

Evaluation of Effectiveness of a Vehicle-Infrastructure Cooperative System under Real-World Conditions

2013.10.14

Toyota Motor Corporation

1 . Overview

2 . Field Operational Test in Toyota city

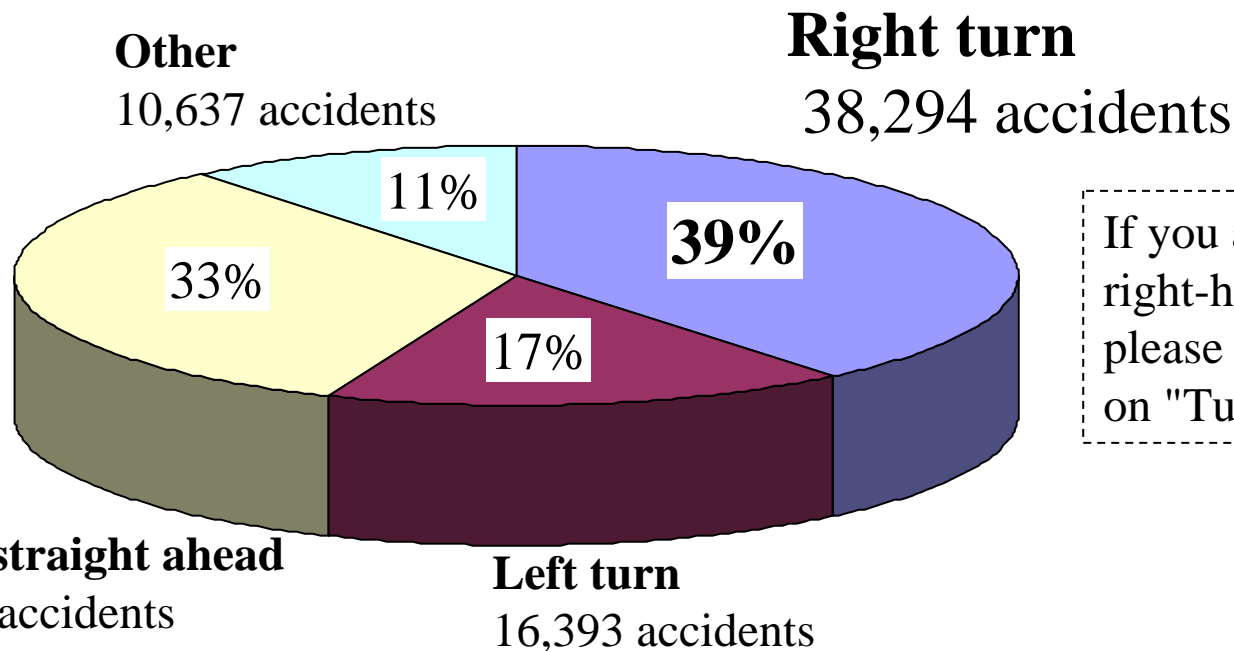
3 . Evaluation of effect

4 . Conclusion

1 . Overview

< Status of the accident at the signalized intersection in Japan >

- The rate of right turn accident is the highest.
- To reduce accidents in the intersection, measures against right turn accident is important.



If you are living in country of right-hand traffic, please replace the "Turn left" on "Turn right".

[Fig. The number of accidents caused by car at signalized intersections in 2011]

Source: Investigation of Institute for Traffic Accident Research and Data Analysis.




1. Overview

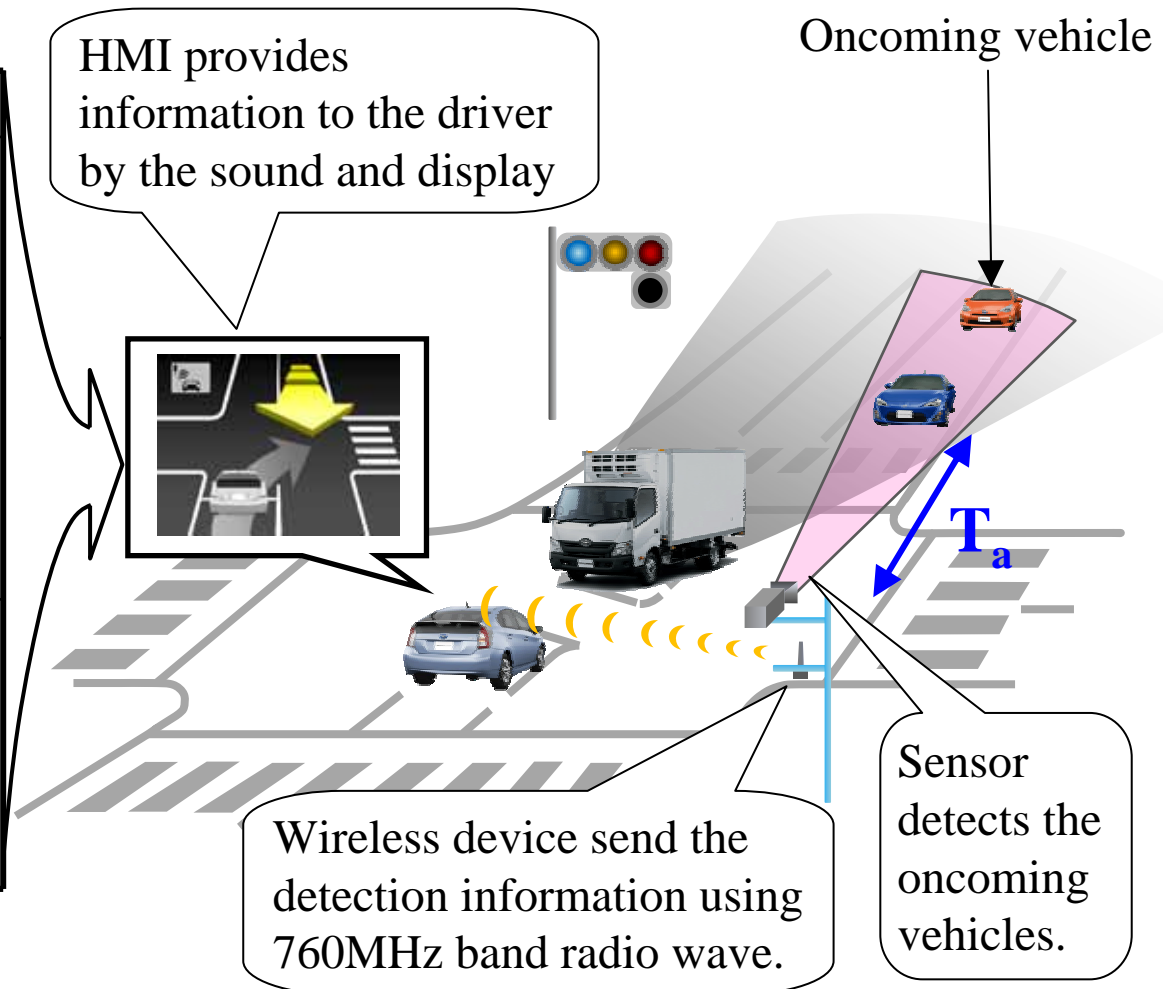
3

< Overview of Right-turn collision prevention system >

This system prevent the right straight accident by informing the presence of oncoming vehicles to the driver to turn right.

[HMI (Human Machine Interface)]

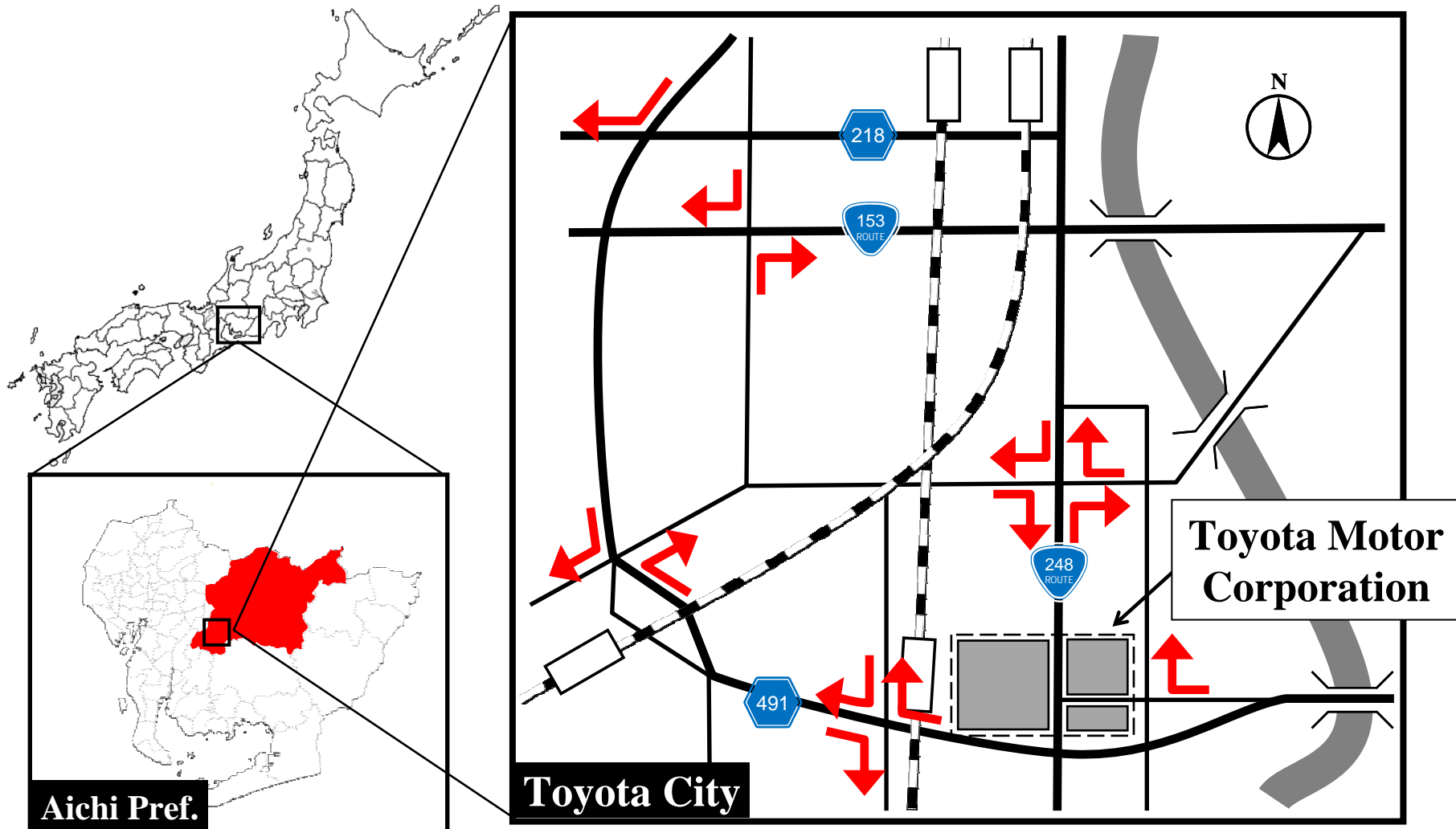
	Display	Sound	Mean
1		None	No oncoming vehicle
2		None	Vehicle is approaching ($T_a < 6\text{sec}$)
Despite vehicle is approaching the driver tried to turn right			
3		Beep	Vehicle is approaching ($T_a < 6\text{sec}$)



2 . Field Operational Test in Toyota city

< Target intersections >

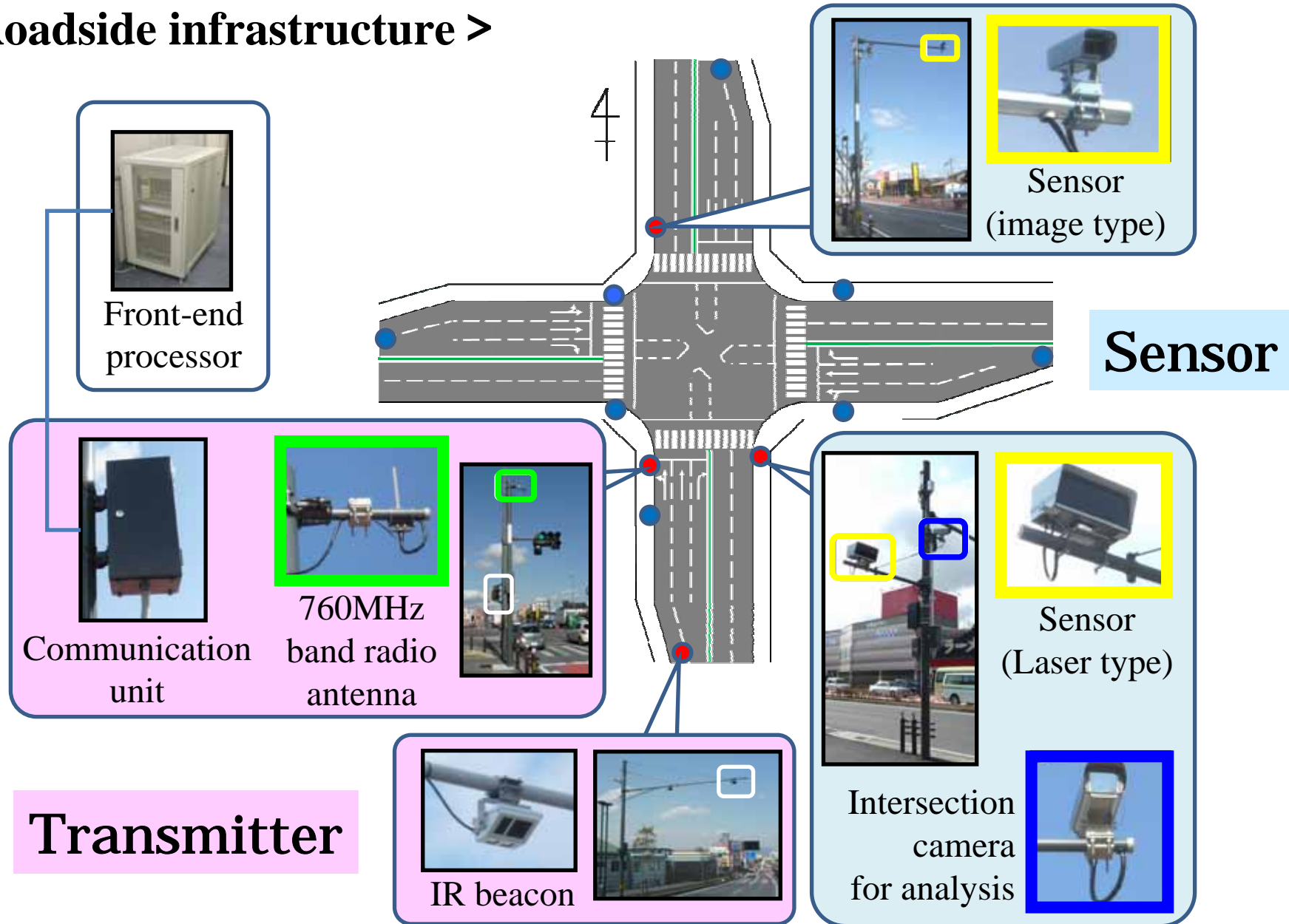
13 direction of 6 intersection of Toyota City, Aichi Pref.



2 . Field Operational Test in Toyota city

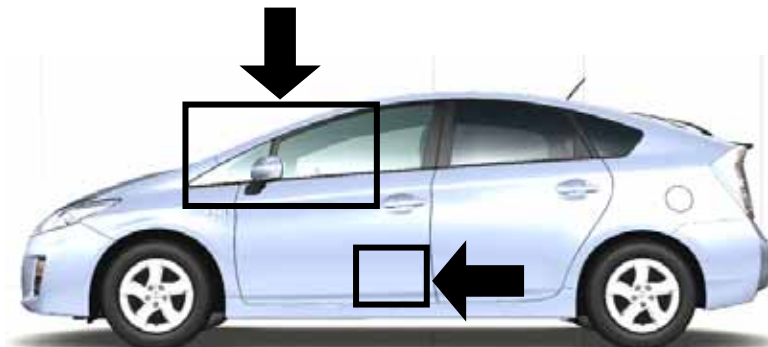
5

< Roadside infrastructure >



2 . Field Operational Test in Toyota city

< OBD (Onboard device) >



2 . Field Operational Test in Toyota city

7

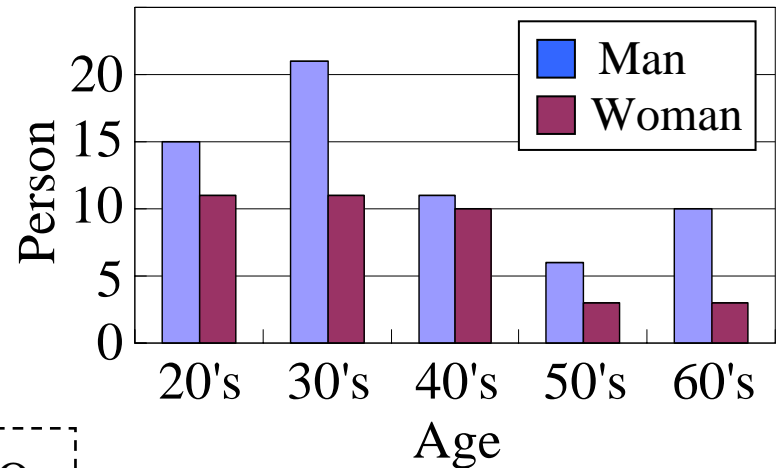
< Test subject >

101 ordinary drivers

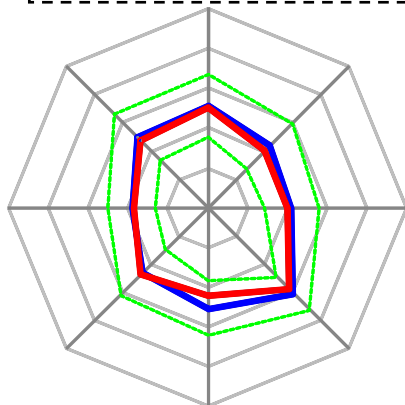
who use the intersection in daily life

· Age: 20 ~ 69 (AVE 39.7)

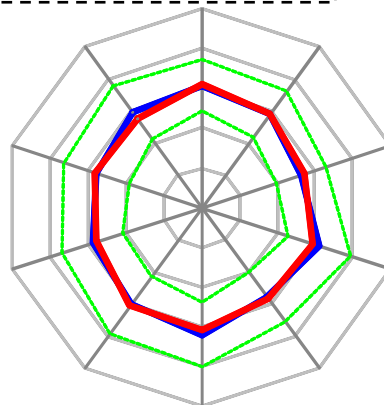
· 63 men & 38 women



By questionnaire technique called DSQ WSQ, there is almost no difference characteristic between the test subjects and ordinary drivers.



DSQ



WSQ

(Driving Style Questionnaire) (Workload Sensitivity Questionnaire)

- Average of test subjects
- Average of ordinary drivers
- - -1 standard deviation from ordinary driver average
- -1 standard deviation from ordinary driver average

2 . Field Operational Test in Toyota city

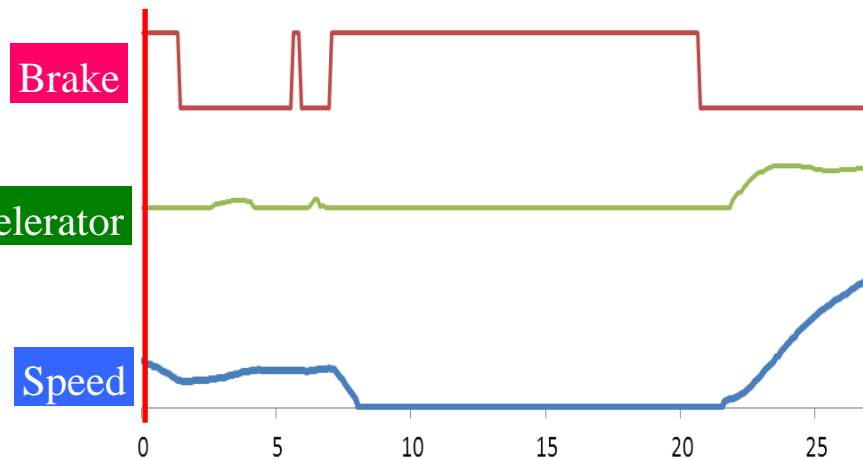
< Recorded data >



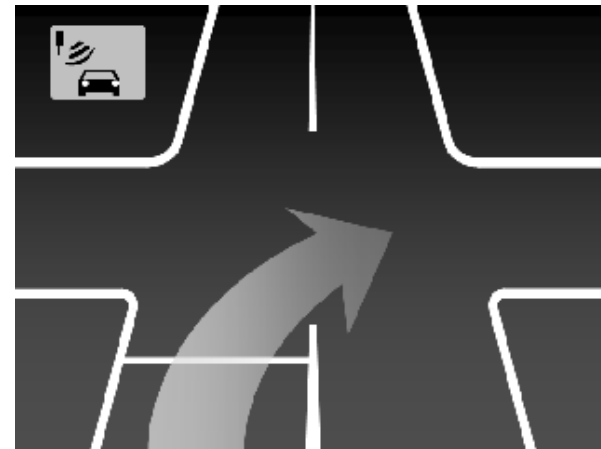
Video of intersection camera



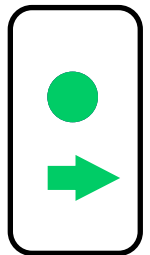
Video of drive recorder



Driving data



HMI



State of
traffic signal

2 . Field Operational Test in Toyota city

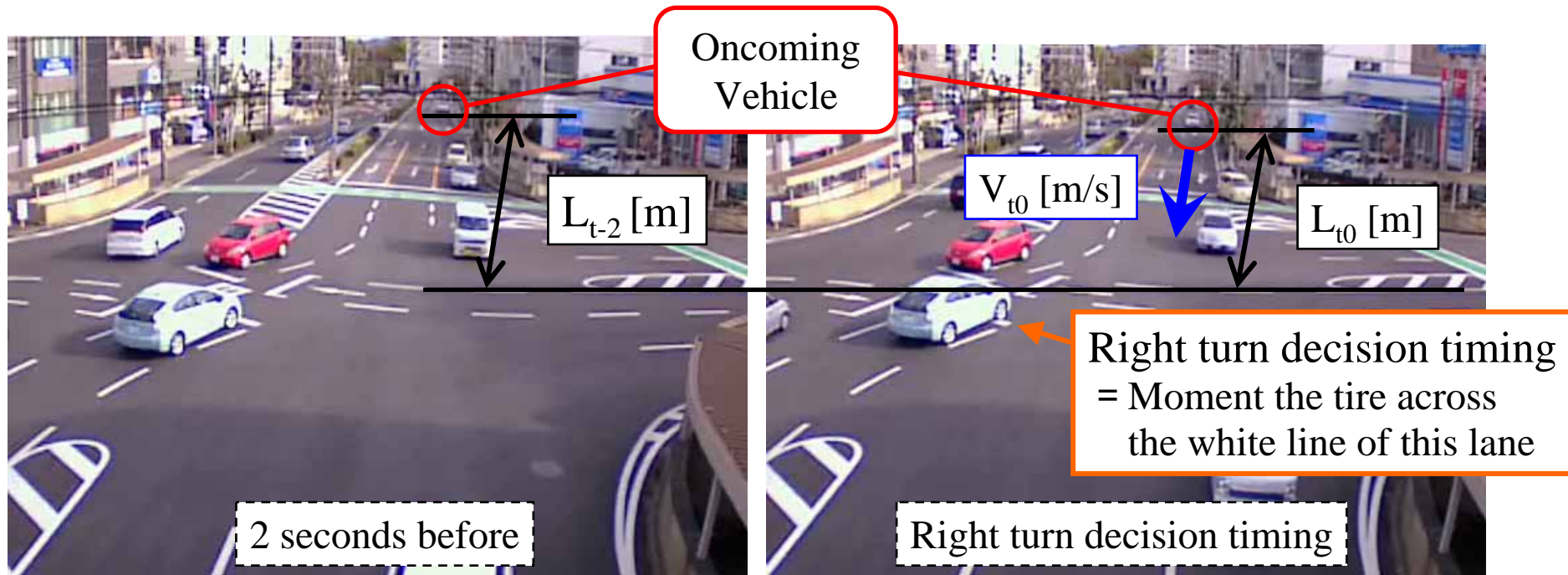
< Criteria for design of right-turn collision prevention system >

Time To Collision (TTC)

Time oncoming vehicle to reach the center of intersection at the right turn decision timing.

$$TTC = L_{t0}/V_{t0} \text{ [sec]}$$

$$V_{t0} = (L_{t-2} - L_{t0})/2 \text{ [m/s]}$$



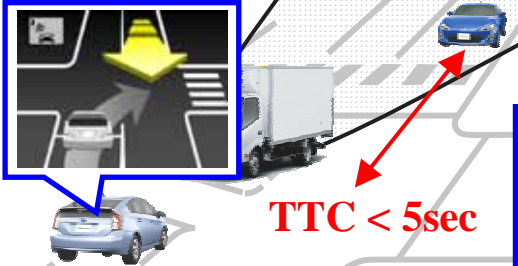
3 . Evaluation of effect

< Definition of effects >

Enter the intersection on a green light

Right turn decision timing

Vehicle is approaching



Before entering opposite lane

Turn right without stopping



Effect 1

Effect 1 to wait safely in the right turn lane to see the display

No oncoming vehicles going straight on

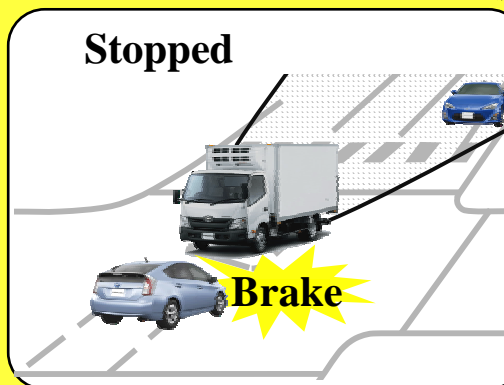


Safe turn right

Effect 2

Effect 2 to stop before entering the opposite lane to hear the sound

Stopped



Safe turn right

Turn right

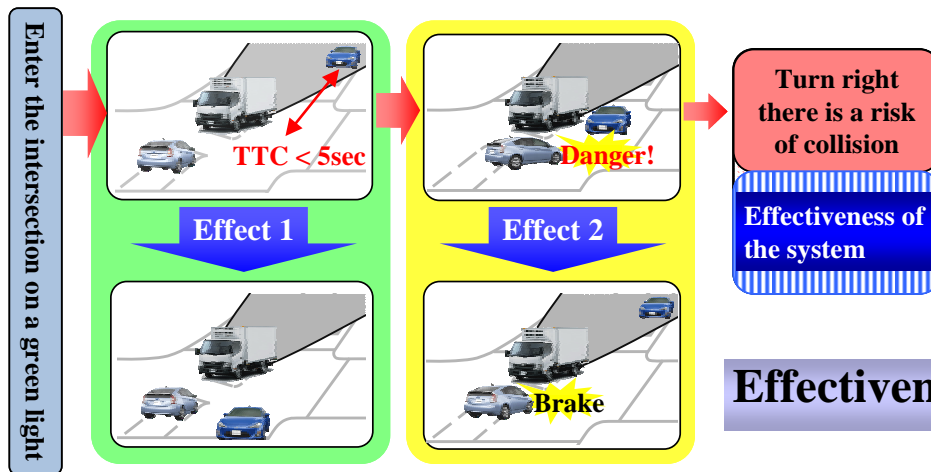
Effectiveness of the system

3 . Evaluation of effect

< Calculated results >

Effectiveness of the system

Visibility of right-turn at intersection	Effect1	Effect2	Total
Poor	0.14	0.44	0.54
Good	0.09	0.01	0.10



【Number of data】
4967 without system support
5506 with system support

$$\text{Effectiveness of the system} = 1 - (1 - \text{Effect1})(1 - \text{Effect2})$$

$$[A] \quad \text{Effect 1} = 1 - \frac{\text{Number of } / \text{ Number of All (with system support)}}{\text{Number of } / \text{ Number of All (without system support)}}$$

$$[B] \quad \text{Effect 2} = 1 - \frac{\text{Number of } / \text{ Number of (with system support)}}{\text{Number of } / \text{ Number of (without system support)}}$$

3 . Evaluation of effect

< Calculated results by categorizing of drivers >

The effect to the young, elderly and female group is large.

			Number of subjects	Effectiveness of the system
Poor visibility of right turn at intersection	All subjects		101	0.54
	Age	Young (29 or less)	26	0.87
		Middle-age (30 to 59)	62	0.24
		Elderly (60 or over)	13	0.57
	gender	Male	63	0.42
		Female	38	0.71
	Experience of accidents within 5 years	Nothing	87	0.49
		Experienced	14	0.80

- The first large scale field operational test has done for aiming to reduce dangerous or uneasy right turn action. The feature of this test is to establish the concept of TTC and to keep the service area in the intersection with use of 760MHz band.
- The effects by the information guidance based on TTC-rule was confirmed.
 - The effectiveness of system becomes 54% in the poor visibility
- For practical use of the system, further improvements from HMI view point and more adequate judgment of necessity of guidance should be required.

Thank you for your attention.