Submitted by the IWG on VMAD

Informal document **GRVA-05-19**
5th GRVA, 10-14 February 2020
Provisional agenda item 4(a)

Draft Appendix on Traffic Critical Scenarios to the Annex on audit/assessment to the new UN Regulation on Automated Lane Keeping systems (ALKS)

I. Justification

This informal document was drafted as an Appendix to the Annex 4 to the new regulation on Automated Lane Keeping systems (ALKS) to address 'scenarios" pillar especially for the traffic critical scenarios of the new test and assessment methods.

[This document reflects the ongoing investigation of the VMAD group to use scenarios for approval testing and is based on an attentive skilled driver model that reacts on a single most important object based on simulation. VMAD further investigates requirements for validation of more complex vehicle-environment interaction, transition of control and the possibilities of various types of simulation methods to validate specific requirements of the AD-functions.]

This document defines traffic critical scenarios for Annex 4 of the regulation which needs to be divided into preventable and unpreventable, according to the requirement in the regulation which stipulates:

"*The activated system shall not cause any collisions that are reasonably foreseeable and preventable.*"

Preventable scenarios are those where the validation should prove that ALKS does not result in an accident.

Unpreventable scenarios are those where the validation should prove that collision mitigation strategy of ALKS should be implemented in an accident.

II. Proposal

Appendix

Traffic critical scenarios for ALKS

1. Traffic critical scenarios

The following three are traffic critical scenarios:

- Cut-in: the 'other vehicle' merges in front of the 'ego vehicle'
- Cut-out: the 'other vehicle' exits the lane of the 'ego vehicle'
- Deceleration: the 'other vehicle' decelerates in front of the 'ego vehicle'

Each of these traffic critical scenarios can be created using the following parameters/elements:

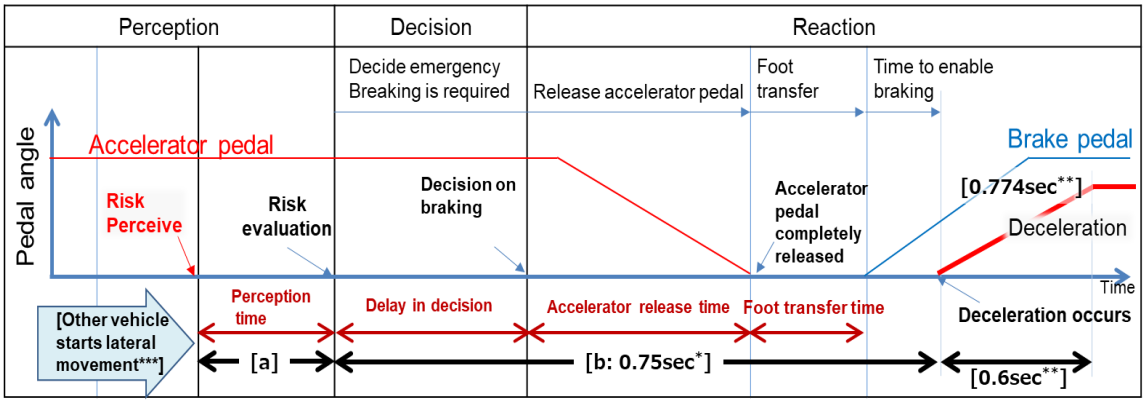
- Road geometry
- Ego vehicle's behavior/ manoeuvre
- Other vehicle's behavior/ manoeuvre

2. Performance model of ALKS

Traffic critical scenarios of ALKS are divided into preventable and unpreventable scenarios. They are determined based on the performance model of the ALKS shown below;

- Human driver with ADAS model

In low-speed ALKS scenario, the avoidance capability required for the driver model is braking control only. As a result, this driver model is separated into the following three segments: “Risk perceive situation”; “Delay in time”; and, “Deceleration degree and Max. G-force”. Following is a visual representation of these segments:

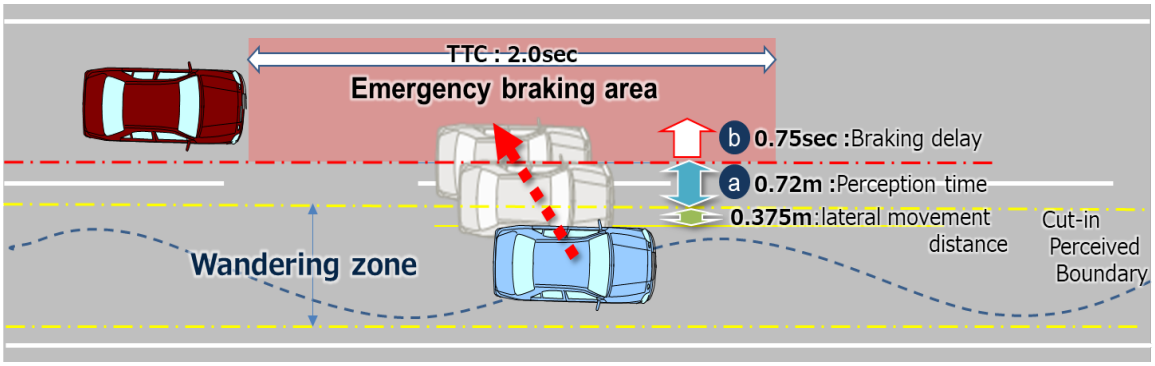


Note: [a] depend on each scenario

[*/ = 0.75sec is a common data in Japan.
**/ = 0.6sec and 0.774G are a data from experiments of NHTSA and Japan. (Coefficient of road friction is 0.6.)
***/= Timing of other vehicles start moving from lane keep to cut-in (or cut-out). It is indicated by lateral movement distance.

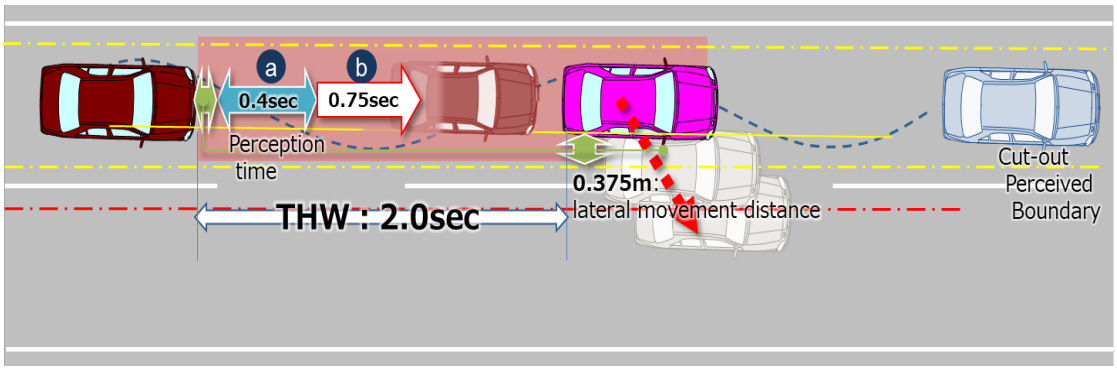
2.1. Driver model for the three ALKS scenarios:

2.1.1. 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 (prior to lane change)
[a] is perception distance. It defines the distance required to perceive that a vehicle is executing a cut-in manoeuvre [a] is obtained from the following formula;
[a:0.72m] = (Max lateral movement speed: 1.8m/s) x (Risk perception time: 0.4sec)
Max lateral movement speed is real world data in Japan.
Risk perception time is driving simulator data in Japan.
[2sec*] is specified as the maximum Time To Collision (TTC) for which we conclude that there is a danger in the longitudinal direction.
[*/=TTC 2.0sec is based on the UNR guidelines on warning signals.]

2.1.2. For Cut out scenario:



The lateral movement distance of leading vehicle when it starts lateral movement is [0.375m]. This parameter is skilled human driver that assumes a critical situation when leading vehicle moves [0.375m].
[a:0.4sec] is perception time (= delay in risk evaluation). Risk perceived position of side vehicle is determined by lateral movement speed of it.
[2sec**] is specified as the maximum Time Head Way (THW) for which we conclude that there is a danger in longitudinal direction.

[**/=THW 2.0sec is according to other countries' regulations and guidelines.]

2.1.3. For Deceleration scenario:

The delay in perception (= Risk evaluation delay time) is [a:0.4sec]. Risk perceived timing of leading vehicle is determined by deceleration rate of it.

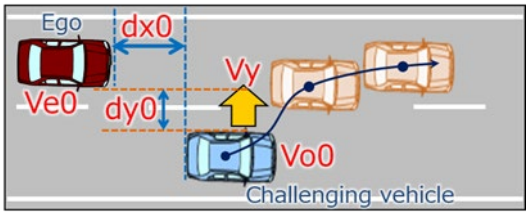
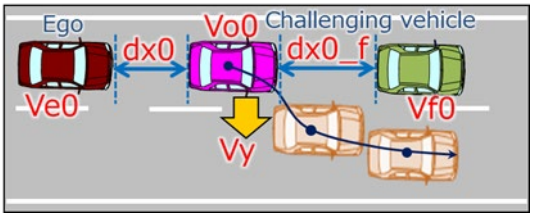
2.2. Parameters

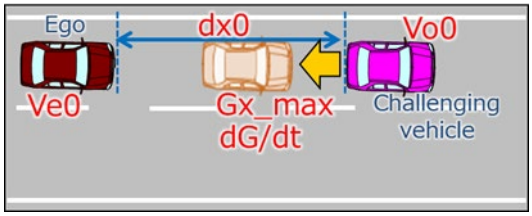
Parameters below are essential when describing the pattern of the traffic critical scenarios in section 2.1.

Additional parameters could be added according to the ODD/OD (e.g. friction rate of the road).

Initial condition	Initial velocity	**Ve0** = Ego vehicle
		Vo0 = Leading vehicle in lane or in adjacent lane
		Vf0 = Vehicle in front of leading vehicle in lane
	Initial distance	**dx0** = Distance in Longitudinal direction between ego and leading vehicle in lane or in adjacent lane
		dy0 = 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 another vehicle in parallel to the vehicle's median longitudinal plane in adjacent lines.
		dx0_f = Distance in longitudinal direction between front end of leading vehicle and rear end of vehicle in front of leading vehicle
Vehicle motion	Lateral motion	**Vy** = Lateral velocity
	Deceleration	**Gx_max** = Maximum deceleration G
		dG/dt = Deceleration rate (Jerk)

Following are visual representations of parameters for the three types of scenarios

Cut in	
Cut out	

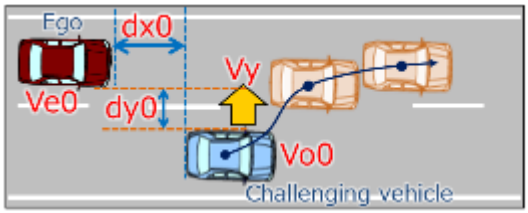
Deceleration	

2.3. Data sheet

In addition to the above-mentioned driver models, following data sheets are available for checking within each scenario if the ADS would avoid a collision, taking into account any combination of each parameter within the vehicle speed that ALKS is able to function.

2.3.1. Cut in

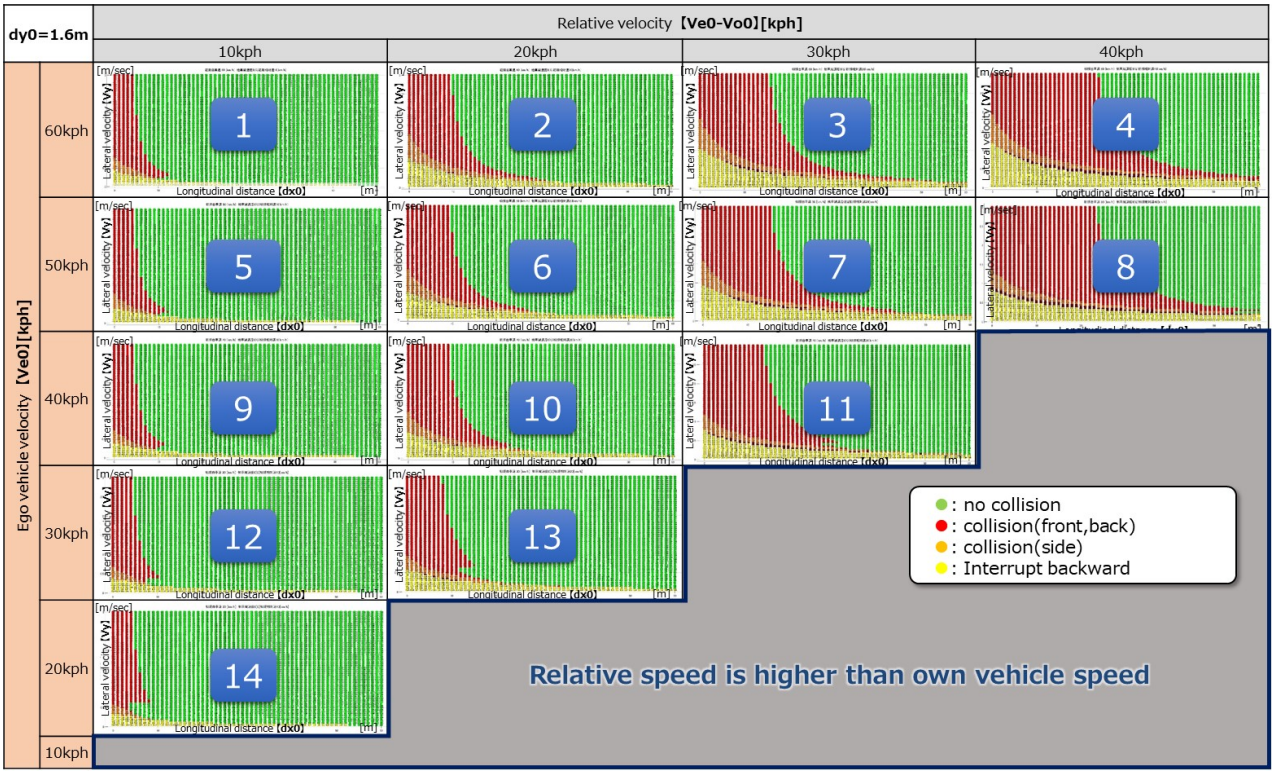
(Data sheets image)



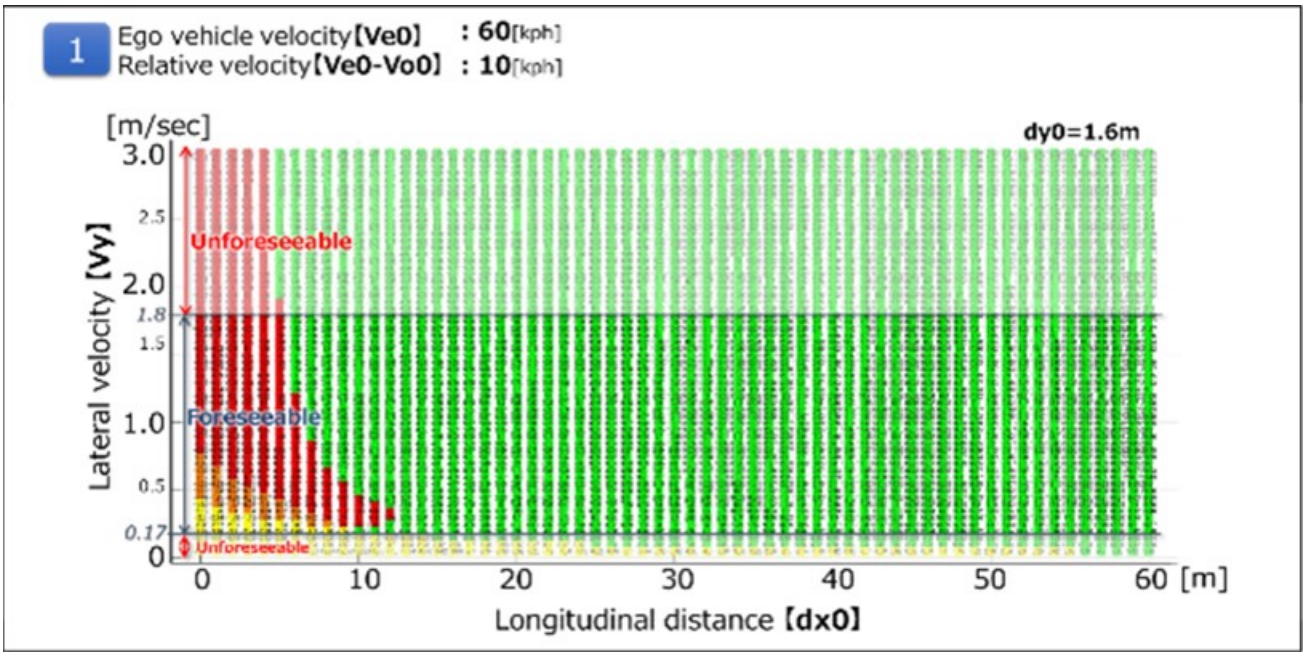
Initial condition	Initial velocity	**【Ve0】**	Ego vehicle velocity
		【Ve0-Vo0】	Relative velocity
	Initial distance	**【dy0】**	Latteral distance※
		【dx0】	Longitudinal distance
Vehicle motion	Lateral motion	**【Vy】**	Lateral velocity

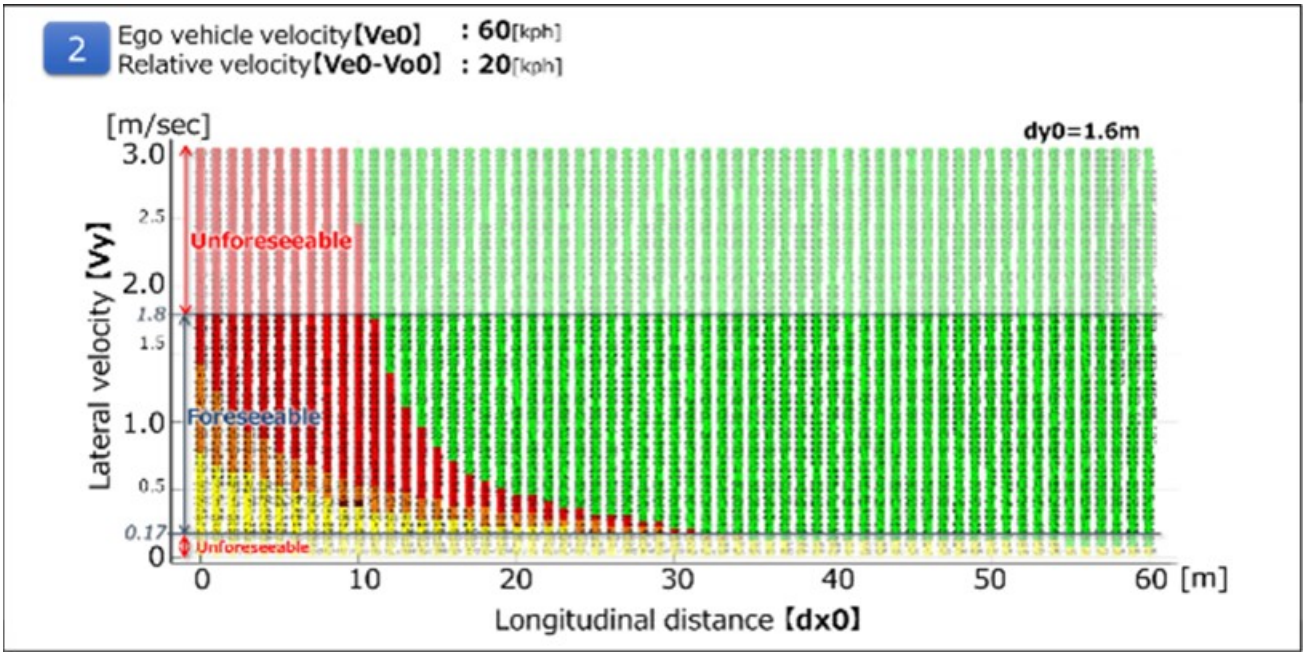
※Latteral distance

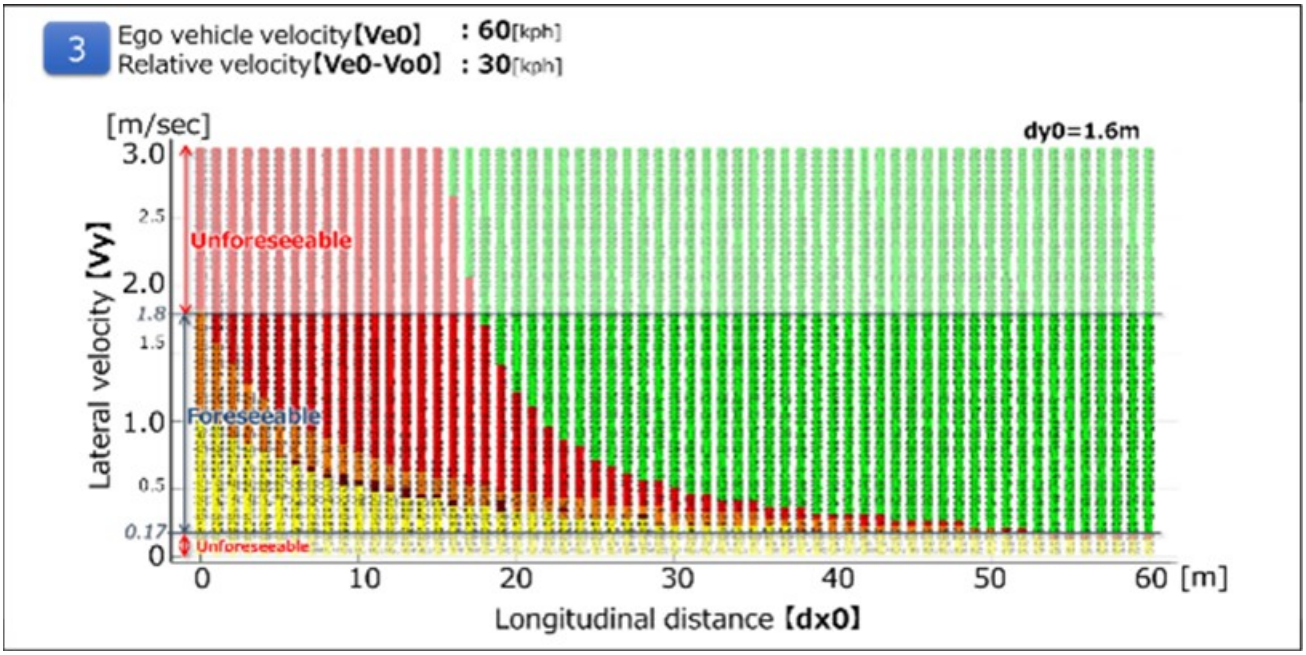
ex) Lane width : 3.5[m]
Vehicle width:1.9[m]
Driving in the center of the lane
dy=1.6[m]

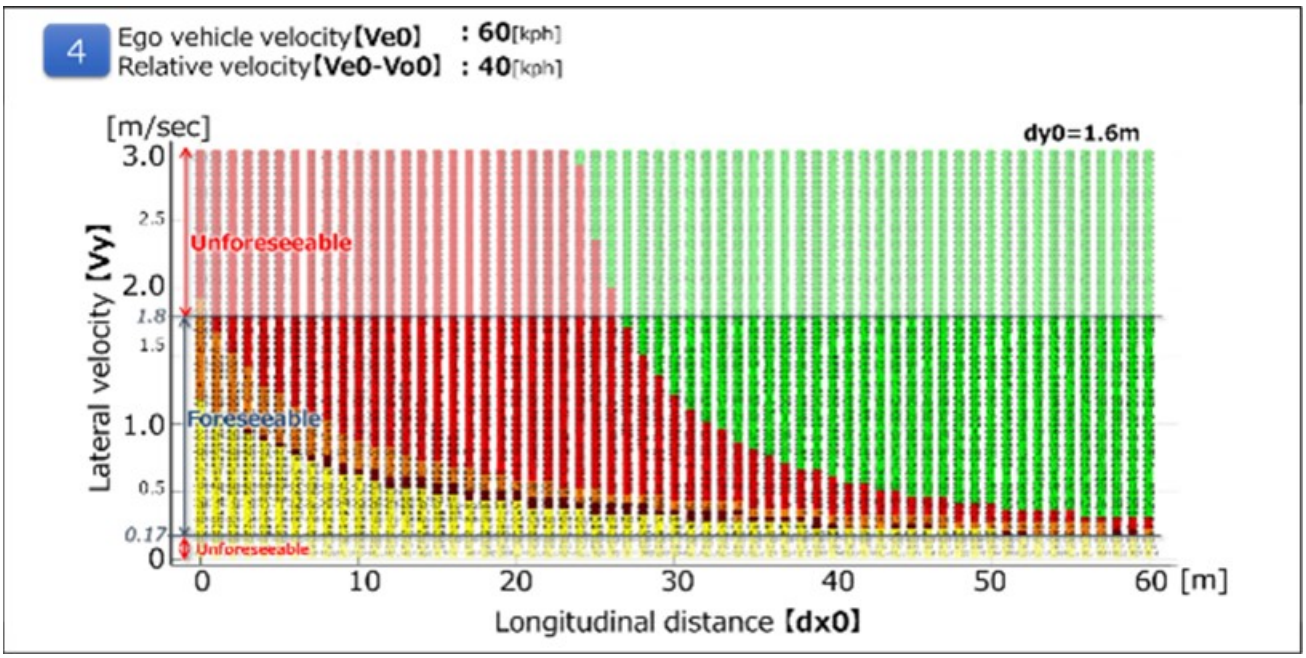


Ve0：60[kph]

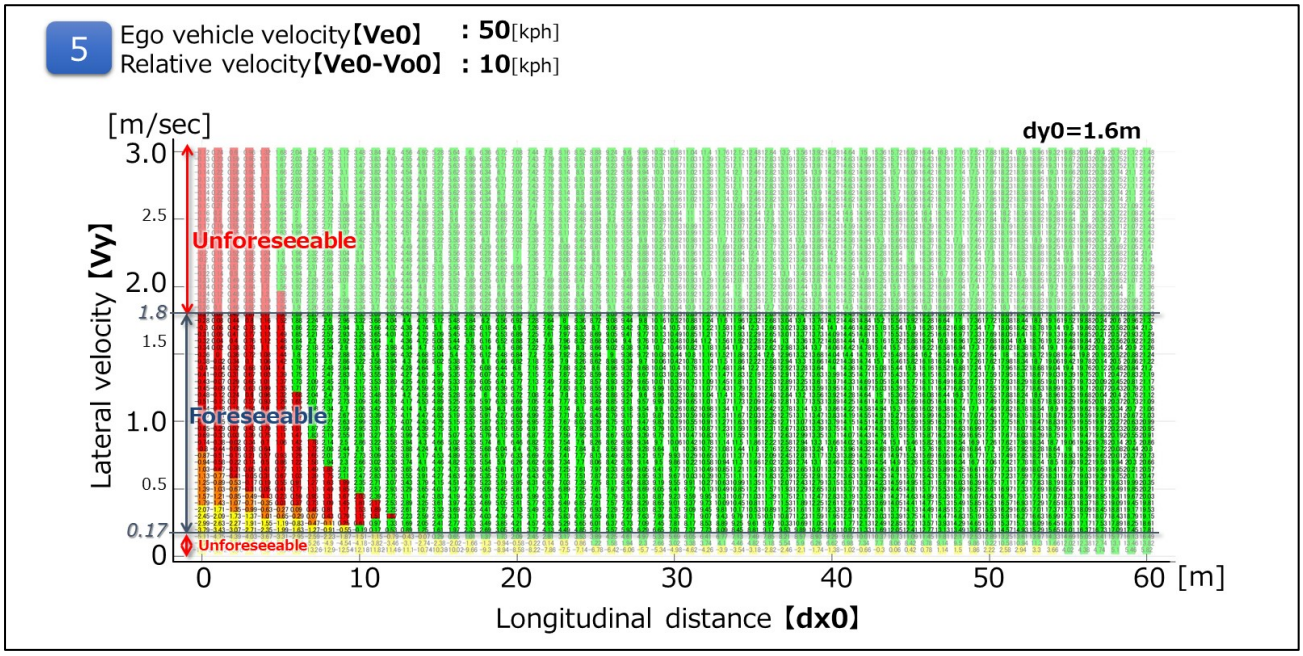

1
Ego vehicle velocity【Ve0】 : 60[kph]
Relative velocity【Ve0-Vo0】 : 10[kph]
[m/sec]
dy0=1.6m
3.0
2.5
2.0
1.8
1.5
1.0
0.5
0.17
0
Unforeseeable
Foreseeable
Unforeseeable
Lateral velocity【Vy】
0
10
20
30
40
50
60 [m]
Longitudinal distance【dx0】

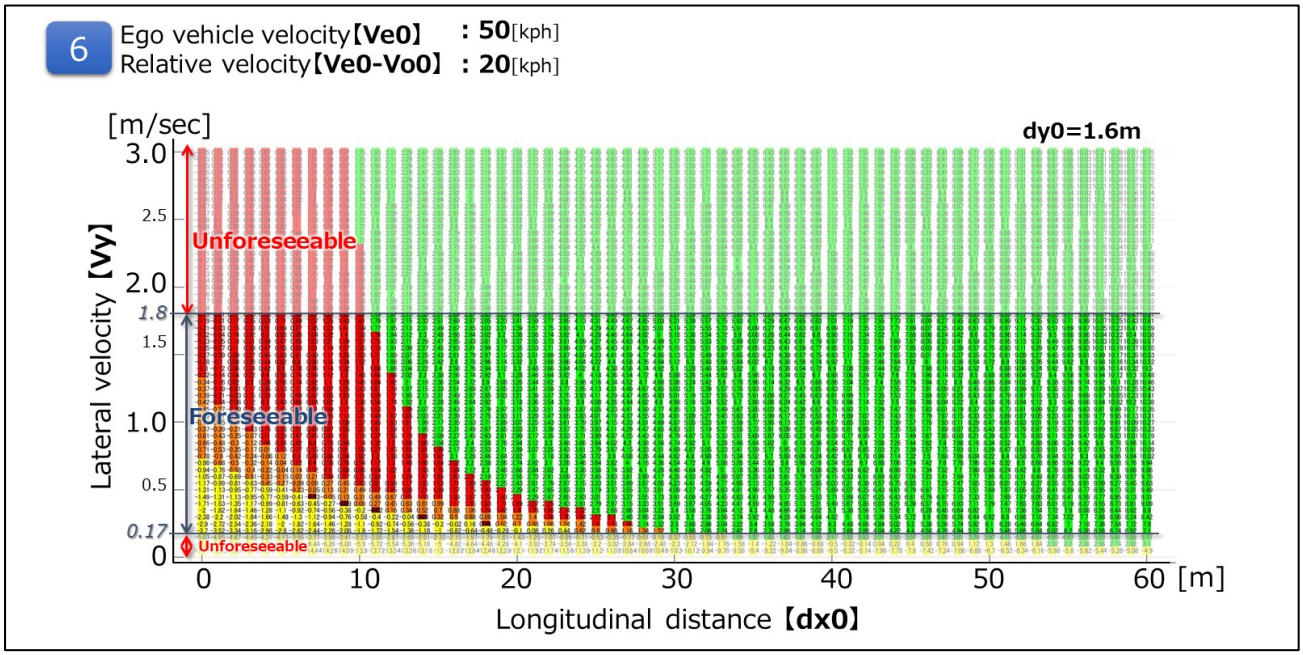

2
Ego vehicle velocity【Ve0】 : 60[kph]
Relative velocity【Ve0-Vo0】 : 20[kph]
[m/sec]
dy0=1.6m
3.0
2.5
2.0
1.8
1.5
1.0
0.5
0.17
0
Unforeseeable
Foreseeable
Unforeseeable
Lateral velocity【Vy】
0
10
20
30
40
50
60 [m]
Longitudinal distance【dx0】

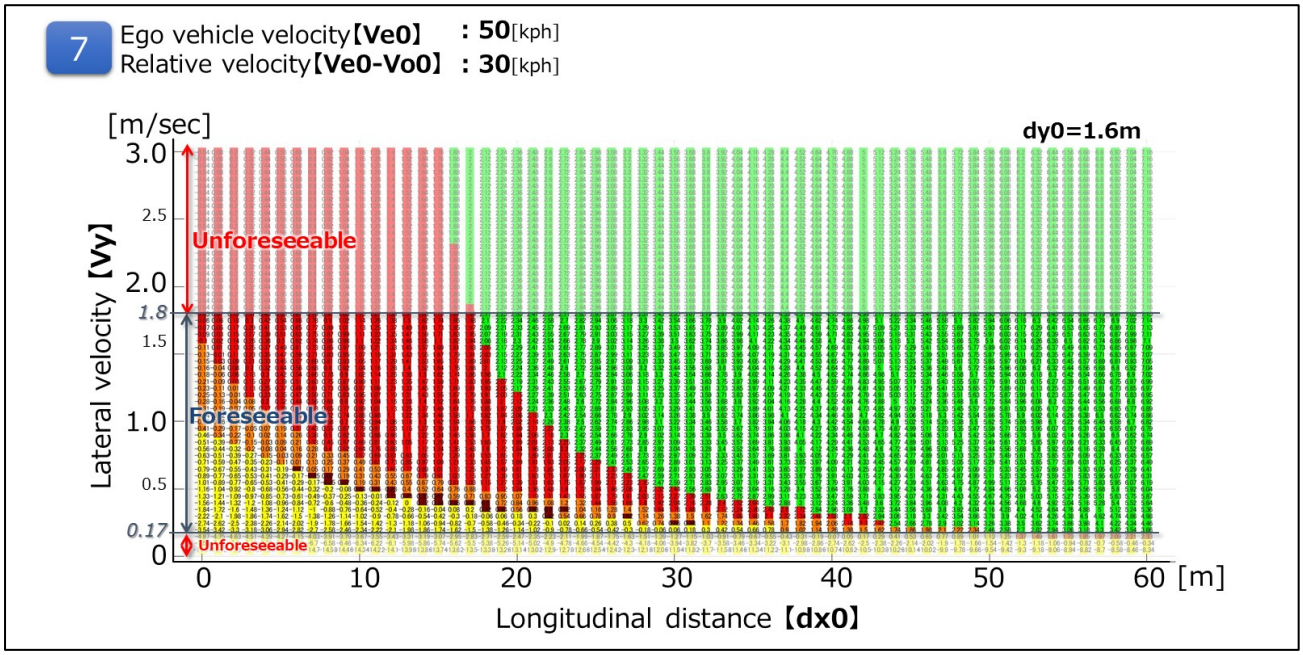

3
Ego vehicle velocity【Ve0】 : 60[kph]
Relative velocity【Ve0-Vo0】 : 30[kph]
[m/sec]
dy0=1.6m
3.0
2.5
2.0
1.8
1.5
1.0
0.5
0.17
0
Unforeseeable
Foreseeable
Unforeseeable
Lateral velocity【Vy】
0
10
20
30
40
50
60 [m]
Longitudinal distance【dx0】

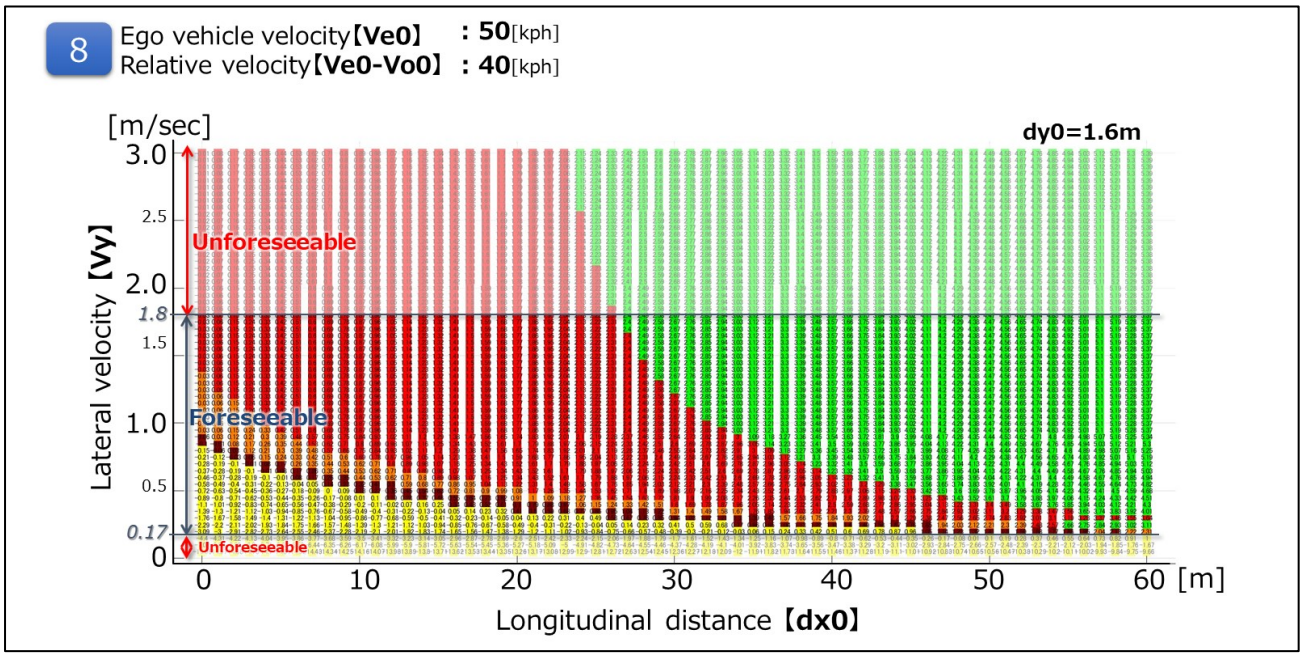

4
Ego vehicle velocity【Ve0】 : 60[kph]
Relative velocity【Ve0-Vo0】 : 40[kph]
[m/sec]
dy0=1.6m
3.0
2.5
2.0
1.8
1.5
1.0
0.5
0.17
0
Unforeseeable
Foreseeable
Unforeseeable
Lateral velocity【Vy】
0
10
20
30
40
50
60 [m]
Longitudinal distance【dx0】

Ve0：50[kph]

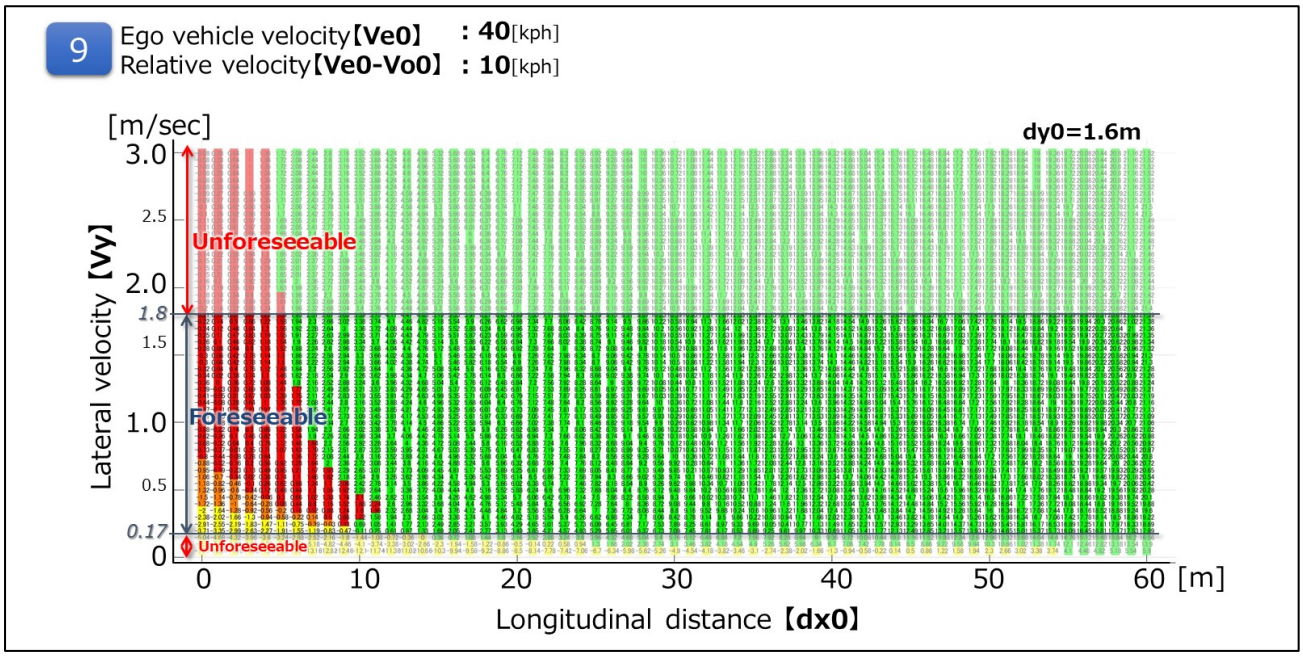

5
Ego vehicle velocity【Ve0】 : 50[kph]
Relative velocity【Ve0-Vo0】 : 10[kph]
[m/sec]
dy0=1.6m
Lateral velocity【Vy】
Unforeseeable
Foreseeable
Unforeseeable
3.0
2.5
2.0
1.8
1.5
1.0
0.5
0.17
0
0
10
20
30
40
50
60 [m]
Longitudinal distance【dx0】

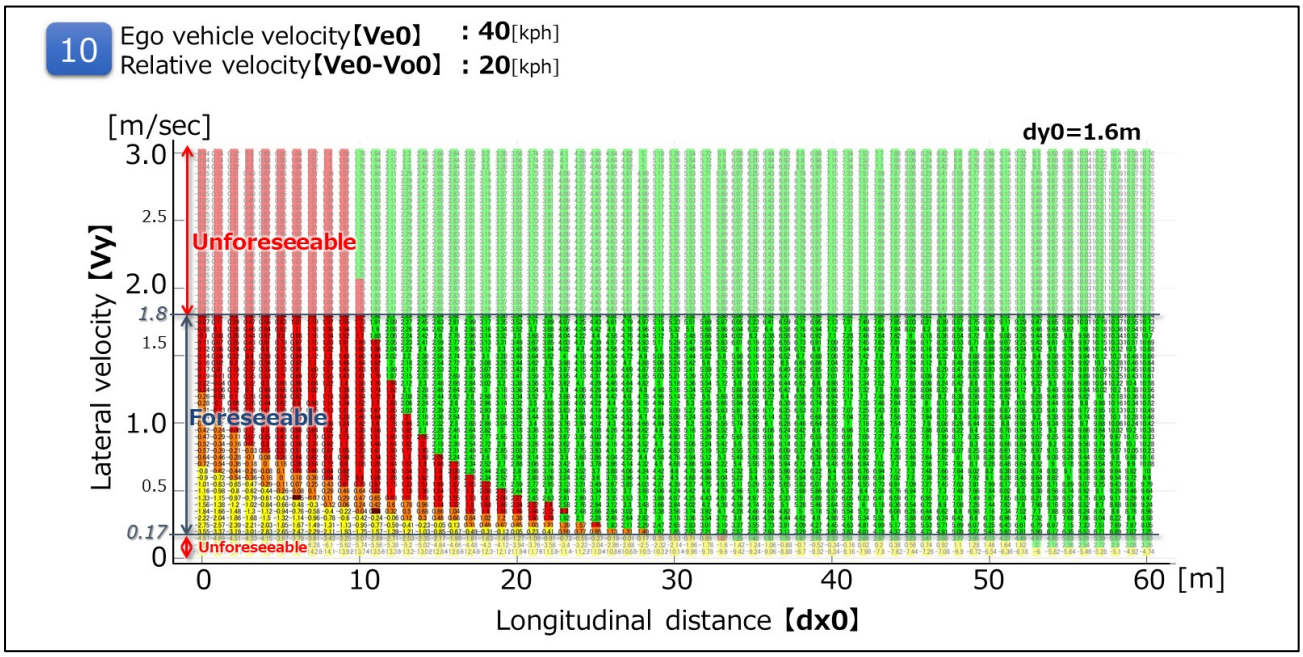

6
Ego vehicle velocity【Ve0】 : 50[kph]
Relative velocity【Ve0-Vo0】 : 20[kph]
[m/sec]
dy0=1.6m
Lateral velocity【Vy】
Unforeseeable
Foreseeable
Unforeseeable
3.0
2.5
2.0
1.8
1.5
1.0
0.5
0.17
0
0
10
20
30
40
50
60 [m]
Longitudinal distance【dx0】

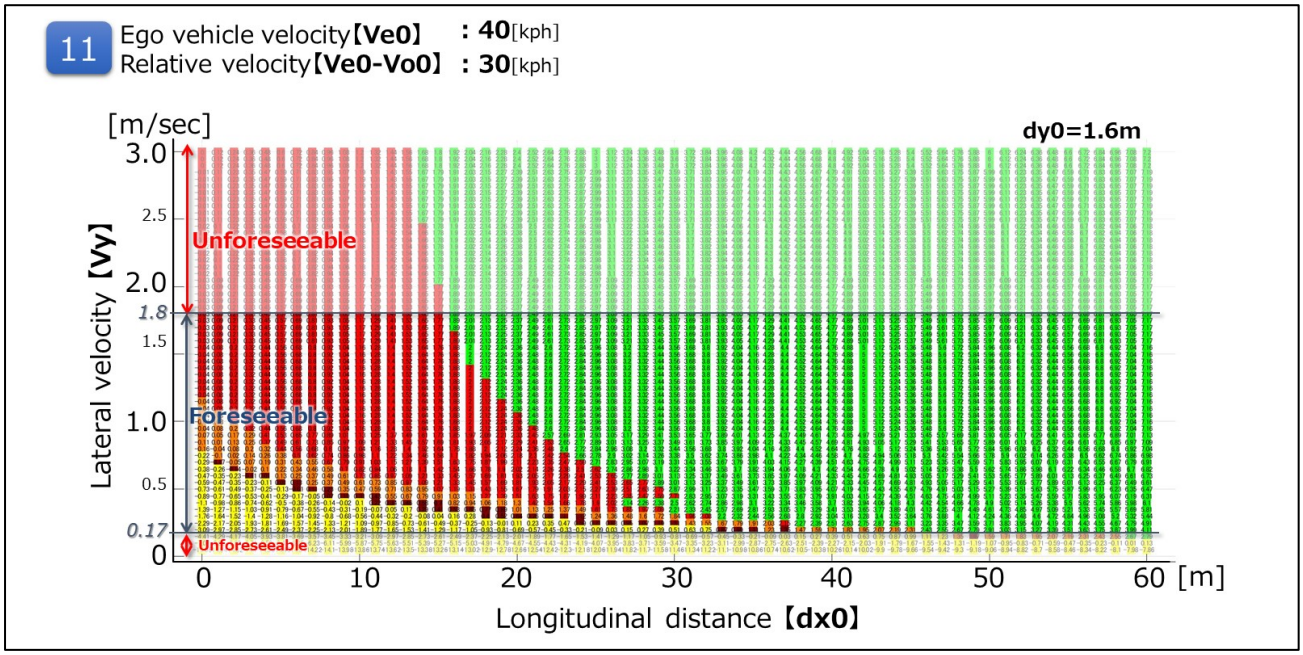

7
Ego vehicle velocity【Ve0】 : 50[kph]
Relative velocity【Ve0-Vo0】 : 30[kph]
[m/sec]
dy0=1.6m
Unforeseeable
Foreseeable
Unforeseeable
Lateral velocity【Vy】
3.0
2.5
2.0
1.8
1.5
1.0
0.5
0.17
0
0
10
20
30
40
50
60 [m]
Longitudinal distance【dx0】


8
Ego vehicle velocity【Ve0】 : 50[kph]
Relative velocity【Ve0-Vo0】 : 40[kph]
[m/sec]
dy0=1.6m
Unforeseeable
Foreseeable
Unforeseeable
Lateral velocity【Vy】
3.0
2.5
2.0
1.8
1.5
1.0
0.5
0.17
0
0
10
20
30
40
50
60 [m]
Longitudinal distance【dx0】

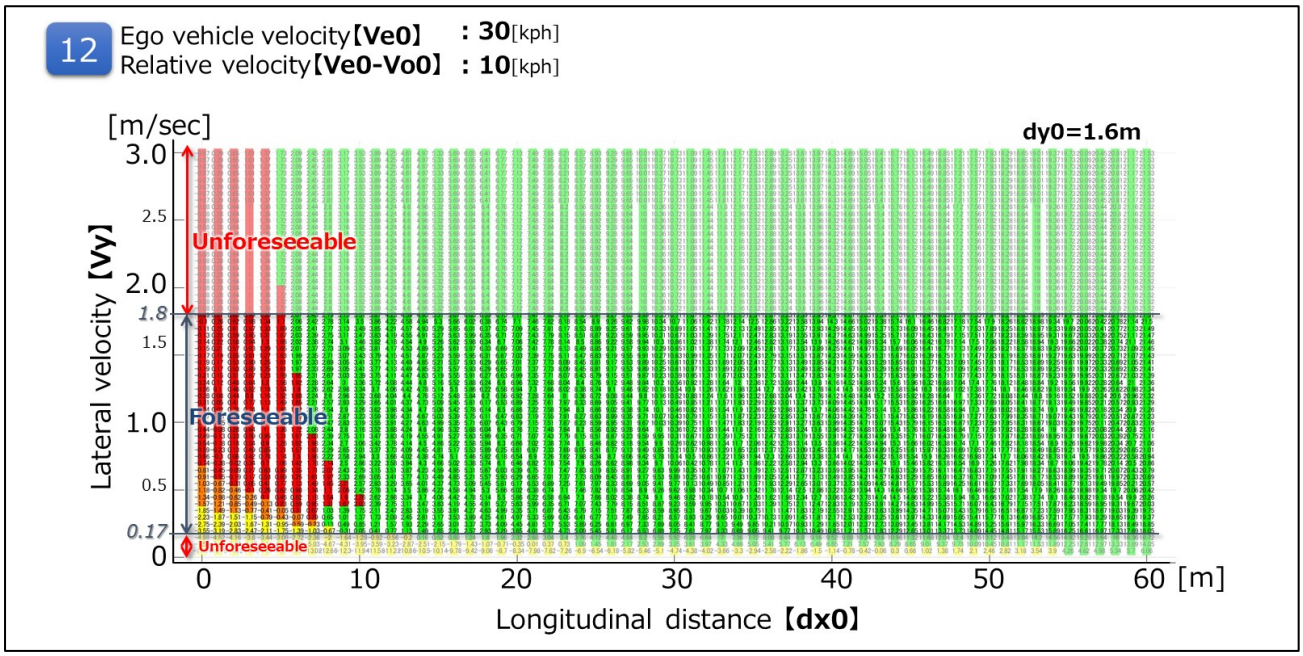
Ve0：40[kph]

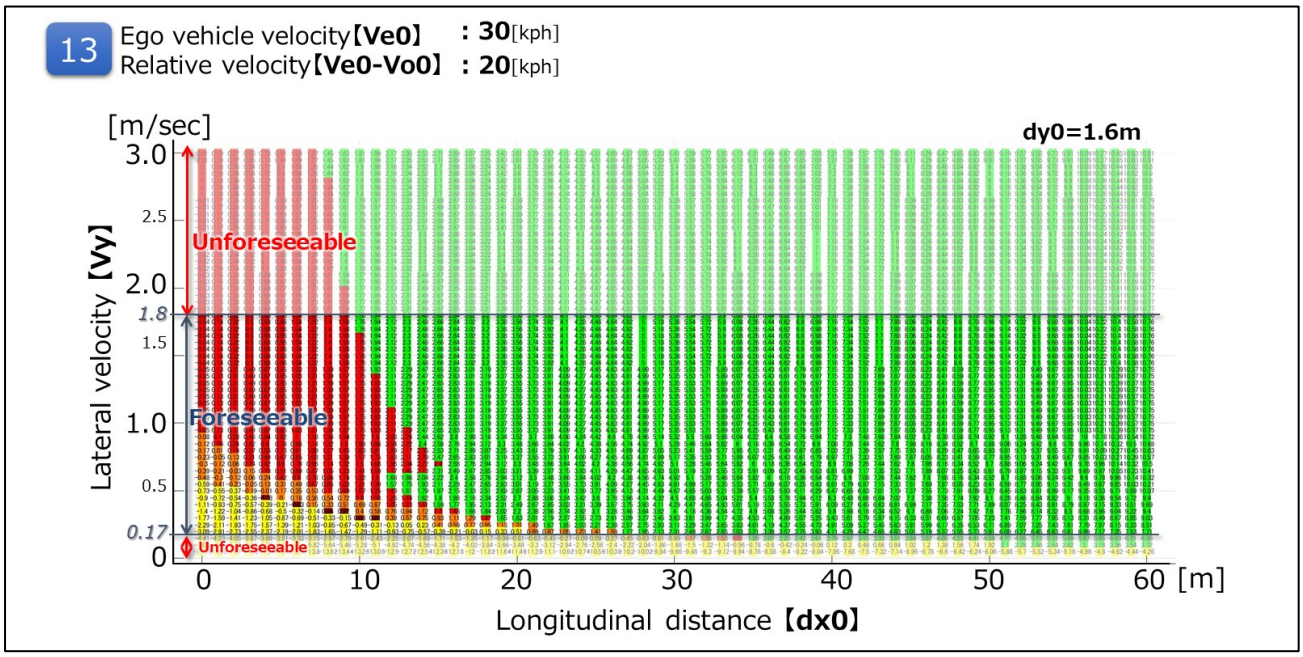

9
Ego vehicle velocity【Ve0】 : 40[kph]
Relative velocity【Ve0-Vo0】 : 10[kph]
[m/sec]
dy0=1.6m
Lateral velocity【Vy】
3.0
2.5
2.0
1.8
1.5
1.0
0.5
0.17
0
Unforeseeable
Foreseeable
Unforeseeable
0
10
20
30
40
50
60 [m]
Longitudinal distance【dx0】


10
Ego vehicle velocity【Ve0】 : 40[kph]
Relative velocity【Ve0-Vo0】 : 20[kph]
[m/sec]
dy0=1.6m
Lateral velocity【Vy】
3.0
2.5
2.0
1.8
1.5
1.0
0.5
0.17
0
Unforeseeable
Foreseeable
Unforeseeable
0
10
20
30
40
50
60 [m]
Longitudinal distance【dx0】

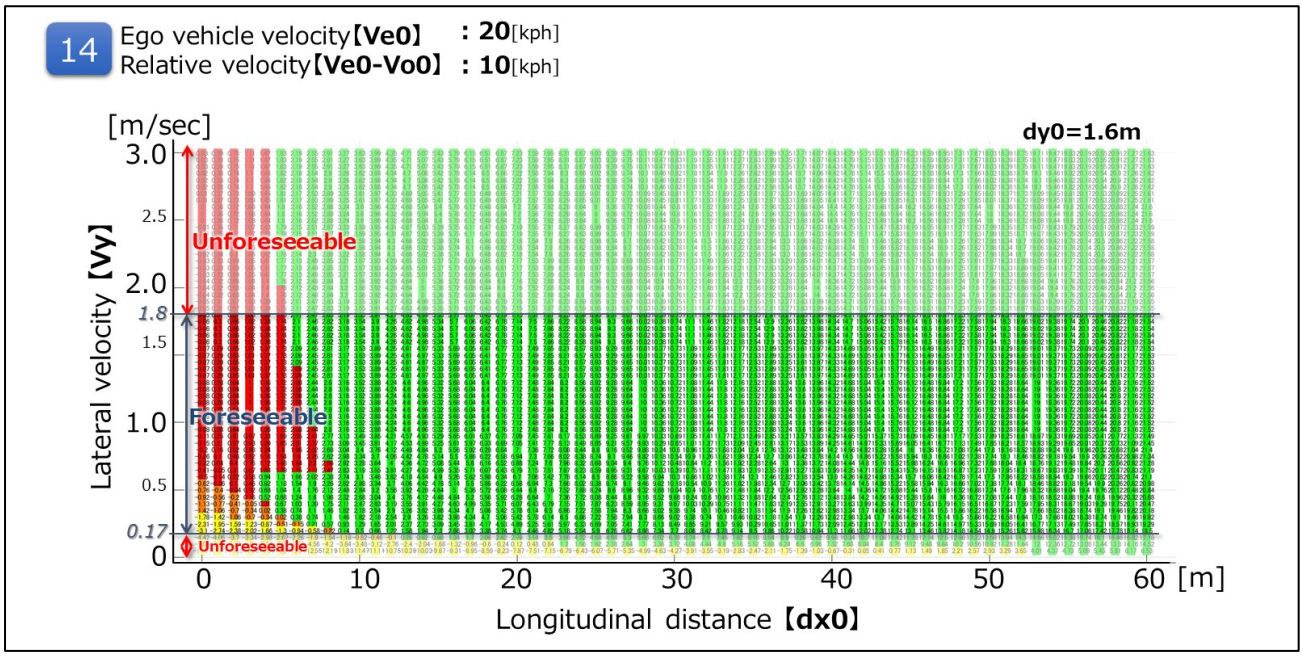

11
Ego vehicle velocity【Ve0】 : 40[kph]
Relative velocity【Ve0-Vo0】 : 30[kph]
[m/sec]
dy0=1.6m
3.0
2.5
2.0
1.8
1.5
1.0
0.5
0.17
0
Unforeseeable
Foreseeable
Unforeseeable
Lateral velocity【Vy】
0
10
20
30
40
50
60 [m]
Longitudinal distance【dx0】

Ve0：30[kph]


12
Ego vehicle velocity【Ve0】 : 30[kph]
Relative velocity【Ve0-Vo0】 : 10[kph]
[m/sec]
dy0=1.6m
Lateral velocity【Vy】
3.0
2.5
2.0
1.8
1.5
1.0
0.5
0.17
0
Unforeseeable
Foreseeable
Unforeseeable
0
10
20
30
40
50
60 [m]
Longitudinal distance【dx0】


13
Ego vehicle velocity【Ve0】 : 30[kph]
Relative velocity【Ve0-Vo0】 : 20[kph]
[m/sec]
dy0=1.6m
Lateral velocity【Vy】
3.0
2.5
2.0
1.8
1.5
1.0
0.5
0.17
0
Unforeseeable
Foreseeable
Unforeseeable
0
10
20
30
40
50
60 [m]
Longitudinal distance【dx0】

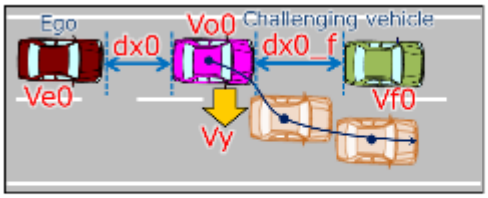
Ve0：20[kph]


14
Ego vehicle velocity【Ve0】 : 20[kph]
Relative velocity【Ve0-Vo0】 : 10[kph]
[m/sec]
dy0=1.6m
3.0
2.5
2.0
1.8
1.5
1.0
0.5
0.17
0
Unforeseeable
Foreseeable
Unforeseeable
Lateral velocity【Vy】
0
10
20
30
40
50
60 [m]
Longitudinal distance【dx0】

2.3.2 Cut out

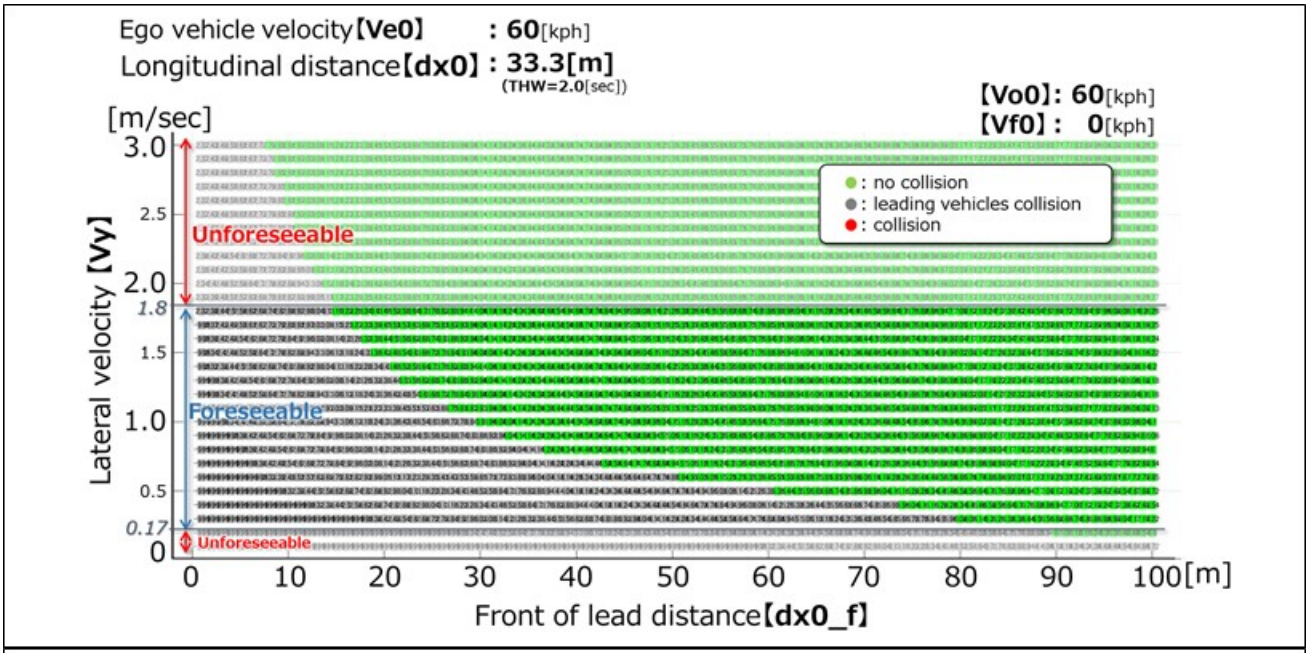
It is possible to avoid all the deceleration (stop) vehicles ahead of the preceding vehicle cut-out in the following running condition at THW 2.0 sec.

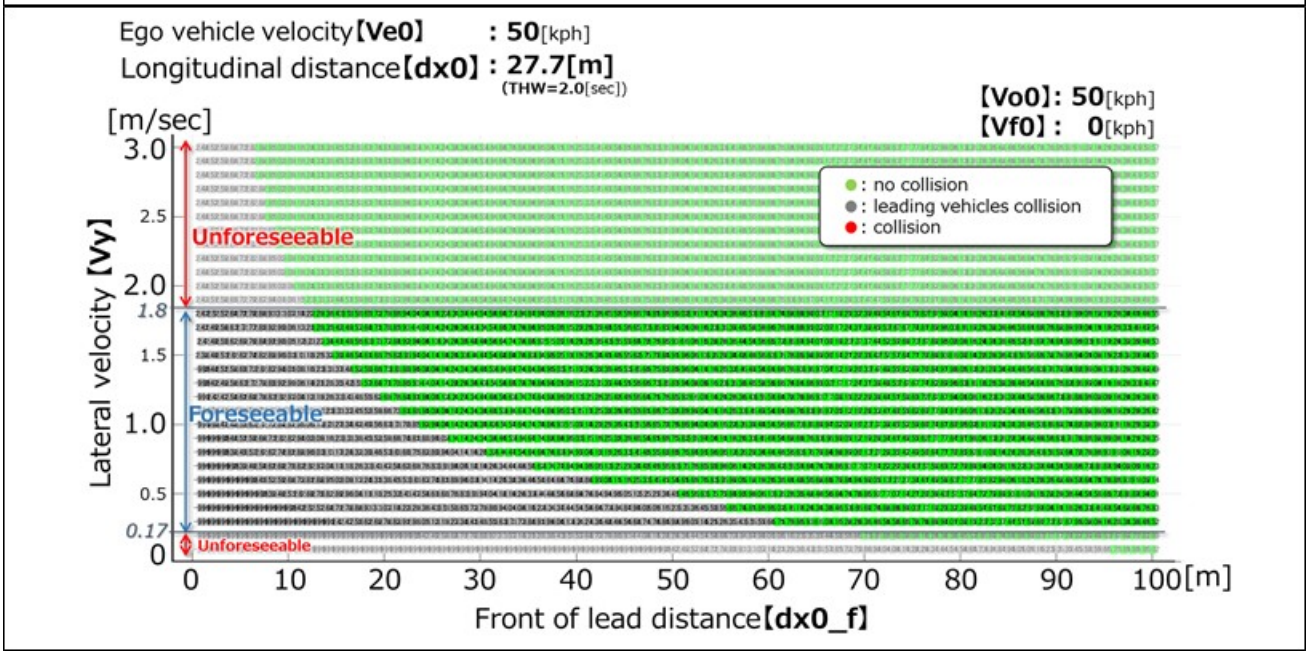
(Data sheets image)

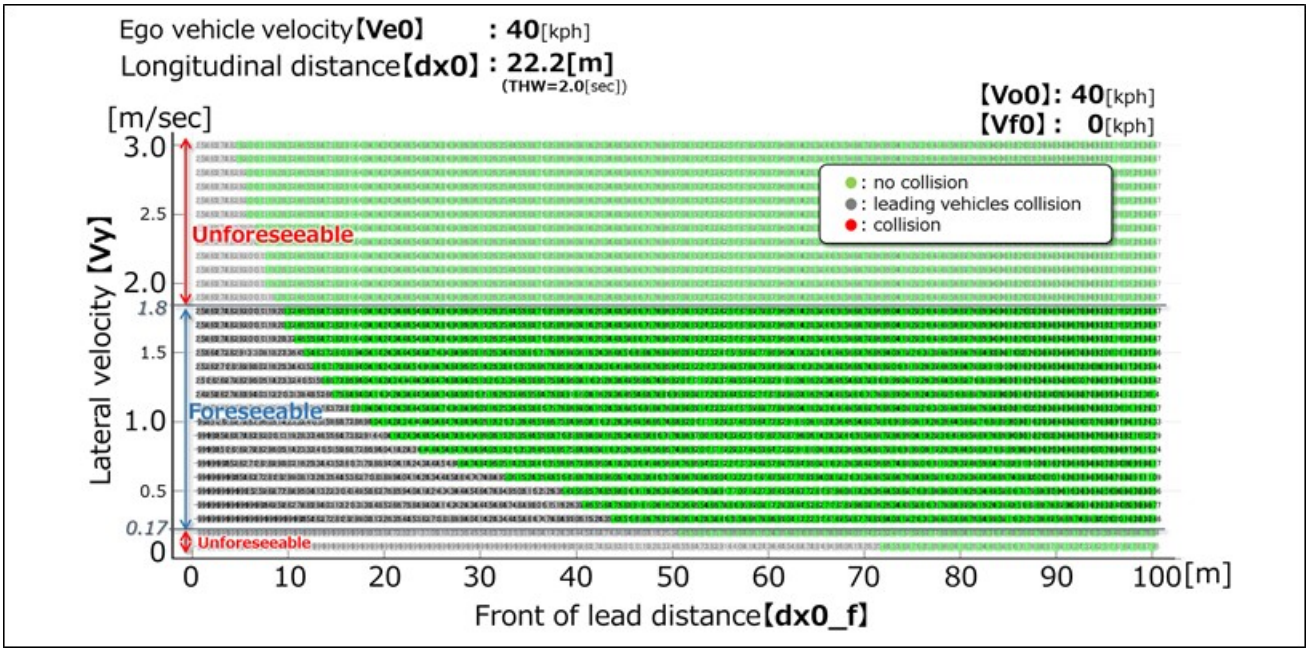


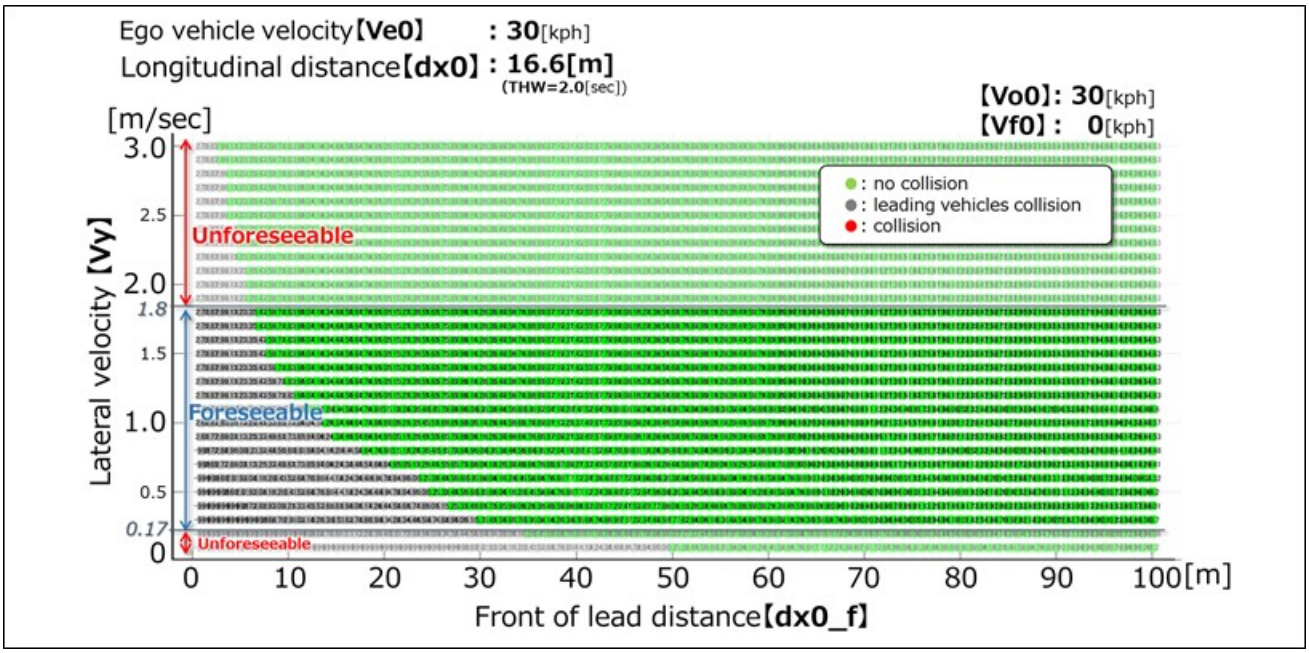
Initial condition	Initial velocity	**【Ve0】**	Ego vehicle velocity
		【Vo0】	Leading vehicle velocity
		【Vf0】	Vehicle in front of leading vehicle
	Initial distance	**【dx0】**	Longitudinal distance※
		【dx0_f】	Front of lead distance
Vehicle motion	Lateral motion	**【Vy】**	Lateral velocity

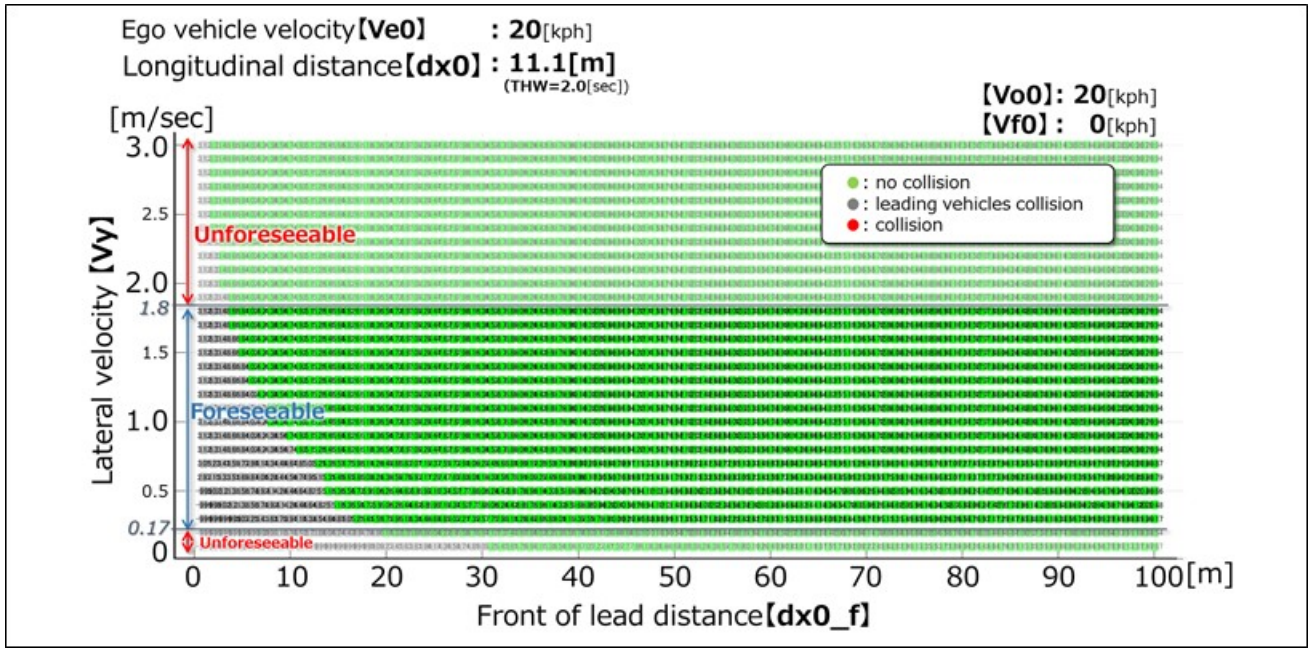
※ Follow the leading vehicle in THW=2sec
Vo0 = Ve0(Same speed as the leading vehicle)
Vf0 = 0 (stop vehicle)

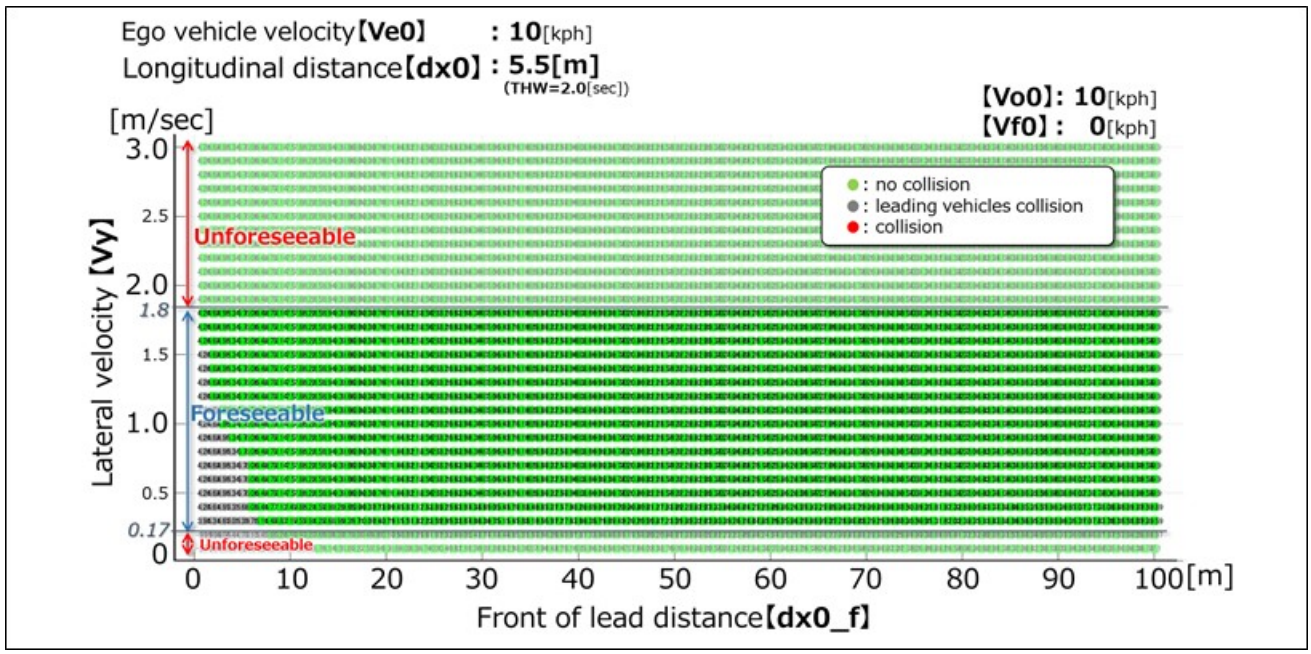





Ego vehicle velocity【Ve0】 : 40[kph]
Longitudinal distance【dx0】 : 22.2[m]
(THW=2.0[sec])
【Vo0】: 40[kph]
【Vf0】 : 0[kph]
[m/sec]
3.0
2.5
2.0
1.8
1.5
1.0
0.5
0.17
0
Unforeseeable
Foreseeable
Unforeseeable
: no collision
: leading vehicles collision
: collision
Lateral velocity【Vy】
0 10 20 30 40 50 60 70 80 90 100[m]
Front of lead distance【dx0_f】


Ego vehicle velocity【Ve0】 : 30[kph]
Longitudinal distance【dx0】 : 16.6[m]
(THW=2.0[sec])
【Vo0】: 30[kph]
【Vf0】 : 0[kph]
[m/sec]
3.0
2.5
2.0
1.8
1.5
1.0
0.5
0.17
0
Unforeseeable
Foreseeable
Unforeseeable
: no collision
: leading vehicles collision
: collision
Lateral velocity【Vy】
0 10 20 30 40 50 60 70 80 90 100[m]
Front of lead distance【dx0_f】

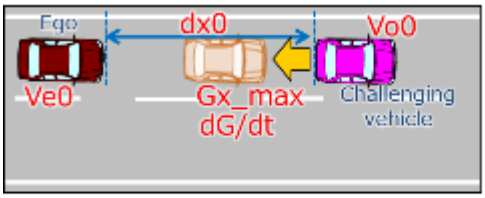

Ego vehicle velocity【Ve0】 : 20[kph]
Longitudinal distance【dx0】 : 11.1[m]
(THW=2.0[sec])
【Vo0】: 20[kph]
【Vf0】 : 0[kph]
[m/sec]
3.0
2.5
2.0
1.8
1.5
1.0
0.5
0.17
0
Unforeseeable
Foreseeable
Unforeseeable
: no collision
: leading vehicles collision
: collision
Lateral velocity【Vy】
0 10 20 30 40 50 60 70 80 90 100[m]
Front of lead distance【dx0_f】

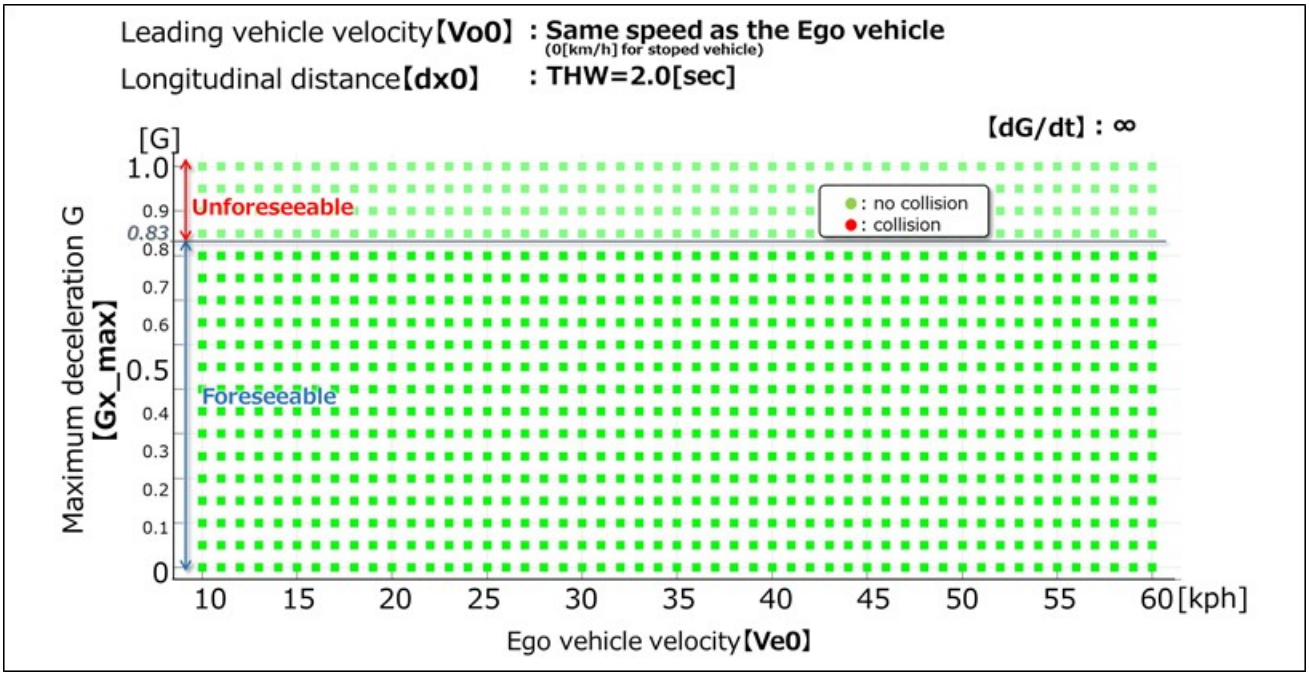

Ego vehicle velocity【Ve0】 : 10[kph]
Longitudinal distance【dx0】 : 5.5[m]
(THW=2.0[sec])
【Vo0】: 10[kph]
【Vf0】 : 0[kph]
[m/sec]
3.0
2.5
2.0
1.8
1.5
1.0
0.5
0.17
0
Unforeseeable
Foreseeable
Unforeseeable
: no collision
: leading vehicles collision
: collision
Lateral velocity【Vy】
0 10 20 30 40 50 60 70 80 90 100[m]
Front of lead distance【dx0_f】

2.3.3. 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	**【Ve0】**	Ego vehicle velocity
		【Vo0】	Leading vehicle velocity
	Initial distance	**【dx0】**	Longitudinal distance※1
Vehicle motion	Deceleration	**【Gx_max】**	Maximum deceleration G
		【dG/dt】	Deceleration rate※2

※1 Follow the leading vehicle in THW=2sec
Vo0 = Ve0(Same speed as the leading vehicle)
※2 The most severe conditions ∞