Informal Document VMAD-03-05
3rd VMAD IWG, July 1-2,2019
Agenda item X.

Safety Criteria study for New Assessment/Test Methods of Automated Driving System (3rd Report)

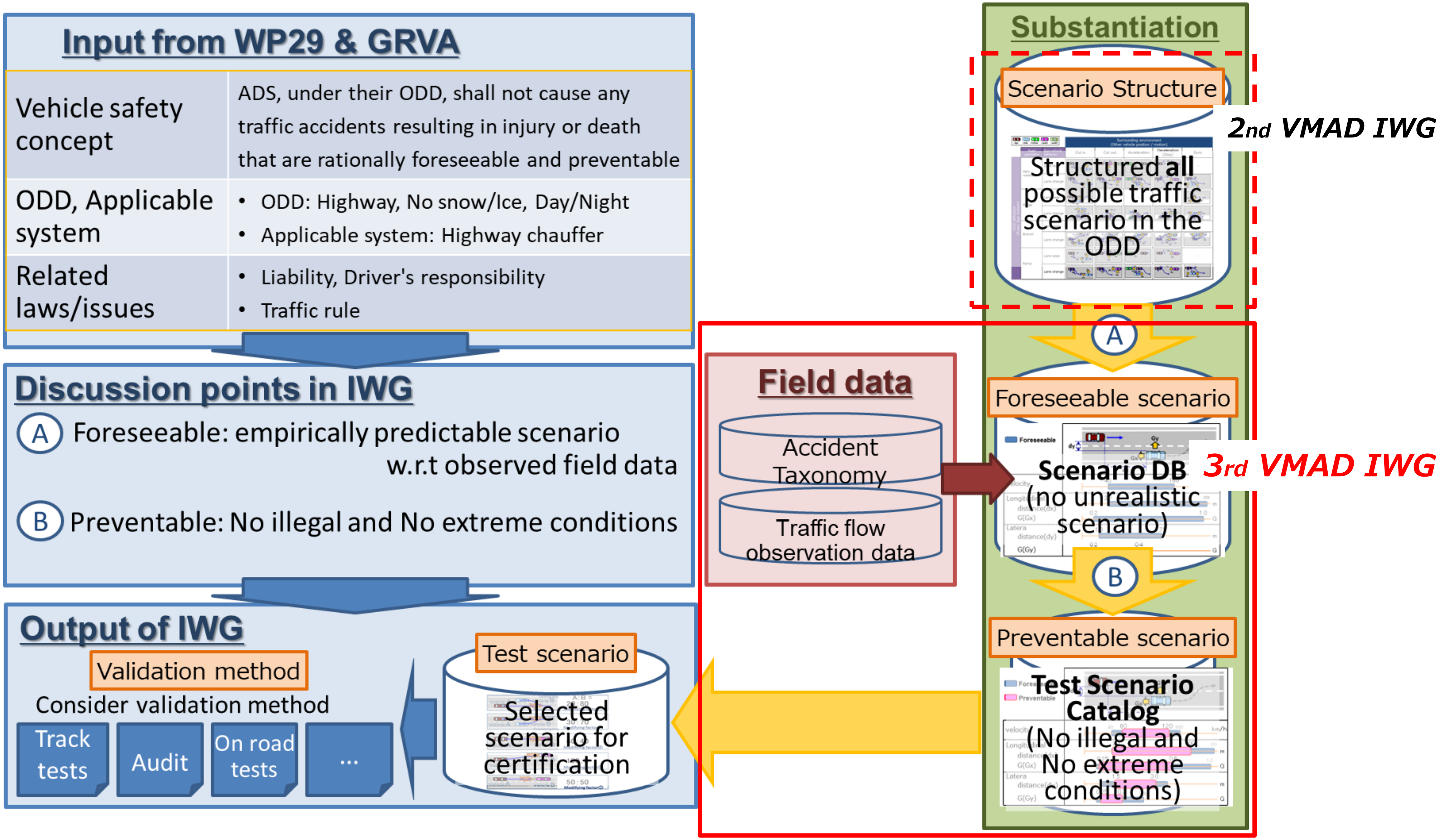
July 1-2, 2019

Transmitted by the expert of Japan

Overall approach

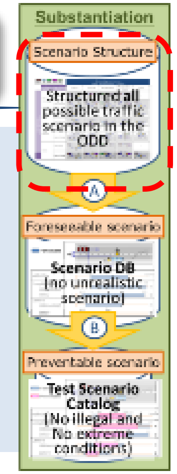
Reprint

3. Structure of the translation process with an example



Traffic Scenario Structure

Reprint

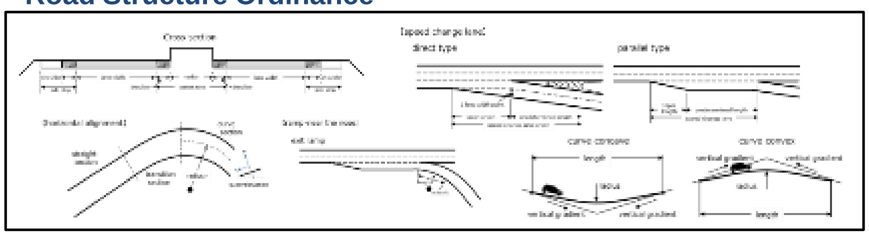


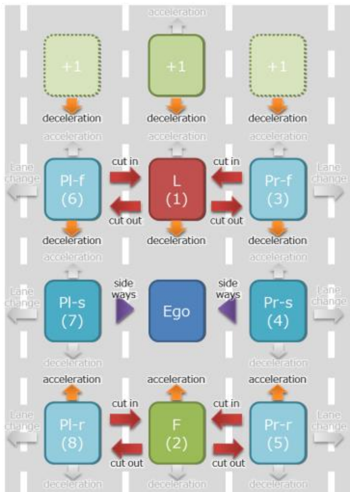
1. Extract the most demanding parameter from real environment data for each road geometry classification based existing laws and regulations.
2. Define 8+1 position around ego-vehicle and movement which can invade the ego trajectory.
Basically, traffic disturbance scenario can be described with two vehicles

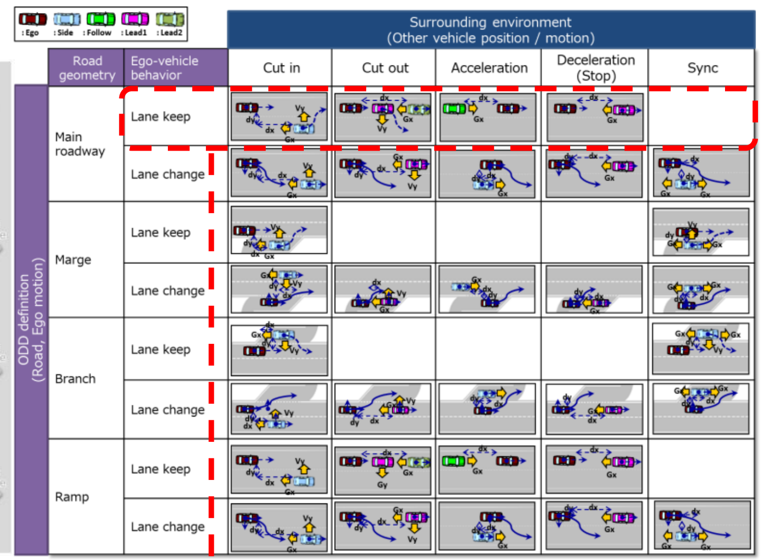
1 Road geometry ✖ Ego-vehicle behavior ✖ 2 Traffic participants' position ✖ surrounding vehicle behavior

Road geometry		Ego-vehicle behavior	
		Lane keep	Lane change
Road geometry	Main roadway	Free Driving Following	Lane change Overtaking
	Merge	Merging in front	Merge
	Branch	---	Branch
	Ramp	Free Driving Following	Lane change Overtaking

Road Structure Ordinance

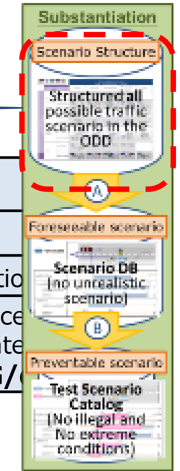




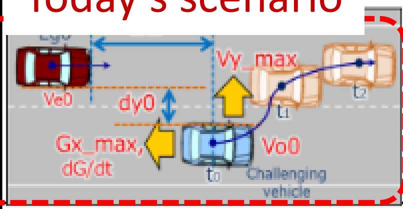
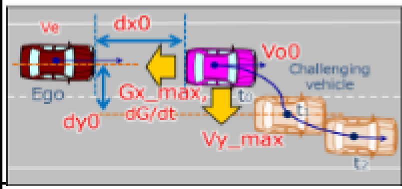
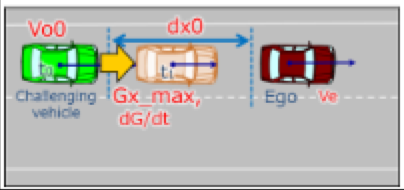
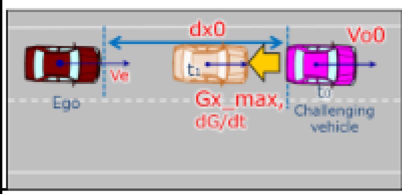
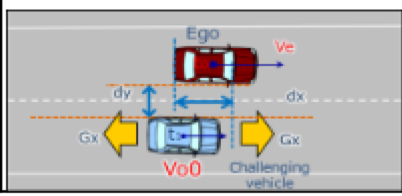


Applicable scenarios to Lane keeping system

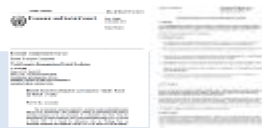
Applicable traffic scenarios for Lane Keeping system



Today's scenario

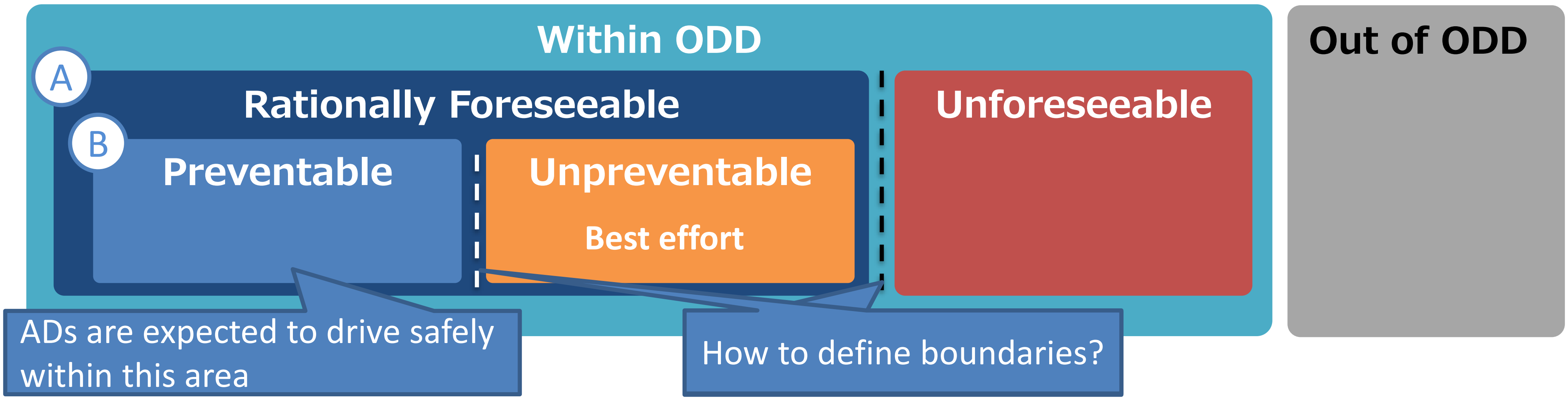
Other Vehicle's maneuver	Traffic Scenario Image	Parameters										
		Initial condition			Vehicle motion							
		Initial Velocity	Initial distance		Lateral motion		Deceleration			Acceleratio		
		【Vo0】	Longitudinal distance 【dx0】	Lateral distance 【dy0】	Max Lateral Velocity 【Vy_max】	motion timing	Max decel G 【Gx_max】	Decel rate 【dG/dt】	Decel timing	Max accel G 【Gx_max】	Acce rate 【dG/(	
Cut in		✓	✓	✓	✓	✓	✓	✓	✓	-----	-----	-----
Cut out		✓	✓	✓	✓	✓	✓	✓	✓	-----	-----	-----
Acceleration		✓	✓	-----	-----	-----	-----	-----	-----	✓	✓	✓
Deceleration		✓	✓	-----	-----	-----	✓	✓	✓	-----	-----	-----
Sync.		✓	✓	-----	-----	-----	-----	-----	-----	-----	-----	-----

Schematic structure of the safety requirement



[WP29 Framework Document Draft]

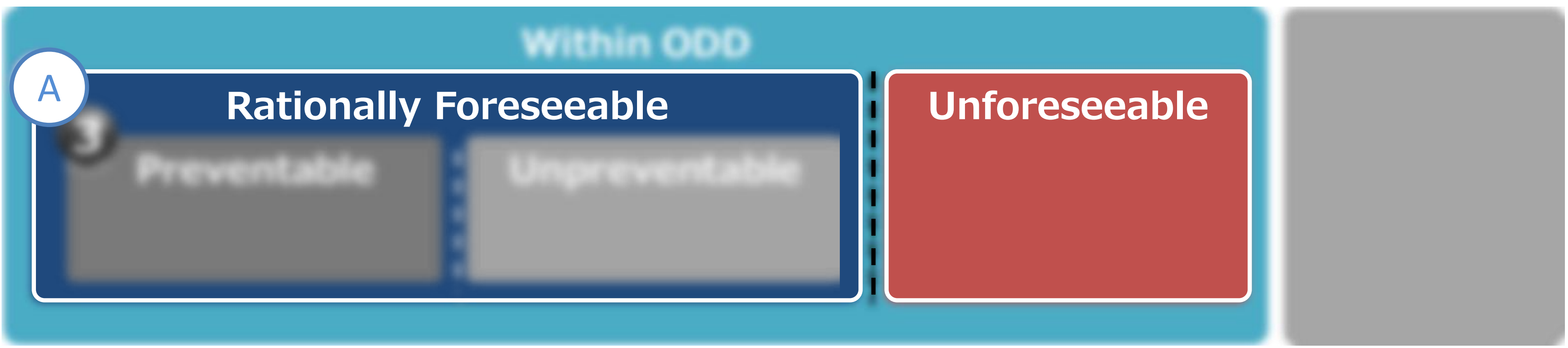
Within ODD, AD shall not cause (A) rationally foreseeable and (B) preventable accident resulting injury or death



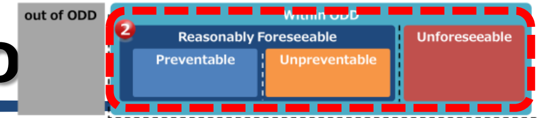
(A) Foreseeable: It is important to cover the events occurring in the actual traffic society.
=>Specify the foreseeable range based on the actual traffic data in line with the scenario structure.

(B) Preventable: Socially acceptable criteria for AD needs to be defined through further discussion

Ⓐ Foreseeable



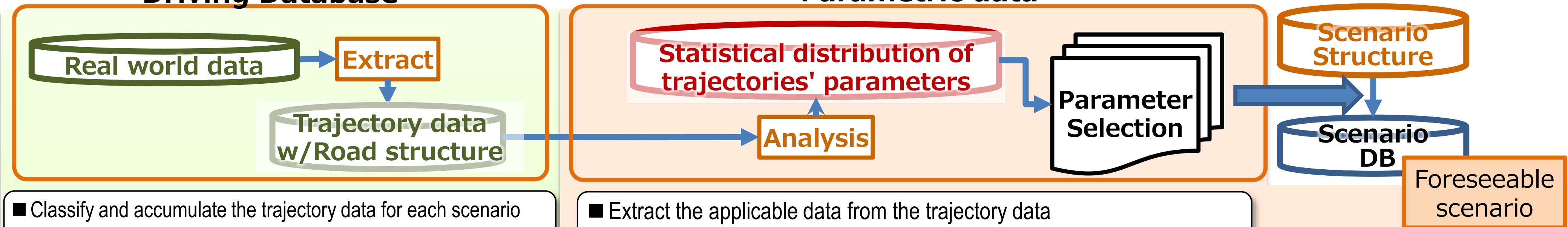
Derivation Process of Foreseeable Scenario



- ✓ Collect and analyze the traffic flow data including near miss which represents the actual traffic environment.
- ✓ Based on the statistical analysis, the parameter range which covers not only **a)the measured data** but also **b) the reasonably foreseeable future events** is defined.

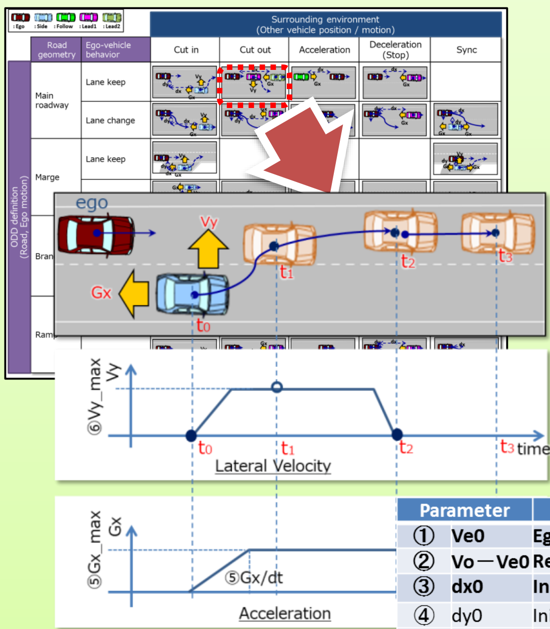
Driving Database

Parametric data

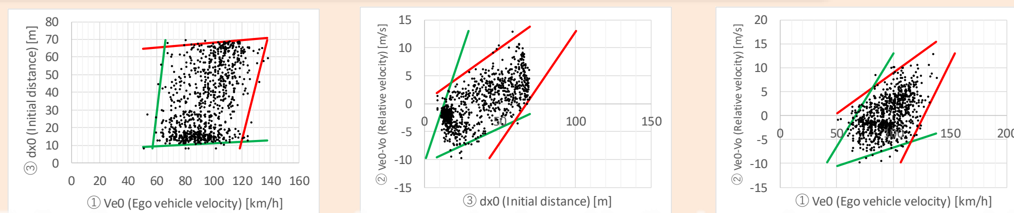


- Classify and accumulate the trajectory data for each scenario
- Define the critical parameter and model the scenario

- Extract the applicable data from the trajectory data
- Analyze the data and correlation, and define the parameter range

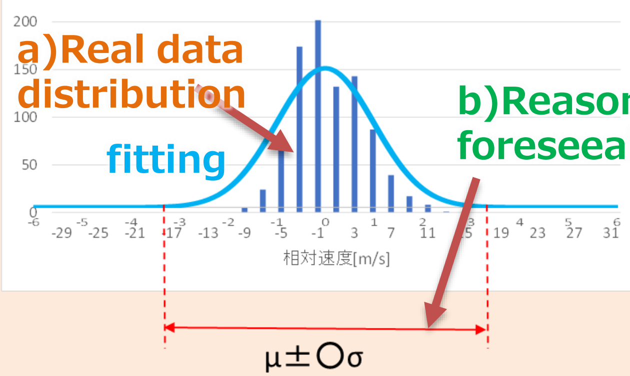


Parameter		Name
①	Ve0	Ego vehicle velocity
②	Vo－Ve0	Relative velocity
③	dx0	Initial distance
④	dy0	Initial lateral distance
⑤	Gx	Deceleration
⑥	Vy	Lateral velocity

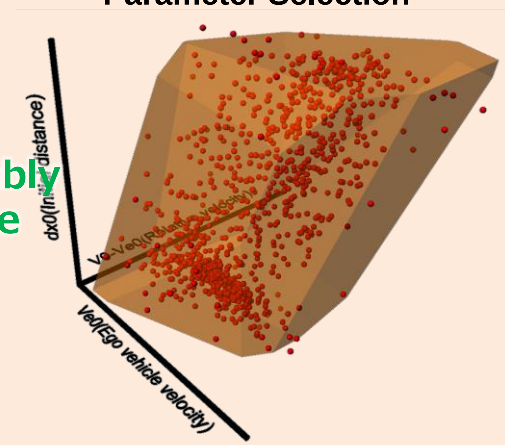


Define the possible range of parameters' combination by analyzing the correlation (e.g.: ego-vehicle velocity x intravehicular distance x relative velocity)

Using the statistical analysis,
Define the range including the foreseeable events



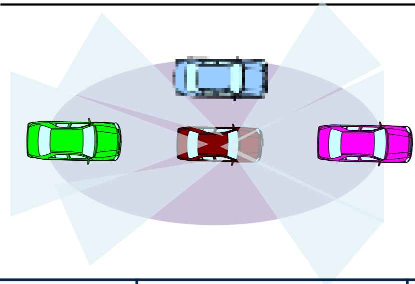
Parameter Selection



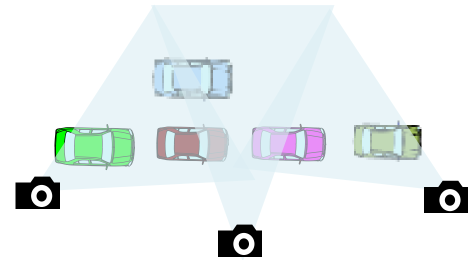
Traffic data collection in Japan

- ✓ actual traffic data collection by third party.
- ✓ In order to effectively establish the holistic coverage of traffic monitoring data, the fixed camera is utilized in specific area like ramp, marge, and exit.

Measurement vehicles



Fixed camera



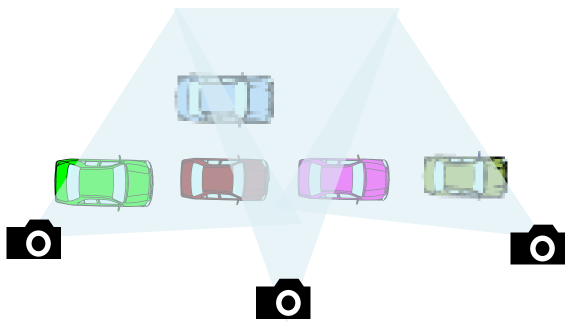
Data Source	TUAT* Driving Recorder Data (~2018~)	JAMA Driving Recorder Data (2008)	Driving Database (2017)	On road Recognition Database (2017)	Measurement Vehicle Data Correction (2018~)	Fixed Location Camera (2018~)
◎ / ◎ Parameter available (Camera/Lidar) ○ Video only △ visible × Not recorded	△ △ ○ △ × Ego × × × ×	△ ○ ○ ○ × Ego × × × ×	△ ○ ◎ ○ ○ Ego ○ △ ○ △	△ ○ ◎ ○ △ Ego △ △ △ △	△ ◎ ◎ ◎ ◎ Ego ◎ ◎ ◎ ◎	○ ○ ○ ○ ○ Ego ○ ○ ○ ○
Logging Vehicles	-	60 vehicles	30 vehicles	6 vehicles	3 vehicles	3 cameras / each location
Driver	Taxi driver	Ordinal driver	Ordinal driver	Staff	Staff	-

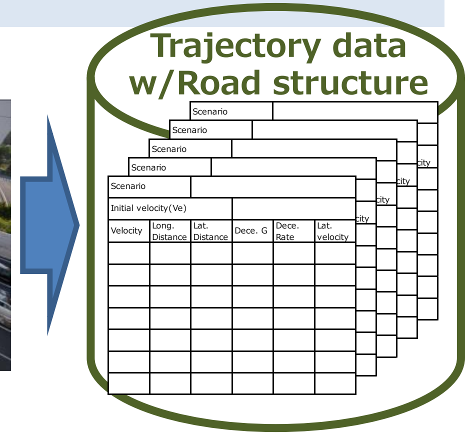
※TUAT : Tokyo University of Agriculture and Technology

Ongoing data collection

Traffic data accuracy evaluation

- ✓ Generate the trajectory data from the traffic flow monitoring data and classify it according to the scenario structure.





Fixed camera

- Video data output

Reference

- High precision GPS Car

Object detection library

- Detection & Tracking → Trajectory generation

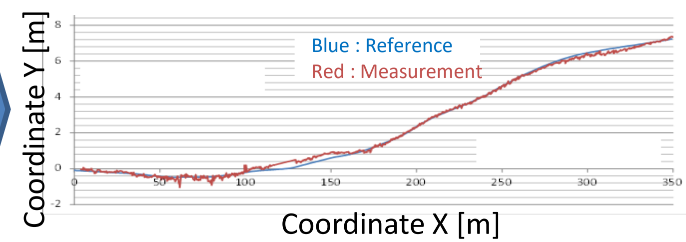
Fixed camera value (x, y)

- Coordination convert → Precision comparison

Reference value (x, y)

Data processing

Fixed camera and reference data（X-Y）

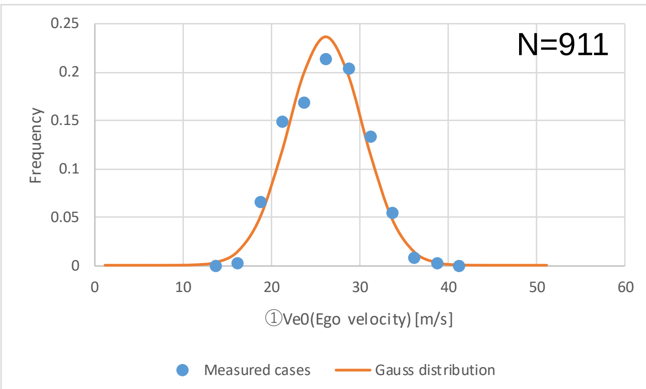


[Accuracy verification]
Sufficient accuracy of the data has been ensured by using the reference vehicle.

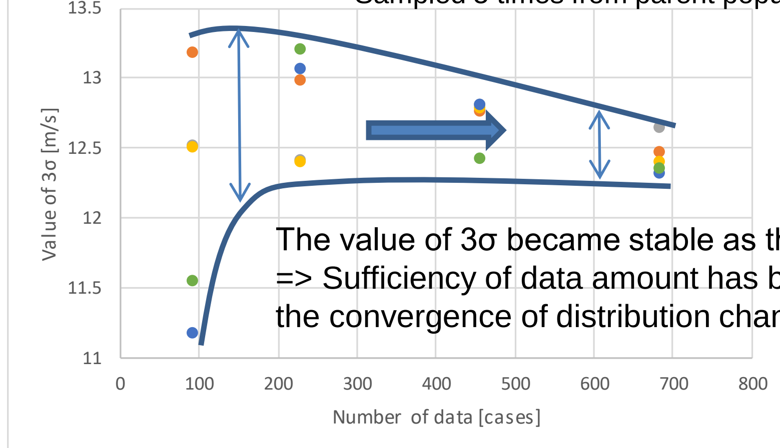
Parameter Range Derivation

Statistically analyze the actual data to derive the parameter range.
While ensuring the **a) sufficiency of data amount,** derive the appropriate parameter range by **b) extrapolating the non-measured events** and **c) eliminating the inconceivable events.**

a) Sufficiency of data amount



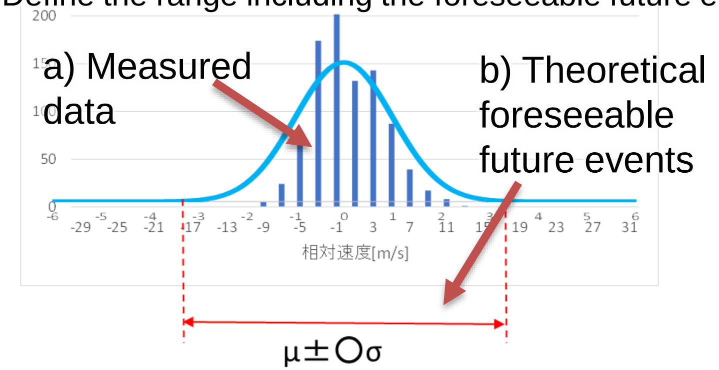
*Sampled 5 times from parent population



The value of 3σ became stable as the data amount increased.
=> Sufficiency of data amount has been ensured by analyzing the convergence of distribution change.

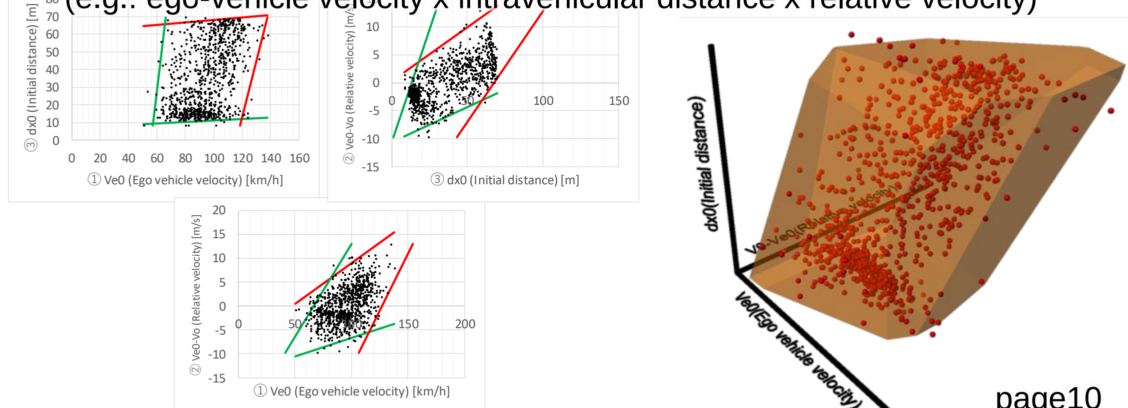
b) Extrapolation of non-measured events

Using the statistical analysis, define the reasonable parameter range
=>Define the range including the foreseeable future events



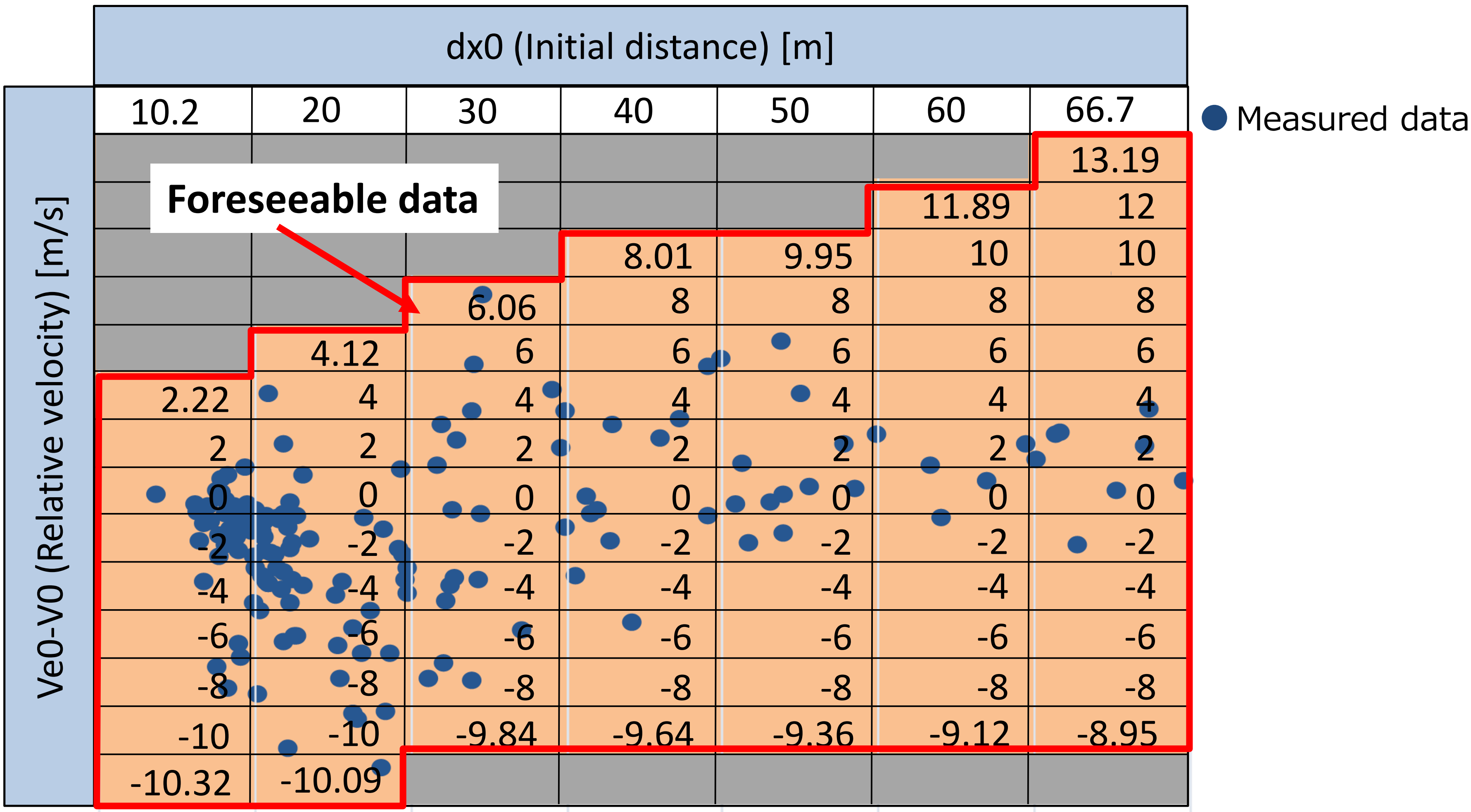
c) Elimination of inconceivable events

Analyze the correlation between parameters and define the possible parameter range
(e.g.: ego-vehicle velocity x intravehicular distance x relative velocity)



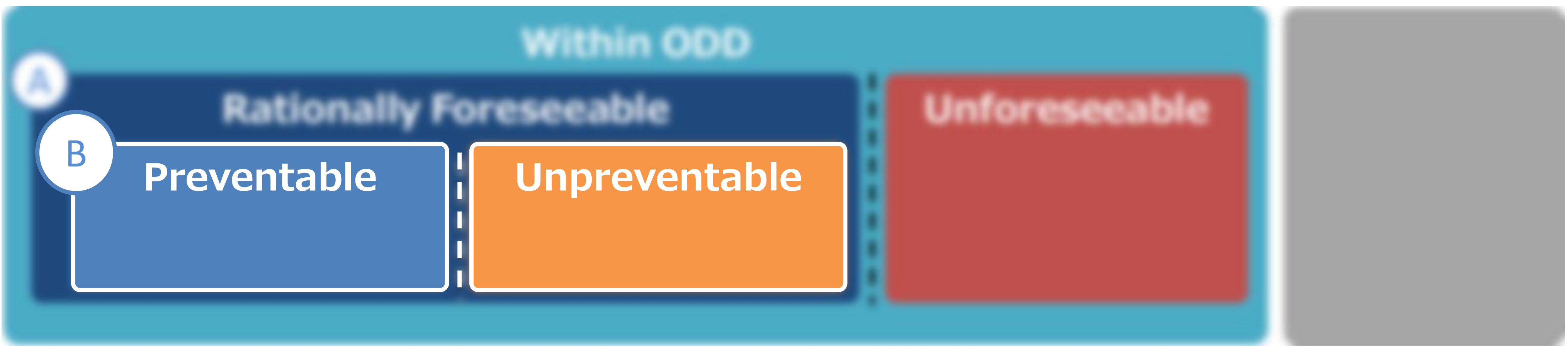
Correlation of Field data and Foreseeable data

Precondition data :Ve0=80kph, Vy=1.72m/s

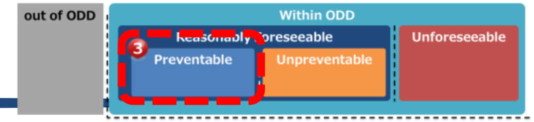


⇒ **Not only the observed data but also the data that may theoretically occur in the future is covered.**

Ⓑ Preventable



Precondition of Case study



In order to verify crush avoidance performance, Ego vehicle's driving model is necessary.
Parameters of expert driver model and AD vehicle model are set as examples.

Avoidance performance

Perception

❶ Perception timing of accident/near miss

Judgment [time from perception to action (start braking)]

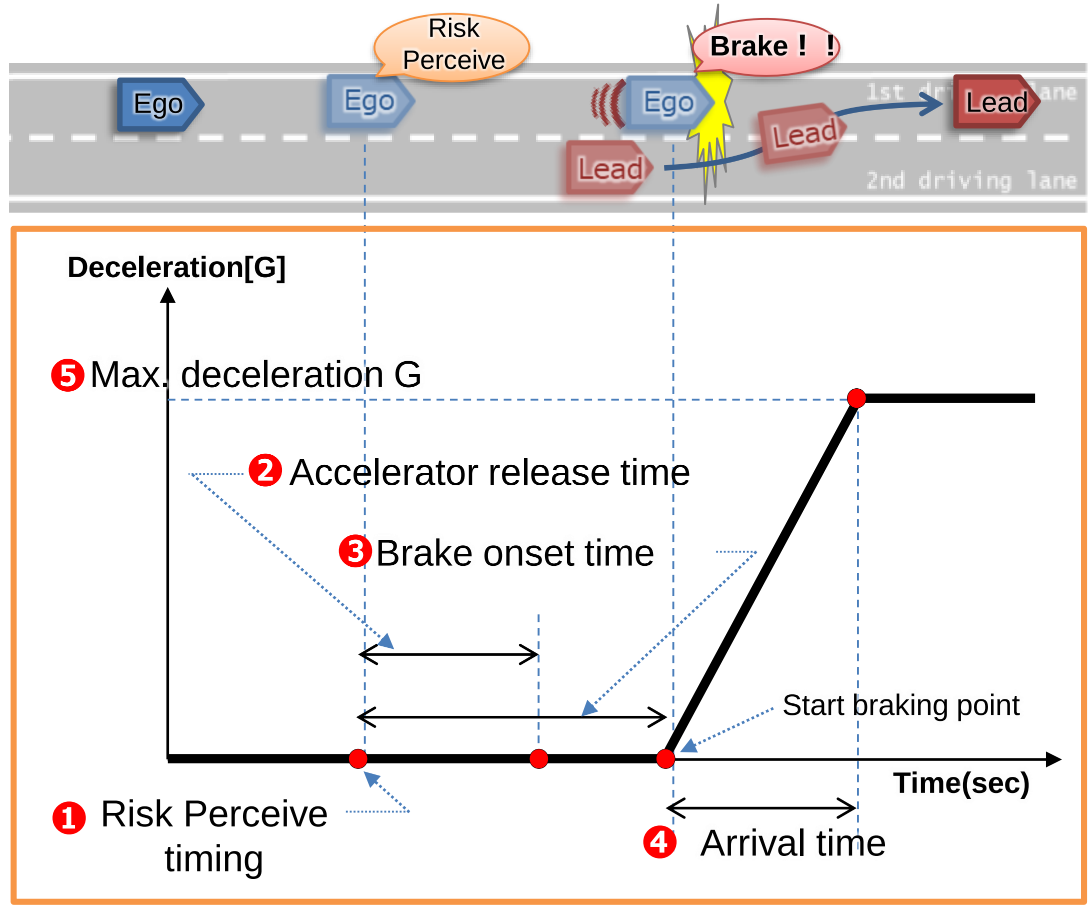
❷ Accelerator release time

❸ Brake onset time

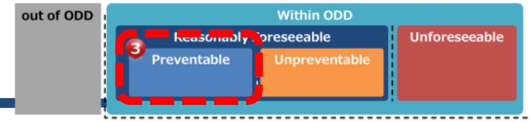
Action (time to reach target control amount)

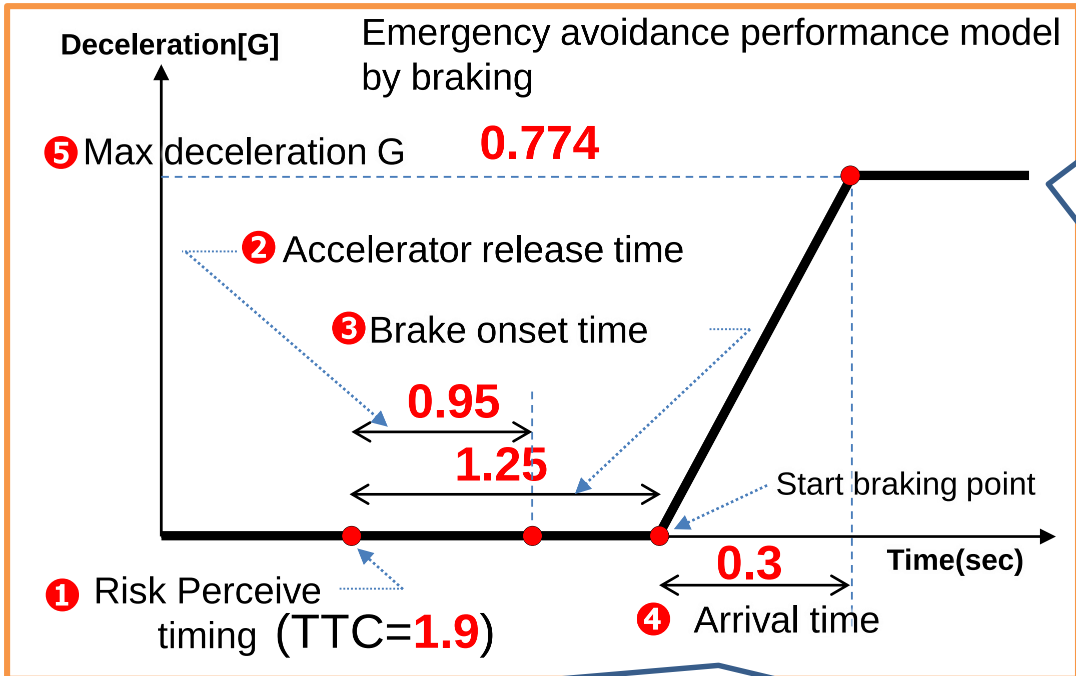
❹ Time to reach max. deceleration G

❺ Max. deceleration G



Parameters of expert driver model

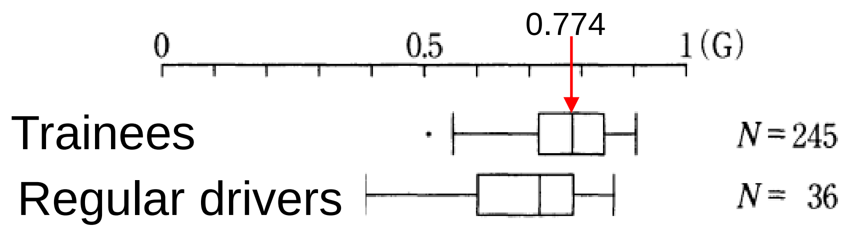




5 A study example of emergency braking characteristics of driving trainees in Japan

- General driver : 0.689G
- Driving trainees* : 0.774G

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



The difference in distribution of the trainees and the regular drivers average deceleration values

Reference: Makisita et al.(2001)

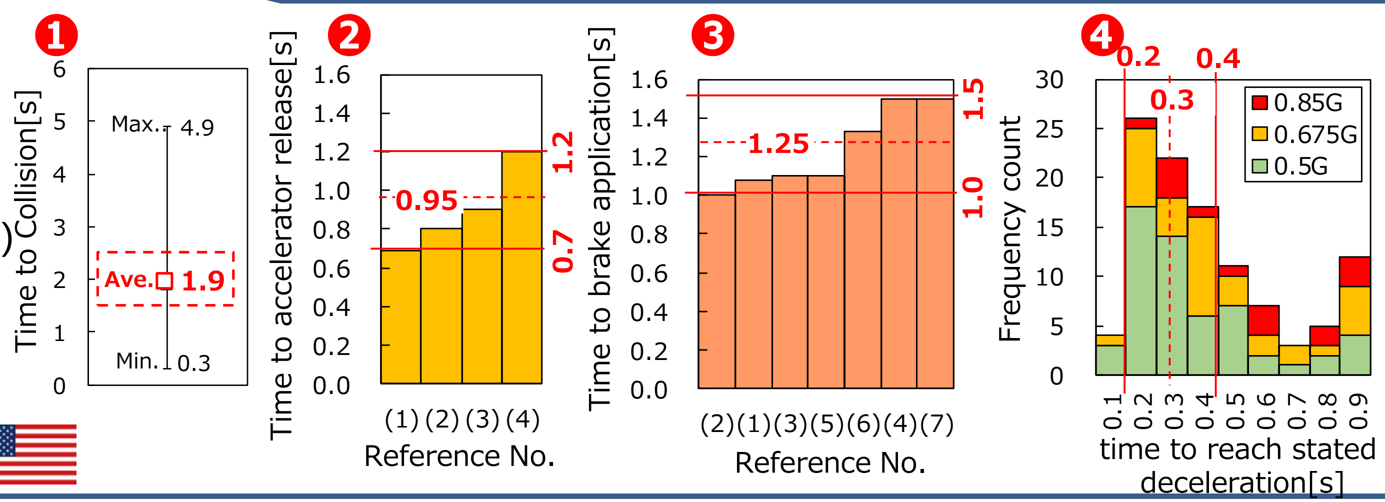
Evaluation data of attentive drivers

Evaluation subjects:

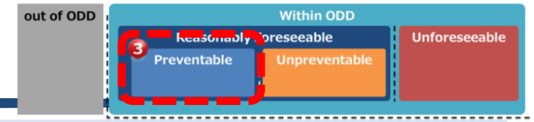
Average age (35yrs, 18-68 yrs)

66 Males and 43 Females

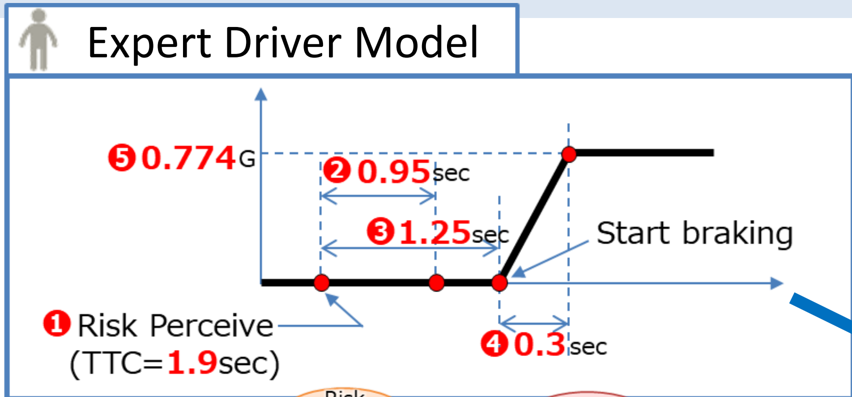
Reference: Development of an FCW Algorithm Evaluation Methodology With Evaluation of Three Alert Algorithms (NHTSA June2009)

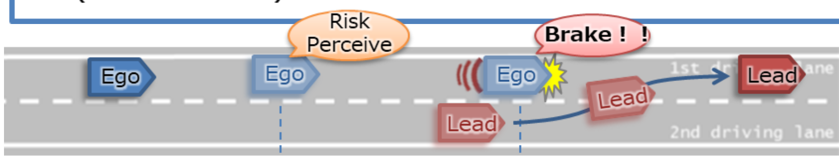


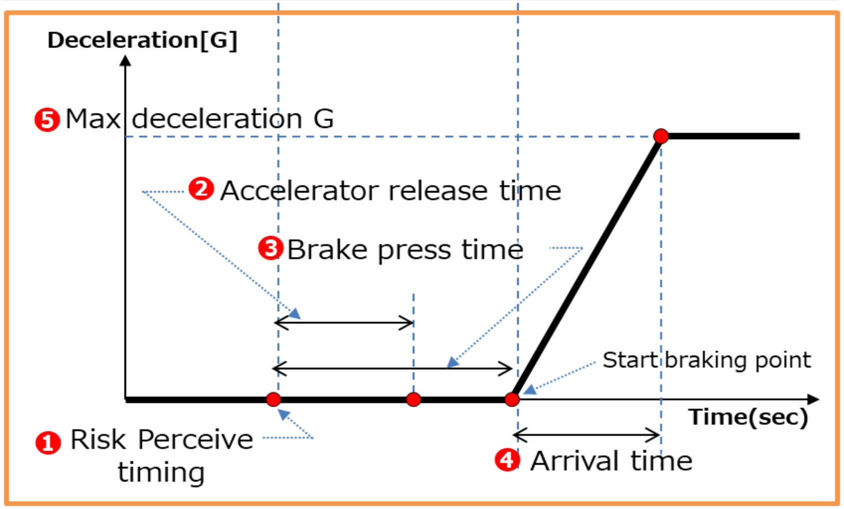
Virtual test result

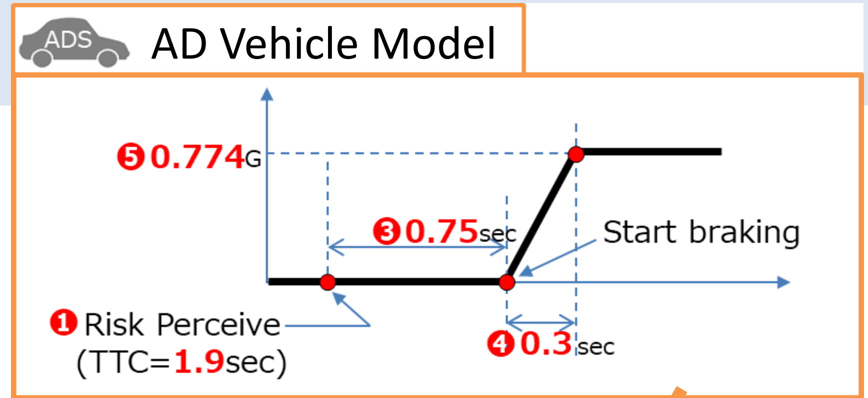


Through the virtual test by using the performance of the expert driver, the preventable level could be determined. Then, using this, the test scenario catalog database will be created.









Result (Ve0=80kph, Vy=1.72m/s)

Ve0-V0(Relative Velocity)[m/s] / dx0(Initial Distance) [m]

10.2	20	30	40	50	60	66.7
						✗ ✓ 13.19
					✗ ✓ 11.89	✗ ✓ 12
			✗ ✓ 8.01	✗ ✓ 9.95	✗ ✓ 10	✗ ✓ 10
		✓ ✓ 6.06	✗ ✓ 8	✗ ✓ 8	✗ ✓ 8	✗ ✓ 8
	✓ ✓ 4.12	✓ ✓ 6	✓ ✓ 6	✓ ✓ 6	✓ ✓ 6	✓ ✓ 6
✗ ✗ 2.22	✓ ✓ 4	✓ ✓ 4	✓ ✓ 4	✓ ✓ 4	✓ ✓ 4	✓ ✓ 4
✗ ✗ 2	✓ ✓ 2	✓ ✓ 2	✓ ✓ 2	✓ ✓ 2	✓ ✓ 2	✓ ✓ 2
✓ ✓ 0	✓ ✓ 0	✓ ✓ 0	✓ ✓ 0	✓ ✓ 0	✓ ✓ 0	✓ ✓ 0
✓ ✓ −2	✓ ✓ −2	✓ ✓ −2	✓ ✓ −2	✓ ✓ −2	✓ ✓ −2	✓ ✓ −2
✓ ✓ −4	✓ ✓ −4	✓ ✓ −4	✓ ✓ −4	✓ ✓ −4	✓ ✓ −4	✓ ✓ −4
✓ ✓ −6	✓ ✓ −6	✓ ✓ −6	✓ ✓ −6	✓ ✓ −6	✓ ✓ −6	✓ ✓ −6
✓ ✓ −8	✓ ✓ −8	✓ ✓ −8	✓ ✓ −8	✓ ✓ −8	✓ ✓ −8	✓ ✓ −8
✓ ✓ −10	✓ ✓ −10	✓ ✓ −9.84	✓ ✓ −9.60	✓ ✓ −9.36	✓ ✓ −9.12	✓ ✓ −8.95
✓ ✓ −10.32	✓ ✓ −10.09					

✓ : Success (non−crash), ✗ : Fail (Crash)

Way to apply Test Scenario Catalog Database

Access the required information through the Test Scenario Catalog according to the test environment

Test Scenario Catalog Database

Scenario XML


```xml
<?xml version="1.0" encoding="UTF-8"?>
-<SimScenario Name="LS-G1-2-E1-10-00B-3030">
<Description>Lane keeping(Steady running) Ego vehicle constant speed、Side vehicle(Pr-s) changes the lane(Cut in: (right -> left)</Description>
<Road ID="2"/>
-<Object Name="Ego vehicle" Category="EgoVehicle">
<VehicleInit Speed="40" Abscissa="0" Ordinate="0" Lane="1stDrivingLane"/>
</Object>
-<Object Name="Side vehicle(Pr-s)" Category="OtherVehicle">
<VehicleInit Speed="40" Abscissa="0" Ordinate="100" Lane="2ndDrivingLane"/>
<VehicleScene Speed="40" Abscissa="0" Lane="2ndDrivingLane" Time="3"/>
<VehicleScene Speed="20" Abscissa="0" Lane="1stDrivingLane" Time="1.5"/>
<VehicleScene Speed="20" Abscissa="0" Lane="1stDrivingLane" Time="200"/>
</Object>
</SimScenario>
```


Road geometry XML

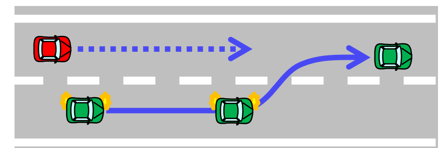

```xml
<?xml version="1.0" encoding="utf-8"?>
<OpenDRIVE>
  <header revMajor="1" revMinor="1" name="" version="1.00"
date="2018/10/18 0:00:00" north="0.0000000000000000e+00"
south="0.0000000000000000e+00" east="0.0000000000000000e+00"
west="0.0000000000000000e+00" vendor="TOYOTA"></header>
  <road name="Mainroad_1Line" length="3000" id="1" junction="-1">
    <link>
</lane>
      <lane id="2" type="border" level="0">
        <width sOffset="0.0000000000000000e+00"
a="2.5000000000000000e+00" b="0.0000000000000000e+00"
c="0.0000000000000000e+00" d="0.0000000000000000e+00" />
</road>
</OpenDRIVE>
```


Test data

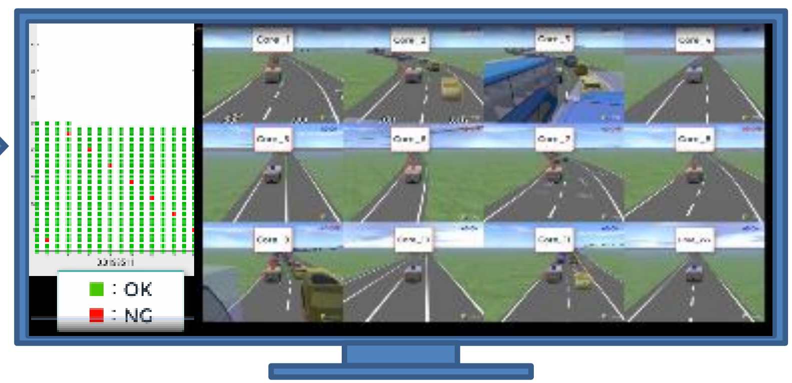
Real-traffic tests, Proving ground tests

Test procedure

Scenario					
Initial velocity(Ve)					
Velocity	Long. Distance	Lat. Distance	Dece. G	Dece. Rate	Lat. velocity



Audit (Virtual tests)



Summary

- The process to define criteria which is possibly applicable for certification by using a concrete case was shown

Next step

Need to discuss

1) Definition of “rationally Foreseeable and Preventable” criteria
2) Qualified real world driving data

To Consider

- common understanding of the socially acceptable criteria
- issues if each country uses this process to derivate the criteria

End