The Estimation and the Prediction of Real World Driving Emission from Diesel Passenger Vehicle Based on SEMS Measurement

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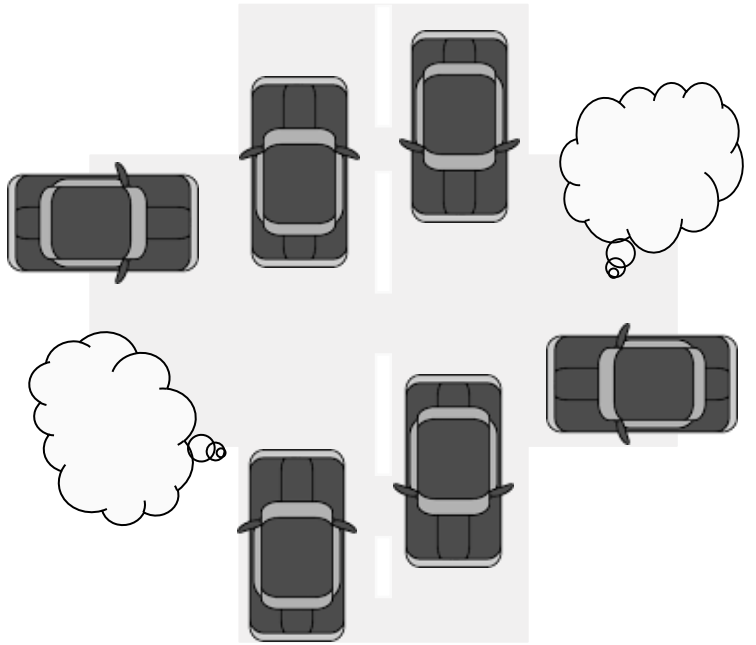
Motivation

✓ Stringent emission regulation

➡ Total emission ○

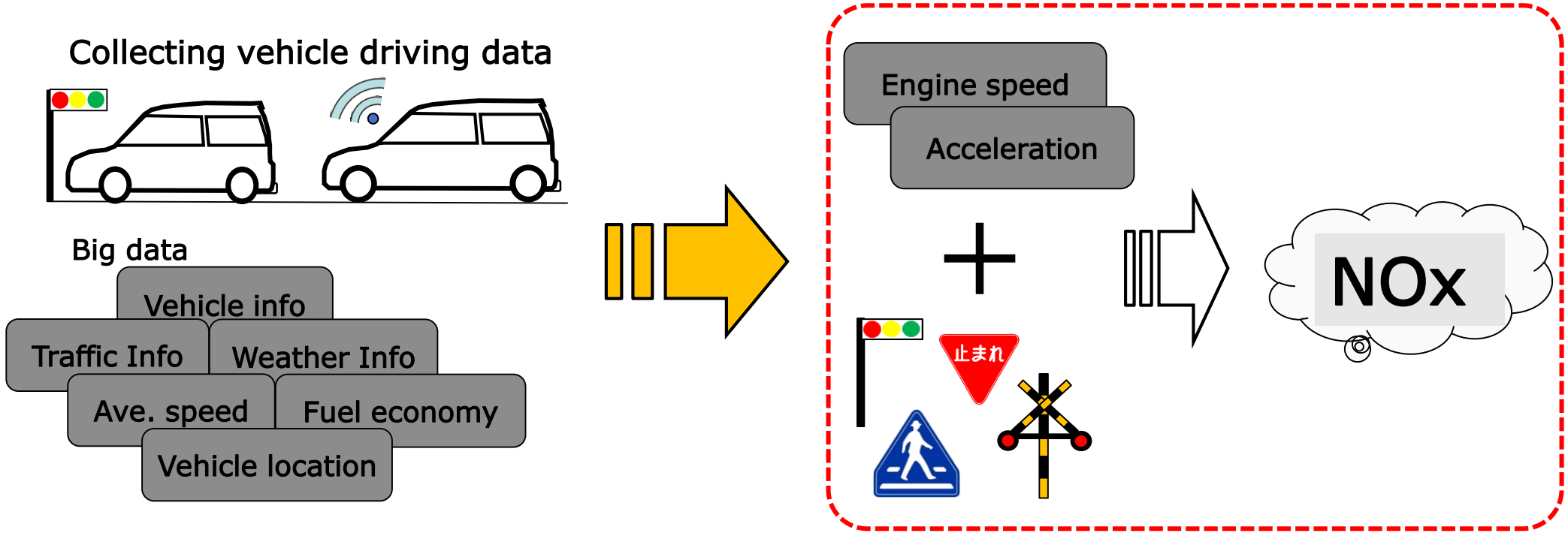
➡ Roadsides emission ×



✓ How much and Where air pollutant are emitted?

✓ Evaluation of the roadside real-world emission using On-board Emission Measurement System

Research Background, objective



✓ On-road driving test to investigate the local roadside emission: diesel passenger vehicle

✓ Prediction of NOx mass emission with engine speed – acceleration map

Procedures

✓ On-road measurement test and analysis

1. Multiple times of on-road driving tests

   → NOx mass emission, engine speed, vehicle speed, acceleration, etc.

2. Analysis of NOx mass emission affected by the traffic situation

3. Data categorization with traffic situation

   → NOx emission map (engine speed vs. acceleration vs. NOx mass emission)

✓ Prediction of NOx mass emission

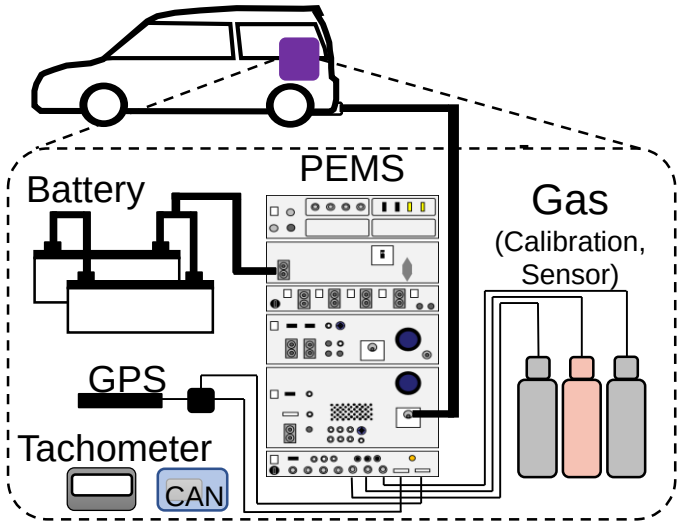
1. The verification test route is divided into each 25 m

2. Predict NOx mass emission from the “NOx emission map” for each traffic situation

PEMS or SEMS ?

PEMS

Portable Emissions Measurement System



Heavy weight for passenger vehicle

SEMS

Sensor-based Emissions Measurement System

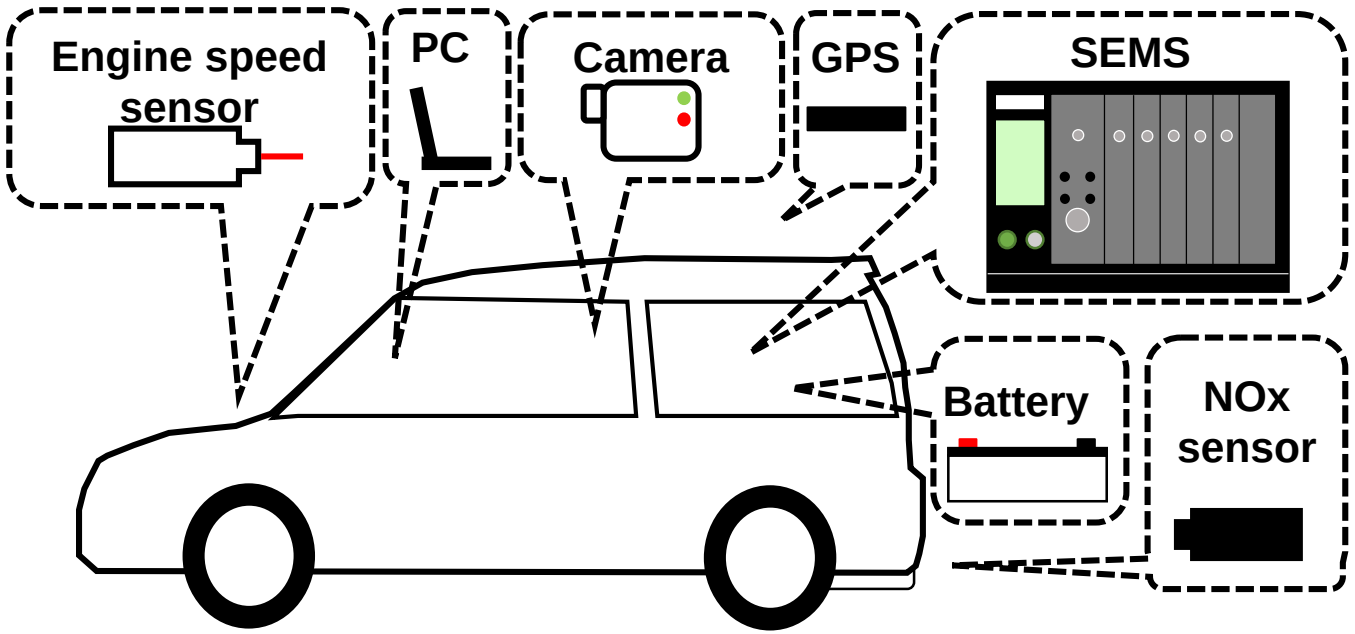
SEMS

NOx Sensor

No measurement devise for exhaust flowrate

	PEMS	SEMS
Weight	Approx. 100kg	Approx. 10kg
Available time by one battery	Approx. 2 hours	More than half day
Exhaust gas flow rate	by Pitot tube	by calculating

On-board measurement system with SEMS



- ✓ Exhaust flowrate is calculated with intake mass air flowrate (MAF signal from OBD) and A/F
- ✓ The accuracy of the calculated exhaust flowrate is confirmed by chassis dynamometer test with CVS system and PEMS

Test vehicle: DEMIO (Mazda 2)

Diesel passenger vehicle
adapted to Japan 2009 regulation
&
NOx reduction only by EGR

Type	Station Wagon	Height [m]	1.50	Compression Ratio	14.8
Riding Capacity [people]	5	Weight [kg]	1220	Fuel Supply System	Common-rail Fuel Injection
Length [m]	4.06	Engine Type	Series 4-Cylinder DOHC	After Treatment System	DOC, DPF
Width [m]	1.69	Displacement [L]	1.49	Emission Regulation	Post New Long Term (2009) NOx < 0.08g/km

Calculation method of NOx mass emission

Formulas for normal operation and fuel cut

The time of intake mass air flowrate from OBD signal and the time of NOx sensor data are aligned from chassis dynamometer test results

$$E_{NOx.t} = C_{NOx} * \rho_{NOx} * Q_{ex}$$

$$\begin{cases} Q_{ex} = G_{ex} / \rho_{ex} \\ G_{ex} = G_a + G_f \\ \qquad = G_a \left(1 + \frac{1}{AF}\right) \\ G_f = G_a / AF \end{cases}$$

Fuel cut

$$\begin{cases} G_{ex} = G_a \\ Q_{ex} = G_{ex} / \rho_{air} \end{cases}$$

$E_{NOx.t}$: NOx mass emission [g/s]

C_{NOx}: NOx concentration [ppm]

ρ_{NOx}: NOx density [g/m^3]

Q_{ex}: Exhaust volume flowrate [m^3/s]

ρ_{ex}: Exhaust gas density [g/m^3]

G_{ex}: Exhaust mass flowrate [g/s]

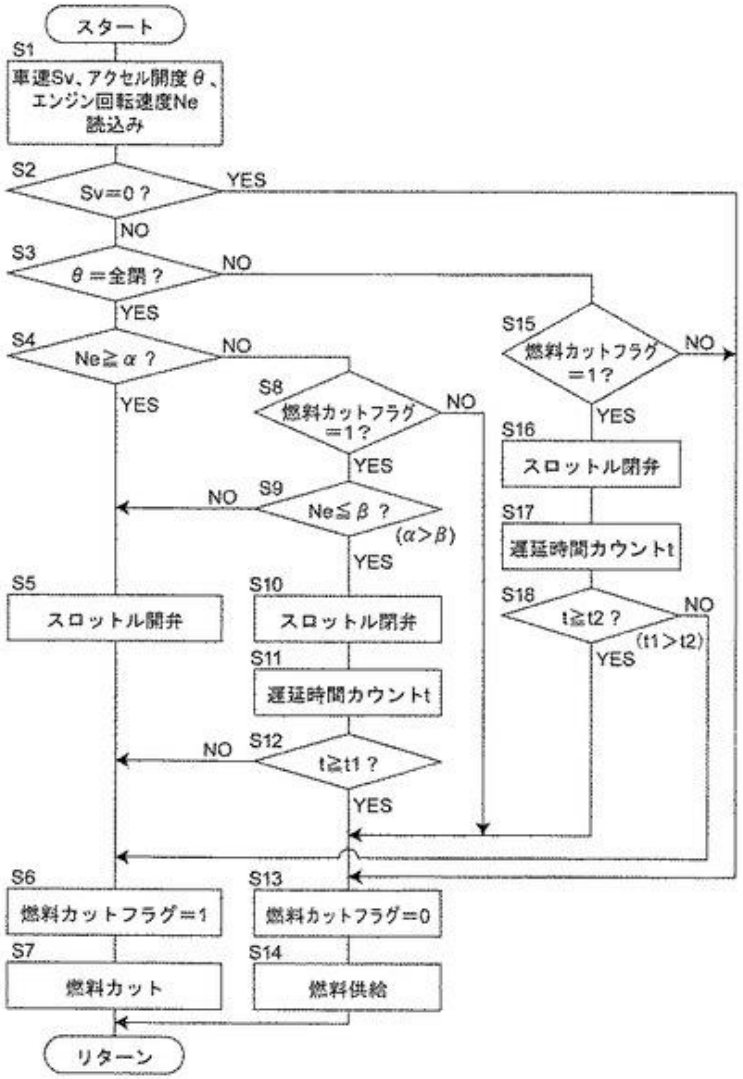
G_a: Intake air mass flowrate [g/s]

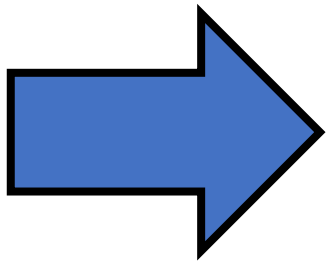
G_f: Fuel mass flowrate [g/s]

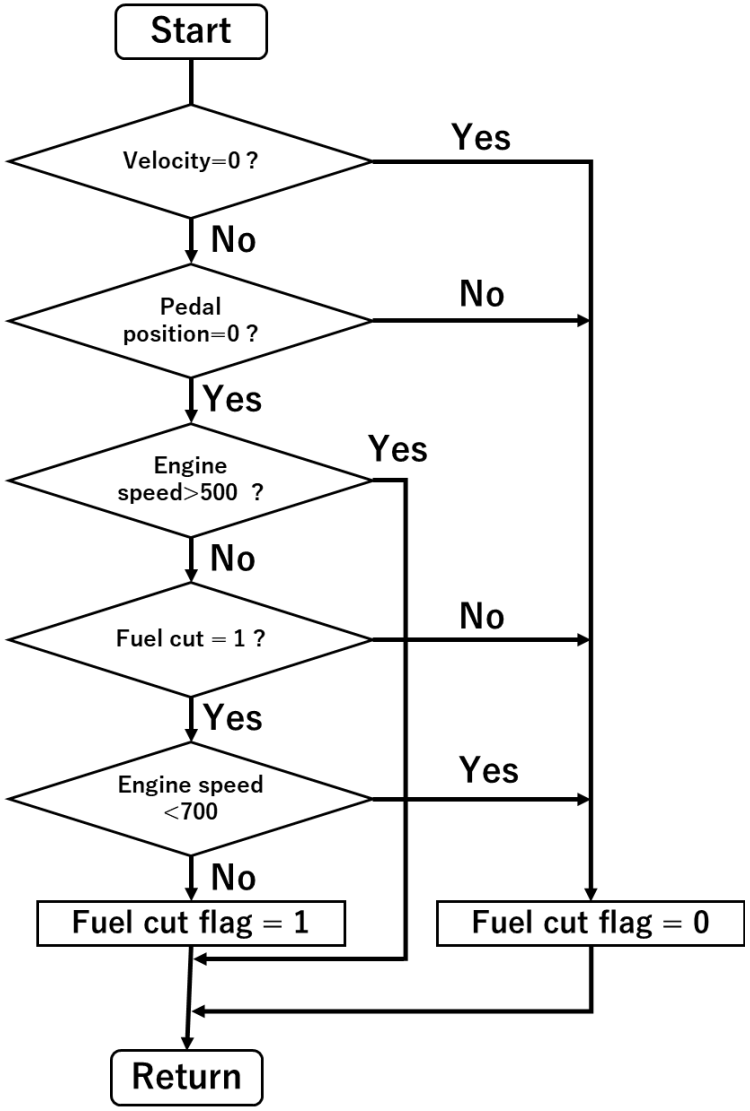
ρ_{air}: Air density [g/m^3]

AF: Air/fuel ratio [-]

Determination method of fuel cut







* Mazda patent P2010-84611A (in Japan)

Test route No.1 & No. 2

Route No.1, Route No.2

Tokyo Tech. main gate

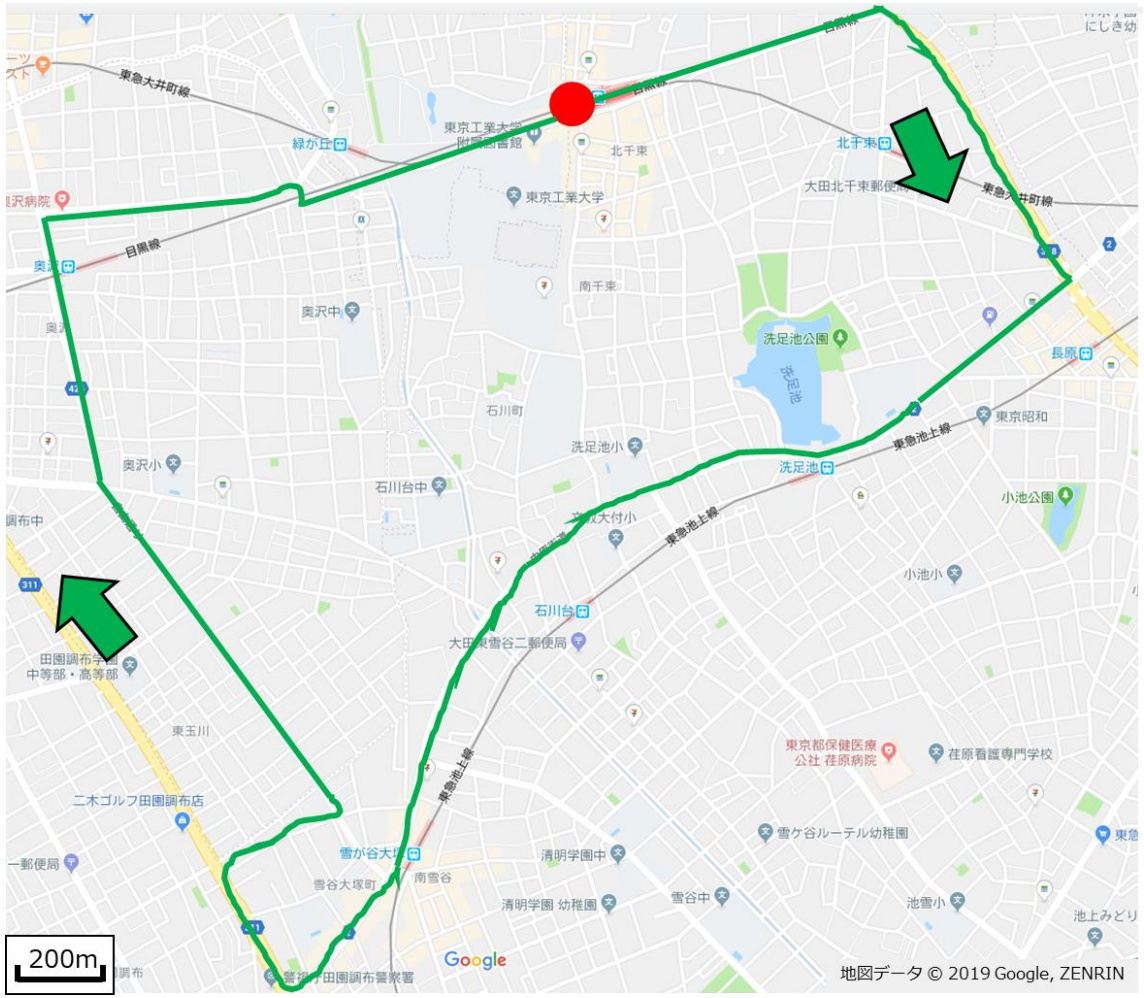
	Route 1	Route 2
Distance [km]	9.19	6.16
Number of Signals	31	21

	Route 1	Route 2		Route 1	Route 2
V=50 [km]	4 .90	2.85	V=30 [km]	2.18	3.17
V=40 [km]	2.11	0	V=20 [km]	0	0.140

Test route No.3

Route No.3

Tokyo Tech. main gate

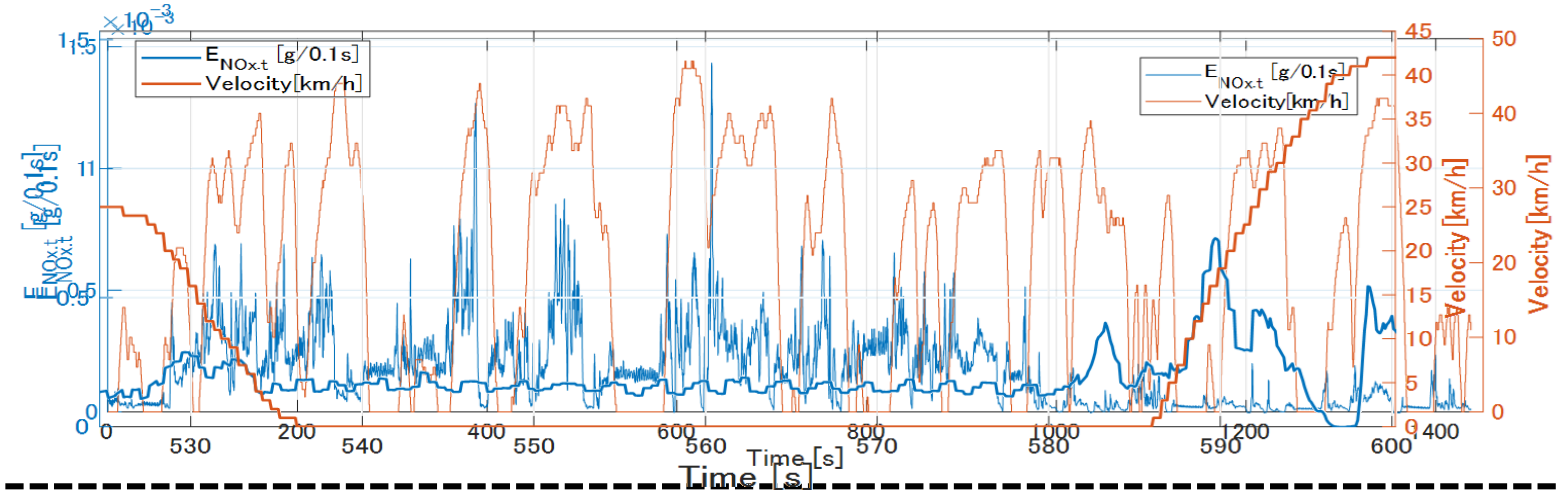


Distance [km]	7.47
Number of Signals	31

V=50 [km]	3.64	V=30 [km]	3.94
V=40 [km]	0	V=20 [km]	0

Time series emission vs. Distance series emission

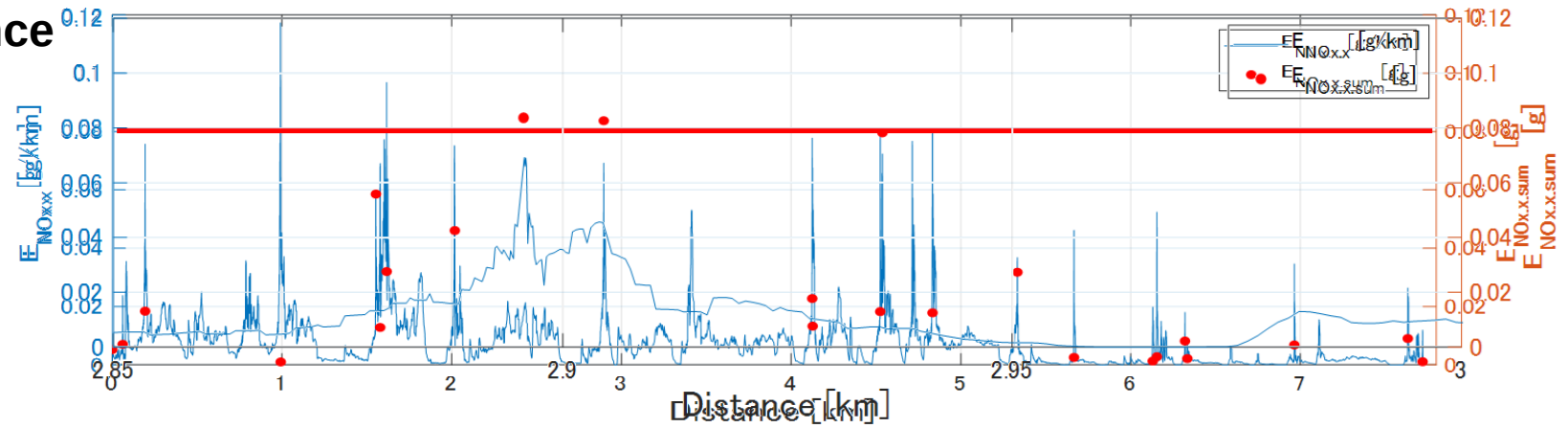
Time series



When vehicle stops, mass emission is accumulated

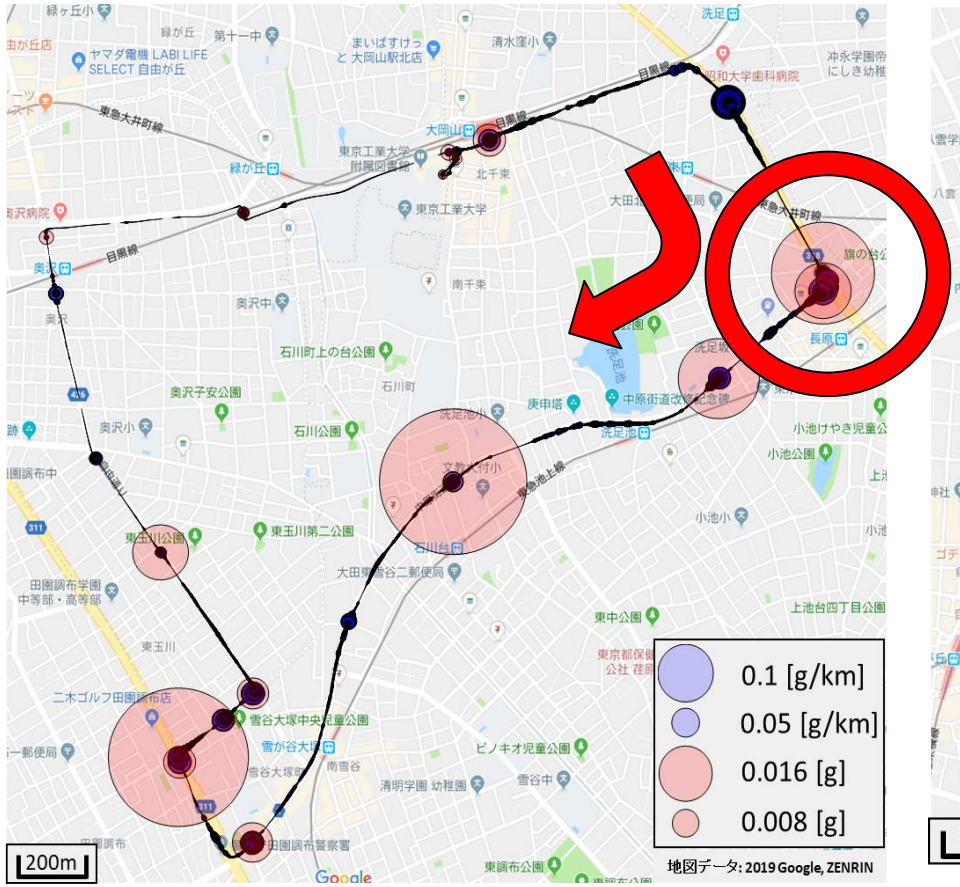
$$\begin{cases} E_{NOx.x} = E_{NOx.t}/V & (V > 2km/h) \\ E_{NOx.x.sum} = \sum_{k=t.stop}^{t.start} E_{NOx.t}(k) & (V \le 2km/h) \end{cases}$$

Distance series

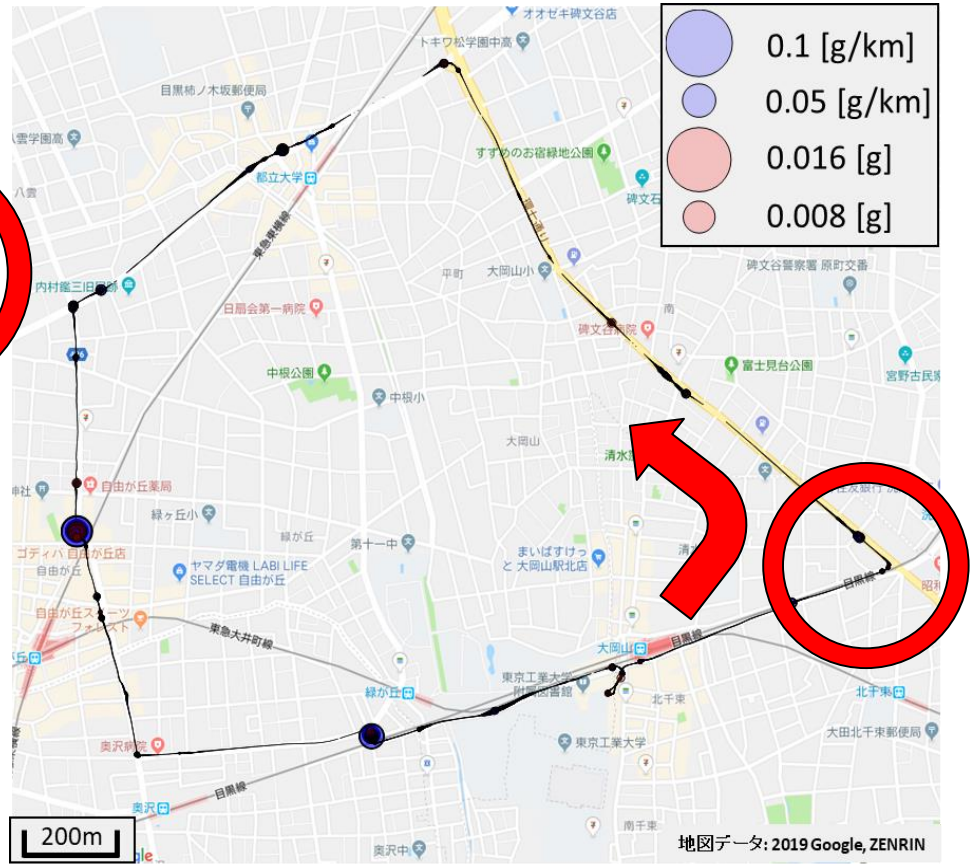


NOx emission for different traffic condition

- Route No.3

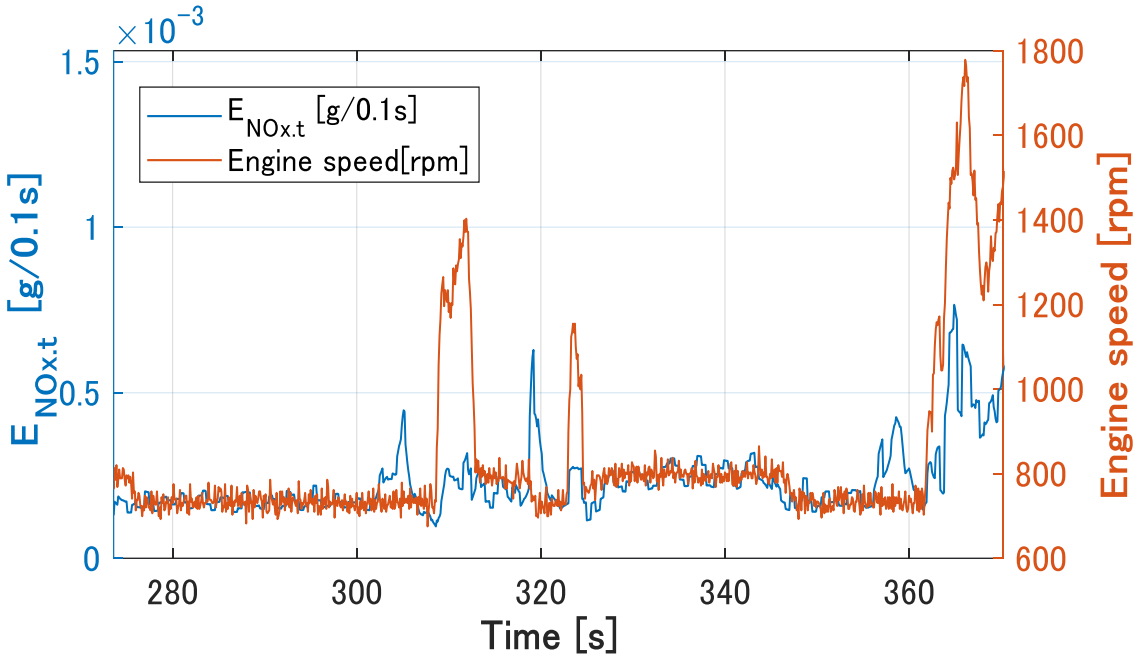


- Route No.2

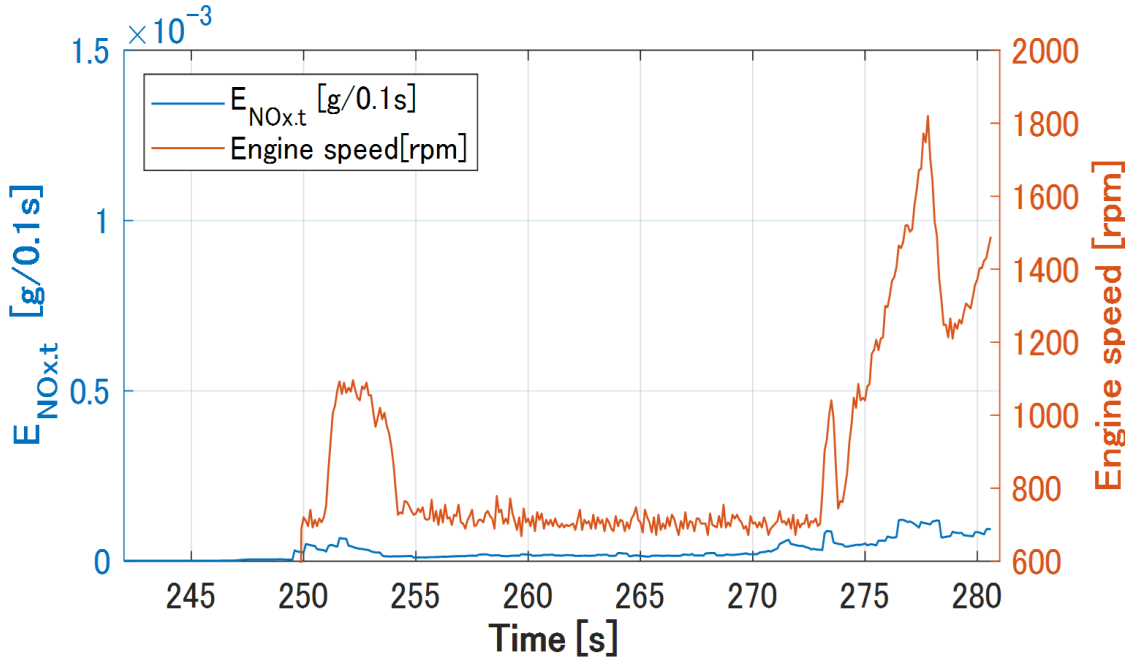


NOx emission for different traffic condition

Right turn

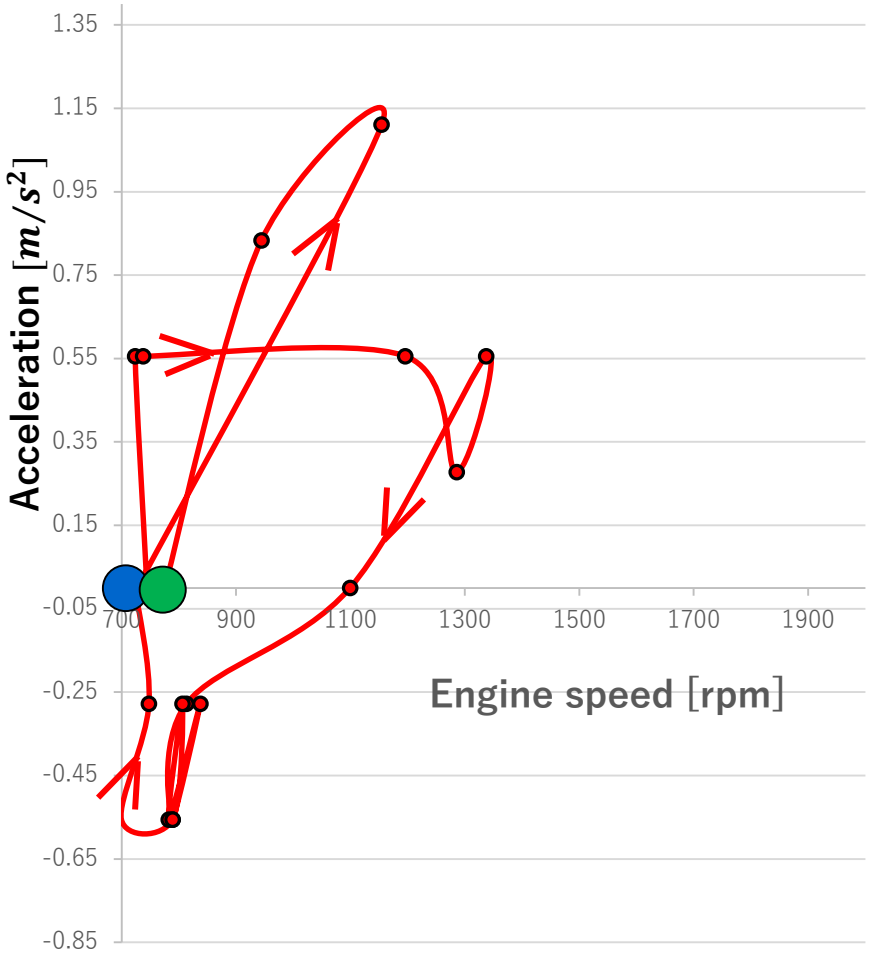


Left turn

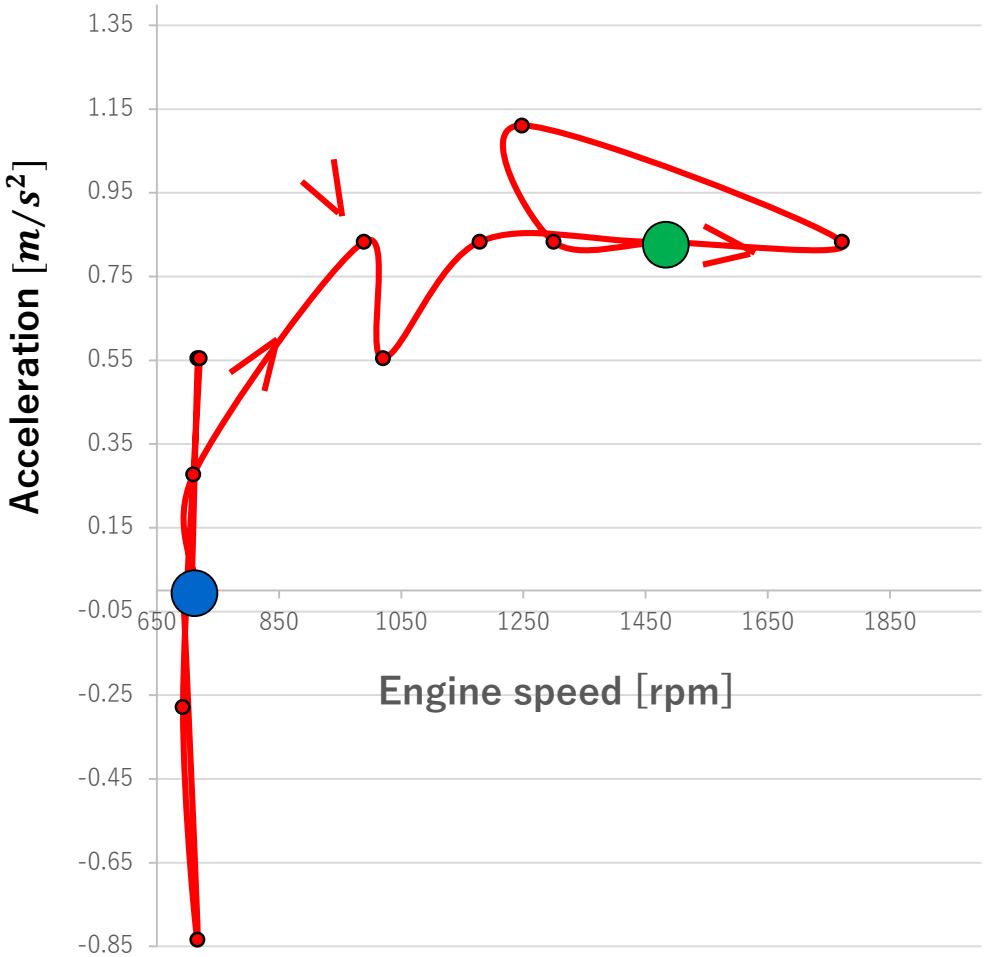


Acceleration for different traffic condition

- Right turn & acceleration (Route No.3)

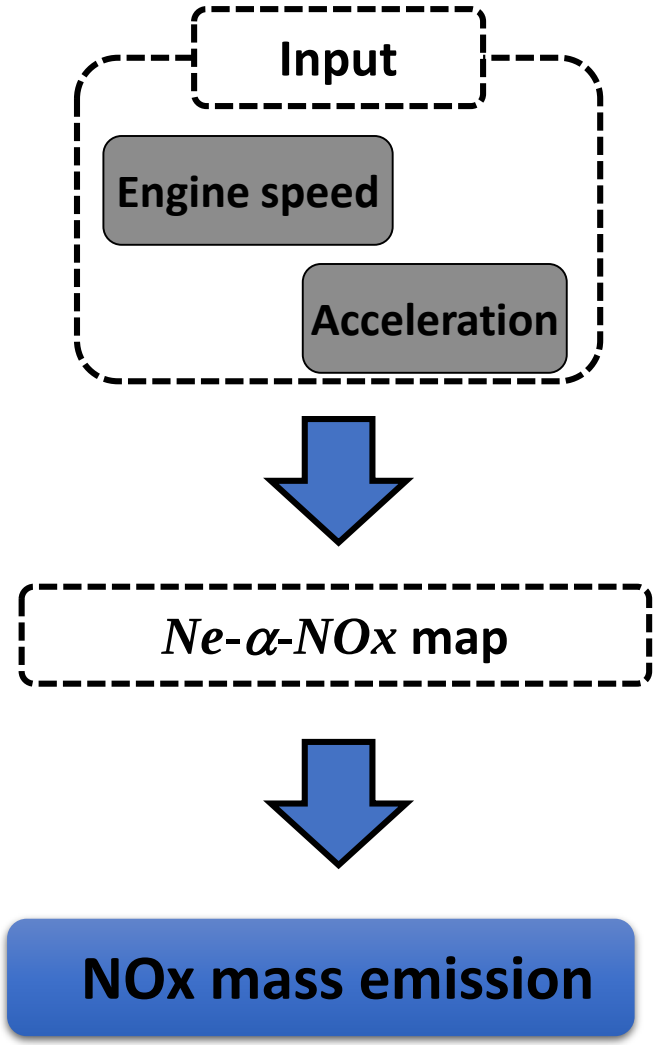


- Left turn & acceleration (Route No.2)



: Start
: End

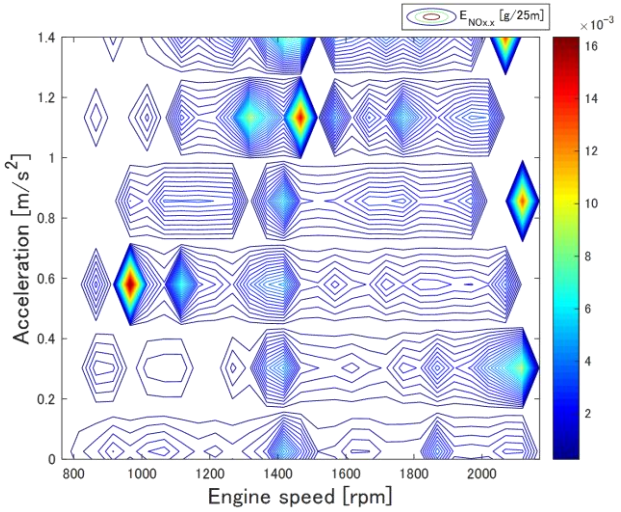
Procedures of NOx emission prediction



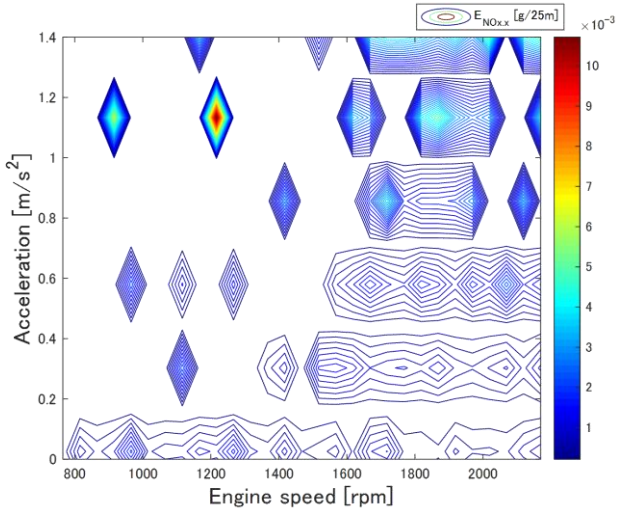
1. NOx emission is measured in the verification route
2. The verification route is divided into each 25 m
3. In the each 25 m, the Ne-α-NOx map is used for each traffic condition to predict NOx mass emission with input of engine speed and acceleration

Ne-α-NOx map

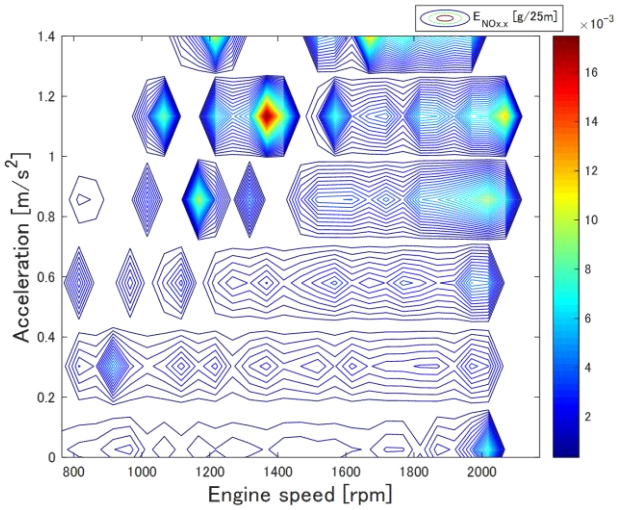
・30km/h speed limit



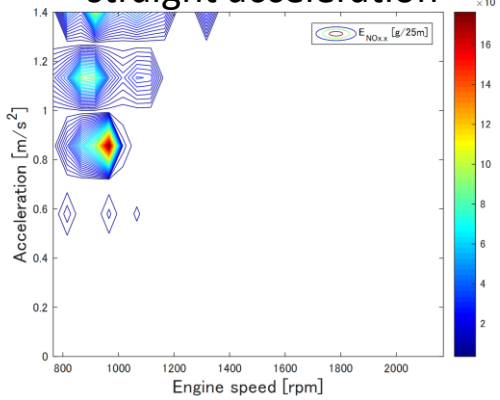
・40km/h speed limit



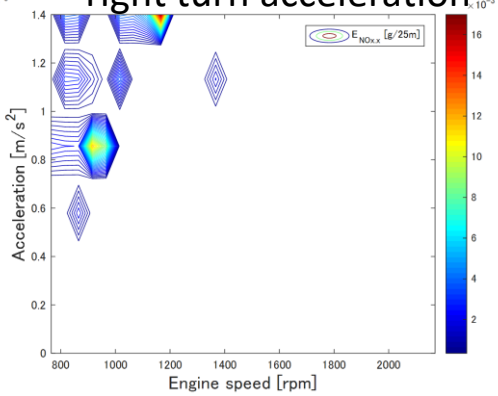
・50km/h speed limit



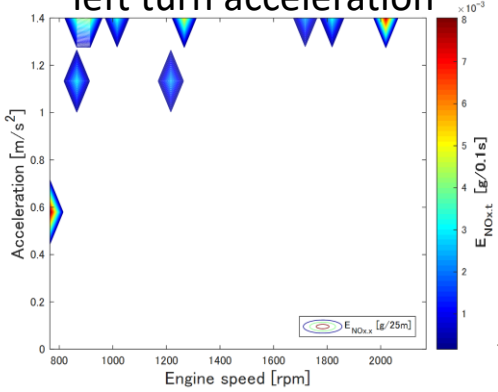
・straight acceleration



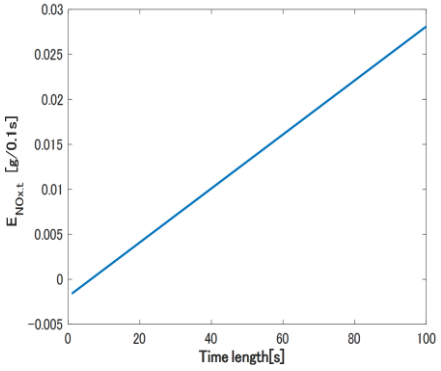
・right turn acceleration



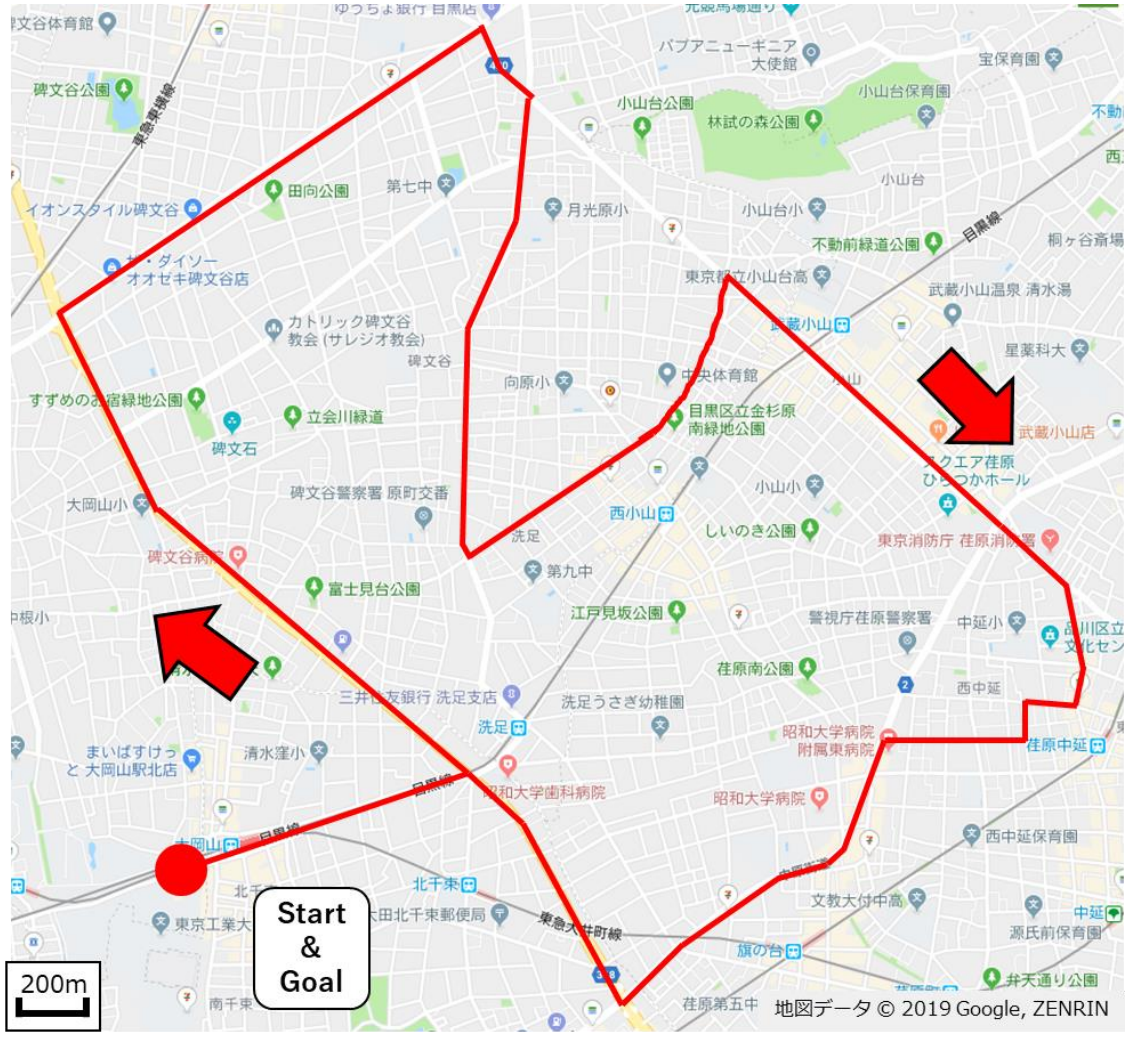
・left turn acceleration



・Idling



Verification route

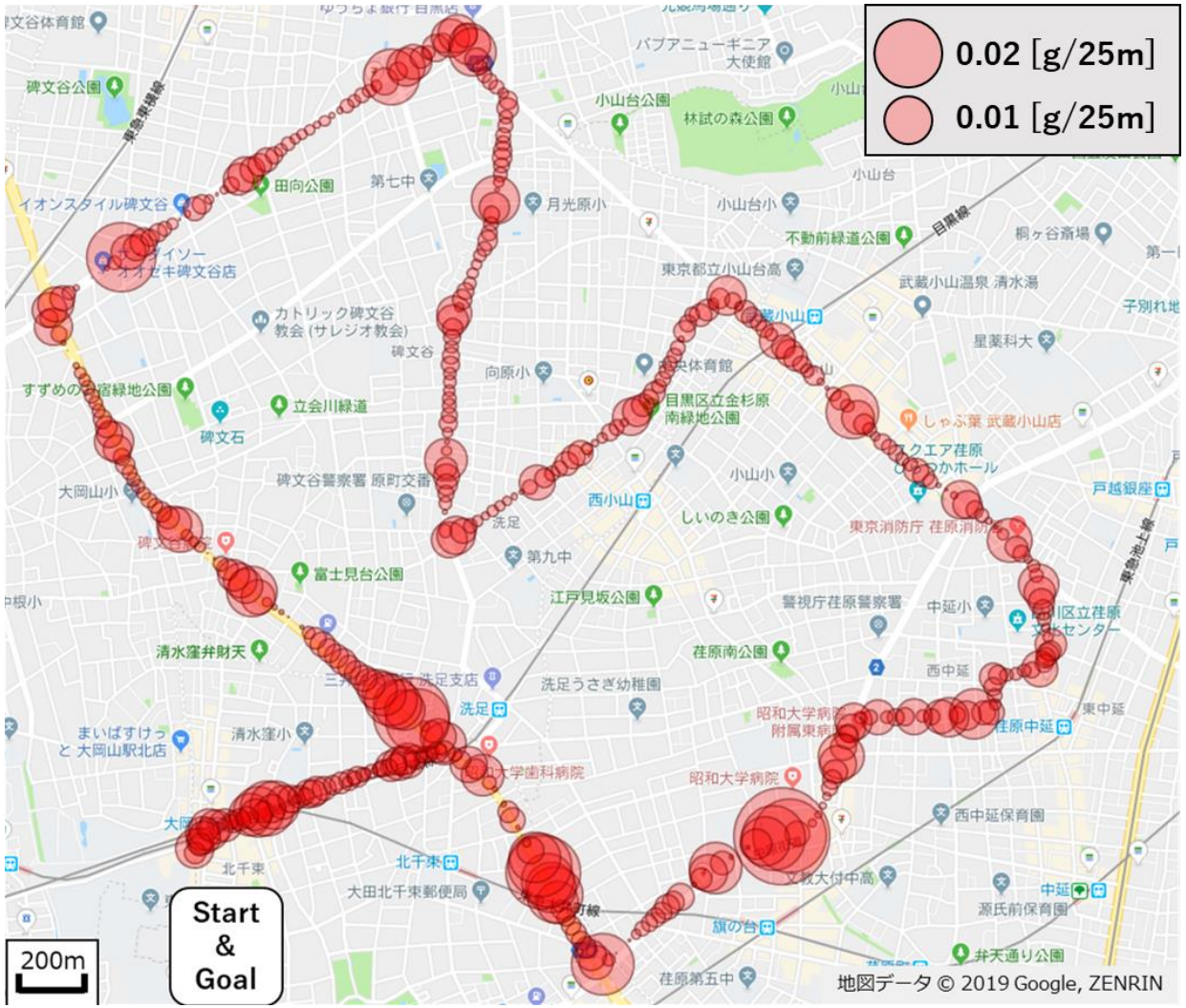


Distance [km]	11.22
Number of Signals	53

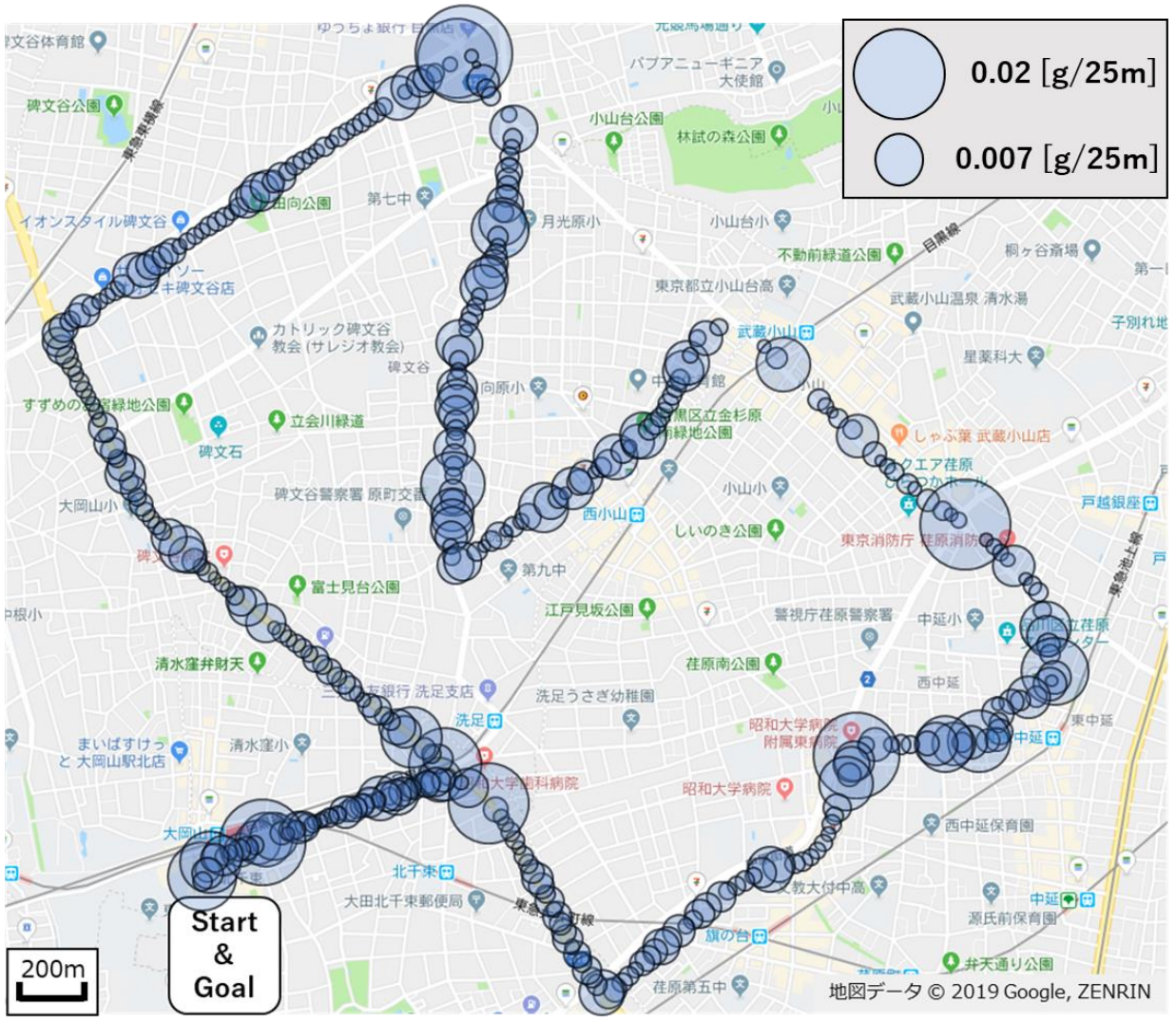
V=50 [km]	4.93	V=30 [km]	4.86
V=40 [km]	1.43	V=20 [km]	0

Prediction results

- **Measured**



- **Predicted**



Summary

- ✓ Traffic factors that are expected to increase NOx mass emissions (g/km) which exceeds regulation limit are signals, temporary stops, railroad crossing, turning left / right point.
- ✓ All of the traffic factors mentioned above forced to stop the vehicle. It was confirmed that the NOx mass emission for unit distance is increased by the acceleration from the stopped state generated by them.
- ✓ NOx mass emissions for unit distance during normal driving without stop are much less than driving including stop.
- ✓ It is possible to predict NOx emissions in the non-stopped state by maps of the engine speed, acceleration and NOx mass emissions. In this case, it is necessary to selectively use the maps to be referred to for each traffic factor such as the speed limit of each unit distance

Thank You for Your Attention !

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