

# **Additional research of False Reaction scenarios**

- Measurement data of driving behavior  
by normal drivers -**

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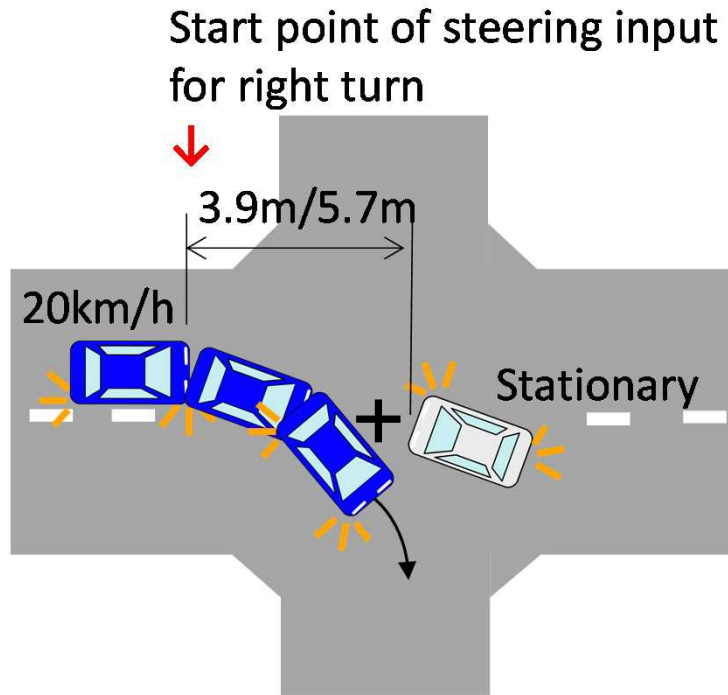
# 1. Background and Purpose

- Japan studied eight draft scenarios as the false reaction scenarios in a wider view point, and system behavior in each scenario was validated by several test vehicles (AEBS-10-03).
- In some scenarios, some conditions such as vehicle speed and approaching situation to the related objects (TTC) should be considered based on data of driving behavior of normal drivers.
- In this research, some experiments were carried out in order to collect data of driving behavior of normal drivers in some scenarios.
- Based on the results of the experiment in some scenarios, modification of some conditions is proposed.
- **It is considered that the False Reaction scenarios shall be used as the tool in order to share technical information which clarifies behaviour and the safety concept of the system between the Technical Service and the vehicle manufacturer.**

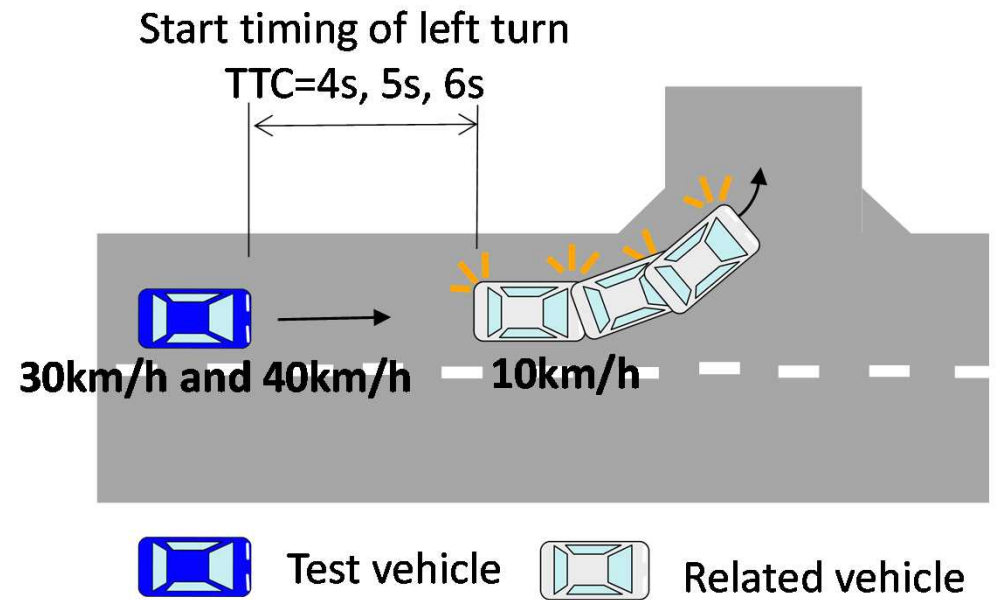
## 2. Draft scenarios proposed in AEBS-10-03

Remind from AEBS-10-03

### Draft Scenario 1

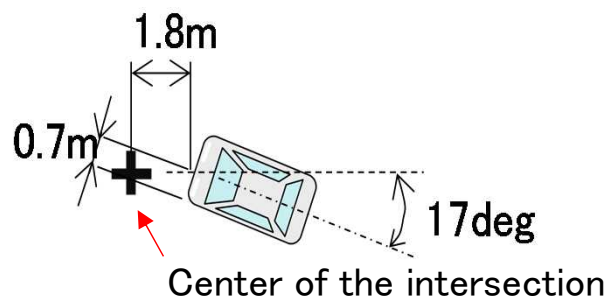


### Draft Scenario 2



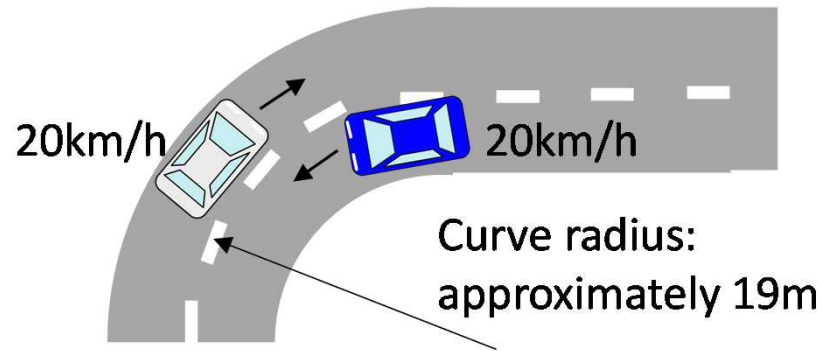
Test vehicle

Related vehicle



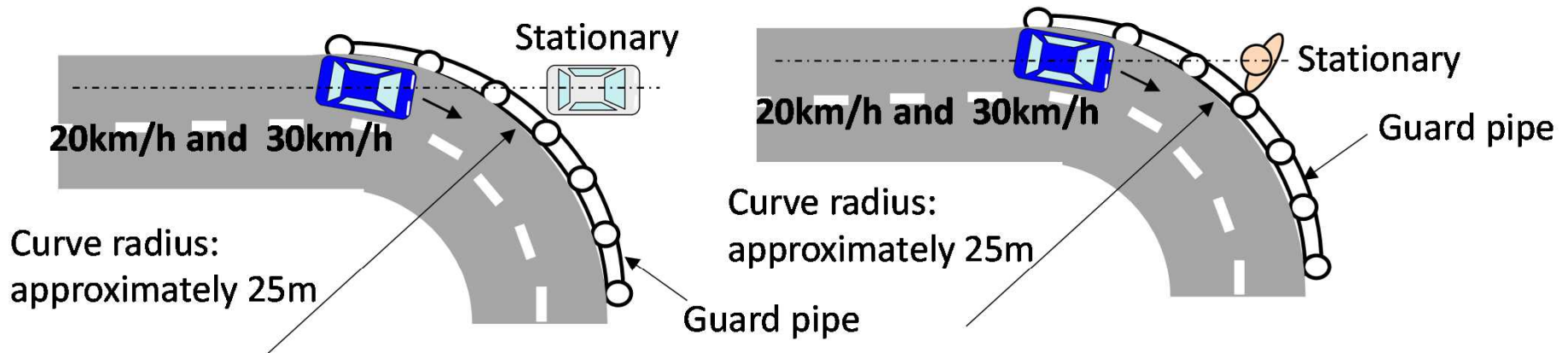
## Draft Scenario 3

Remind from AEBS-10-03



 Test vehicle  Related vehicle

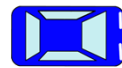
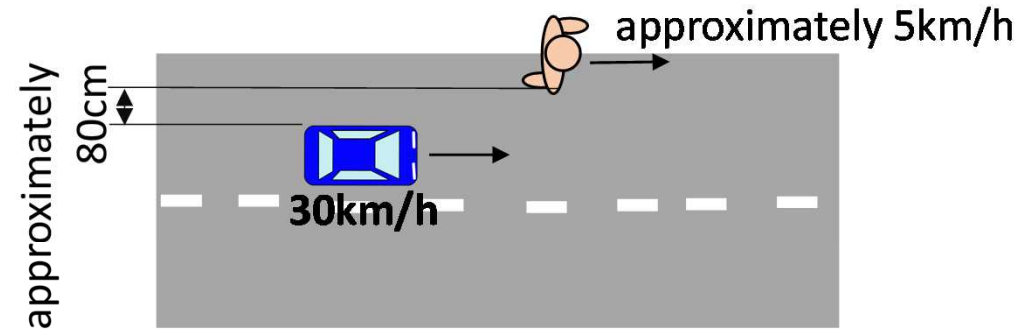
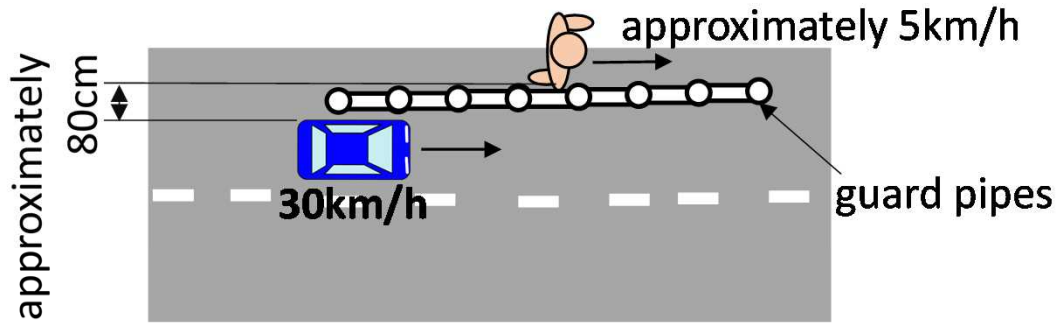
## Draft Scenario 4



 Test vehicle  Related vehicle  Pedestrian target

## Draft Scenario 5

Remind from AEBS-10-03

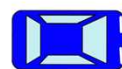
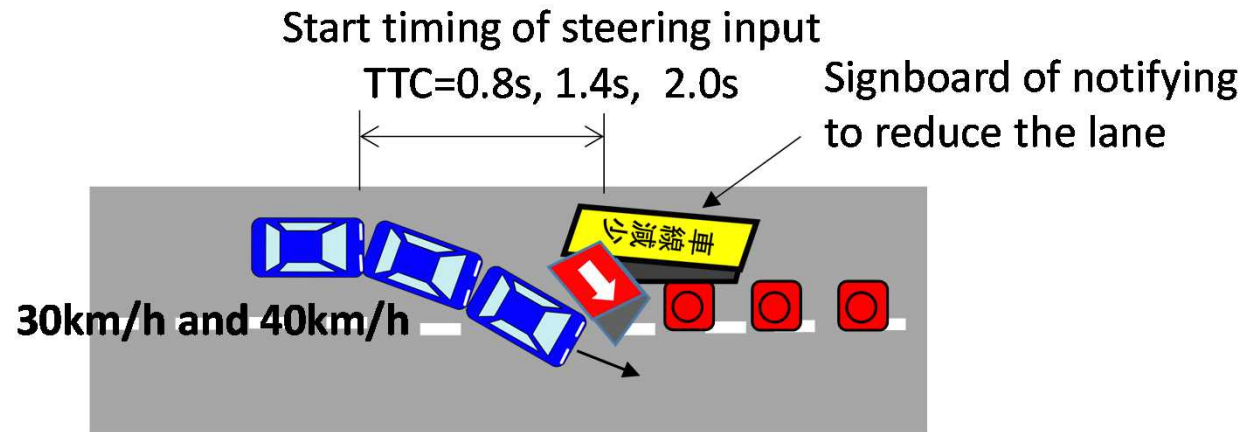


Test vehicle



Real pedestrian

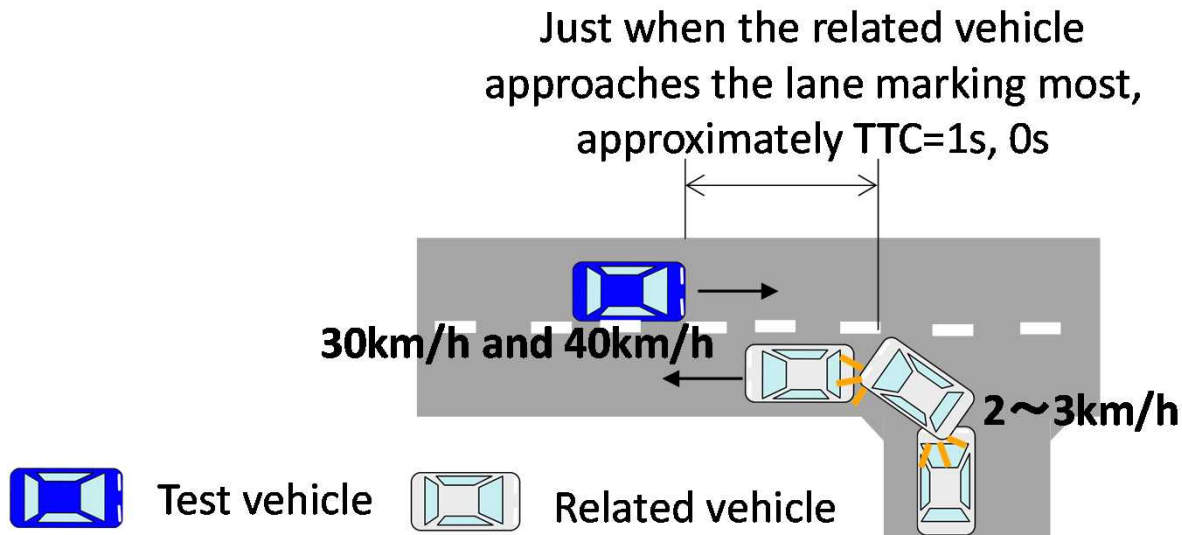
## Draft Scenario 6



Test vehicle

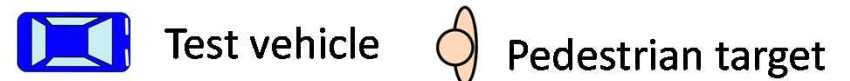
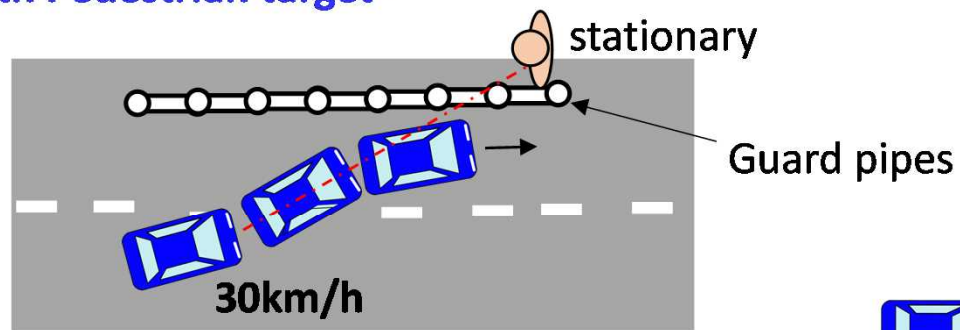
## Draft Scenario 7

Remind from AEBS-10-03



## Draft Scenario 8

with Pedestrian target\*

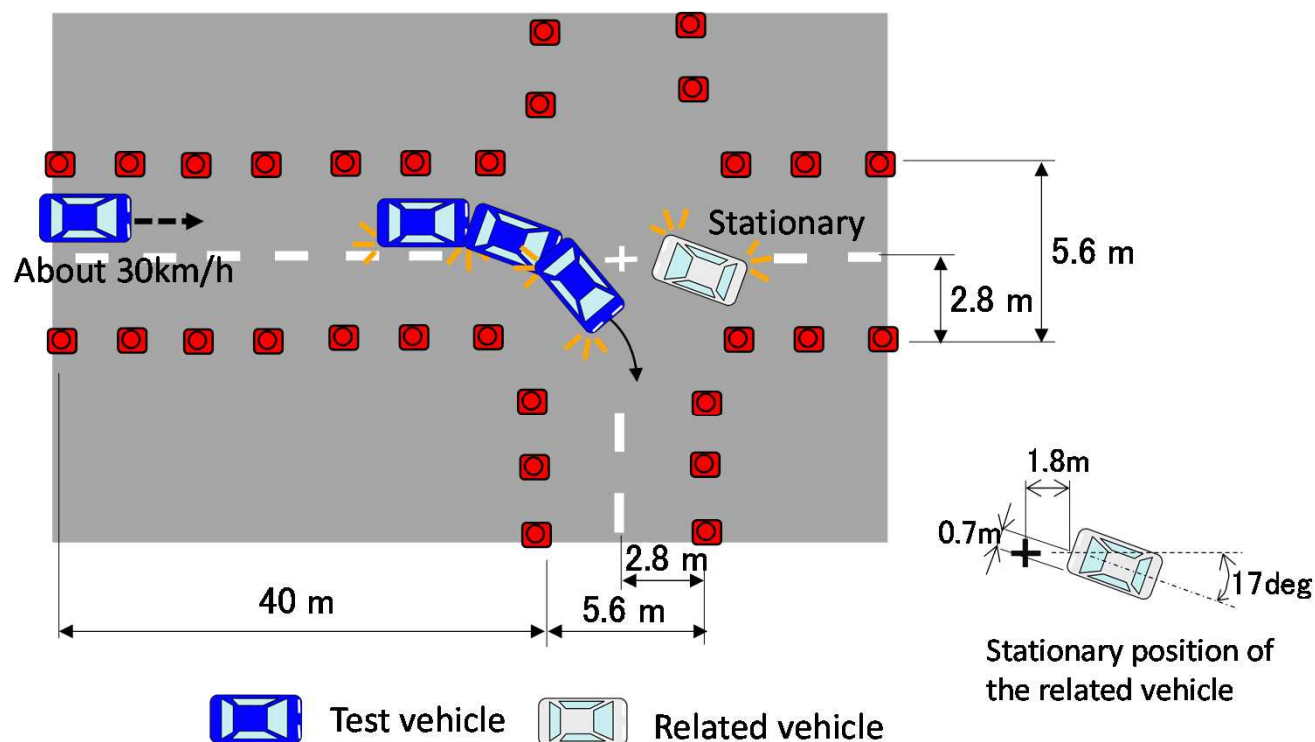


\*The condition of "without Pedestrian target" is also carried out.

### 3. Scenarios for data measurement of driving behavior by normal drivers

- Data measurement was carried out in the following four scenarios.

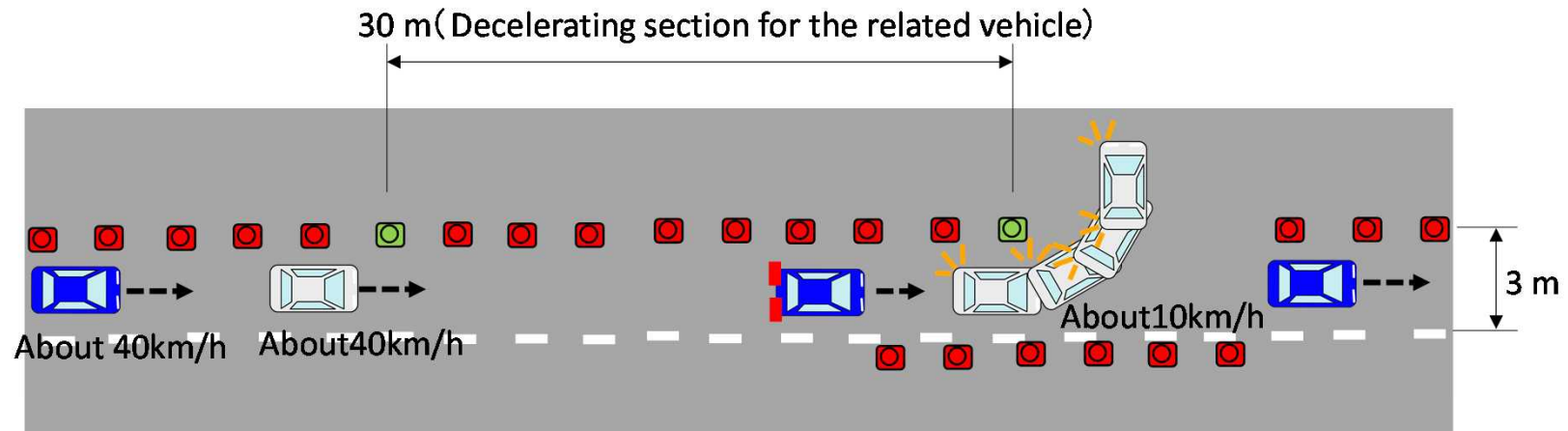
#### Scenario A (Based on draft Scenario 1)



- The test vehicle drives the straight section at the speed of about 30km/h.
- The test vehicle starts to flash the turn signal indicator, and decelerate itself.
- The test vehicle turns right at the intersection.\*
- The experiment of one time is finished at when the test vehicle completes turning right.

**\*During turning right at the intersection, the speed and the trajectory depend on driving behavior of the experimental participants.**

## Scenario B (Based on draft Scenario 2)

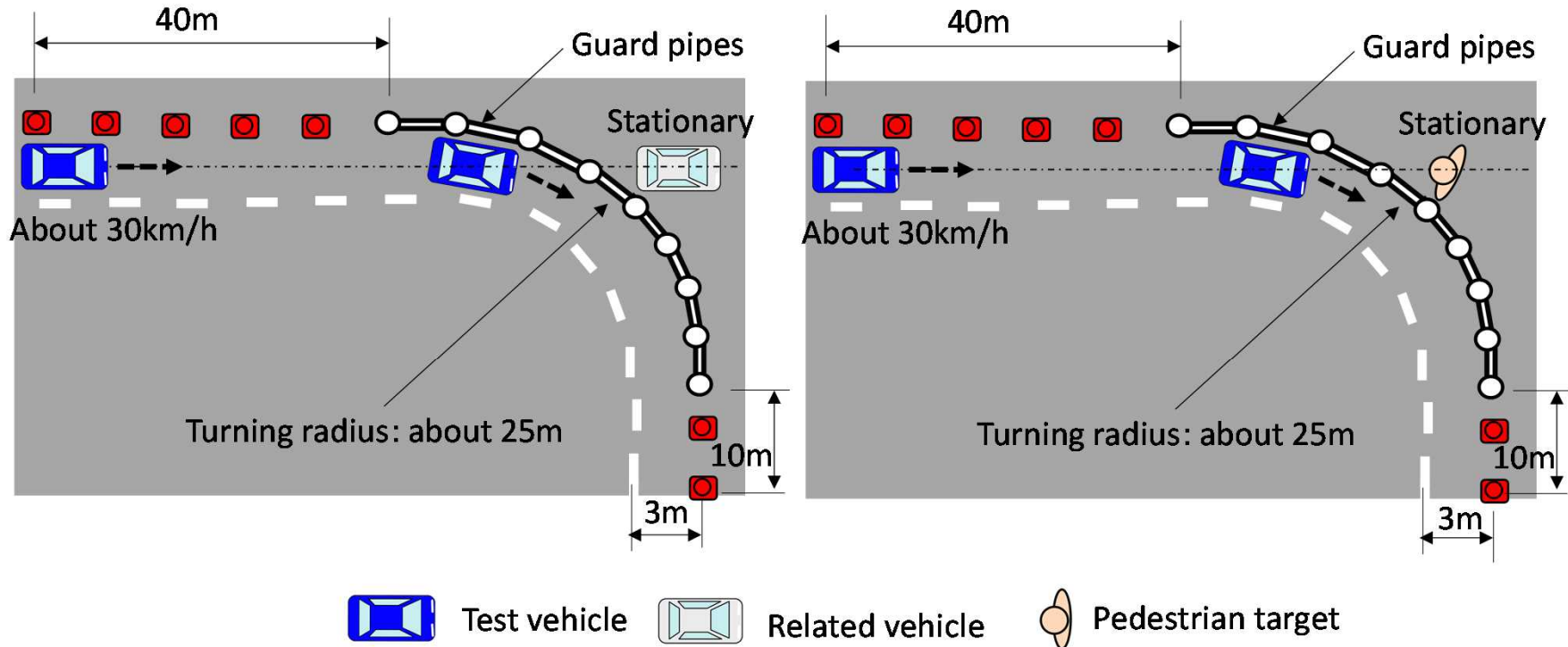


- The test vehicle follows the related vehicle and drives the straight section at the speed of about 40km/h.\*
- The related vehicle starts to flash the turn signal indicator about 30m before the point of turning left.
- The related vehicle decelerates the speed from about 40km/h to about 10km/h in the decelerating section.
- The related vehicle turns left with the speed of about 10km/h.
- The test vehicle decelerates itself in order to avoid a collision with the related vehicle, and then, drives itself straight and accelerates.
- The experiment of one time is finished at when the speed of the test vehicle is recovered to about 40km/h.

**\*During following the related vehicle at the speed of about 40km/h, the distance between the two vehicles depends on driving behavior of the experimental participants**



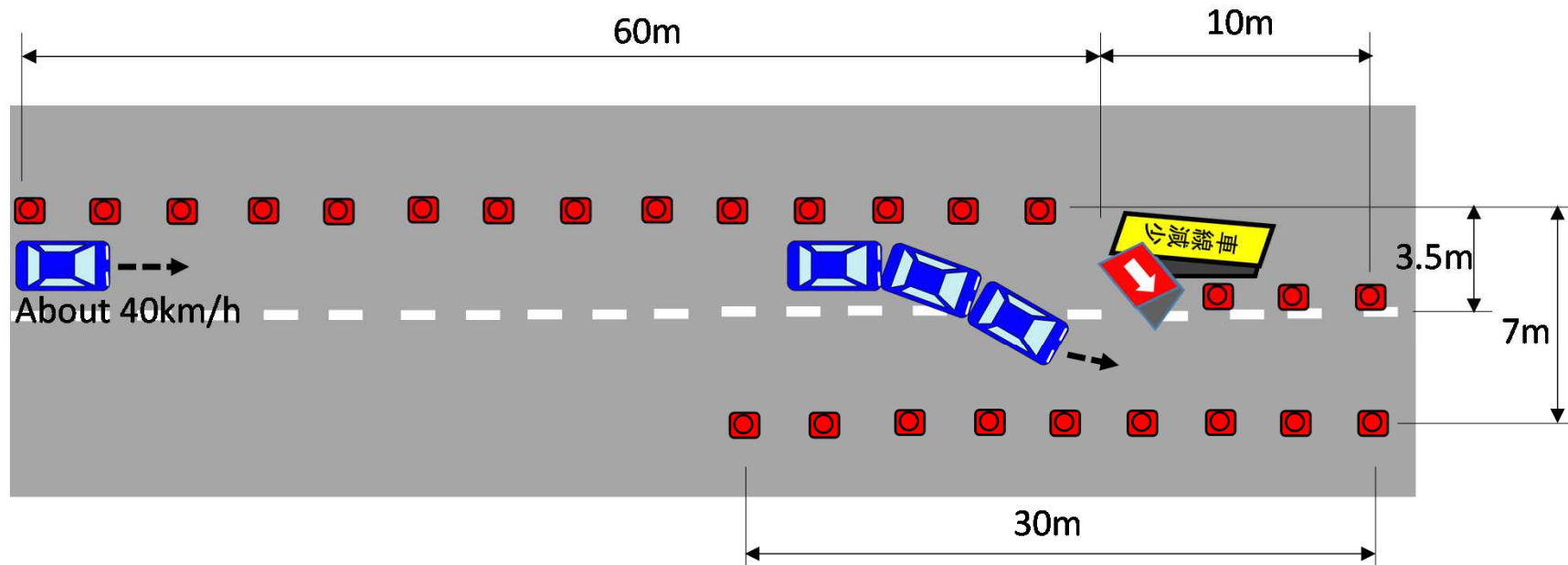
## Scenario C (Based on draft Scenario)



- The test vehicle drives the straight section at the speed of about 30km/h.
- The test vehicle enters the curved section.\*
- The test vehicle passes through the curved section.
- The experiment of one time is finished at when the test vehicle moves to the straight section.

**\*During driving the curved section, the speed and trajectory within the lane depend on driving behavior of the experimental participants.**

## Scenario D (Based on draft Scenario 6)

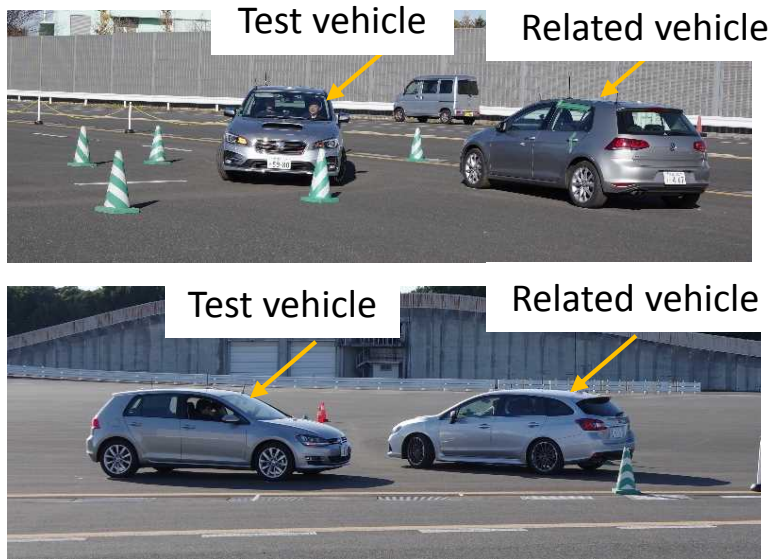


- The test vehicle drives the straight section at the speed of about 40km/h.
- The test vehicle changes the lane in front of the signboard which notifies reducing the lane.\*
- The experiment of one time is finished at when the test vehicle moves to the right side lane.

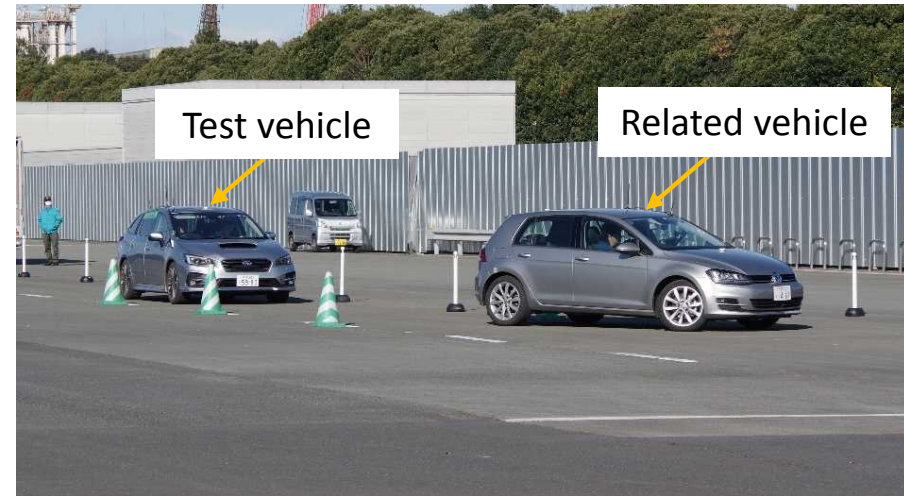
**\*Start timing of changing the lane depend on driving behavior of the experimental participants.**

# Examples of the pictures during the experiments

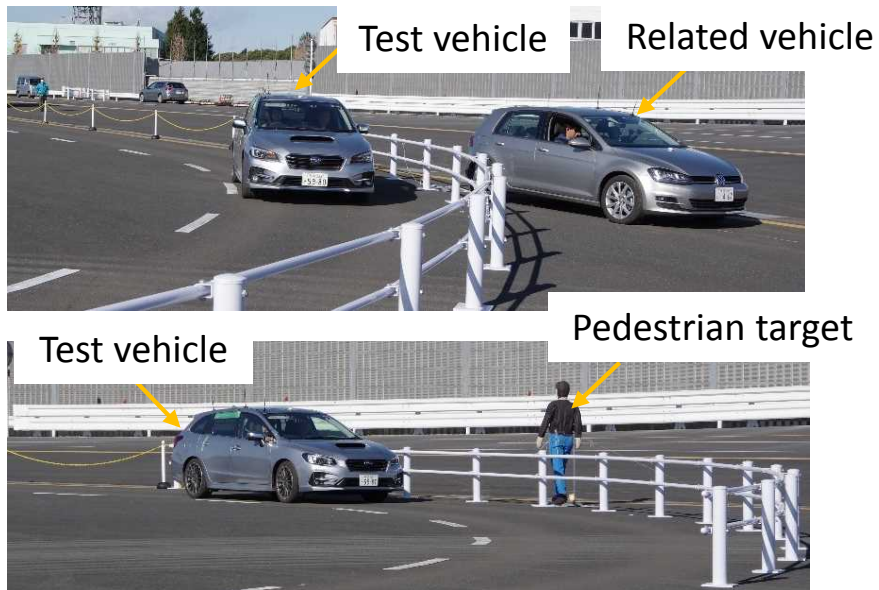
## Scenario A



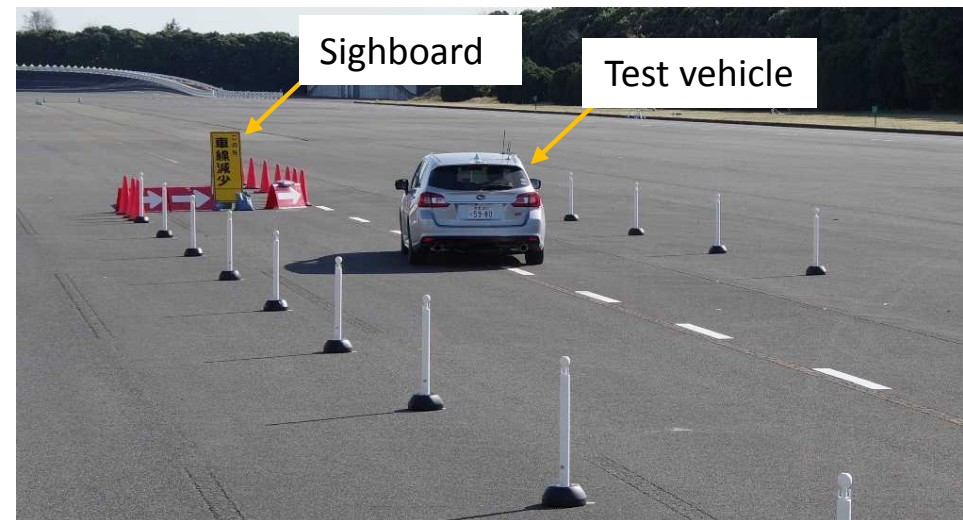
## Scenario B



## Scenario C



## Scenario D



## 4. Profile of the experiment participants and procedure

- Ten normal drivers who drive car in their daily life participated the experiments.

Profile of the experiment participants

ID	Sex	Age	Driving career
1	Female	20	about 1year
2	Female	35	about 15years
3	Male	38	about 16years
4	Male	56	about 38years
5	Male	52	about 30years
6	Male	44	about 25years
7	Female	54	about 35years
8	Female	28	about 10years
9	Female	48	about 30years
10	Female	29	about 12years

## 4. Profile of the experiment participants and procedure

- The experiments were carried out based on the rule of ethic applied to experiments carried out to human being in NTSEL.
- Informed consent was confirmed.
- Outline of each scenario was explained to the experiment participants.
- Before start of the experiment, practice driving to experience the test vehicle well was carried out (ex. acceleration, deceleration, turning, keeping appropriate distance to the related vehicle). And practice driving in each scenario was also carried out approximately two times.
- The number of experiments in each scenario to one experiment participant was three times.

## 5. Test vehicle and Related vehicle

### <Test vehicle>

- A passenger car made by a Japanese manufacturer was used.
- During the experiments, **AEBS and LDWS were deactivated (switched off)**.

### <Related vehicle>

- A passenger car made by a German manufacturer was used.



Test vehicle



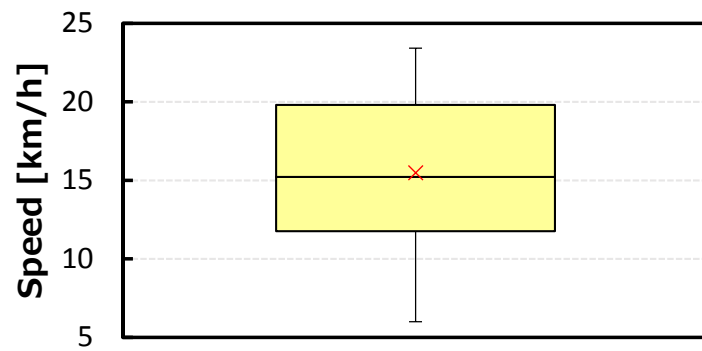
Related vehicle

## 6. Result of the experiments

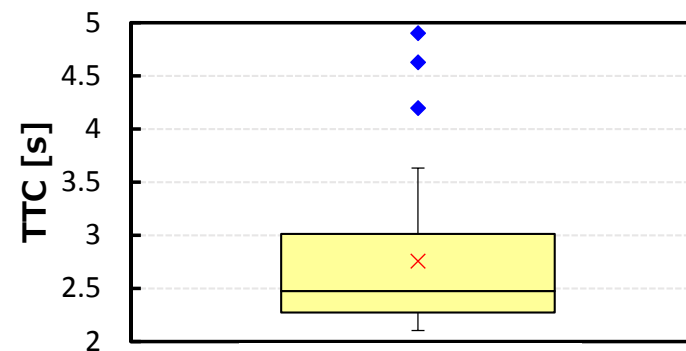
### Scenario A

#### 1) At the timing of beginning to steer for right turn at the intersection

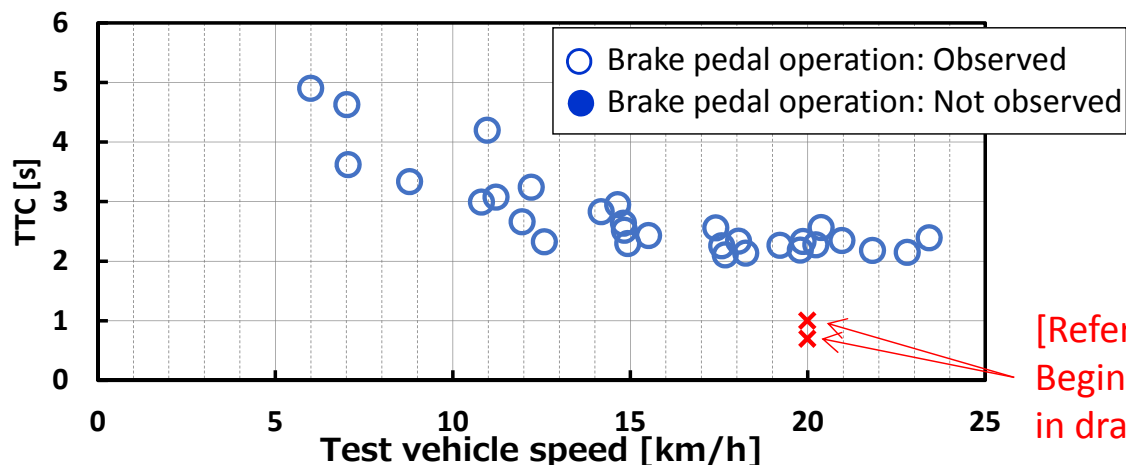
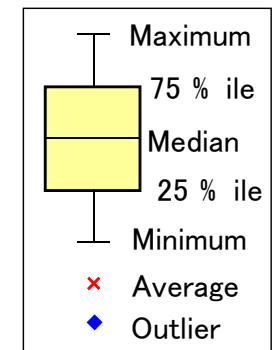
- A lot of data of the test vehicle speed exists between 12km/h and 20km/h.
- A lot of data of TTC to the related vehicle exists between 2.3 sec. and 3.0sec..  
⇒ It is larger than TTC at the same timing of draft scenario 1.
- Brake pedal operation is observed in all data.



Beginning to steer

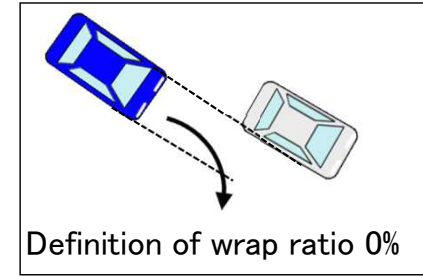


Beginning to steer



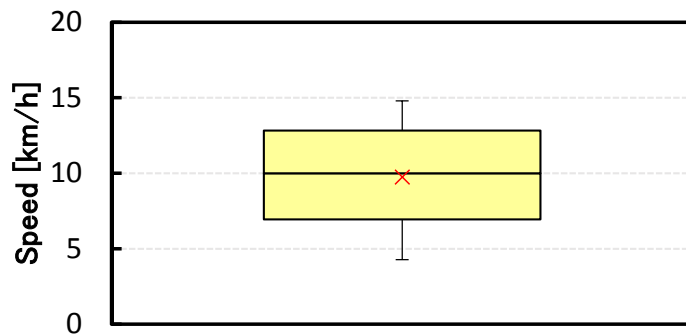
[Reference]  
Beginning to steer  
in draft scenario 1

## Scenario A

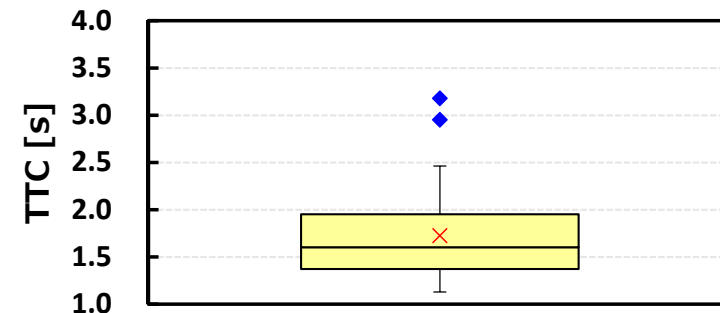


### 2) At the timing of becoming 0% of wrap ratio to the related vehicle

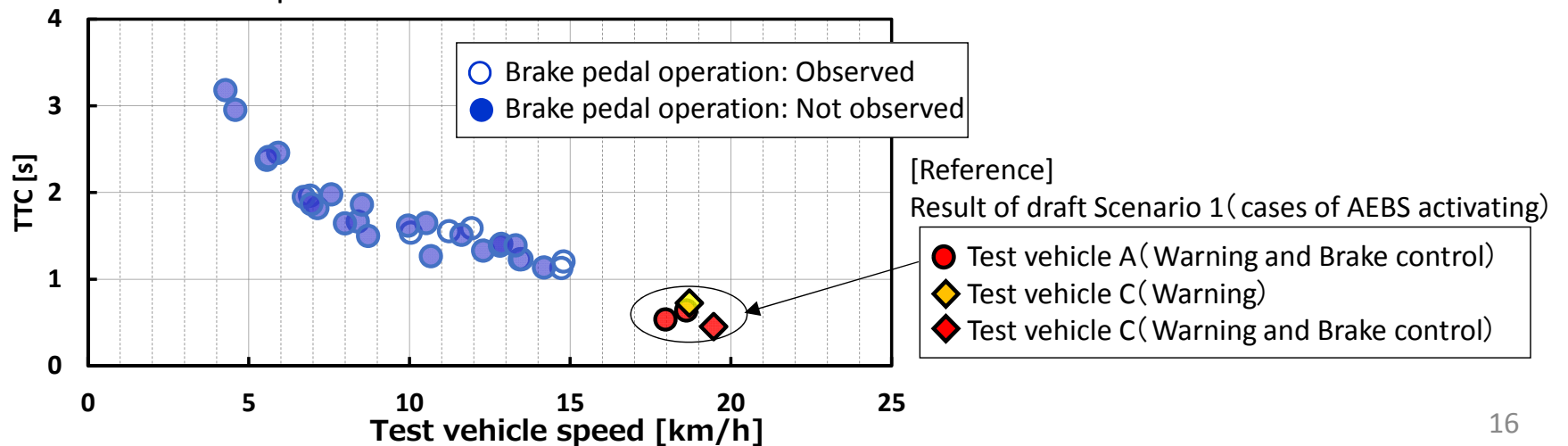
- A lot of data of the test vehicle speed exists between 7km/h and 13km/h.
- A lot of data of TTC to the related vehicle exists between 1.4 sec. and 2.0sec..  
⇒ It is larger than TTC of the cases of AEBS activating in draft scenario 1.
- No brake pedal operation is observed in 73% of data.



Wrap ratio 0%



Wrap ratio 0%



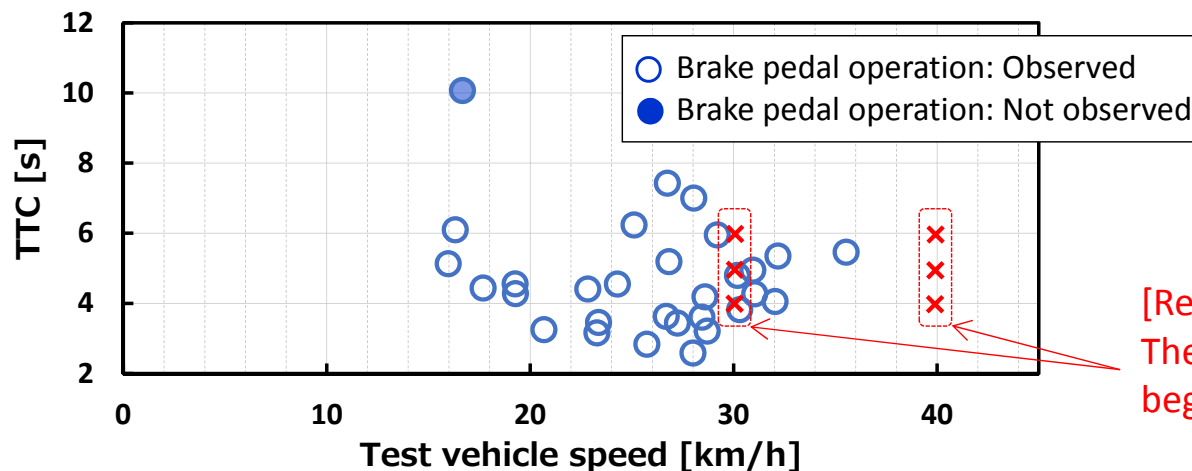
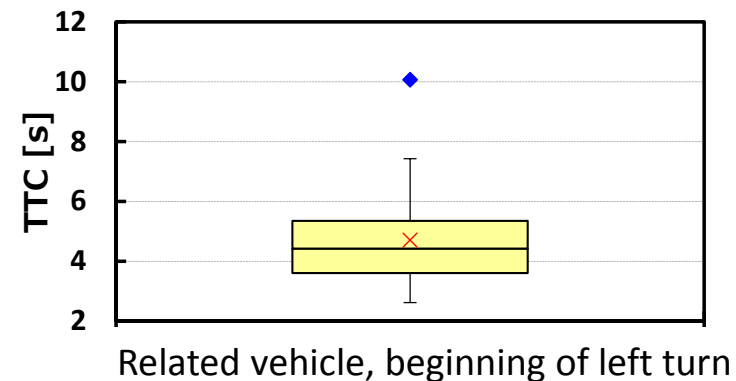
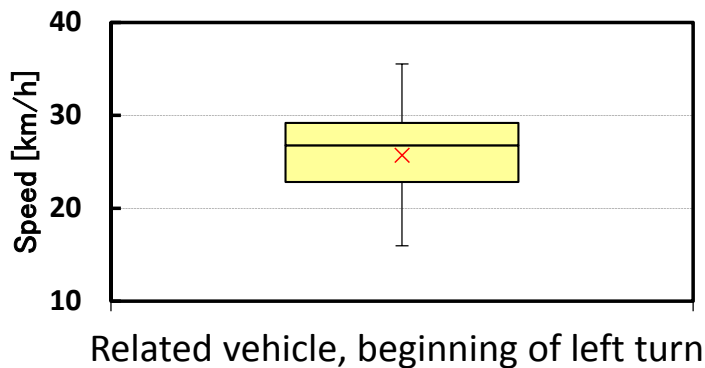


## Scenario B

\*The timing when the relative yaw angle between the test vehicle and the related vehicle becomes 2 deg.

### 1) At the timing when the related vehicle begins left turn\*

- A lot of data of the test vehicle speed exists between 22km/h and 29km/h.
- A lot of data of TTC to the related vehicle exists between 3.6 sec. and 5.4sec..  
⇒ It is approximate to TTC at the timing of beginning to steer to in draft scenario 2.
- Brake pedal operation is observed in 97% of data.

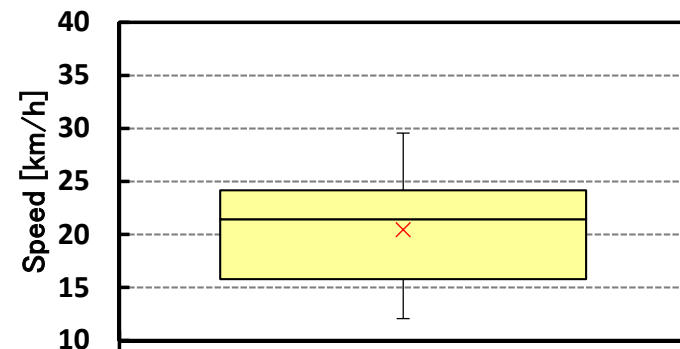


[Reference]  
The timing when the related vehicle begins to steer in draft scenario 2

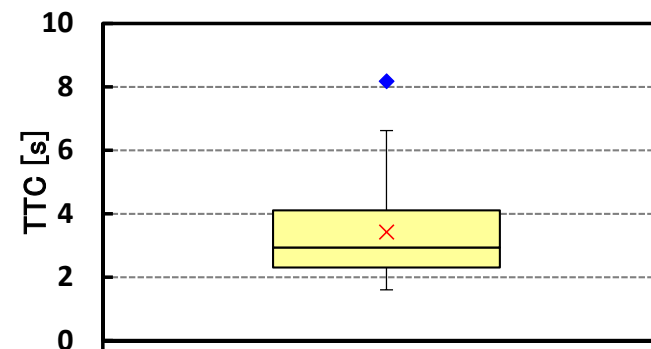
## Scenario B

### 2) At the timing of becoming 50% of wrap ratio to the related vehicle

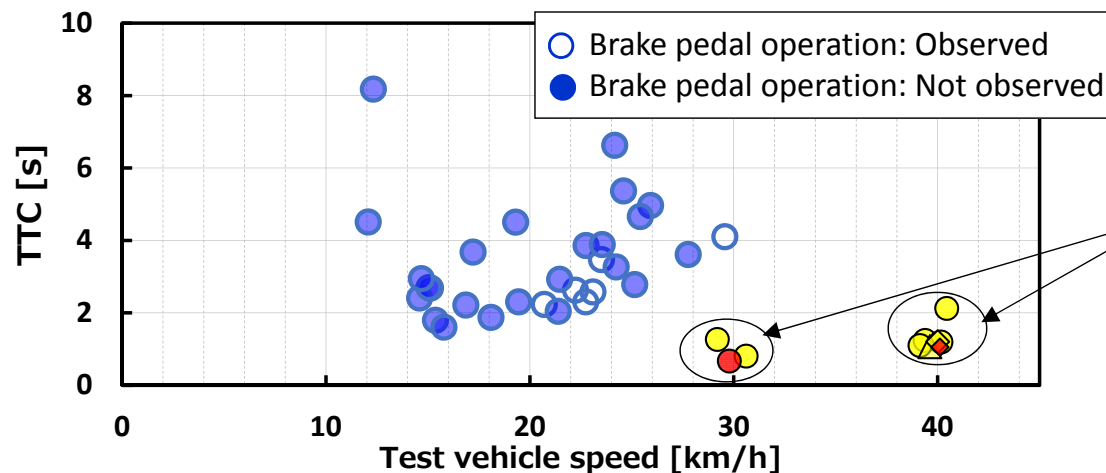
- A lot of data of the test vehicle speed exists between 16km/h and 24km/h.
- A lot of data of TTC to the related vehicle exists between 2.3 sec. and 4.1sec..  
 $\Rightarrow$  2.3 sec. is approximate to TTC of the cases of AEBS activating in draft scenario 2.
- No Brake pedal operation is observed in 80% of data.



Wrap ratio 50%



Wrap ratio 50%



[Reference]

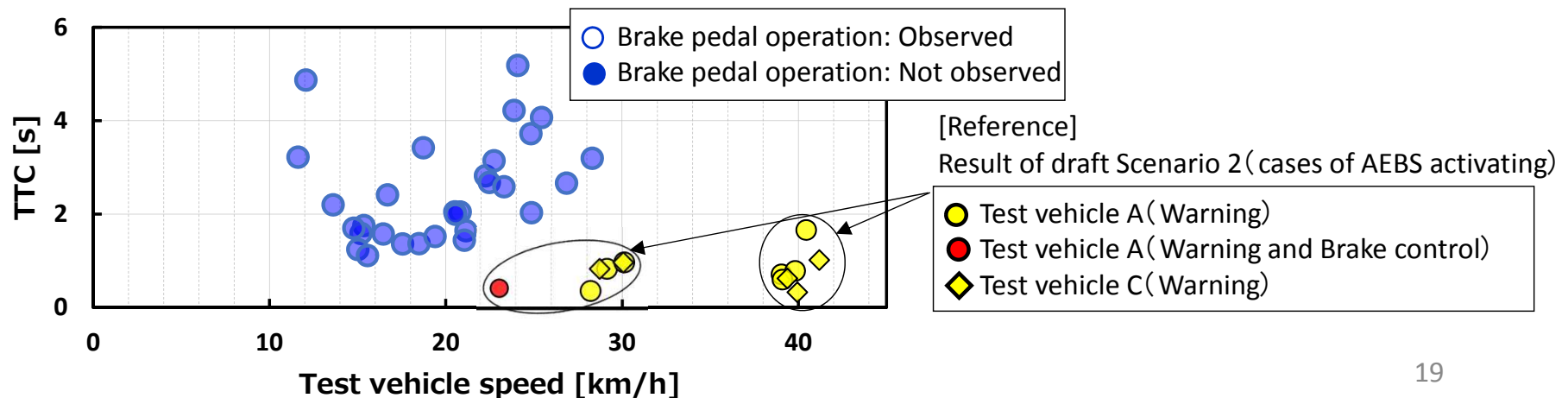
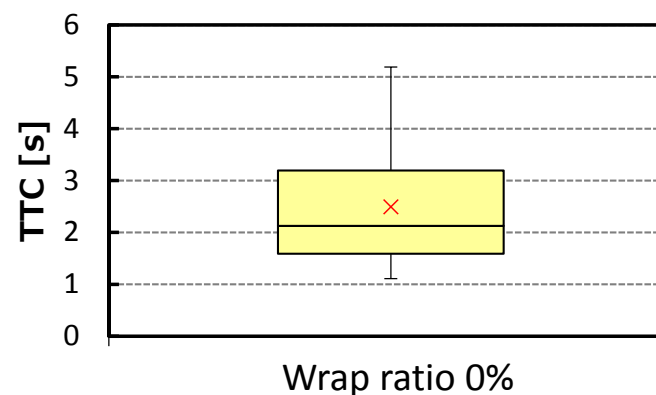
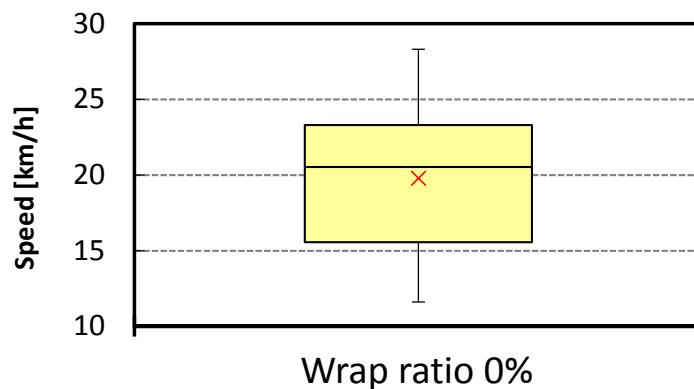
Result of draft Scenario 2 (cases of AEBS activating)

- Test vehicle A (Warning)
- Test vehicle A (Warning and Brake control)
- ▲ Test vehicle B (Warning)
- ◆ Test vehicle C (Warning)
- ◆ Test vehicle C (Warning and Brake control)

## Scenario B

### 3) At the timing of becoming 0% of wrap ratio to the related vehicle

- A lot of data of the test vehicle speed exists between 16km/h and 23km/h.
- A lot of data of TTC to the related vehicle exists between 1.6 sec. and 3.2sec..  
⇒ 1.6 sec. is approximate to TTC of the case of AEBS activating in draft scenario 2.
- No Brake pedal operation is observed in all of data.

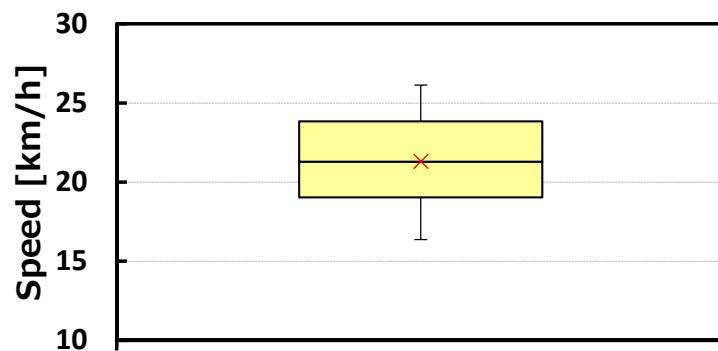


## Scenario C (Stationary vehicle)

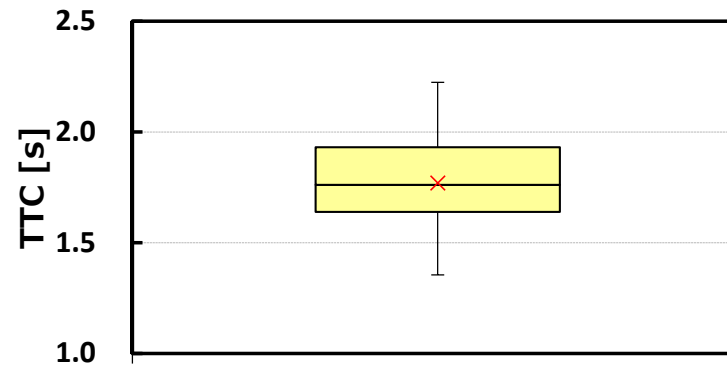
\*The timing when the yaw angle of the test vehicle exceeds 2 deg.

### 1) At the timing of beginning to turn right\*

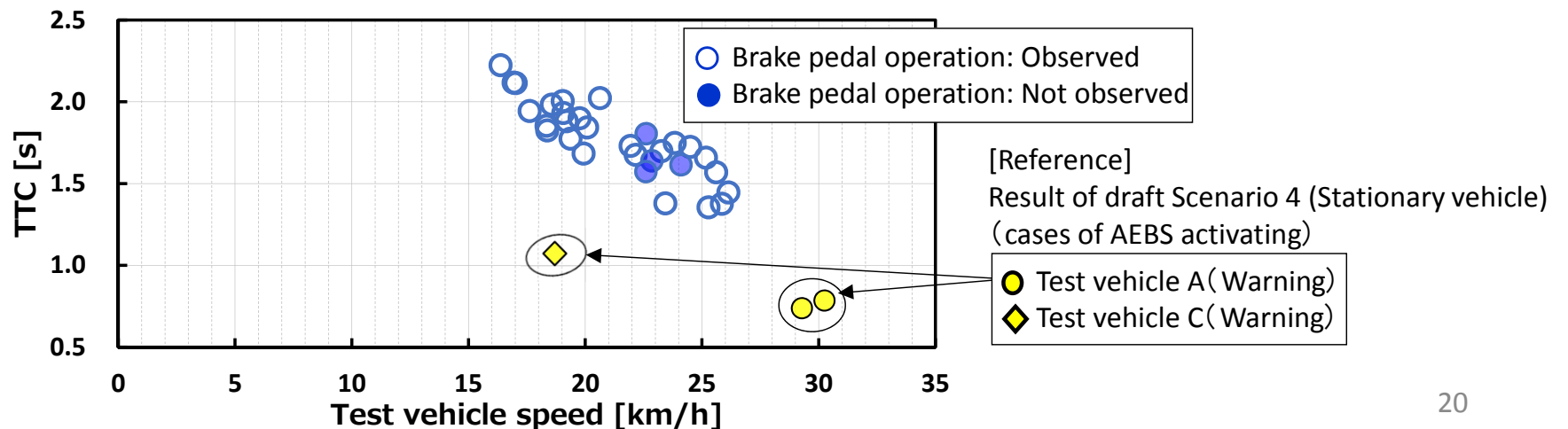
- A lot of data of the test vehicle speed exists between 19km/h and 24km/h.
- A lot of data of TTC to the related vehicle exists between 1.6 sec. and 1.9sec..  
⇒ It is larger than TTC of the cases of AEBS activating in draft scenario 4.
- Brake pedal operation is observed in 87% of data.



Beginning of turning right



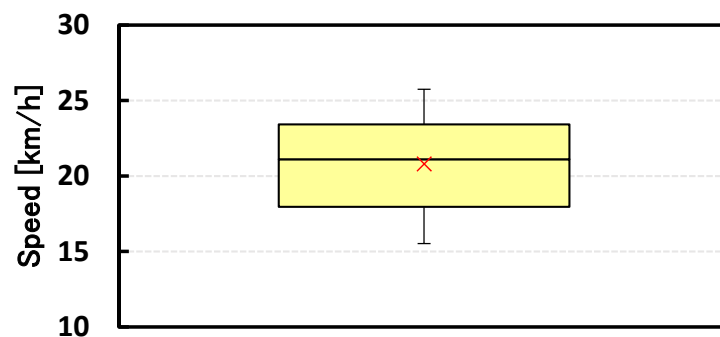
Beginning of turning right



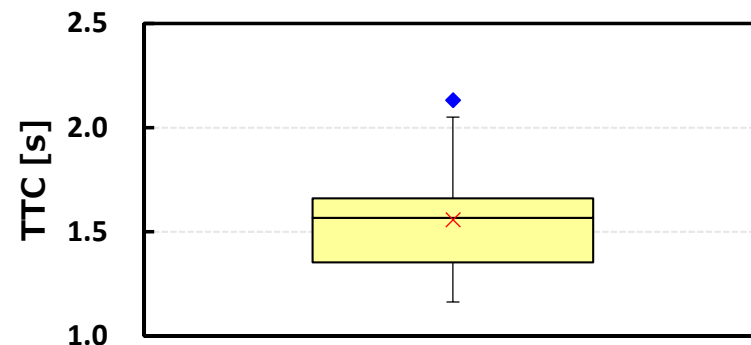
## Scenario C (Stationary vehicle)

### 2) At the timing of becoming 50% of wrap ratio to the stationary vehicle

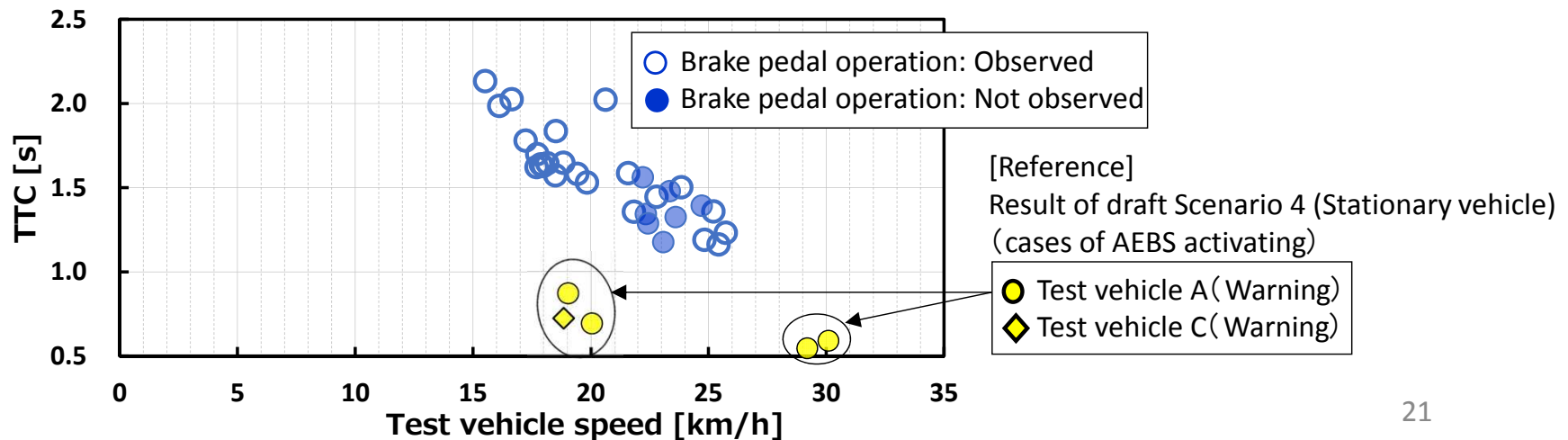
- A lot of data of the test vehicle speed exists between 18km/h and 23km/h.
- A lot of data of TTC to the related vehicle exists between 1.4 sec. and 1.7sec..  
⇒ It is larger than TTC of the cases of AEBS activating in draft scenario 4.
- Brake pedal operation is observed in 77% of data.



Wrap ratio 50%



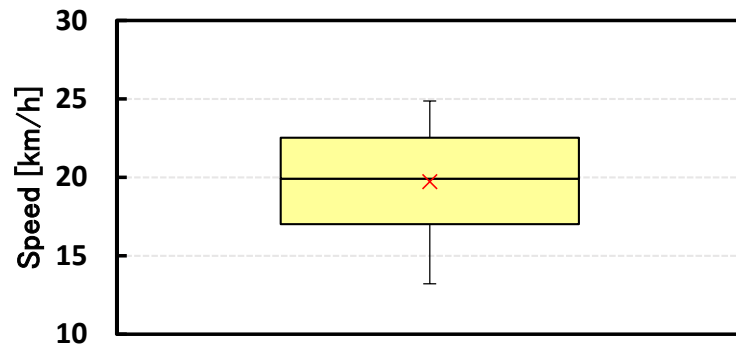
Wrap ratio 50%



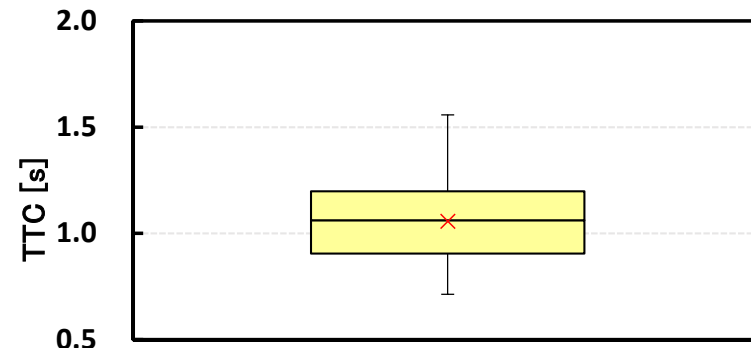
## Scenario C (Stationary vehicle)

### 3) At the timing of becoming 0% of wrap ratio to the stationary vehicle

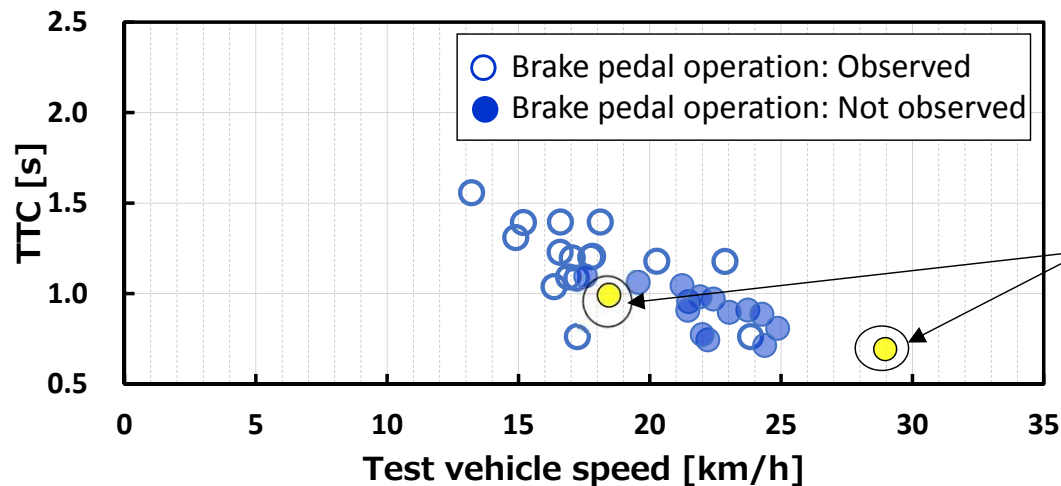
- A lot of data of the test vehicle speed exists between 17km/h and 23km/h.
- A lot of data of TTC to the related vehicle exists between 0.9 sec. and 1.2sec..  
⇒ It is approximate to TTC of the cases of AEBS activating in draft scenario 4.
- No Brake pedal operation is observed in 47% (80% in case of above 20km/h) of data.



Wrap ratio 0%



Wrap ratio 0%



[Reference]  
Result of draft Scenario 4 (Stationary vehicle)  
(cases of AEBS activating)

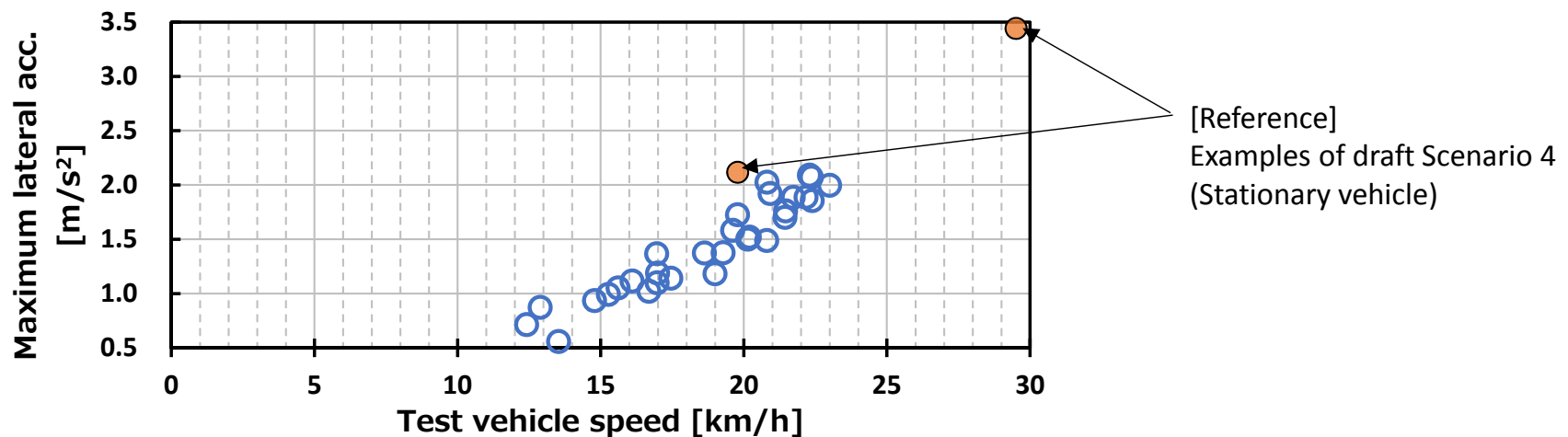
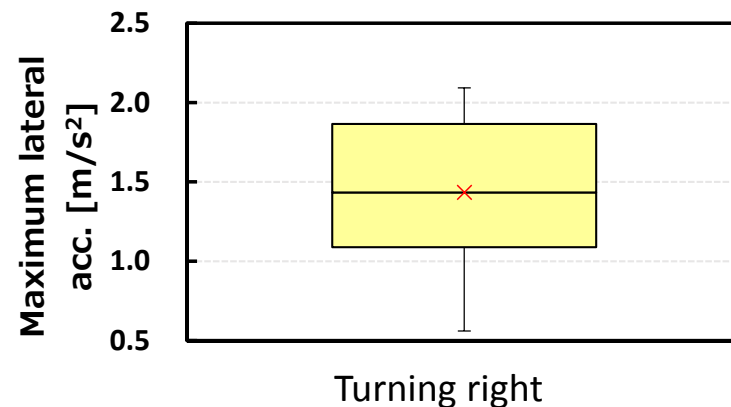
● Test vehicle A (Warning)

## Scenario C (Stationary vehicle)

### 3) Maximum lateral acceleration during turning right

- A lot of data of the maximum lateral acceleration exists between  $1.1\text{m/s}^2$  and  $1.9\text{m/s}^2$ .

⇒ It is approximate to the maximum lateral acceleration of the condition of the speed of test vehicle  $20\text{km/h}$  in draft scenario 4.

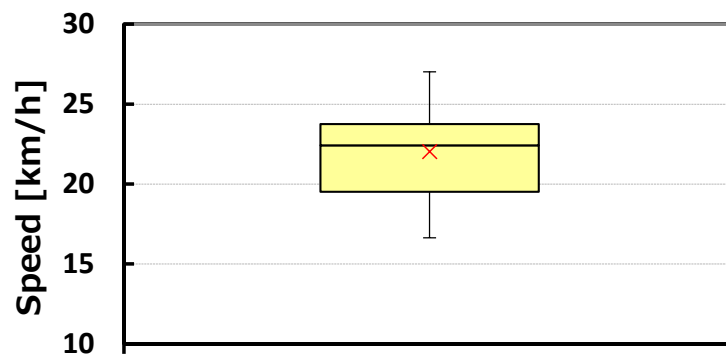


## Scenario C (Pedestrian target)

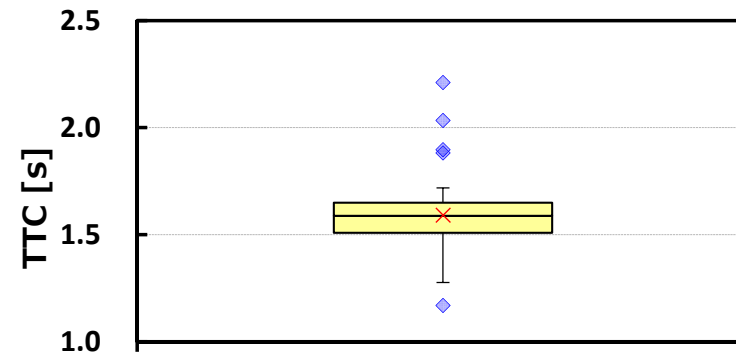
\*The timing when the yaw angle of the test vehicle exceeds 2 deg.

### 1) At the timing of beginning to turn right\*

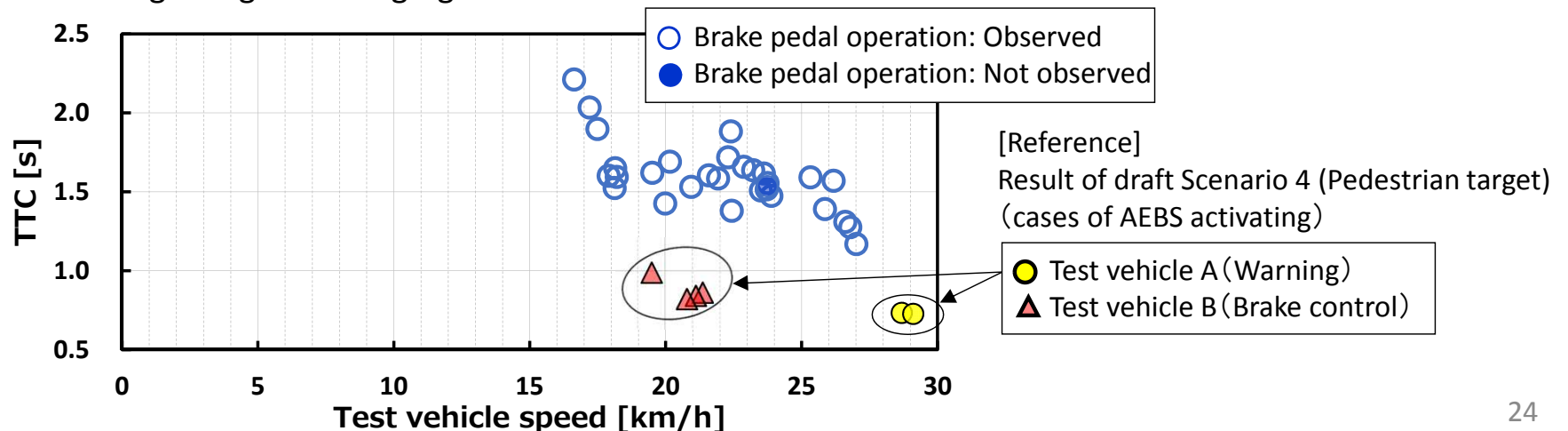
- A lot of data of the test vehicle speed exists between 19km/h and 24km/h.
- A lot of data of TTC to the related vehicle exists between 1.5 sec. and 1.7sec..  
⇒ It is larger than TTC of the cases of AEBS activating in draft scenario 4.
- Brake pedal operation is observed in 97% of data.



Beginning of turning right

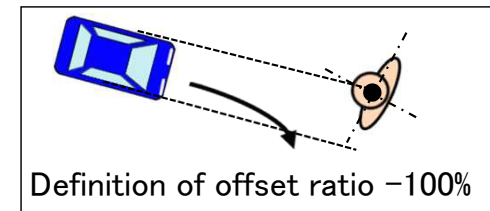


Beginning of turning right



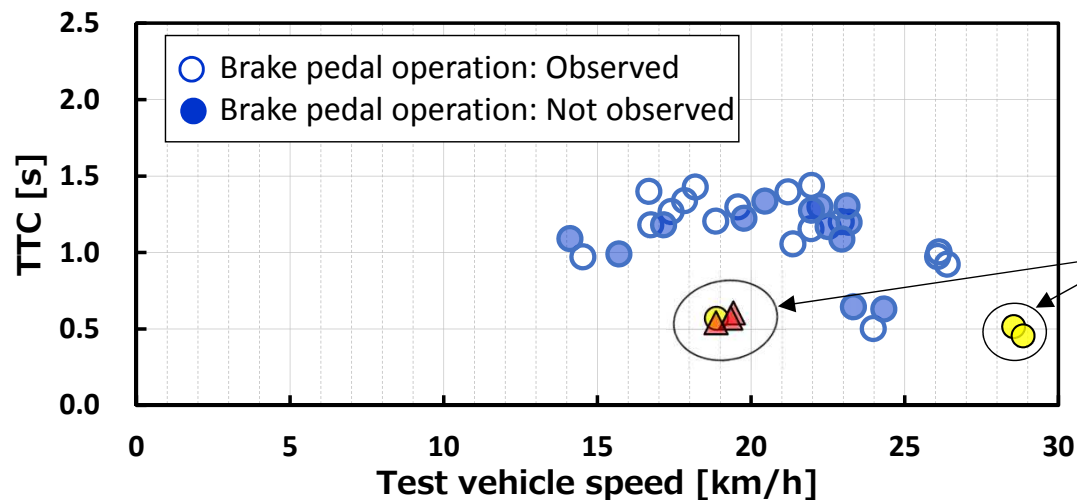
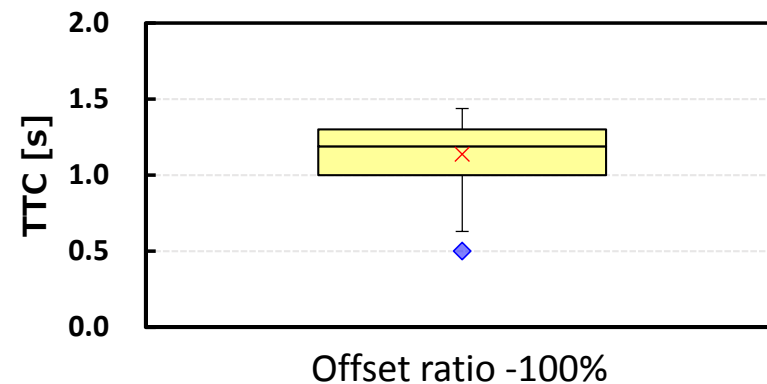
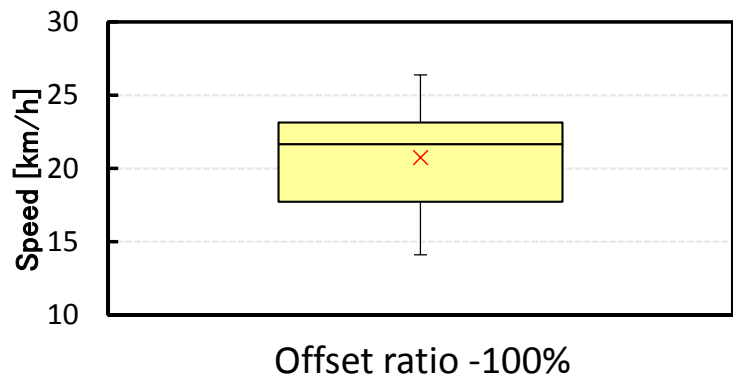


## Scenario C (Pedestrian target)



### 2) At the timing of becoming -100% of offset ratio to the pedestrian target

- A lot of data of the test vehicle speed exists between 18km/h and 23km/h.
- A lot of data of TTC to the related vehicle exists between 1.0 sec. and 1.3sec..  
⇒ It is larger than TTC of the cases of AEBS activating in draft scenario 4.
- No Brake pedal operation is observed in 43% (50% in case of above 20km/h) of data.



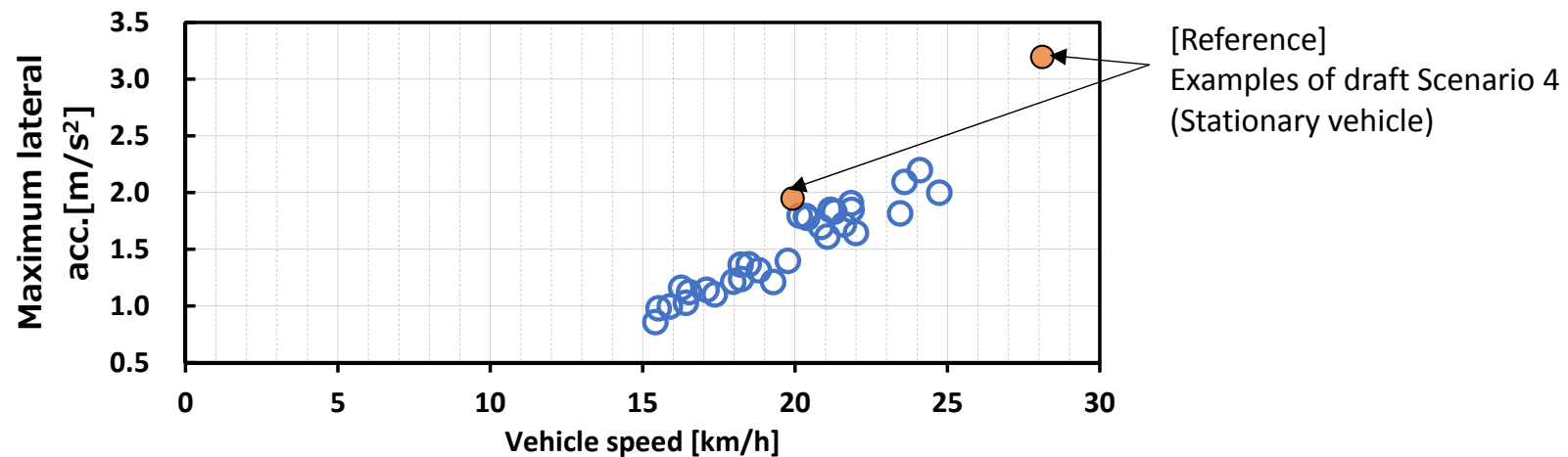
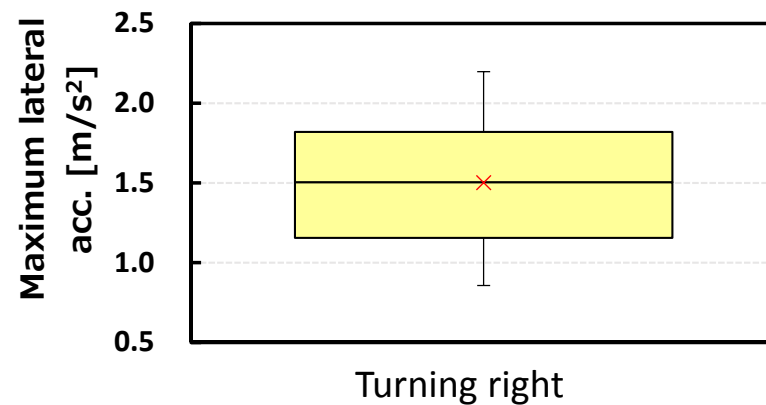
[Reference]  
Result of draft Scenario 4 (Pedestrian target)  
(cases of AEBS activating)

- Test vehicle A (Warning)
- ▲ Test vehicle B (Brake control)

## Scenario C (Pedestrian target)

### 3) Maximum lateral acceleration during turning right

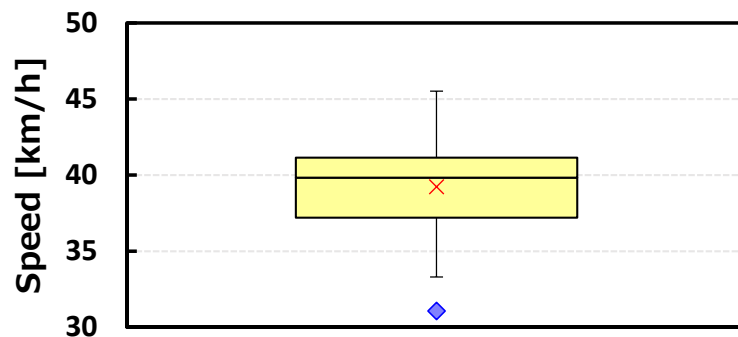
- A lot of data of the maximum lateral acceleration exists between  $1.2\text{m/s}^2$  and  $1.8\text{m/s}^2$ .
- ⇒ It is approximate to the maximum lateral acceleration of the condition of the speed of test vehicle  $20\text{km/h}$  in draft scenario 4.



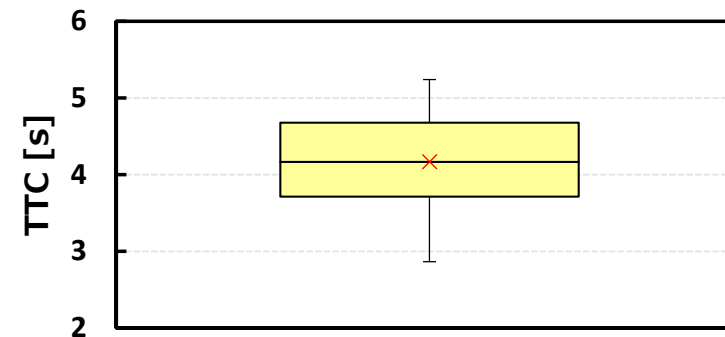
## Scenario D

### 1) At the timing of beginning to steer for changing the lane

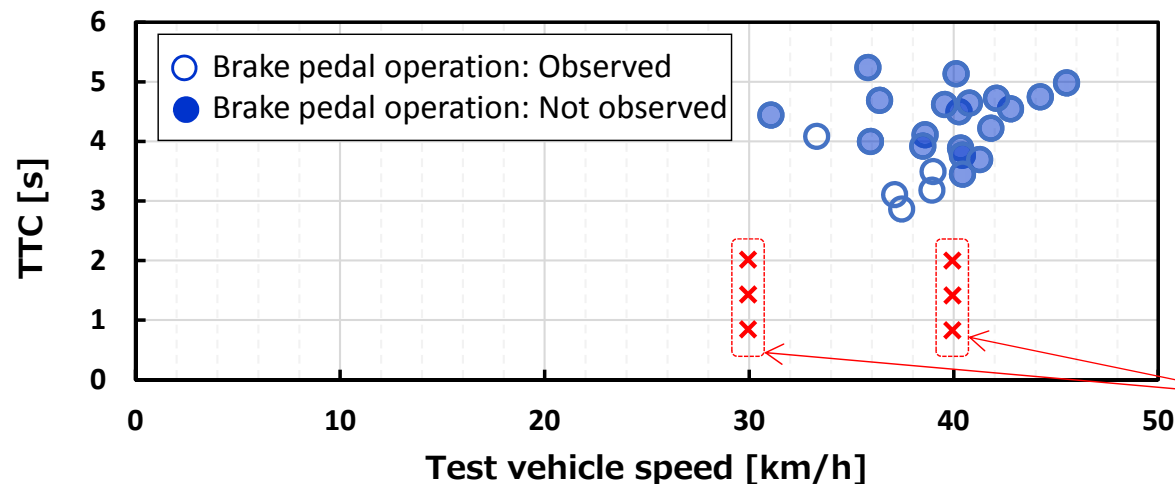
- A lot of data of the test vehicle speed exists between 37km/h and 41km/h.
- A lot of data of TTC to the related vehicle exists between 3.7 sec. and 4.7 sec..  
⇒ It is larger than TTC of the cases of AEBS activating in draft scenario 6.
- No Brake pedal operation is observed in 79% of data.



Beginning to steer

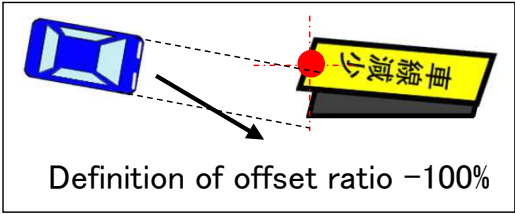


Beginning to steer



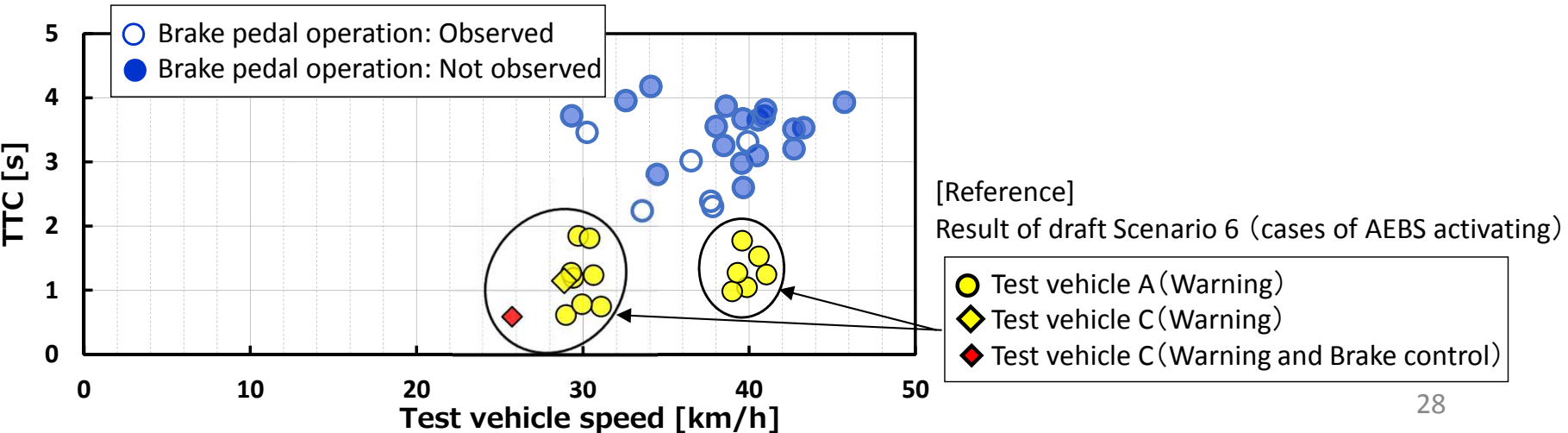
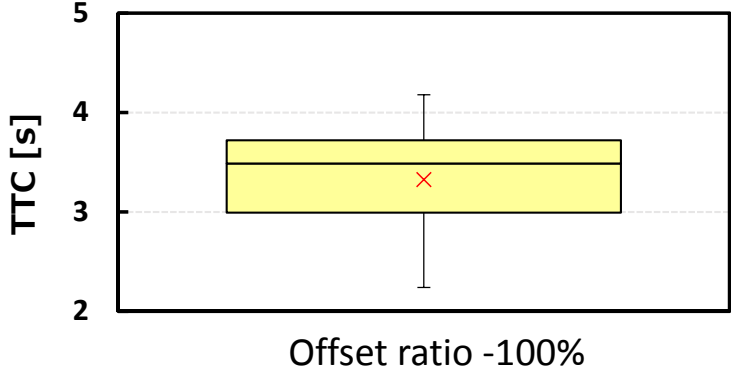
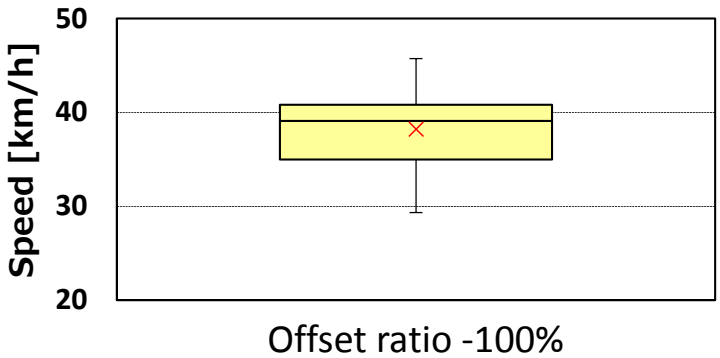
[Reference]  
Beginning to steer  
in draft scenario 6

# Scenario D



## 2) At the timing of becoming -100% of offset ratio to the signboard

- A lot of data of the test vehicle speed exists between 35km/h and 41km/h.
- A lot of data of TTC to the related vehicle exists between 3.0 sec. and 3.7 sec..  
 ⇒ It is larger than TTC of the cases of AEBS activating in draft scenario 6.
- No Brake pedal operation is observed in 75% of data.



## 7. Summary of the results of the experiments

Scenario	The point of data extraction	Driving behavior of normal drivers (experiment participants)			
		Speed (25%ile - 75%ile)	TTC (25%ile - 75%ile)	Brake pedal operation	Others
A	Beginning to steer for right turn	12~20km/h	2.3~3.0 sec.	Observed (all of data)	
	Wrap ratio 0%	7~13km/h	1.4~2.0 sec.	Not observed (73% of data)	
B	Beginning of left turn (related vehicle)	22~29km/h	3.6~5.4 sec.	Observed (97% of data)	
	Wrap ratio 50%	16~24km/h	2.3~4.1 sec.	Not observed (80% of data)	
	Wrap ratio 0%	16~23km/h	1.6~2.3 sec.	Not observed (all of data)	

## 7. Summary of the results of the experiments

Scenario	The point of data extraction	Driving behavior of normal drivers (experiment participants)			
		Speed (25%ile - 75%ile)	TTC (25%ile - 75%ile)	Brake pedal operation	Others
C (Stationary vehicle)	Beginning to turn right	19~24km/h	1.6~1.9 sec.	Observed (87% of data)	Maximum lateral acceleration 1.1~1.9m/s <sup>2</sup>
	Wrap ratio 50%	18~23km/h	1.4~1.7 sec.	Observed (77% of data)	
	Wrap ratio 0%	17~23km/h	0.9~1.2 sec.	Observed (53% of data)	
C (Pedestrian target)	Beginning to turn right	19~24km/h	1.5~1.7 sec.	Observed (97% of data)	Maximum lateral acceleration 1.2~1.8m/s <sup>2</sup>
	Offset ratio -100%	18~23km/h	1.0~1.3 sec.	Observed (57% of data)	
D	Beginning to steer for changing a lane	37~41km/h	3.7~4.7 sec.	Not observed (79% of data)	
	Offset ratio -100%	35~41km/h	3.0~3.7 sec.	Not observed (75% of data)	

## 8. Proposal of modification in the draft scenarios

Based on the experiment results of measuring driving behavior of normal drivers, some modification is proposed in the draft scenario 1, 2, 4 and 6.

### Draft Scenario 1

Driving condition		New proposal	Original proposal
Straight section	Speed	30km/h	20km/h
Beginning to steer for right turn	Speed	Decelerating to not less than 20km/h by braking	20km/h (constant) Without braking
	TTC to the related vehicle	not more than 2.3 sec.	about 0.7 sec. and about 1.0 sec.
During right turn	Speed	Decelerating to about 13km/h by braking, and then keeping constant speed	20km/h (constant) Without braking
	TTC to the related vehicle	not more than 1.4 sec. (timing of wrap ratio 0%)	Not prescribed

## Draft Scenario 2

Driving condition			New proposal	Original proposal
During following the related vehicle	Speed	Test vehicle	40km/h (constant)	30km/h (constant) and 40km/h (constant)
		Related vehicle	40km/h (constant)	10km/h (constant)
During decelerating before left turn (related vehicle)	Speed	Test vehicle	Decelerating to not less than 30km/h	(Not decelerating before left turn)
		Related vehicle	Decelerating to 10km/h	
Beginning of left turn (related vehicle)	Speed	Test vehicle	not less than 30km/h (continuing of braking)	30km/h (constant) and 40km/h (constant)
		Related vehicle	10km/h (constant)	10km/h (constant)
	TTC to the related vehicle		not more than 3.5 sec.	4sec., 5sec. and 6sec.* *Timing of beginning to steer for left turn



## Draft Scenario 2

Driving condition			New proposal	Original proposal
During left turn (related vehicle)	Speed	Test vehicle	Decelerating to not less than 21km/h by braking, and then keeping constant speed	30km/h (constant) and 40km/h (constant)
		Related vehicle	10km/h (constant)	10km/h (constant)
	TTC to the related vehicle			not more than 1.6 sec. (timing of wrap ratio 0%)

## Draft Scenario 4\*

\*Same modification is proposed in the two types of the objects (a stationary vehicle and a pedestrian target).

Driving condition		New proposal	Original proposal
Straight section	Speed	30km/h (constant)	20km/h (constant) and 30km/h (constant)
	TTC to the object	not more than 1.5 sec.	Not prescribed
Beginning to turn right	Speed	Decelerating to not less than 24km/h by braking	20km/h (constant) and 30km/h (constant) Without braking
	TTC to the object	not more than 1.5 sec.	Not prescribed
	Lateral acceleration	equal or less than about 2m/s <sup>2</sup>	Not prescribed
During turning right	Speed	not less than 24km/h Without braking	20km/h (constant) and 30km/h (constant) Without braking
	TTC to the object	not more than 1.0 sec. (timing of wrap ratio 0% to the stationary vehicle or offset ratio -100% to the pedestrian target)	Not prescribed
	Lateral acceleration	equal or less than about 2m/s <sup>2</sup>	Not prescribed

## Draft Scenario 6

Driving condition		New proposal	Original proposal
<b>Straight section</b>	<b>Speed</b>	<b>40km/h (constant)</b>	<b>30km/h (constant) and 40km/h (constant)</b>
<b>Beginning to steer for changing a lane</b>	<b>Speed</b>	<b>40km/h (constant) Without braking</b>	<b>30km/h (constant) and 40km/h (constant) Without braking</b>
	<b>TTC to the object</b>	<b>not more than 3.7 sec.</b>	<b>0.8 sec., 1.6 sec. and 2.4 sec.</b>
<b>During changing a lane</b>	<b>Speed</b>	<b>40km/h (constant) Without braking</b>	<b>30km/h (constant) and 40km/h (constant) Without braking</b>
	<b>TTC to the object</b>	<b>not more than 3.0 sec. (timing of offset ratio - 100% to the signboard)</b>	<b>Not prescribed</b>