Scenario Validation method
for Lane Change
Status report

September 13, 2021

MLIT, Japan

Back ground

- Japan has explained in this SIG that we should consider Emergency lane change(ELC) as a top priority, when SIG considers ALKS extension. And Japan suggests that Regular lane change (RLC) should be considered with sufficient time taking account the progress of FRAV and VMAD discussion in order to avoid divergence between them.

- At the same time, Japan understood some SIG members are willing to consider RLC in parallel with ELC. We think "scenario validation" is necessary to access safety aspect of ADS function, so we propose to introduce scenario validation method into UNR157 extension, mainly for the sake of RLC, like original UNR157(Annex4) and on the base of VMAD NATM concept .

- Due to the lack of time, Japan has not yet presented detail pass/fail criterion. Japan is trying to gather technical data and to propose in coming session.

- Today, we explain our concept. Taking into account your feedback, we will continue to work.

Proposal for Functional Scenarios

These scenarios are in line with NATM MD, so if you know the detail of this concept, please check NATM-MD.

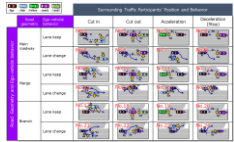Legend: : Ego   : Side   : Follow   : Lead1   : Lead2

Road Geometry and Ego-vehicle behavior	Road geometry	Ego-vehicle behavior	Surrounding Traffic Participants' Position and Behavior			
			Cut in	Cut out	Acceleration	Deceleration (Stop)
	Main roadway	Lane keep	No.1	No.2	No.3	No.4
		Lane change	No.5	No.6	No.7	No.8
	Marge	Lane keep	No.9	No.10	No.11	No.12
		Lane change	No.13	No.14	No.15	No.16
	Branch	Lane keep	No.17	No.18	No.19	No.20
		Lane change	No.21	No.22	No.23	No.24

24 Functional Scenarios & Logical Scenario

- For validation, we need to convert from functional scenario to logical scenario. Converting to logical scenario means to add parameters into functional scenario.
- We suggest logical scenarios by using parameters such as "number of lanes", "kind of lane of ego-vehicle" and "relative positon between ego and other vehicle".
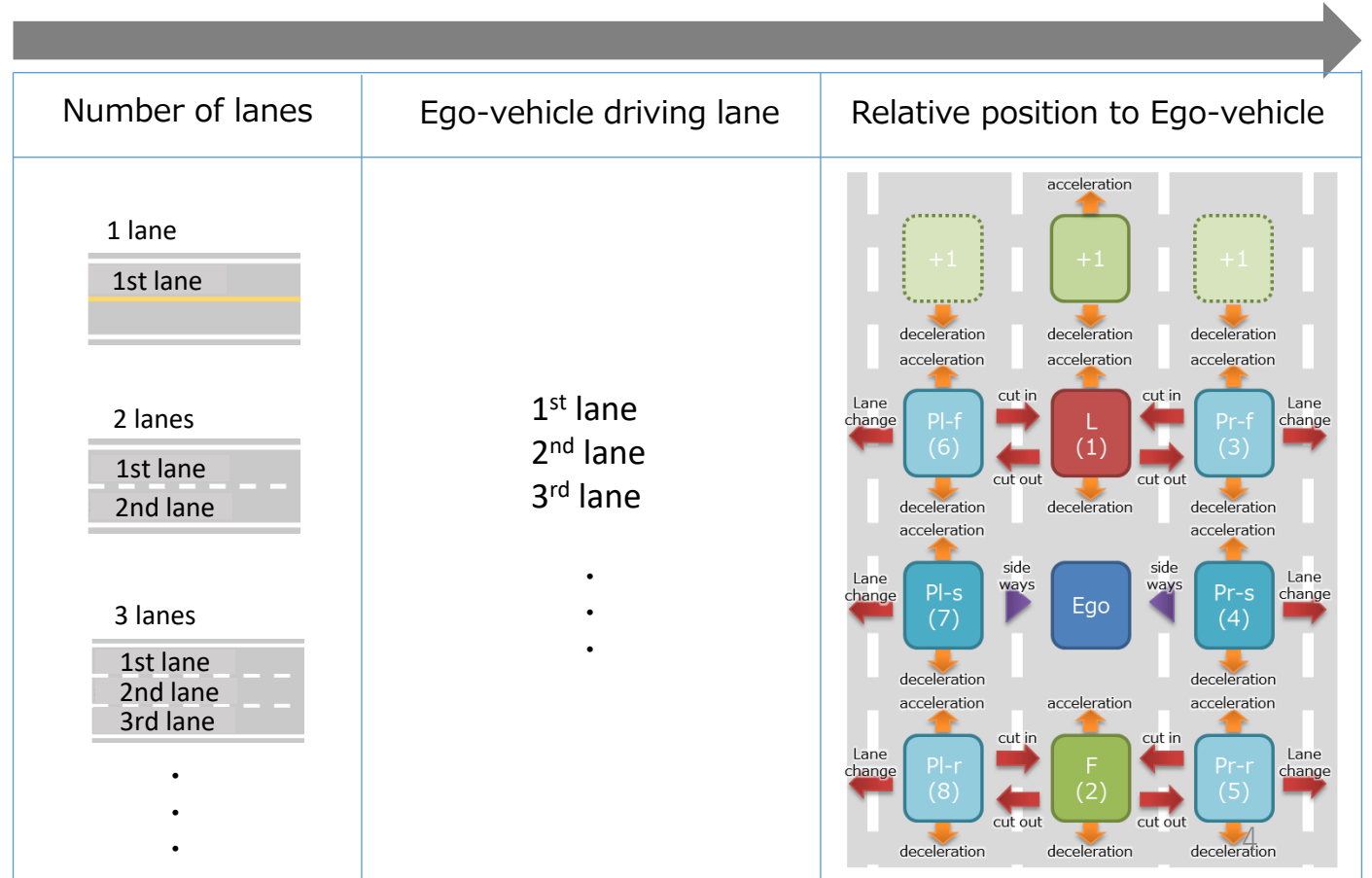
Functional Scenario

Road geometry	Ego-vehicle behavior	Surrounding Traffic Participants' behavior
3types	**2**types	**4**types
Main roadway Marge Branch	LK (LaneKeep) LC (LaneChange)	CutIn※ CutOut※ Acceleration Deceleration

total : 3×2×4 = 24scenarios

※The LC scenario is the relative movement of the own vehicle and other vehicles. Therefore, organize in the relative direction of LC
(LC in the same direction, LC in the opposite direction)

Logical Scenario

Number of lanes	Ego-vehicle driving lane	Relative position to Ego-vehicle
1 lane 1st lane 2 lanes 1st lane 2nd lane 3 lanes 1st lane 2nd lane 3rd lane ⋮	1st lane 2nd lane 3rd lane ⋮	

Regarding "relative positon between ego and other vehicle"

- When we think about relative position between ego- vehicle and other vehicle, we should think about possibility of surrounding ego-vehicle and 2 ahead leading vehicles in case of lane keep.(see left figure)
- In addition, in case of ego-vehicle's lane change, we need to consider more possibility of relative position of other vehicle(see right figure).
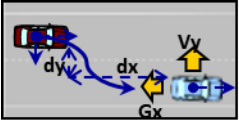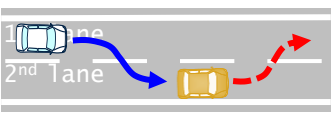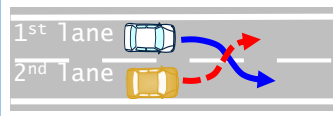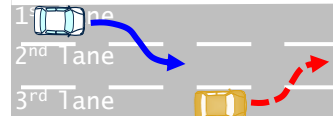
In case of ego-vehicle's lane keep
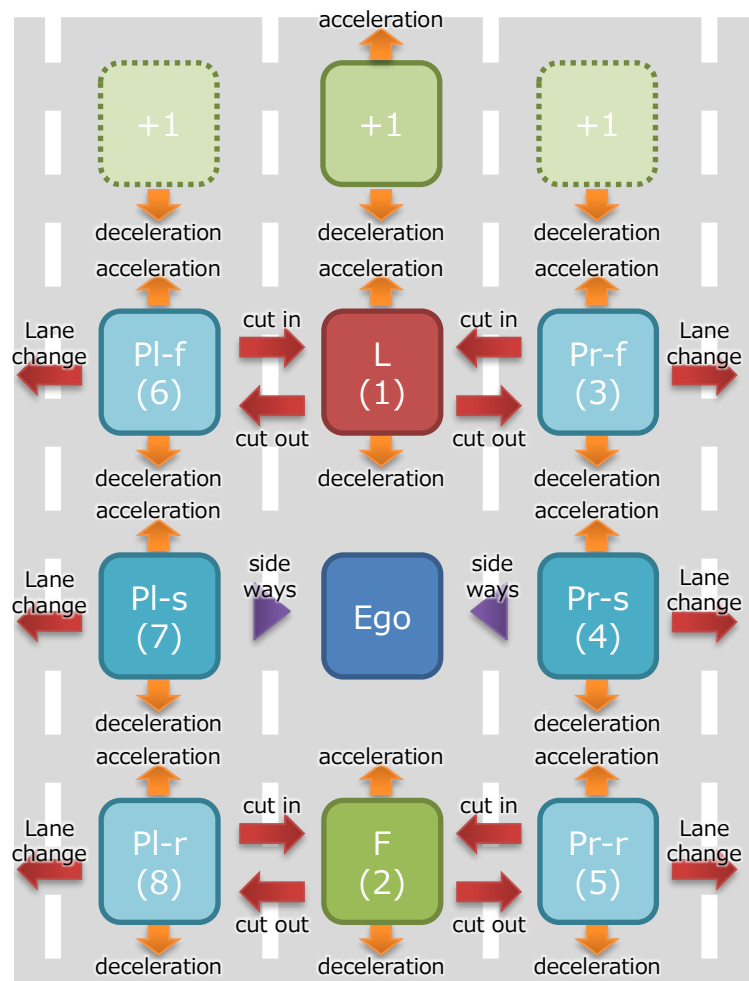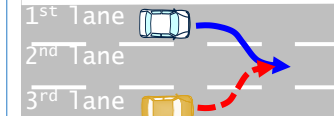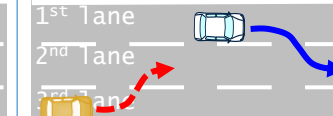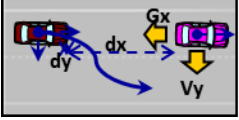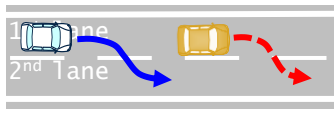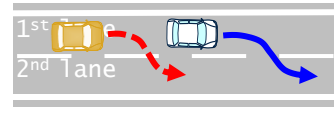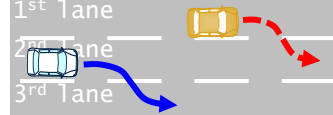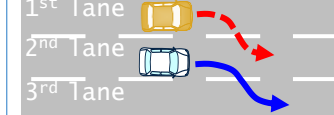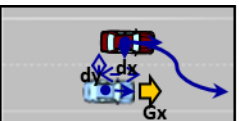
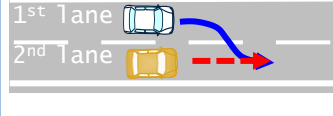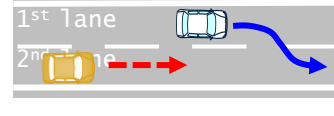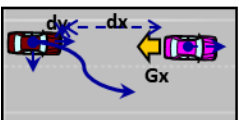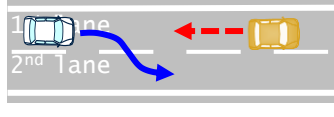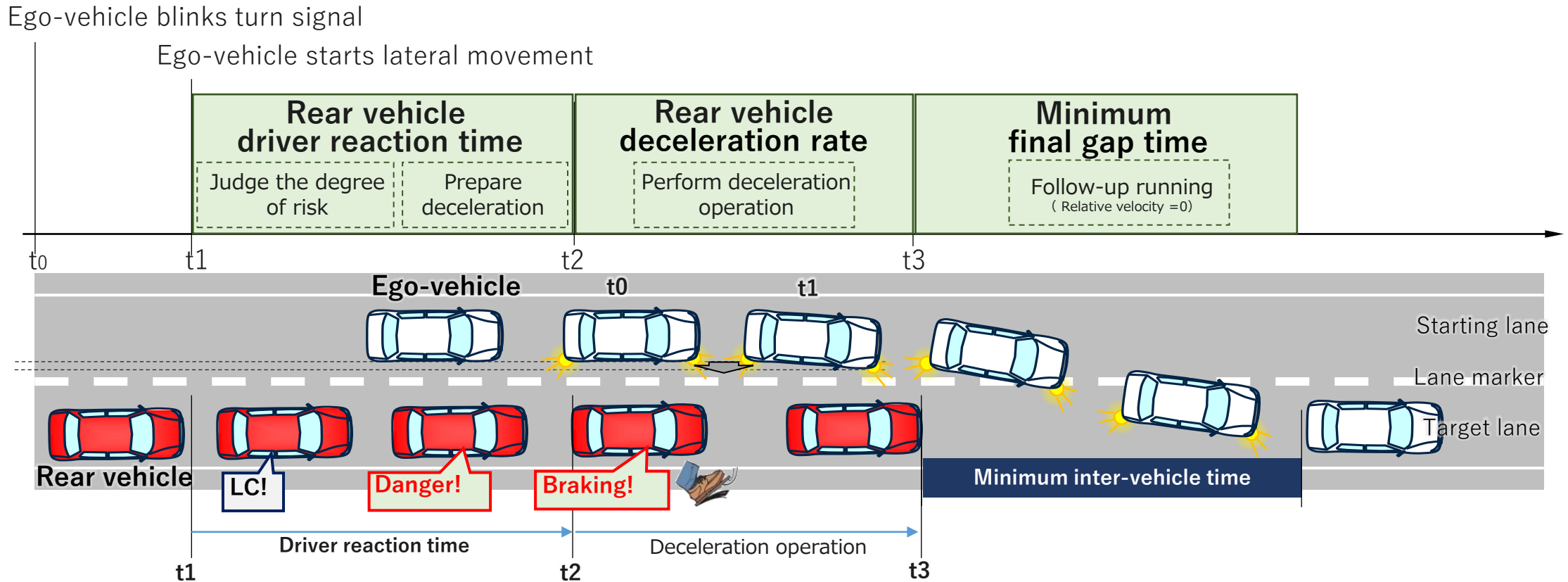In case of ego-vehicle's lane change
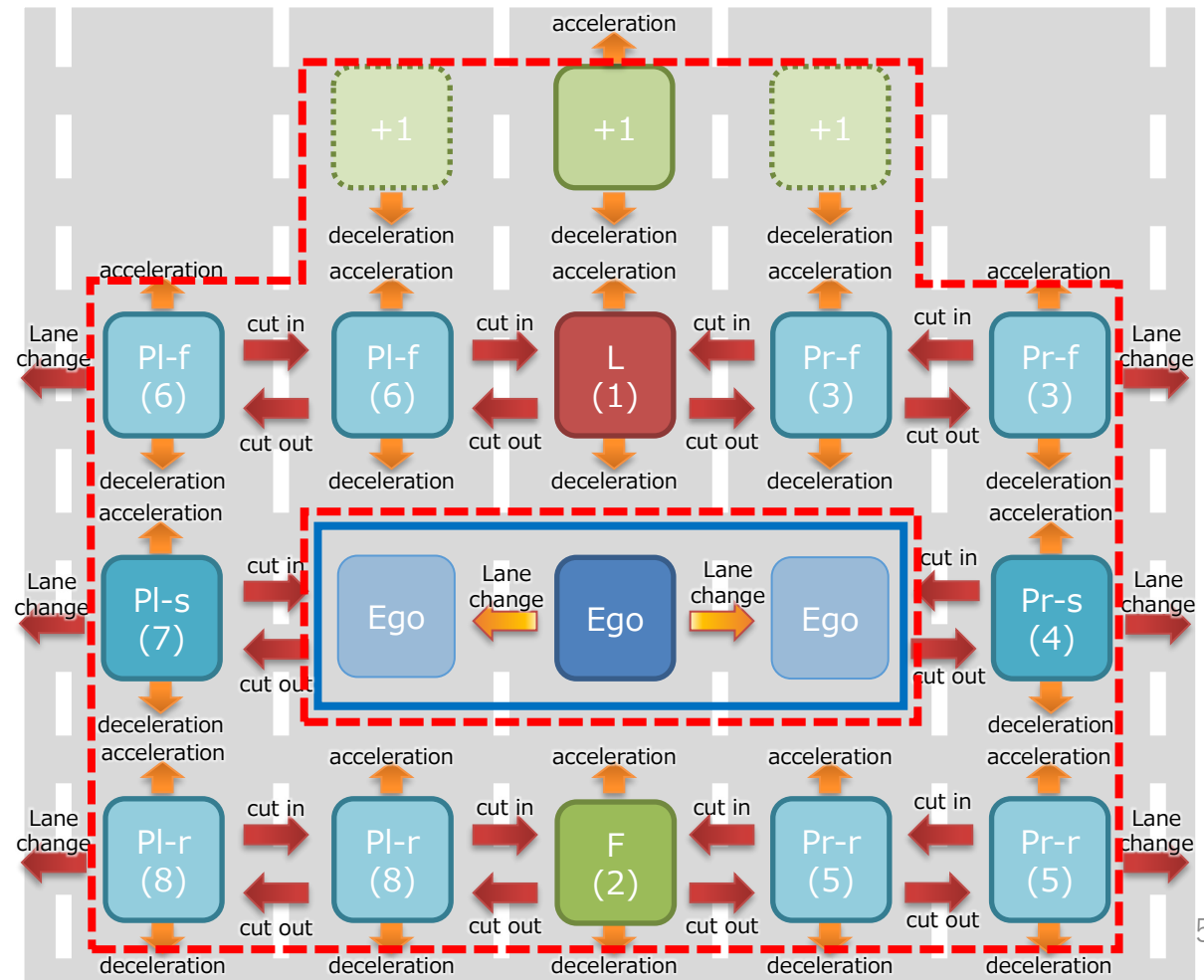
List of logical scenario to be accessed(main road case)

- We can select some logical scenarios to be accessed for the case of main road.
- In addition to main road case, other cases such as merged road and branched road case should be considered

	Main road 2 lanes			Main road 3 lanes		
	Forward	Parallel running	Rear	Forward	Parallel running	Rear
No.5 LC in the opposite direction						
No.6 LC in the same direction						
No.7 Acceleration						
No.8 Deceleration						

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How to define Parameters

Ego-vehicle blinks turn signal

Ego-vehicle starts lateral movement

Rear vehicle driver reaction time		Rear vehicle deceleration rate	Minimum final gap time
Judge the degree of risk	Prepare deceleration	Perform deceleration operation	Follow-up running (Relative velocity =0)

t_0 t_1 t_2 t_3

Ego-vehicle   t0   t1

Starting lane

Lane marker

Target lane

Rear vehicle

LC!   Danger!   Braking!

Minimum inter-vehicle time

Driver reaction time   Deceleration operation

t_1 t_2 t_3
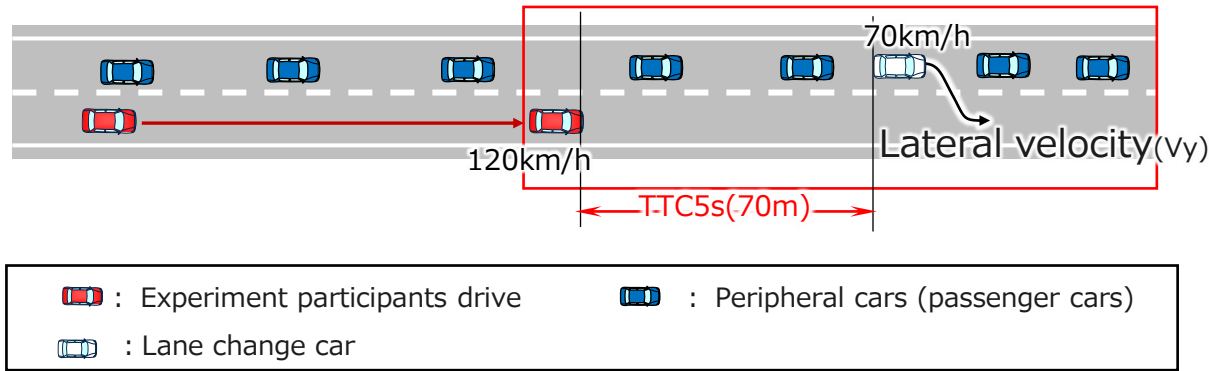
Rear vehicle drivers are not always driving carefully
⇒In order to define parameters of Careless and Poor human driver, we **analyze the experimental data** by the driving simulator.

Driving simulator experiment and past evaluation meter

Outline of DS experiment

Data collection status by cut-in condition
(3 patterns/experimental order)

	Lateral velocity [m/s]	Relative velocity [km/h]	Number of trials (23people×4times)	Number of valid data *
1	0.6	50[km/h]	92	88
2	1.0	·LC vehicle 70km/h ·Following vehicle 120km/h ·Following distance 70m	92	91
3	1.4		92	90

Insufficient evaluation level of relative velocity

* Excludes cases where the preceding vehicle was preparing for braking before LC

Attribute of experiment participants

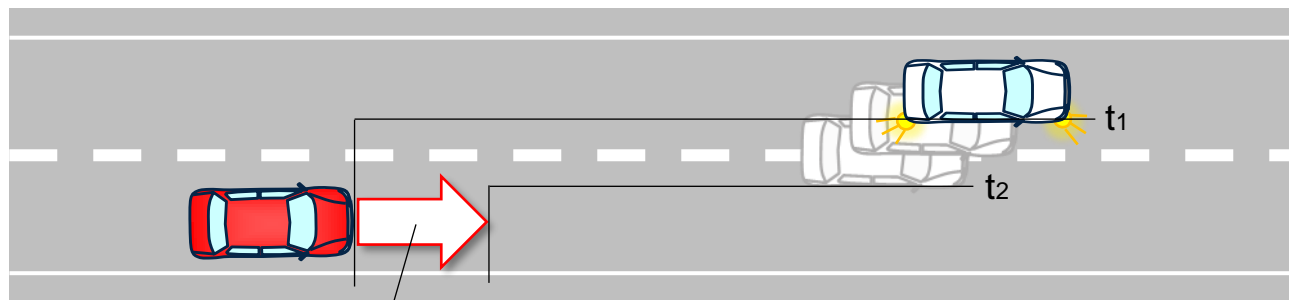| attribute	Number of people	Characteristic	composition
General driver	23 people	◆Use the highway more than 6 times a year ◆Average years of driving experience:14.3 years ◆Average annual mileage : About 13,000km	·Men:14/Women:9 ·Average age:33.7

Image of Driving simulator experiment

・Two lane road
・LC vehicle 70km/h
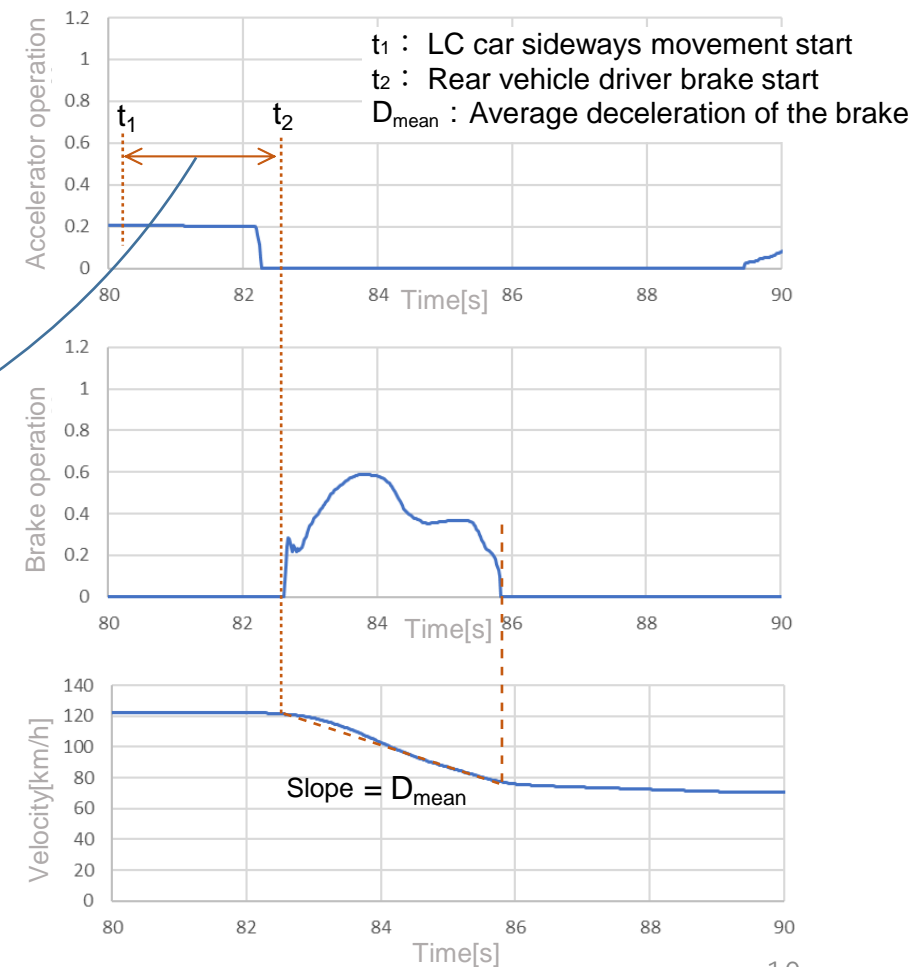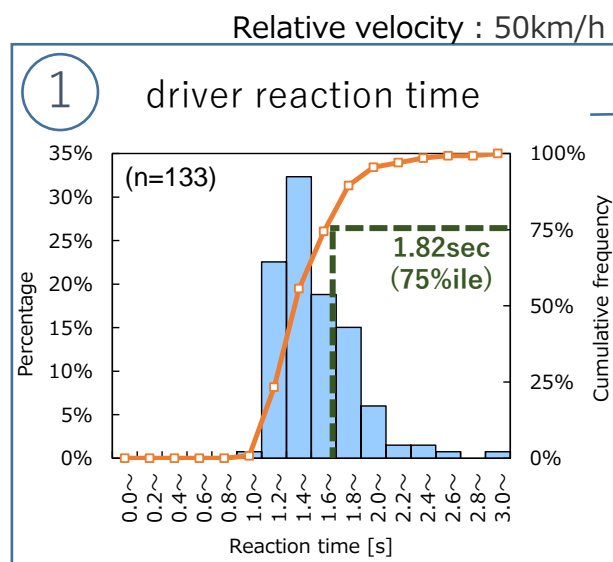・Rear vehicle 120km/h
  (Test vehicle)
・Time to collision 5sec

Setting the careless side as a 75% tile value

t_1 : LC car sideways movement start
t_2 : Rear vehicle driver brake start
D_{mean} : Average deceleration of the brake

Reaction time 1.82s

Relative velocity : 50km/h

① driver reaction time
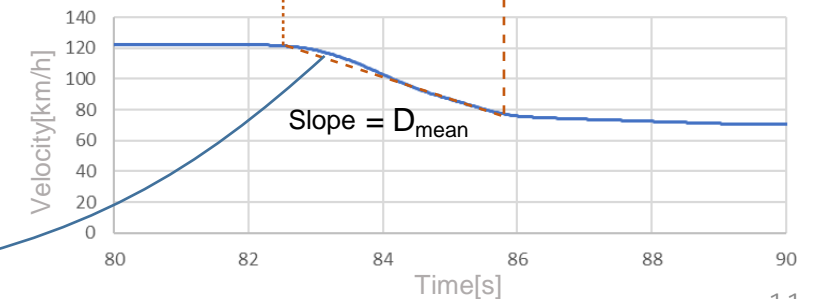
(n=133)
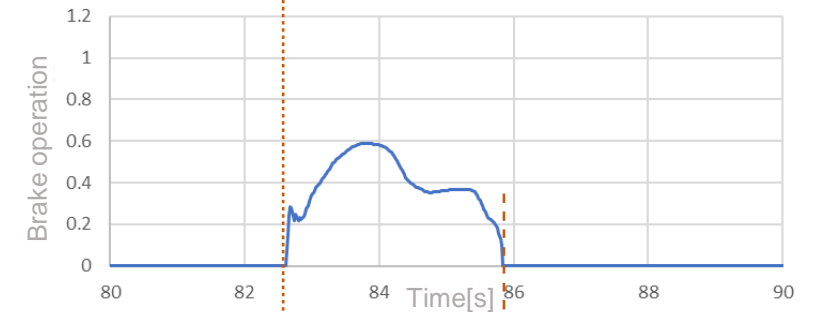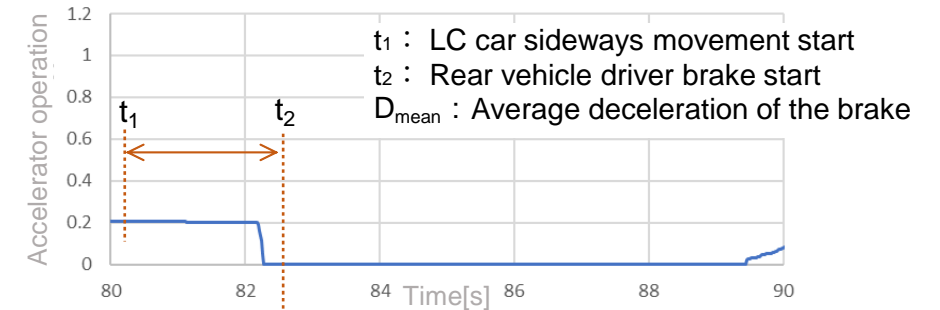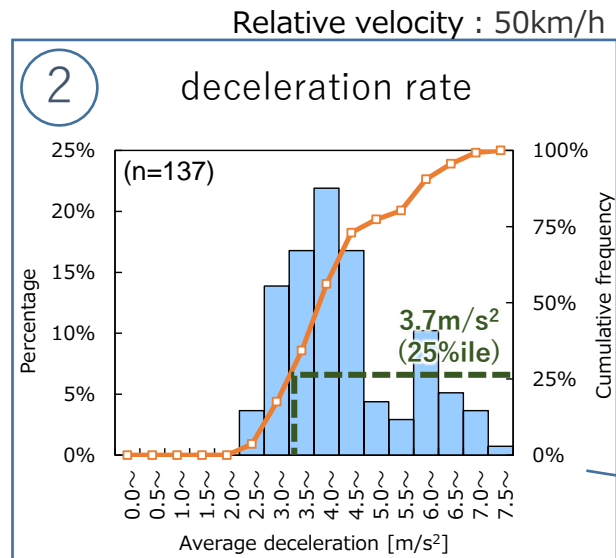
1.82sec (75%ile)

Slope = D_{mean}

10

Rear vehicle parameters (deceleration rate)

Setting the careless side as a 25% tile value
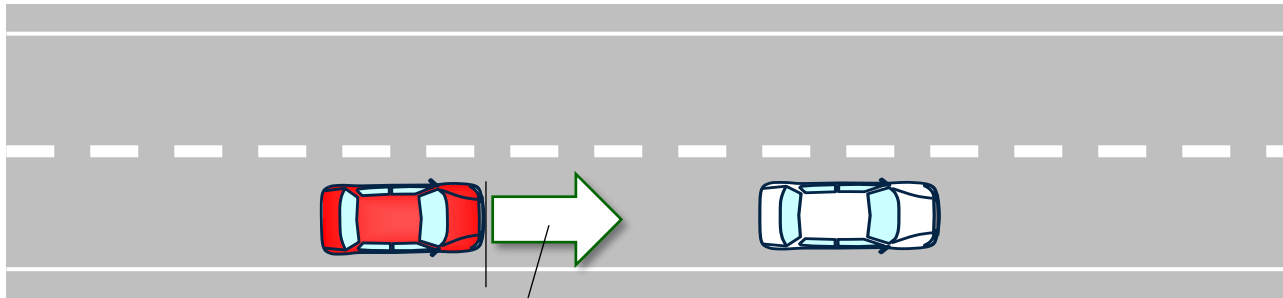
Reaction time
1.82s

Deceleration rate
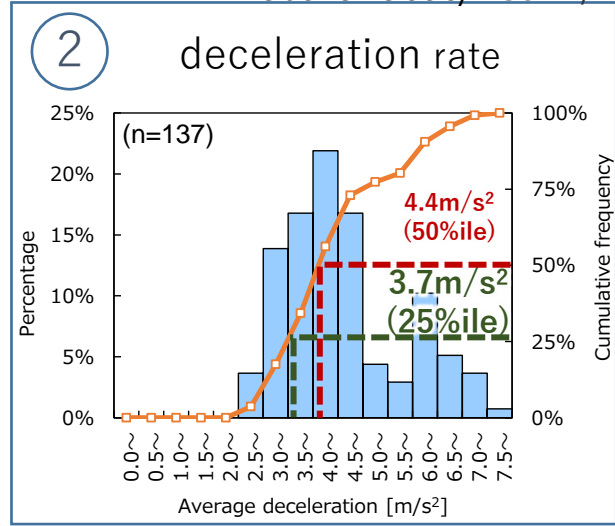**3.7m/s²**

Relative velocity : 50km/h

② deceleration rate

(n=137)

3.7m/s²
(25%ile)

Percentage

Cumulative frequency

Average deceleration [m/s²]

t_1 : LC car sideways movement start
t_2 : Rear vehicle driver brake start
D_{mean} : Average deceleration of the brake

t_1 t_2

Accelerator operation

Time[s]

Brake operation

Time[s]

Velocity[km/h]

Slope = D_{mean}

Time[s]

Tentative Parameters as a careless driver
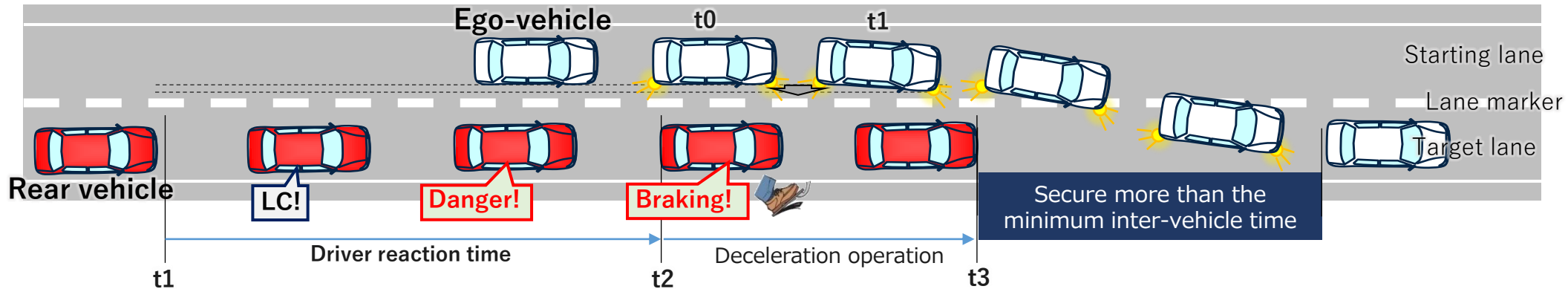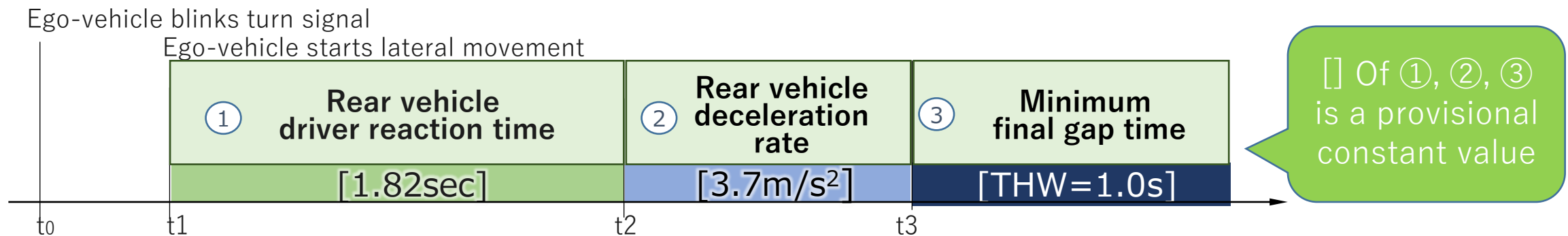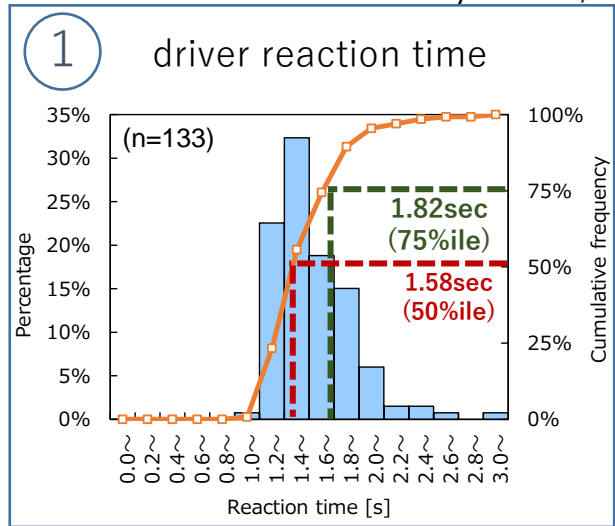
pass/fail criterion

- By using scenarios and parameters, we try to establish pass/fail criterion for regulation.
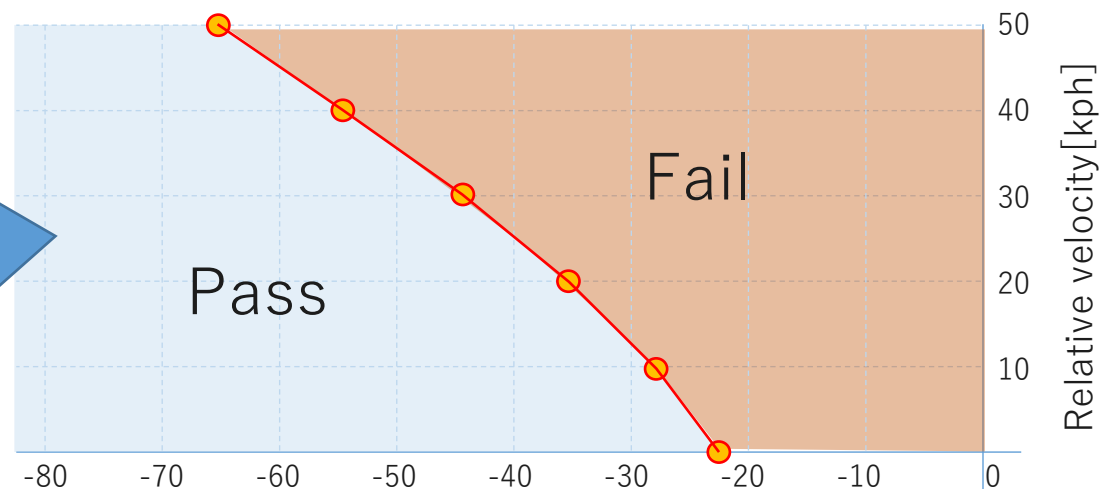- Pass/ fail criterion between ELC and RLC should be different. Especially for RLC criterion, we need sufficient analysis and discussion.

Subsequent vehicle driver parameters in a reasonably foreseeable range
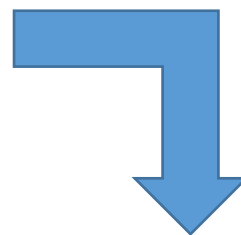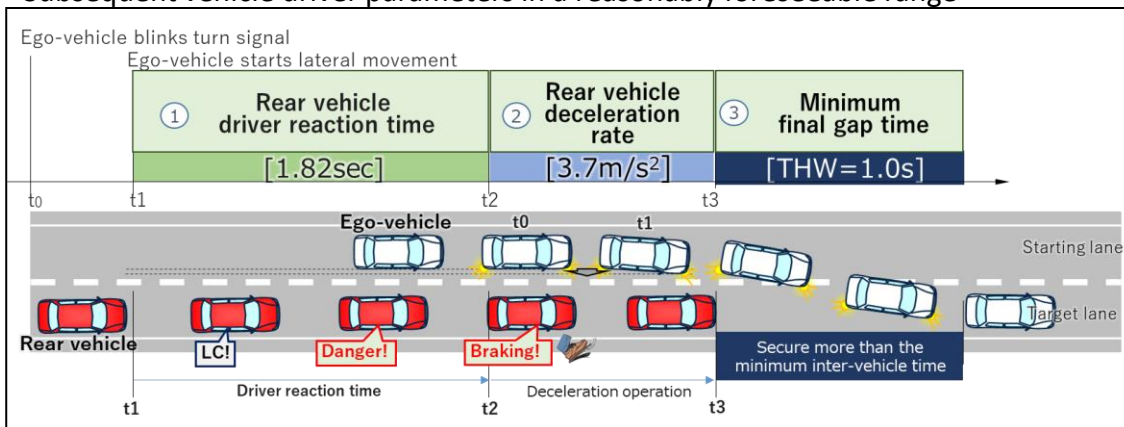
Criteria (image)

Ego vehicle velocity ：60kph

In this area, ALKS can make LC

Safe to the extent reasonably foreseeable of the following vehicle
⇒ It is unavoidable for the behavior* of the following vehicle that cannot be reasonably foreseen.

*Malicious acceleration, insufficient deceleration, delayed response

Fail

Pass

Relative velocity[kph]

-80   -70   -60   -50   -40   -30   -20   -10   0

Distance between vehicles when reaching the vehicle lane marker

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Remaining Issues for RLC scenario evaluation

1. Lack of DS experimental data

responses

Conducted additional experiments at a relative speed of 10 to 50 [km/h]

② Verification of the deceleration amount of the vehicle behind

③ Derivation of the minimum inter-vehicle time required for the driver behind the vehicle

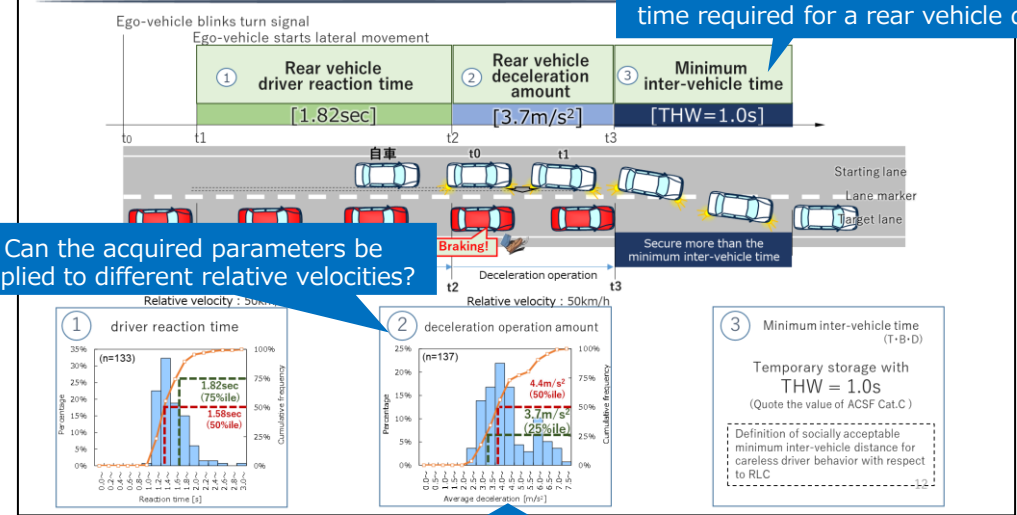## 2. Validity of Parameters compare to actual traffic flow data

responses

Compare the actual LC situation of the actual traffic flow with the draft standard and confirm the validity

– Relationship between inter-vehicle distance and relative speed during LC (by speed range)

– Minimum inter-vehicle time by speed range, etc.

Parameters that can be handled by the follo...

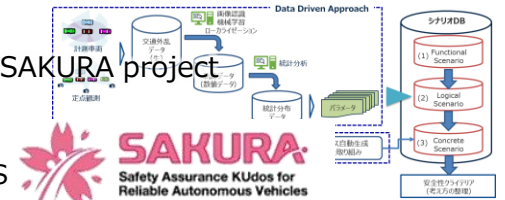What is the minimum inter-vehicle time required for a rear vehicle driver?

Can the acquired parameters be applied to different relative velocities?

Ego-vehicle blinks turn signal
Ego-vehicle starts lateral movement

① Rear vehicle driver reaction time	② Rear vehicle deceleration amount	③ Minimum inter-vehicle time
[1.82sec]	[3.7m/s²]	[THW=1.0s]

What is the relationship between traffic consolidation and draft standards?

Actual traffic flow data

· Actual traffic flow data is collected by the SAKURA project

a) by measuring vehicle
b) by fixed point observation
c) Measurement of driver reaction using DS

Reflecting the results of the above additional experiments and analysis, we will immediately consider specific RLC scenario evaluation and plan to propose them by the ALKS-SIG in December.