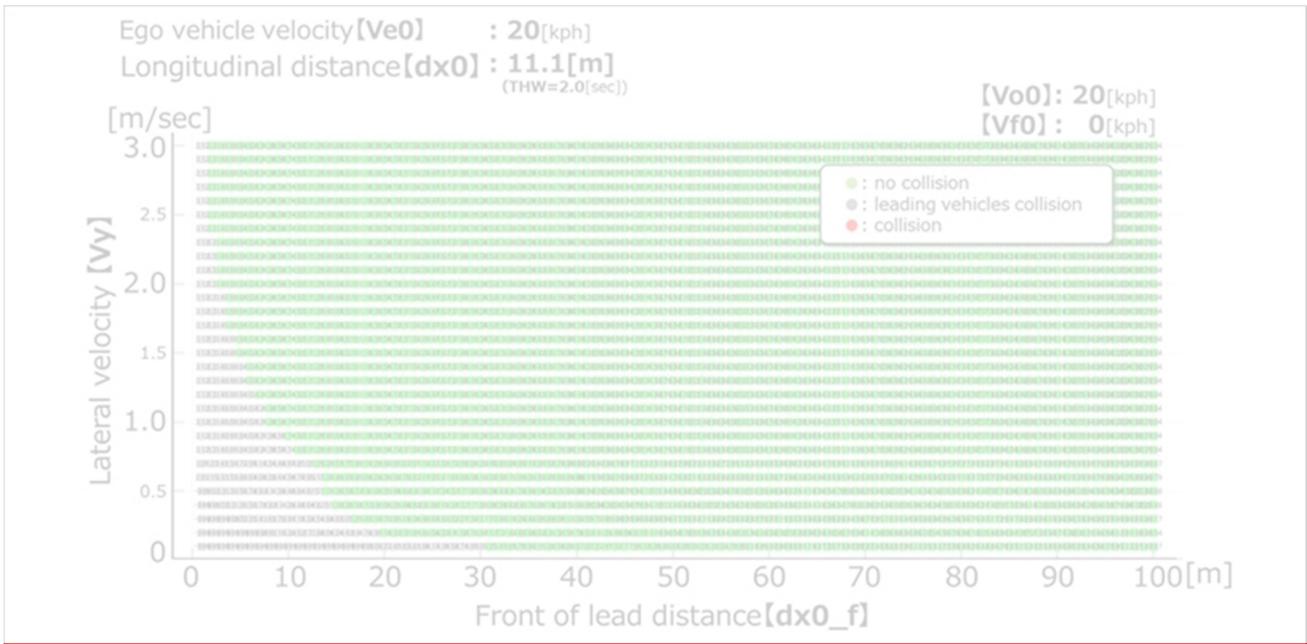


(Data sheets image)





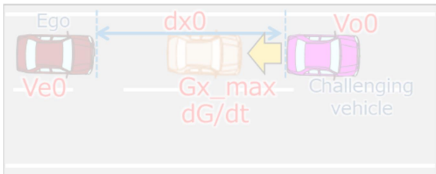




5.4. Deceleration

It is possible to avoid sudden deceleration of  $-1.0G$  or less in the follow up driving situation at THW 2.0sec.

(Data-sheet image)



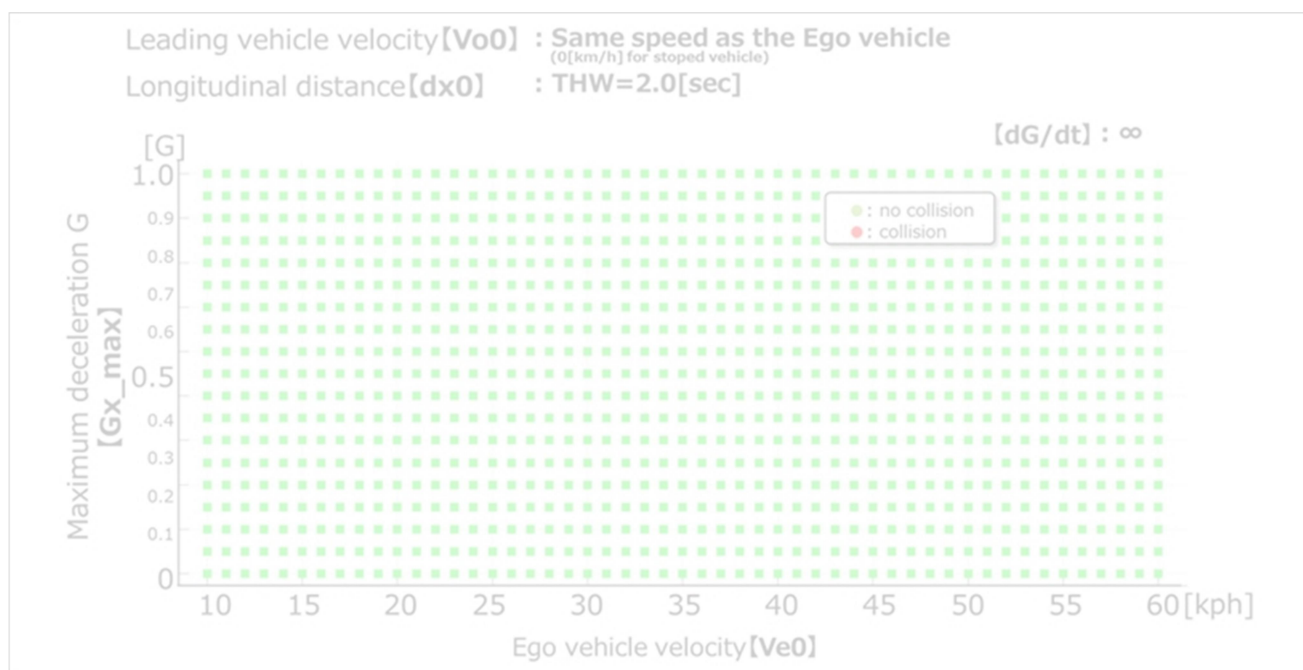
Initial condition	Initial velocity	<b>Ve0</b>	Ego vehicle velocity
		<b>Vo0</b>	Leading vehicle velocity <sup>1</sup>
Vehicle motion	Initial distance	<b>dx0</b>	Longitudinal distance <sup>2</sup>
		<b>Gx_max</b>	Maximum deceleration G
	Deceleration	<b>dG/dt</b>	Deceleration rate <sup>3</sup>

1 Vo0 = Ve0 (Same speed as the leading vehicle)  
0[km/h] for a stopped vehicle

2 Follow the leading vehicle in THW=2sec

3 The most severe conditions ∞

(Data sheets image)



*Annex 5 Paragraph 4, amend to read*

#### **4. Test scenarios to assess the performance of the system with regard to the dynamic driving task**

- 4.1. Lane Keeping
- 4.1.1. The test shall demonstrate that the ALKS does not leave its lane and maintains a stable **position motion** inside its **ego**-lane across the speed range and different curvatures within its system boundaries.
- 4.1.2. The test shall be executed at least:
- (a) With a minimum test duration of 5 minutes;
  - (b) With a passenger car target as well as a PTW target as the lead vehicle / other vehicle;
  - (c) With a lead vehicle swerving in the lane; and
  - (d) With another vehicle driving close beside in the adjacent lane.
- 4.2. Avoid a collision with a road user or object blocking the lane
- 4.2.1. The test shall demonstrate that the ALKS avoids a collision with a stationary vehicle, road user or fully or partially blocked lane up to the maximum specified speed of the system.
- 4.2.2. This test shall be executed at least:
- (a) With a stationary passenger car target;
  - (b) With a stationary powered two-wheeler target;
  - (c) With a stationary pedestrian target;
  - (d) With a pedestrian target crossing the lane with a speed of 5 km/h;
  - (e) With a target representing a blocked lane;
  - (f) With a target partially within the lane;
  - (g) With multiple consecutive obstacles blocking the lane (e.g. in the following order: **ego**ALKS-vehicle -motorcycle - car);
  - (h) On a curved section of road.
- 4.3. Following a lead vehicle
- 4.3.1. The test shall demonstrate that the ALKS is able to maintain and restore the required safety distance to a vehicle in front and is able to avoid a collision with a lead vehicle which decelerates up to its maximum deceleration.
- 4.3.2. This test shall be executed at least:
- (a) Across the entire speed range of the ALKS
  - (b) ~~Using~~**For** a passenger car target as well as a PTW target as lead vehicle, provided standardized PTW targets suitable to safely perform the test are available
  - (c) For constant and varying lead vehicle velocities (e.g. following a realistic speed profile from existing driving database)
  - (d) For straight and curved sections of road
  - (e) For different lateral positions of lead vehicle in the lane
  - (f) With a deceleration of the lead vehicle of at least 6 m/s<sup>2</sup> mean fully developed deceleration until standstill.

- 4.4. Lane change of another vehicle into lane
- 4.4.1. The test shall demonstrate that the ALKS is capable of avoiding a collision with a vehicle cutting into the lane of the ALKS vehicle up to a certain criticality of the cut-in manoeuvre **in accordance with paragraph 4.4.2. of the present annex.**
- 4.4.2. The criticality of the cut-in manoeuvre shall be determined according to TTC, longitudinal distance between rear-most point of the cutting in vehicle and front-most point of the ALKS vehicle, the lateral velocity of the cutting-in vehicle and the longitudinal movement of the cutting-in vehicle, as defined in paragraph 5.2.5. of this Regulation.
- 4.4.3. This test shall be executed taking into consideration at least the following conditions:
- (a) For different TTC, distance and relative velocity values of the cut-in manoeuvre, covering types of cut-in scenarios in which a collision can be avoided and those in which a collision cannot be avoided;
  - (b) For cutting-in vehicles travelling at constant longitudinal speed, accelerating and decelerating;
  - (c) For different lateral velocities, lateral accelerations of the cut-in vehicle;
  - (d) For passenger car as well as PTW targets as the cutting-in vehicle, provided standardized PTW targets suitable to safely perform the test are available.
- 4.5. Stationary obstacle after lane change of the lead vehicle
- 4.5.1. The test shall demonstrate that the ALKS is capable of avoiding a collision with a stationary vehicle, road user or blocked lane that becomes visible after a preceding vehicle avoided a collision by an evasive manoeuvre.
- 4.5.2. The test shall be executed at least:
- (a) With a stationary passenger car target centred in lane
  - (b) With a powered two-wheeler target centred in lane
  - (c) With a stationary pedestrian target centred in lane
  - (d) With a target representing a blocked lane centred in lane
  - (e) With multiple consecutive obstacles blocking the lane (e.g. in the following order: **ego**ALKS-vehicle – lane change vehicle – motorcycle – car)
- 4.6. Field of View test
- 4.6.1. The test shall demonstrate that the ALKS **vehicle** is capable of detecting another road user within the forward detection area up to the declared forward detection range and a vehicle beside within the lateral detection area up to at least the full width of the adjacent lane. **If the ALKS vehicle is capable of performing lane changes, it shall additionally demonstrate that the system is capable of detecting another vehicle within the rear detection range.**
- 4.6.2. The test for the forward detection range shall be executed at least:
- (a) When approaching a motorcycle target positioned at the outer edge of each adjacent lane;
  - (b) When approaching a stationary pedestrian target positioned at the outer edge of each adjacent lane;
  - (c) When approaching a stationary motorcycle target positioned within the ego lane;

- (d) When approaching a stationary pedestrian target positioned within the ego lane.
- 4.6.3. The test for the lateral detection range shall be executed at least:
  - (a) With a motorcycle target approaching the ALKS vehicle from the left adjacent lane;
  - (b) With a motorcycle target approaching the ALKS vehicle from the right adjacent lane.
- 4.6.4. The test for the rear detection range shall be executed at least:**
  - (a) With a motorcycle approaching the ALKS from the rear outer edge of each adjacent lane;**
- 4.7. Lane changing**
- 4.7.1. The test shall demonstrate that the ALKS vehicle does not cause an unreasonable risk to safety of the vehicle occupants and other road users during a Lane Change Procedure (LCP), and that the system is able to correctly perform the assessment of the target lane in accordance with paragraph 5.2.6.6. of the present Regulation before starting the Lane Change Manoeuvre (LCM). The test is only required if the ALKS vehicle is capable of performing lane changes either during a Minimal Risk Manoeuvre or during regular operation.**
- 4.7.2. The following tests shall be executed:**
  - (a) With the ALKS vehicle performing lane change in the adjacent (target) lane;**
  - (b) Merging at motorway entry;**
  - (c) Merging at lane end;**
  - (d) Merging into an occupied lane.**
- 4.7.3. The tests shall be executed at least:**
  - (a) With different vehicles, including a PTW approaching from the rear;**
  - (b) In a scenario where a lane changing manoeuvre in regular operation is possible to be executed;**
  - (c) In a scenario where a lane changing manoeuvre in regular operation is not possible due to a vehicle approaching from the rear;**
  - (d) With an equally fast vehicle following behind in the adjacent lane, preventing a lane change;**
  - (e) With a vehicle driving beside in the adjacent lane preventing a lane change;**
  - (f) In a scenario where a LCM during a minimal risk manoeuvre is possible and executed.**
  - (g) In a scenario where the ALKS vehicle should abort the LCM maneuver due to changing scenario conditions such as an upcoming accelerating vehicle**
- 4.8 Detect and response to traffic rules and road furniture**
- 4.8.1. These tests shall ensure that the ALKS respects traffic rules, detects and adapts to a variation of permanent and temporary road furniture.**
- 4.8.2. The test shall be executed at least with the list of scenarios below, but based on the ODD of the given system:**
  - (a) Different speed limit signs, so that the ALKS vehicle has to change its speed according to the indicated values;**

- (b) Signal lights of an ending lane. The signal lights are set above the belonging lanes, and the signal lights of adjacent lanes are kept in green state, while the one of the current lane for the ALKS vehicle is kept red.;
- (c) Driving through a tunnel: at least [X]m long section of the road with no sunlight and availability of the positioning system.
- (d) Toll station: a section of the motorway with toll station-, speed limit signs and buildings (ticket machines, barriers, etc.).
- (e) Temporary modifications: e.g., road maintenance operations indicated by traffic signs, cones and other modifications.
- 4.8.3. Each test shall be executed at least:
- (a) Without a lead vehicle;
- (b) With a passenger car target as well as a PTW target as the lead vehicle / other vehicle.
- 4.9. Avoid braking before a passable object in the lane
- 4.9.1. The test shall demonstrate that the ALKS vehicle is not braking without a reason before a passable object in the lane (e.g., a manhole lid or a small branch).
- 4.9.2. The test shall be executed at least:
- (a) Without a lead vehicle;
- (b) With a passenger car target as well as a PTW target as the lead vehicle / other vehicle.
- 4.10. String stability
- 4.10.1. The tests shall demonstrate that the ALKS is able to achieve string stable operations when following a car target proceeding with a speed lower than the speed the ALKS would maintain in the same situation in the absence of the same target.
- 4.10.2. The tests can be executed with one or more ALKS vehicles proceeding in platoon formation. The maximum number of ALKS vehicles that the test can include is [5].
- 4.10.3. The following conditions shall be ensured for the correct execution of each test:
- 4.10.3.1. The initial speed of the car target shall be lower than the speed limit or of the speed the ALKS would maintain in the same situation, whatever is the minimum.
- 4.10.3.2. The car target shall keep the constant initial speed for a time sufficient to ensure that all the ALKS vehicles are able to maintain the same constant speed. A fluctuation of the speed of the ALKS vehicles within a range of  $\pm [1]$  m/s from the speed of the car target is allowed. When these conditions are achieved the platoon is in steady state formation and the test can be considered as started.
- 4.10.3.4. Each test shall comprise the deceleration of the car target from steady state platoon formation to achieve a speed reduction of at least [3] m/s. The speed of the car target at the end of the deceleration shall not be lower than [5] m/s. The deceleration adopted by the car target shall be in the range [1-5] m/s<sup>2</sup>.
- 4.10.3.4. At the end of the deceleration, the car target shall maintain the new speed for a time sufficient to bring the platoon again in steady state formation according to the provisions of paragraph 4.10.3.2. When this is achieved the test can be considered as concluded.
- 4.10.3.5. At the end of the test the following quantities have to be computed.

- (a) The difference between the maximum and the minimum speed achieved by the car target during the test ( $L_{target}$ )
  - (b) The difference between the maximum and the minimum speed achieved by the last ALKS vehicle in the platoon during the test ( $L_{ALKS}$ )
  - (c) The ratio between the two differences  $L = \frac{L_{ALKS}}{L_{target}}$
- 4.10.4. The test shall be executed for at least [5] different combinations of initial speed, final speed and deceleration adopted by the car target.
- 4.10.5. The string stability requirement is considered achieved if for all the tests the value of L is lower than 1.
- 4.11 Oncoming traffic / Wrong way driver
- 4.11.1. The test shall demonstrate that ALKS is capable of detecting and reacting to oncoming traffic in an adjacent lane.
- 4.11.2. The test for oncoming vehicle shall be executed at least:
- (a) Without a lead vehicle;
  - (b) With a passenger car target as well as a PTW target as the lead vehicle / other vehicle

## II. Additional comments

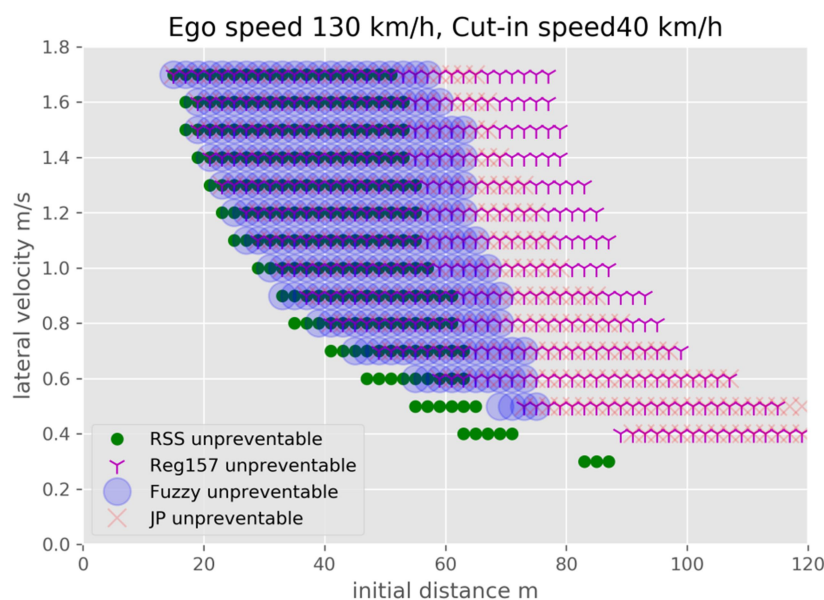
1. Is the current text able to take into account the case of a transition demand initiated by either the driver or the system during the execution of a Lane Change Procedure?
2. A definition of “evasive manoeuvre” (introduced in paragraph 5.3.2.) should be provided
3. The numbering of Sub-sections of Section 5 of Annex 5 is wrong
4. A definition of “early enough” in paragraph 5.4.2.1. should be provided
5. How can the requirement introduced in paragraph 5.4.4.1.1. (namely “In case of a severe ALKS or vehicle failure the ALKS may no longer be capable of fulfilling the requirements of this Regulation, but it shall aim at enabling a safe transition of control back to the driver”) be verified?
6. Should reference to “technical services” throughout the Regulation be replaced by reference to “relevant authorities”
7. To simplify the regulatory text and make it more flexible to the subsequent evolutions, the performance model described in Appendix 3 of Annex 4 could be embedded in an open software package that can be made freely available and kept updated. The JRC is available to take on board this task as done in the near past for other software used for regulatory purposes (e.g. CO2MPAS, VECTO, etc.)

## III. Justification

1. This document proposes an amendment to UN Regulation on ALKS (ECE/TRANS/WP.29/2020/81) including its amendments concerning lane change capabilities of the system (ECE/TRANS/WP29/GRVA/2020/33) and the increase in the maximum speed to 130 km/h (ECE/TRANS/WP29/GRVA/2020/32), submitted by Germany.
2. This proposal follows up on the comments provided by the European Commission (and included in the informal documents GRVA-07-56 and GRVA-08-11) to the previously mentioned documents. Following the request received during the 2<sup>nd</sup> Session of the SIG on UNR157 to make more explicit the effect of the comments provided, the present document suggests ways to incorporate them in the amended legislation. Specifically, this document:



- a. Includes definition, requirement and test procedure for string stability (whose necessity is motivated by the analysis of the behavior of lower level automation vehicles);
- b. Removes operational requirements on safety distance and Lane Change Procedure. Also following the discussions held during the SIG on R157 2<sup>nd</sup> session, there doesn't seem sufficient motivation to keep such explicit requirements in place (neither related to safety, nor related to possible differences with the behavior of the surrounding traffic). On the contrary, considering the limited knowledge about the implications of such requirements on motorway traffic we see the risk that they can hinder innovation and limit the capability of new vehicles to have a positive effect on traffic flow. In particular for what concerns the assessment of the target line, the suggestion is to link it with a safety measure rather than constraining vehicle operations. For this reason, the only requirement requested is linked to the minimum TTC to be guaranteed to the upcoming vehicle in the current lane. The choice of 4s as minimum value for the TTC is motivated by the fact that this threshold 4s is the upper bound of TTC values proposed in literature to identify unsafe traffic situations according to Mahmud et al. (2018): Micro-Simulation Modelling for Traffic Safety: A Review and Potential Application to Heterogeneous Traffic Environment. IATSS Research, 2018. <https://doi.org/10.1016/j.iatssr.2018.07.002>;
- c. Solves the existing ambiguity on the performance requirements on ALKS vehicles introduced in paragraph 5.2.5. The current text indeed proposes two different performance requirement models for ALKS vehicles, one for cutting-in vehicles (as described in 5.2.5.2.) and another for all the other manoeuvres (as described in Appendix 3 to Annex 4). However the model described in Appendix 3 of Annex 4, does not identify any "unpreventable" traffic situation in scenarios other than cut-in. Since the performance requirement for the cut-in is set in another paragraph, the model presented in Appendix 3 of Annex 4 has not any actual role in the Regulation. At the same time we believe that for the case of the cut-in scenario the current approach proposed in 5.2.5.2. does not require a sufficient level of ambition to the first ALKS vehicles and, following the analysis of the state-of-the-art in the field, we proposed an alternative approach now fully described in Appendix 3 of Annex 4.



The Figure above shows a comparison of the unpreventable situations identified by the current requirement (referred to as Reg157), by the current model in Appendix 3 of Annex 4 (referred to as the JP model), by the RSS model and by the Fuzzy-based approach proposed in the present amendment, for the case of an ego vehicle proceeding at 130km/h and having another vehicle cutting-in at 40km/h. All the models use the same hypotheses in terms of reaction time and deceleration

capabilities of the ego vehicle. Still the proposed approach has a lower number of unpreventable cases compared to current approaches and solve some of the inconsistencies of the RSS model proposed by Intel Mobileye.

In line with the other approaches, the proposed model can be easily customized to be used for different vehicle categories, thus not creating problems to the amendment proposal to extend R157 to M2-M3-N2-N3 vehicles;

d. extends the list of test scenarios to additional relevant cases which are currently not included in the regulatory text and the two amendment proposals.