

SIP-adus Workshop 2020



Merging Support Service on Expressways

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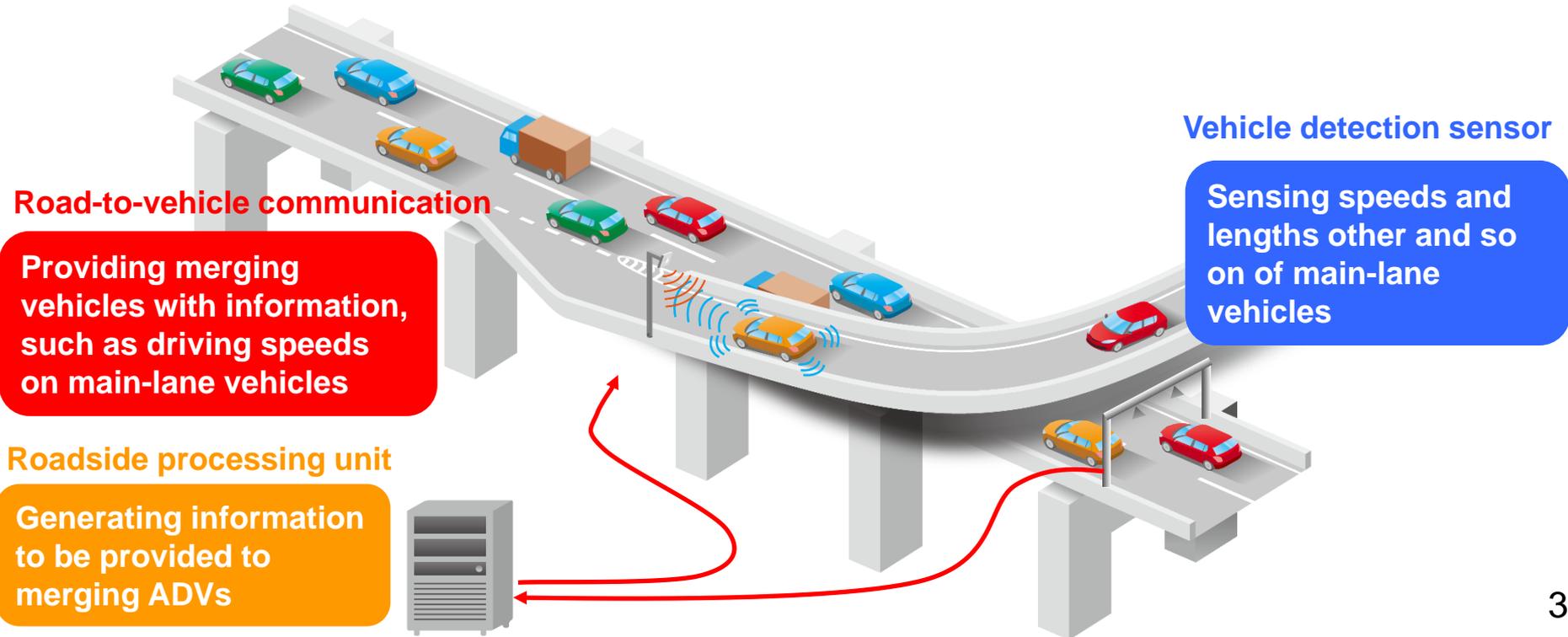
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Overview of Merging Support Service on Expressways

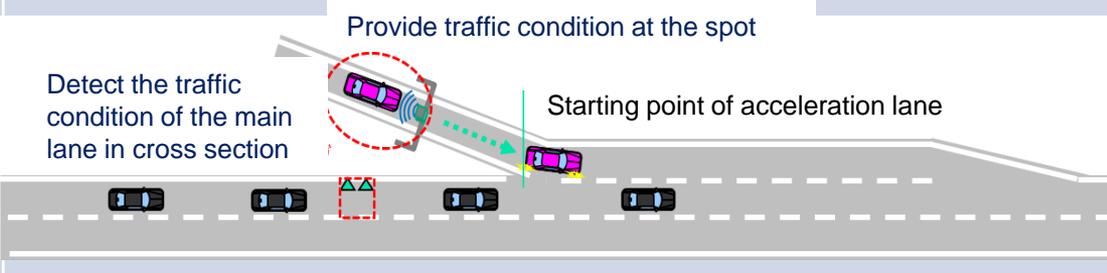
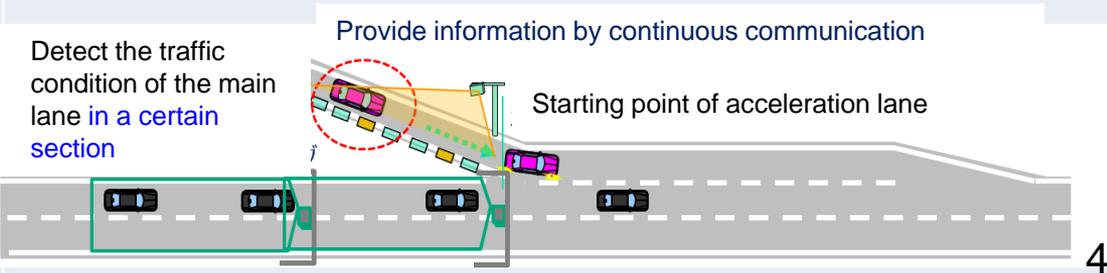
Merging Support Service (Concept)

- Detecting vehicles in main lane and providing the vehicle information to the merging vehicles via V2I communication



Merging Support Service (DAY1/DAY2)

- There are two merging support services: **DAY1** which detects the traffic condition of the main lane **in cross section** and provides information **at the spot**, and **DAY2** which detects the traffic condition of the main lane **in a certain section** and provides information **by continuous communication**

	Detection traffic Situation in main lane	Providing information to merging vehicles	Image
DAY1	<ul style="list-style-type: none">Detect the traffic condition of the main lane in cross section	<ul style="list-style-type: none">Provide traffic condition at the spot	 <p>Provide traffic condition at the spot</p> <p>Detect the traffic condition of the main lane in cross section</p> <p>Starting point of acceleration lane</p>
DAY2	<ul style="list-style-type: none">Detect the traffic condition of the main lane in a certain section	<ul style="list-style-type: none">Provide information by continuous communication	 <p>Provide information by continuous communication</p> <p>Detect the traffic condition of the main lane in a certain section</p> <p>Starting point of acceleration lane</p>

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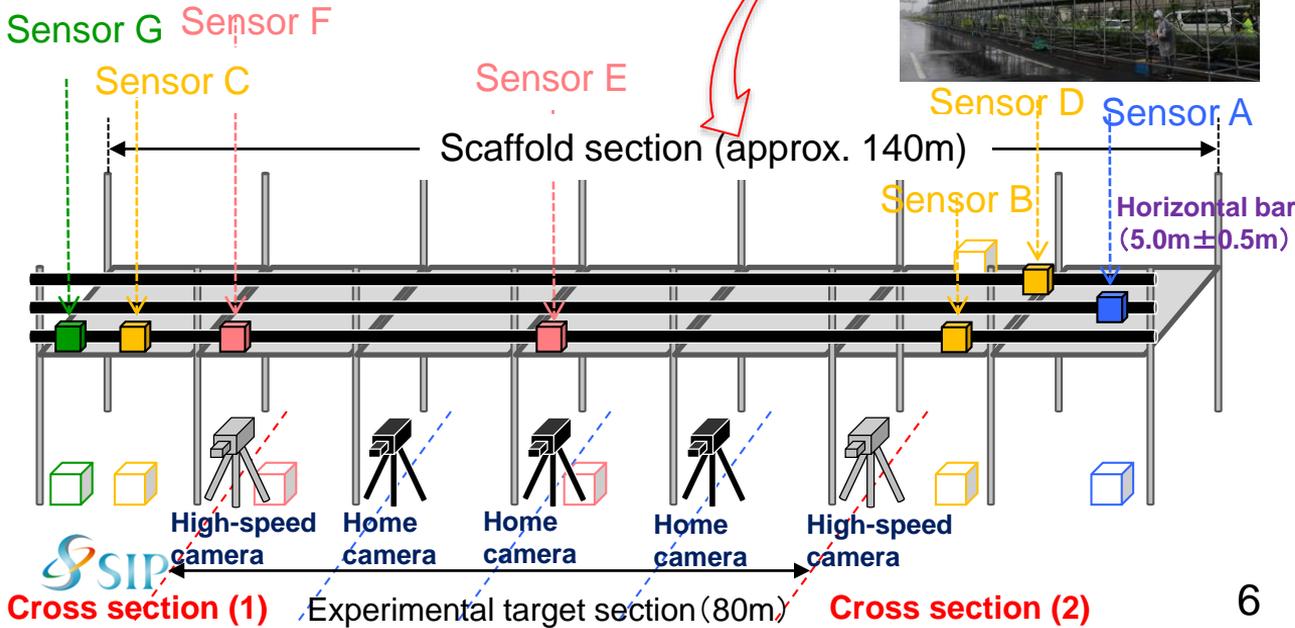
FOTs of Merging Support Service on Expressways

Accuracy Confirmation of Vehicle Detection Sensor (DAY2) (Overview)

- Since it is required to detect a traffic conditions on a main lane accurately, FOT for an accuracy confirmation of a vehicle detection sensor was conducted on NILIM test track.

■ FOT on NILIM test track (Equipment layout)

Evaluation item: speed, length,
Inter-vehicle time, detection range



Sensor	Equipment/Location
Sensor A	Radar/ 30m downstream from cross section (2)
Sensor B	LiDAR/ 10m downstream from cross section (2)
Sensor C	LiDAR/15m upstream from cross section (1)
Sensor D	Radar/ 20m downstream from cross section (2)
Sensor E	LiDAR and CAMERA/ 40m downstream from cross section (1)
Sensor F	LiDAR/ On cross section (1)
Sensor G	Rader/ 20m upstream from cross section (1)

Accuracy Confirmation of Vehicle Detection Sensor (DAY2)

(Result: Speed)

Preliminary figure

- Both the upstream side and the downstream side are not satisfied with the required accuracy (Measurement error is less than 0.1km/h).
- The error tends to be larger on the downstream side than on the upstream side.

Measurement error of speed (All sample) (Unit: km/h)

		Sensor A	Sensor B	Sensor C	Sensor D	Sensor E	Sensor F	Sensor G
Upstream side	Ave.	0.14	0.19	-18.06	-0.02	0.53	0.48	0.85
	Ave. (Absolute)	0.25	1.96	18.40	0.25	1.39	1.39	1.03
	S.D.	0.48	3.05	15.00	0.36	2.02	2.02	1.21
Downstream side	Ave.	0.02	-1.53	0.12	-0.89	-2.37	-0.40	0.19
	Ave. (Absolute)	0.41	2.86	1.99	1.25	5.93	1.13	0.78
	S.D.	1.32	3.27	3.52	1.82	13.08	3.41	1.86

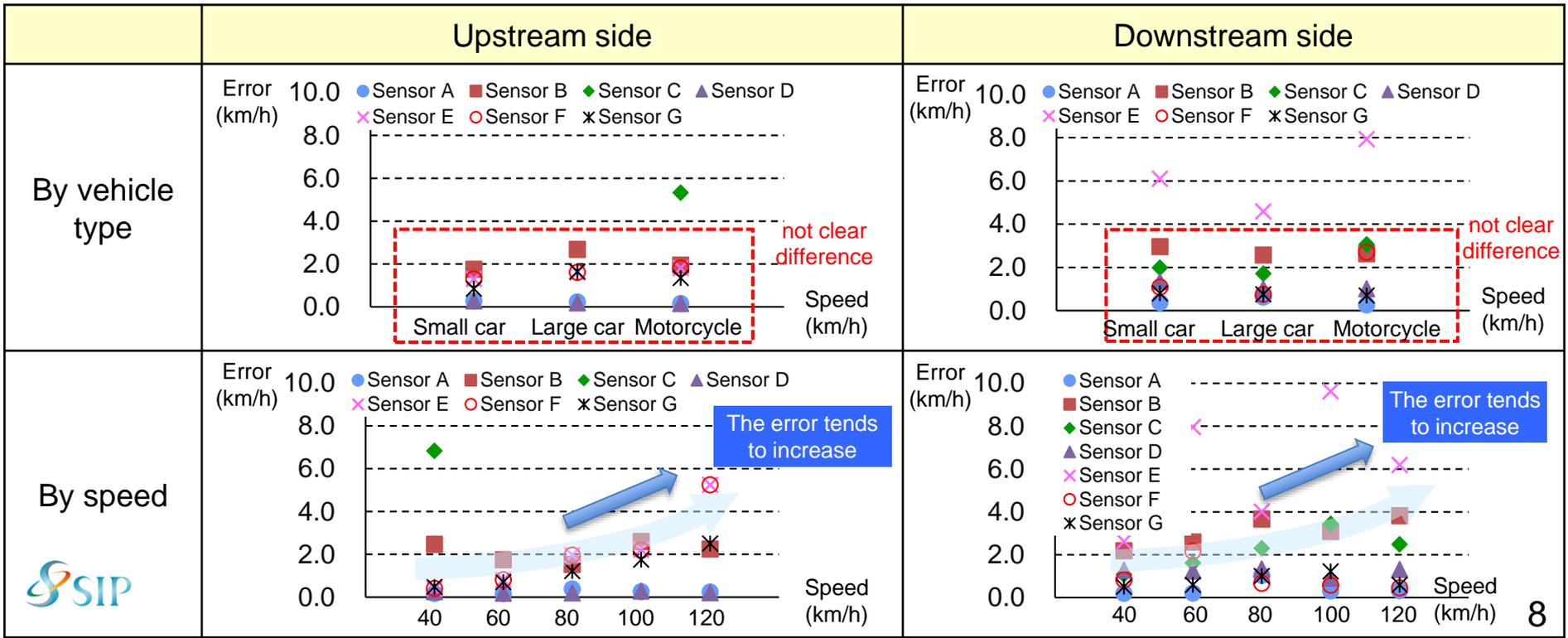
※ N (number of runs) = 170-208

Accuracy Confirmation of Vehicle Detection Sensor (DAY2)

(Result: Speed)

Preliminary figure

- By vehicle type: There is not clear difference in measurement error.
- By speed: The higher the speed is, the larger the error tends to be.

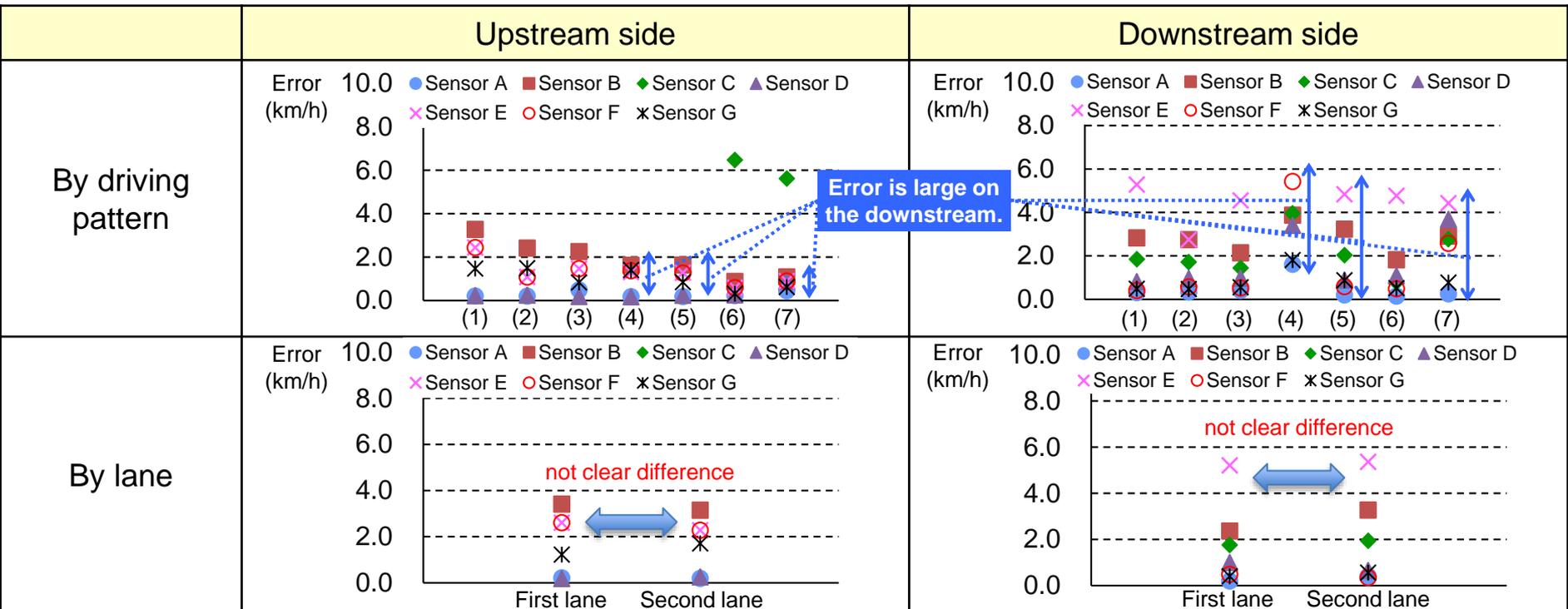


Accuracy Confirmation of Vehicle Detection Sensor (DAY2)

(Result: Speed)

Preliminary figure

- By driving pattern: In "passing", "lane change", and "acceleration", the error on the downstream side tends to increase.
- By lane: For lanes, there is no clear difference in measurement error.



*Driving patterns are "(1) single", "(2) three-car parallel running-1", "(3) three-car parallel running-2", "(4) overtaking", "(5) lane change", "(6) short distance", and "(7) acceleration".

Accuracy Confirmation of Vehicle Detection Sensor (DAY2)

(Result: Vehicle length)

Preliminary figure

- The most accurate sensor is “Sensor F”, with a measurement error of about 0.20m.
- In “Sensor B” and “Sensor G”, the tendency of measurement error differs between upstream and downstream.

Measurement error of vehicle length (All sample) (Unit:m)

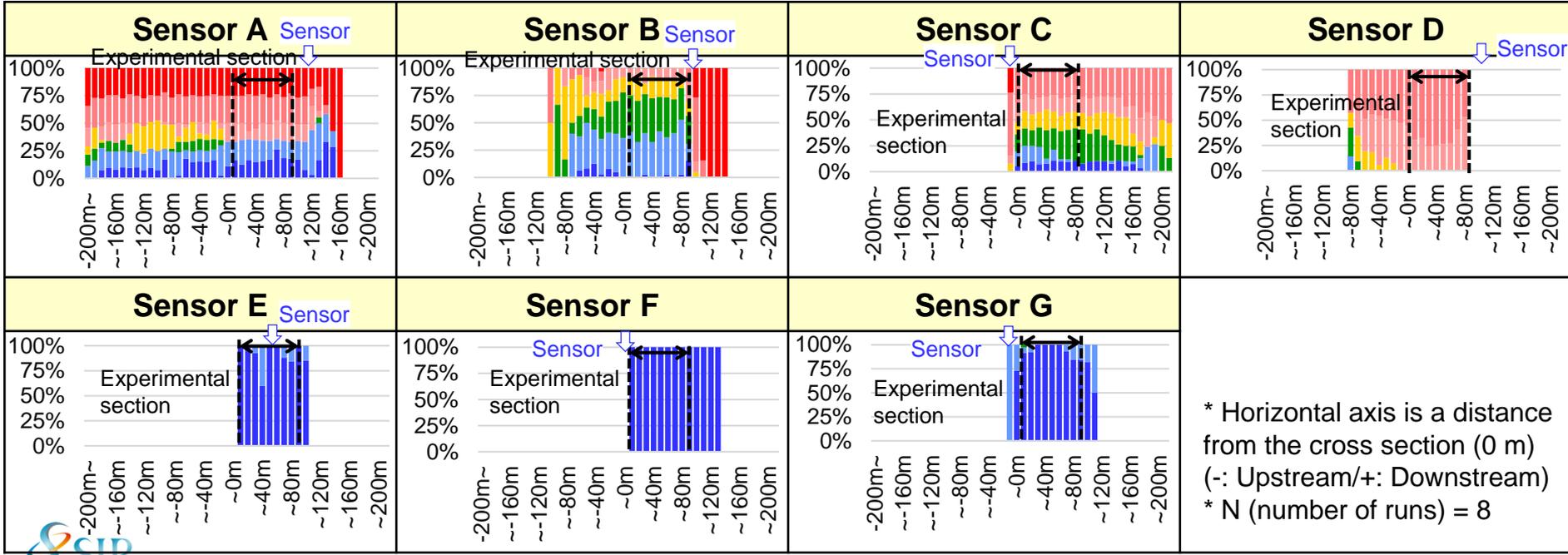
		Sensor A	Sensor B	Sensor C	Sensor D	Sensor E	Sensor F	Sensor G
Upstream side	Ave.	0.68	-3.04	0.89	-3.04	0.03	0.04	-2.19
	Ave. (Absolute)	1.14	3.06	1.11	3.04	0.24	0.21	2.24
	S.D.	1.55	1.36	1.23	0.98	0.76	0.74	1.86
Downstream side	Ave.	0.85	0.90	1.47	-0.41	0.03	0.02	0.28
	Ave. (Absolute)	0.94	1.63	1.57	0.92	0.24	0.23	1.13
	S.D.	0.92	1.84	1.25	1.11	0.76	0.79	1.70

※ N (number of runs) = 215 (Both upstream and downstream)

Accuracy Confirmation of Vehicle Detection Sensor (DAY2) (Result: Detection range (direction of travel))

Preliminary figure

- Sensors with a narrow detection range (E, F, G) have a measurement error of approximately 1m. On the other hand, sensors with a wide detection range (A, B, C, D) tend to have large measurement errors.
- When it is necessary to detect a section of 100m or more, it is desirable to install multiple sensors.

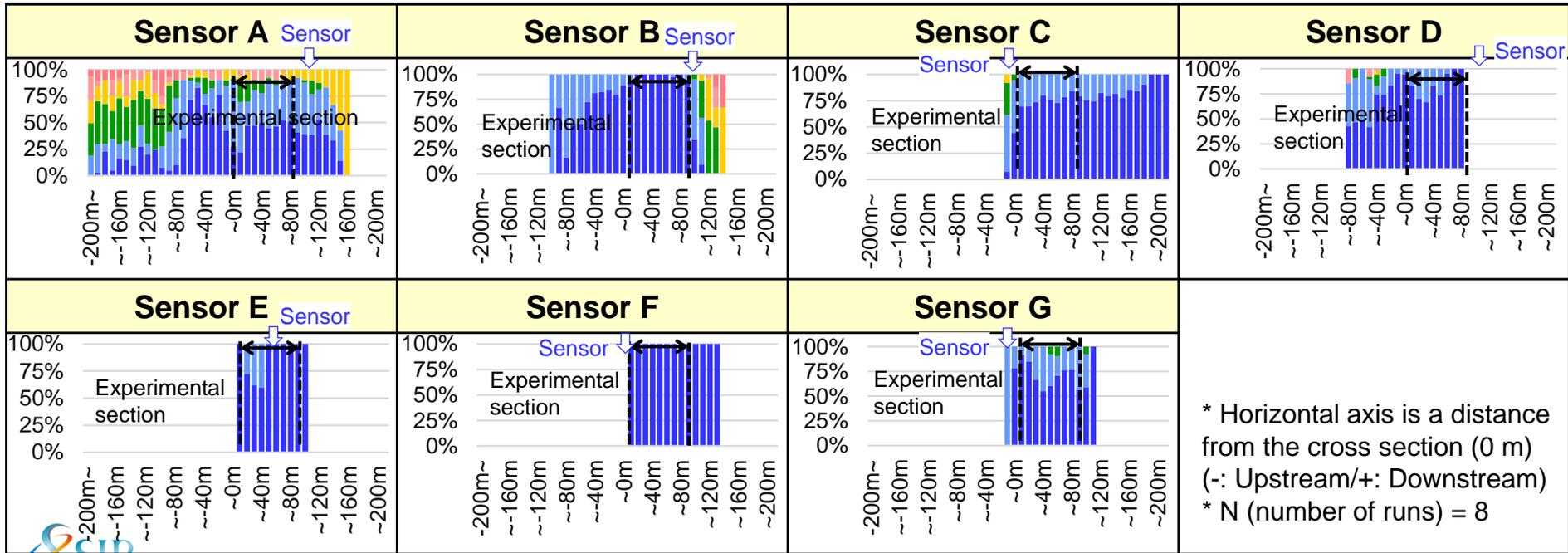


* Horizontal axis is a distance from the cross section (0 m)
 (-: Upstream/+: Downstream)
 * N (number of runs) = 8

Accuracy Confirmation of Vehicle Detection Sensor (DAY2) (Result: Detection range (horizontal direction))

Preliminary figure

- The measurement error in the lateral direction is smaller than that in the traveling direction.
- If the experimental section (80m) is exceeded, the measurement error tends to increase.
- When it is necessary to detect a section of 100m or more, it is desirable to install multiple sensors.



* Horizontal axis is a distance from the cross section (0 m)
 (-: Upstream/+ : Downstream)
 * N (number of runs) = 8

Measurement error ■ ±1m ■ ±2m ■ ±3m ■ ±4m ■ ±5m ■ ±10m ■ ±10m or more

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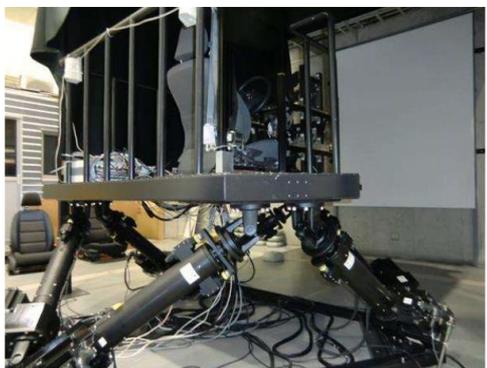
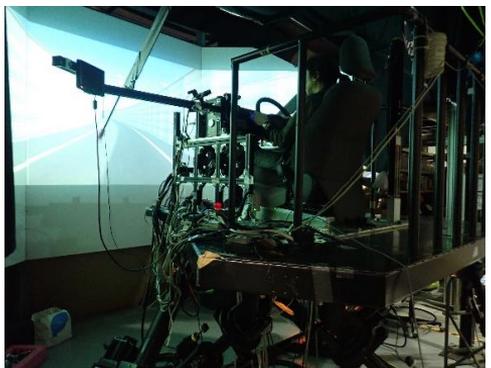


**Effect evaluation
experiment of merging
support information
with driving simulator**

Overview (Purpose)

- The driver (human) evaluates an effect of merging support information (vehicle information in the main lane) provided by a driving simulator.

■ Driving simulator used in the experiment (University of Tokyo)



Overview (Case Setting)

- 6 patterns of traffic on the main lane (inter-vehicle time 2 or 3 seconds/ vehicle speed 50, 70, or 90km/h)
- Experimented with two patterns, "without information" and "with voice information (main lane speed)"
- A questionnaire was given to the persons regarding their understanding, tension, and difficulty of main lane vehicle information, and driving simulator (DS) data was acquired.

		Traffic situation in main lane	
		Speed	Inter-vehicle distance
Inter-vehicle time (2 sec.)		50km/h	30m
		70km/h	40m
		90km/h	55m
		Speed at main lane 50, 70, 90km/h 30 · 40 · 55m	
Inter-vehicle time (3 sec.)		50km/h	45m
		70km/h	60m
		90km/h	80m
		Speed at main lane 50, 70, 90km/h 45 · 60 · 80m	

With/Without	Outline
Without merging support	<p>Without information</p> <p>Acceleration section 160m</p> <p>50m</p> <p>Merging vehicle (person)</p> <p>Main lane vehicle (DS)</p>
With merging support (Speed information in main lane)	<p>80m</p> <p>Location of Information provision</p> <p>Vehicle on main lane (78m-155m)</p> <p>Provide voice information when the merging vehicle reaches the hard nose and the main line vehicle exists within 2 seconds before and after</p> <p>Merging vehicle (person)</p> <p>Main lane vehicle (DS)</p>

Results 1-1 (Analysis of Questionnaire for Drivers)

- "Understanding" is greatly improved by the speed information of the main lane, and the evaluation is **about 5 (7 grades) for all patterns**.
- "Difficulty" is greatly improved (**90km/h-2 seconds** and **50km/h-3 seconds**). It is confirmed **the effect of merging support by voice information**.
- Persons who are not good at merging on expressways tend to **evaluate the merging support information highly** regardless of the traffic conditions on the main lane.

■ Average value of persons who are **bad** at merging on expressways (N = 10) [7-grade evaluation]

Driving pattern		Degree of understanding (The higher the number, the higher of understanding)		Degree of tension (The higher the number, the higher of tension)		Degree of difficulty (The higher the number, the higher of difficulty)	
		Without information	With information	Without information	With information	Without information	With information
Inter-vehicle time (2 sec.)	50km/h	3.1	4.8*	4.8	4.2	5.0	4.6
	70km/h	3.6	5.1*	4.3	4.0	4.4	3.8
	90km/h	2.9	5.2*	4.8	4.3	5.3	4.3*
Inter-vehicle time (3 sec.)	50km/h	3.2	5.2*	4.2	3.9	4.5	3.7*
	70km/h	3.7	5.2*	4.0	4.3	3.9	3.5
	90km/h	2.9	5.3	4.6	3.9	4.5	4.5

* Values improved by 0.5 points or more compared to "without information" are shown in blue. If there is a 5% significant difference in comparison with "no information" (T test), they are shown in red*.

Results 1-2 (Analysis of Questionnaire for Drivers)

- Persons who are not bad at merging on expressways tend to have lower levels of improvement in degree of understanding, tension, and difficulty than those who are bad at merging on expressways.
- Degree of understanding, tension, and difficulty were improved at the easiest case (3 seconds-50 km/h). Even if the speed is lower than the assumed main line speed (about 70km/h), it is rather difficult to merge, and the effect of voice information was confirmed.

■ Average value of persons who are **not bad** at merging on expressways (N = 10) [7-grade evaluation]

Driving pattern		Degree of understanding (The higher the number, the higher of understanding)		Degree of Tension (The higher the number, the higher of tension)		Degree of difficulty (The higher the number, the higher of difficulty)	
		Without information	With information	Without information	With information	Without information	With information
Inter-vehicle time (2 sec.)	50km/h	4.6	5.1	4.0	4.0	3.6	3.6
	70km/h	4.9	5.0	3.5	3.6	3.3	3.4
	90km/h	4.3	4.7	3.9	4.1	3.9	4.5
Inter-vehicle time (3 sec.)	50km/h	4.0	5.9*	3.3	2.6	3.6	2.3
	70km/h	5.0	5.6	2.8	2.8	2.6	2.6
	90km/h	4.5	5.3	4.2	3.5*	3.6	3.0

* Values improved by 0.5 points or more compared to "without information" are shown in blue. If there is a 5% significant difference in comparison with "no information" (T test), they are shown in red*.

Result 2-1 (Analysis of Driving Simulator Data)

- Degree of safety was improved in case of “with information” at 70km/h-2 seconds and 90km/h-2 seconds.
- In other cases degree of safety was generally improved. The effect of providing information can be confirmed.

■ Average value of persons who are **bad** at merging on expressways (N = 10)

Evaluation Item	Inter-vehicle time (2 sec.)						Inter-vehicle time (3 sec.)					
	50km/h		70km/h		90km/h		50km/h		70km/h		90km/h	
	Without	With	Without	With	Without	With	Without	With	Without	With	Without	With
TTC*	29.95	25.74	14.55	44.04	4.76	10.76	16.03	20.77	74.52	50.37	12.25	15.39
Merging speed	48.35	49.55	62.28	64.77	66.97	73.89	53.76	47.84	63.47	62.68	66.72	70.47
Axel operation amount	0.50	0.45	0.65	0.68	0.78	0.79	0.62	0.42	0.62	0.71	0.73	0.77
Deceleration	-0.028	-0.043	-0.011	-0.026	-0.012	-0.013	-0.038	-0.020	-0.016	-0.012	-0.014	-0.008



Green: Safety improved, but no significant difference **Blue:** Safety improved, and significant difference

* TTC (Time-To-Collision): The collision margin time, and the larger it is, the higher the safety.

Result 2-2 (Analysis of Driving Simulator Data)

- Degree of safety was improved in case of “with information” at 90km/h-3 seconds. degree of safety was generally improved and the effect of providing information can be confirmed.
- On the other hand there is no improvement in degree of safety at “with information” at 50km/h-2 seconds and 70km/h-3 seconds. It is considered that the difference between the traffic conditions imaged from the voice information and those experienced affected the driving.

■ Average value of persons who are **not bad** at merging on expressways (N = 10)

Evaluation Item	Inter-vehicle time (2 sec.)						Inter-vehicle time (3 sec.)					
	50km/h		70km/h		90km/h		50km/h		70km/h		90km/h	
	Witho ut	With	Witho ut	With	Witho ut	With	Witho ut	With	Witho ut	With	Witho ut	With
TTC*	77.74	19.50	8.10	12.74	3.72	5.22	31.35	68.86	62.08	19.68	5.12	56.12
Merging speed	45.08	44.79	55.98	59.48	58.73	62.23	49.87	45.04	57.94	58.46	60.66	62.08
Axel operation amount	0.58	0.49	0.67	0.69	0.72	0.78	0.58	0.47	0.71	0.74	0.79	0.80
Deceleration	-0.011	-0.009	-0.006	-0.011	-0.007	-0.012	-0.010	-0.019	-0.013	-0.014	-0.007	-0.008

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Future issues

Future issues to be examined

- It is important to Improve an accuracy of merging support services. For that purpose, it is important to make merging support service more concretely.
- Further Accuracy confirmation of vehicle detection sensor
 - By long-term FOT on expressways
- Consideration of a concept of merging support service
 - Specifications of merging support service (DAY2)
- Examination of places where there is a need for merging support services
 - From the viewpoint of road structure
 - From the viewpoint of traffic condition on a main lane



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Thank you for your kind attention.