Simulation Analysis of Truck Automated Lanes on Intercity Expressways

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Background

Freight transportation

Dominant mode of intercity goods movement

Will keep playing an important role in the near future

However, many problems are also increasing

- Environment
- Accident
- Delay
- Labor force

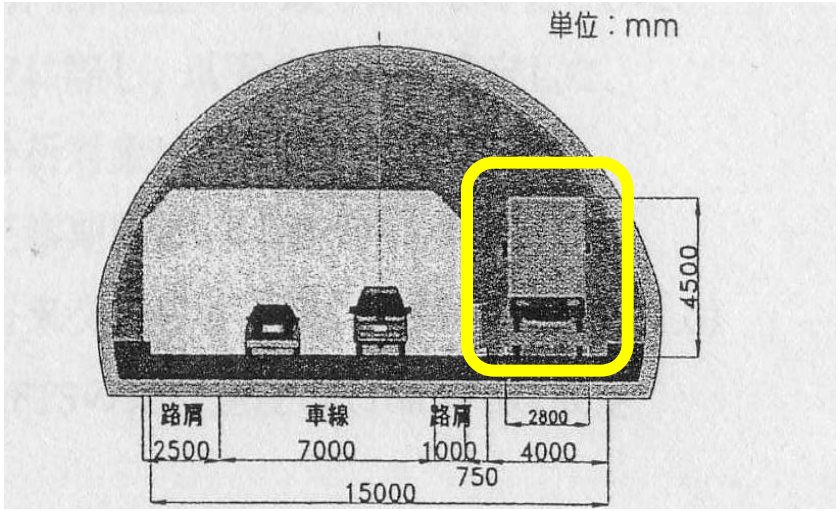
New transportation system is desired

Truck automated lanes

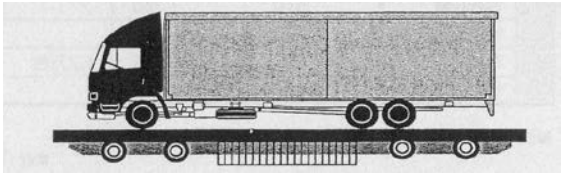
Background

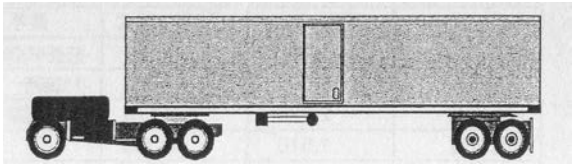
Truck automated lanes

- Dedicated lanes for freight traffic on intercity expressways
- Unmanned or manned control with ICT
- Effective use of lane by platooning

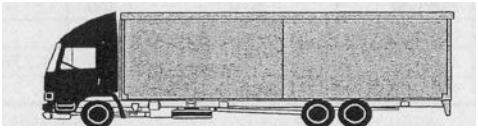


Dedicated lane (Ishizawa, 2006)





Unmanned



Manned

Objective

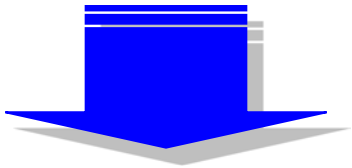
Previous studies including Nishida, et al.（1998）and Ishizawa（2006）

Examined the effects of truck automated lanes on New Tomei-Meishin Expressway

Assuming a fixed demand on the expressway

Not considered

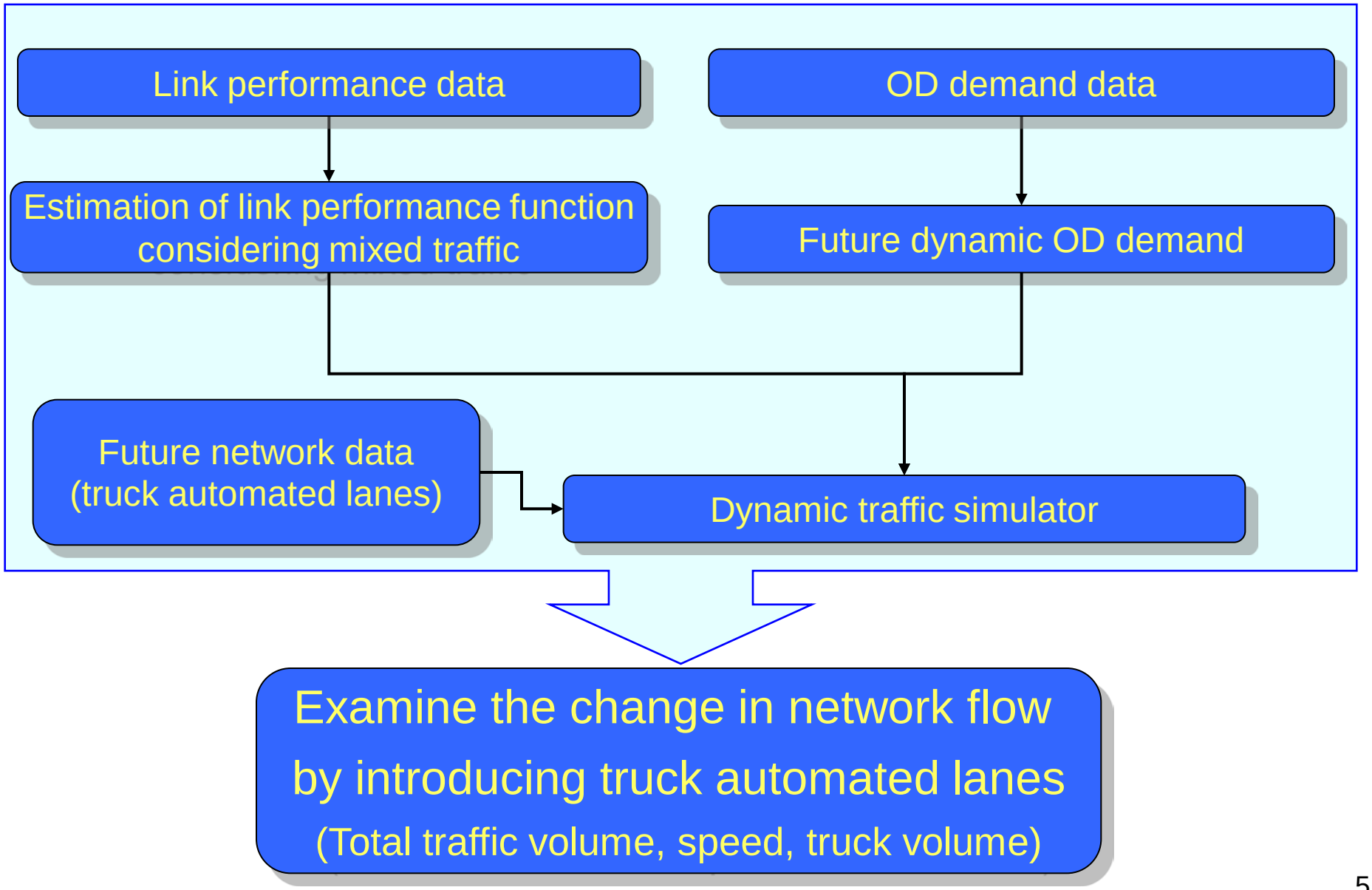
Induced demand from other routes
Change in the traffic flow of whole road network



Investigation of change in whole road network

By using network data and OD demand

Study flow


Link performance data
OD demand data
Estimation of link performance function considering mixed traffic
Future dynamic OD demand
Future network data (truck automated lanes)
Dynamic traffic simulator
Examine the change in network flow by introducing truck automated lanes
(Total traffic volume, speed, truck volume)

Estimation of link performance function

k-v function（density - speed）

■Non-linear model based on car-following theory by Gazis（1961）

$$v = v_f \exp\left[-\alpha\left(\frac{k_P}{C}\right)^{l-1}\right]$$

k : density（veh./km）

C : capacity

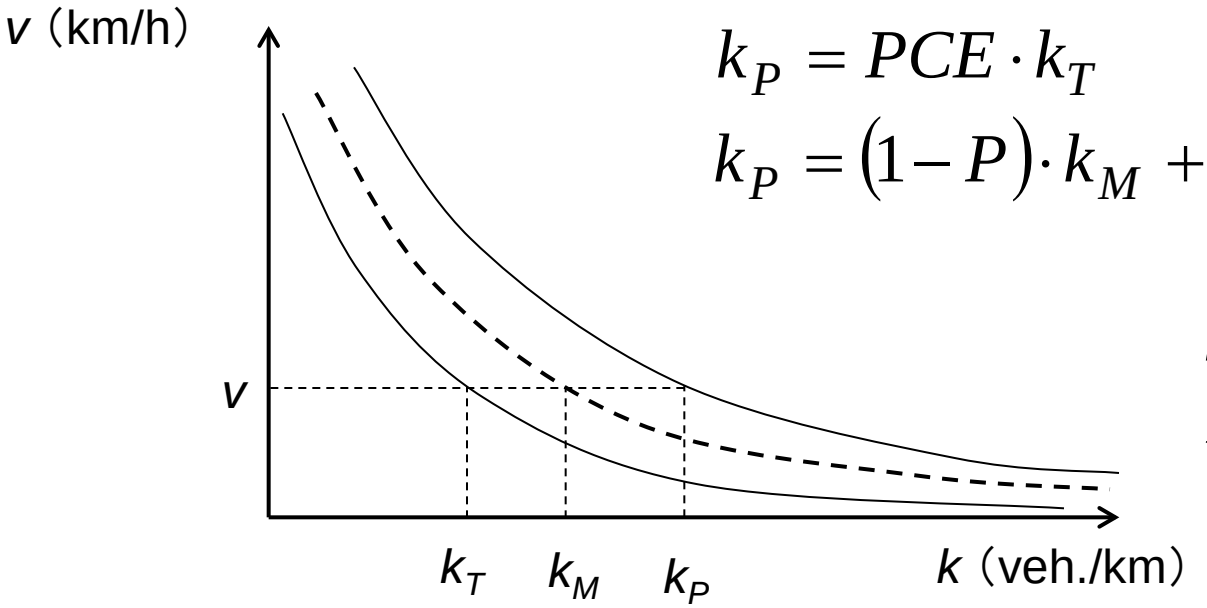
v_f : free flow speed

α, l : parameters

PCE（passenger car equivalence）

$$k_P = PCE \cdot k_T$$

$$k_P = (1-P)\cdot k_M + PCE \cdot P \cdot k_M$$



k_M : density of mixed traffic

P : truck ratio

Estimation of link performance function

k-v function（density - speed）

■Non-linear model based on car-following theory by Gazis（1961）

$$v = v_f \exp\left[-\alpha\left(\frac{k_P}{C}\right)^{l-1}\right]$$

k : density（veh./km）
C : capacity
v_f : free flow speed
α, l : parameters

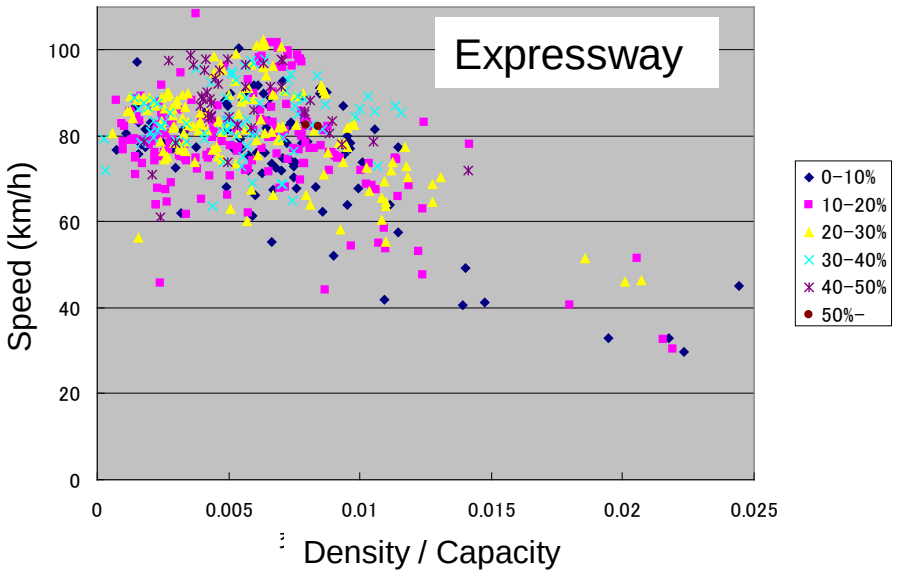
Assumption: passenger car and truck have the same speed
（Huber, 1982; Okura, et al., 1991）

$$v = v_f \exp\left[-\alpha\left(\frac{(1-P)\cdot k_M + PCE \cdot P \cdot k_M}{C}\right)^{l-1}\right]$$

k_M : density of mixed traffic
P : truck ratio

Simultaneous estimation of v_f, α, l, PCE

Link performance data



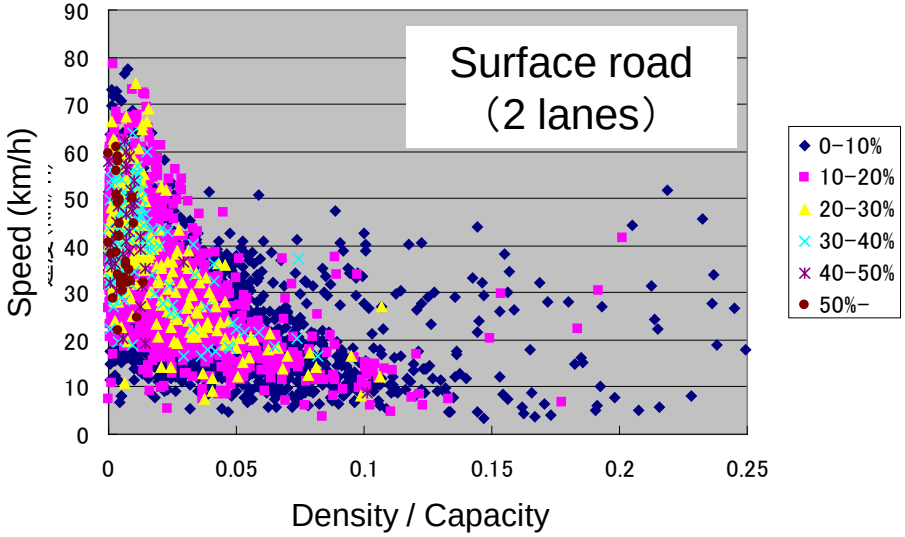
Road traffic census data

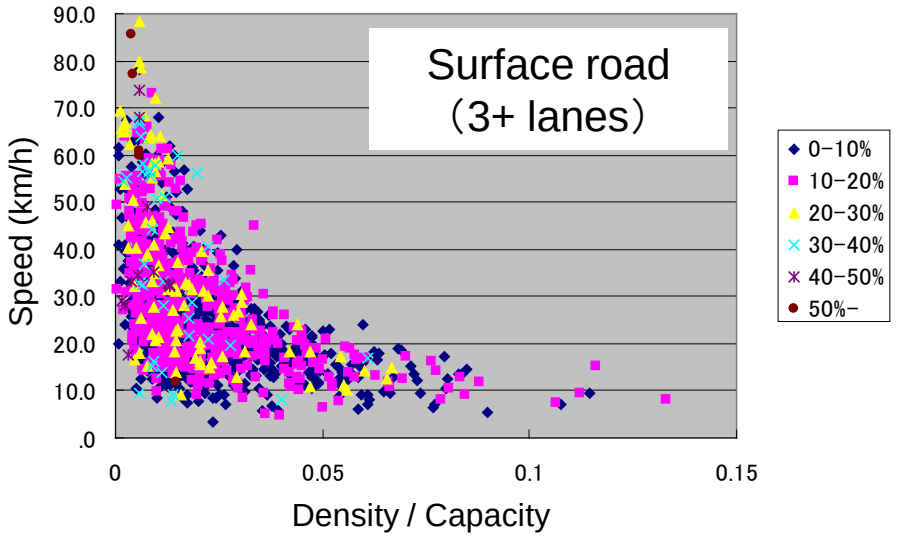
Year：1997, 1999, 2005

Area：Aichi, Gifu, Mie, Shizuoka, Nagano

Traffic speed at peak hour

Density/Capacity





Speed decrease by truck is not obvious

Estimation results of link performance function

$$v = f(k) = f\left((1-P)\cdot k_M + PCE \cdot P \cdot k_M\right)$$

$$f(k) = v_f \exp\left[-\alpha\left(\frac{k}{C}\right)^{l-1}\right]$$

	Free flow speed v_f (km/min)	α	l	PCE	Sample size
Expressway	1.032 + 0.283*speed limit (km/h)	0.217	2.616	1.733	567
Surface road (3+ lanes)	0.952	0.767	1.492	No good	1381
Surface road (2 lanes)	0.756	0.339	1.654	No good	7408

PCE at expressway is estimated at 1.73

⇩

Consistent to the literature

PCE could not be estimated for surface roads

⇩

Might be difficult to estimate with sample including various types of roads

Development of future OD demand

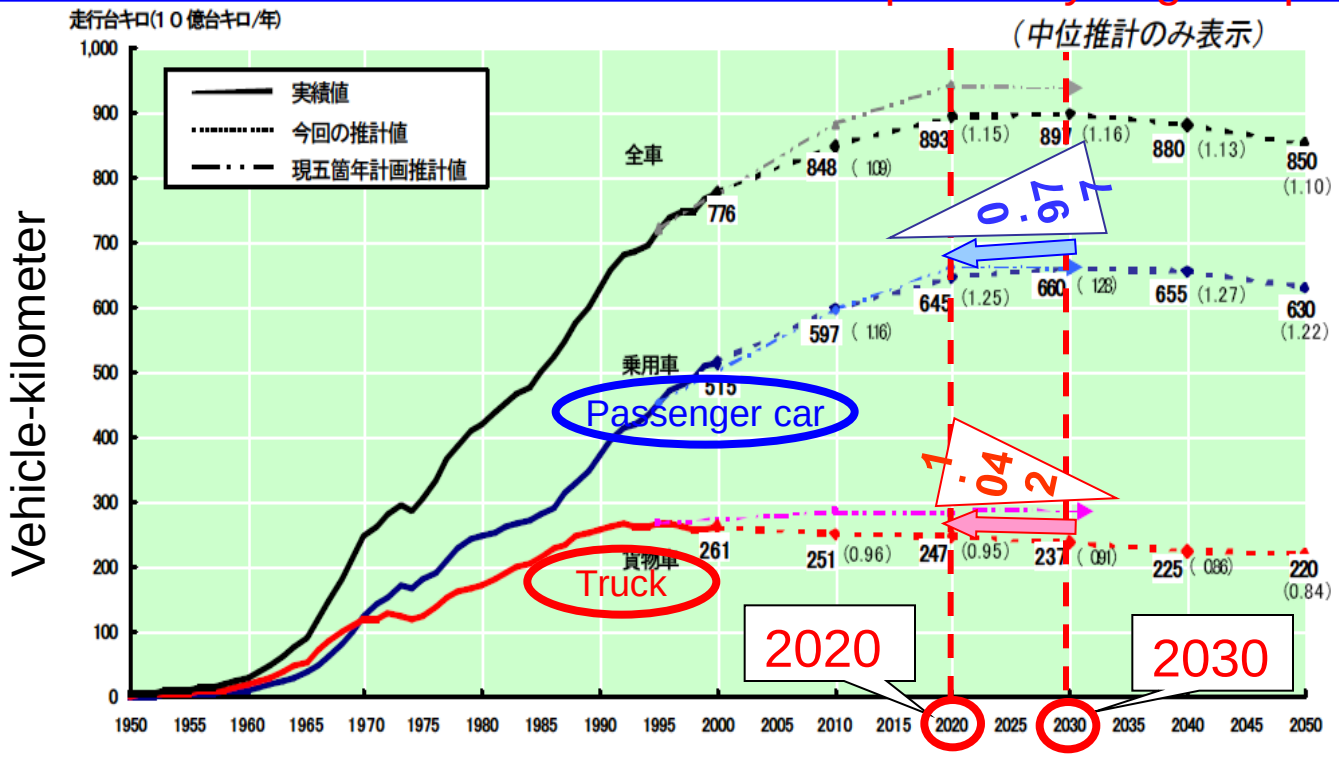
Current OD Road traffic census OD data 1999

Daily demand

Future OD OD data at 2030 by MLIT

→ Adjusted for target year 2020

（New Tomei-Meishin expressway begins operation）



For dynamic simulator

Distribution of current dynamic demand for each OD pair is applied to obtain

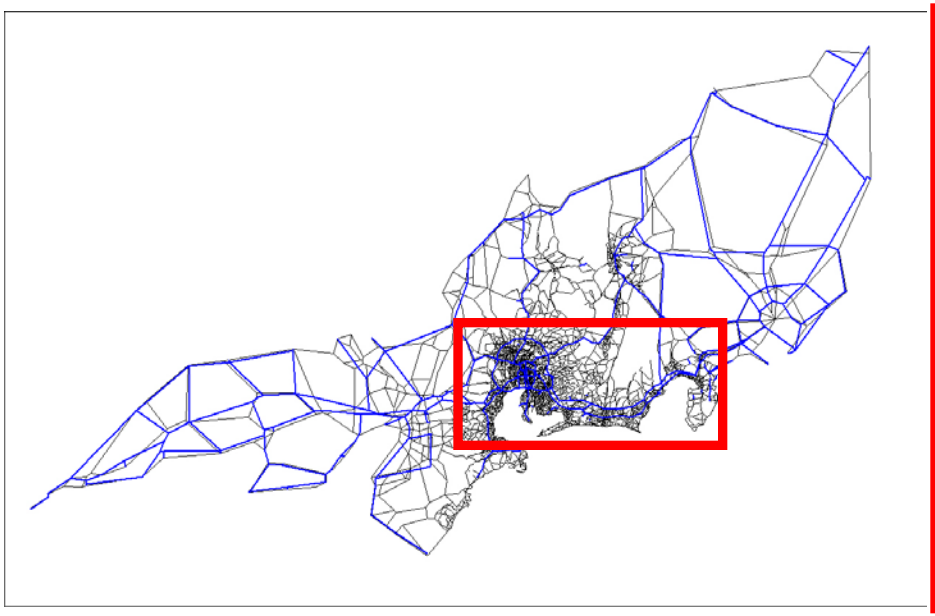
→ future dynamic OD demand

Future network data

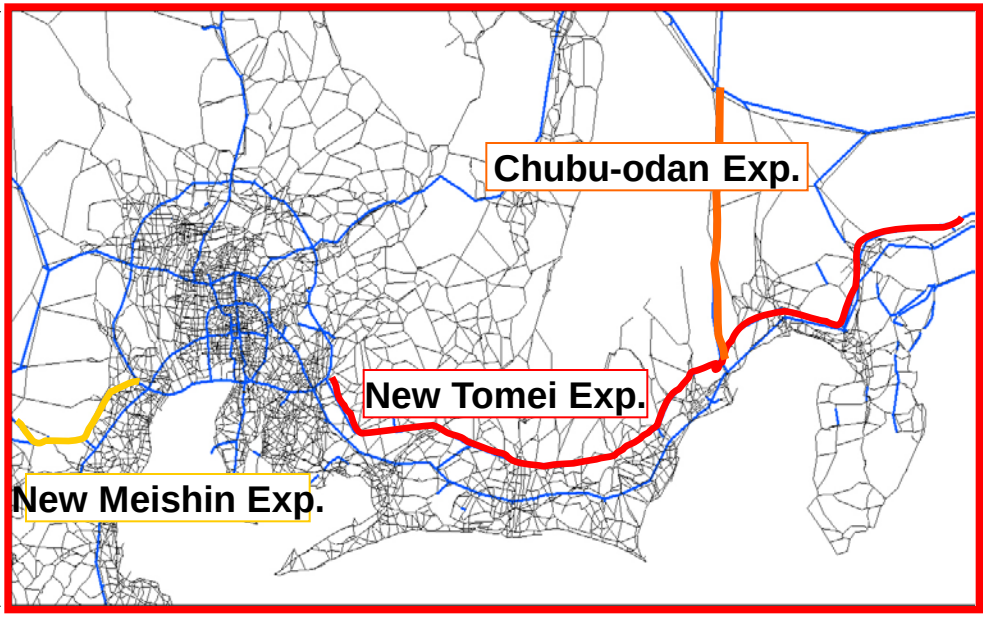
Current network data used for validation of simulation

Future network data Year 2030 data by MLIT

→ Adjusted for year 2020



Network at 2020



Dynamic traffic simulator

Meso-scopic: One packet for 5 vehicles for each vehicle class

Route choice: dynamic user optimum → myopic link choice

Congestion: Point-queue + link capacity → spill back

Vehicle movement: Periodic scanning → 15 second time step

Vehicle class: passenger car, truck

Value of time: 68.7JPY/min. for passenger car

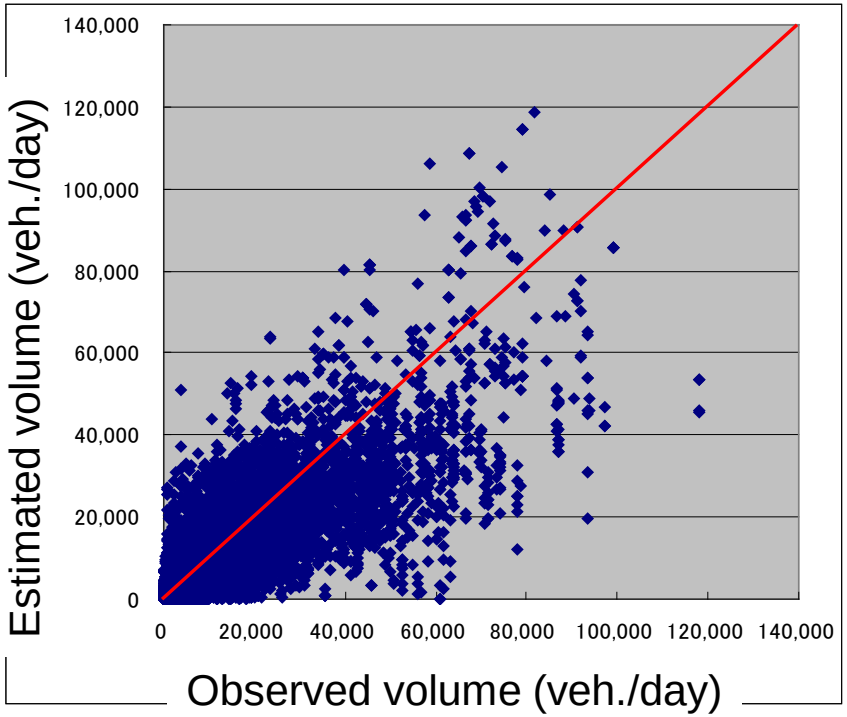
87.4JPY/min. for truck

PCE: 1.73 for both expressway and surface road

Validation of simulator

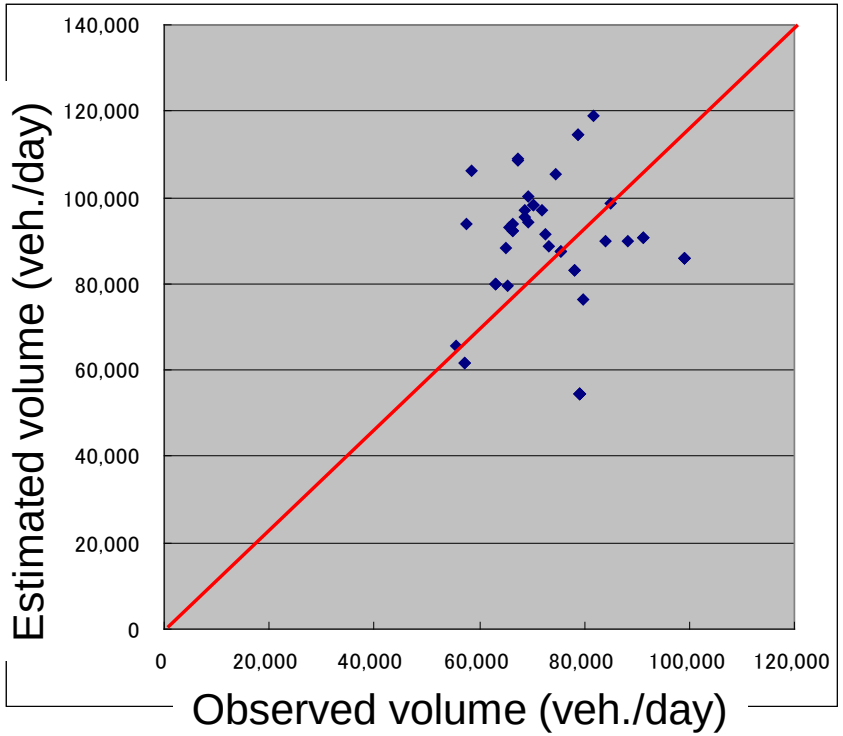
Observed and estimated link traffic volume

using OD demand data at 1999 and network data at 1999



Total

Correlation coefficient : 0.773



Tomei-Meishin expressway

Not biased at expressway

Assumption for truck automated lanes

- **Lanes**: 2 lanes of 6 lanes at New Tomei-Meishin Expressway
- **Vehicle length**: 13.5m （Ishizaka, 2006）
- **Headway**: 13.5m
- **Speed**: 100km/h （Nishida et al.（1998）:100km/h, Ishizaka（2006）:110km）
  - Speed decrease is not considered up to the capacity
- **Capacity**:

$$C_{a,t} = 100 \times \left(\frac{1000}{27.0} \right) = 3703.7 \text{ (Veh./h)}$$

Capacity (Veh./h) v (km/h) k (Veh./km)

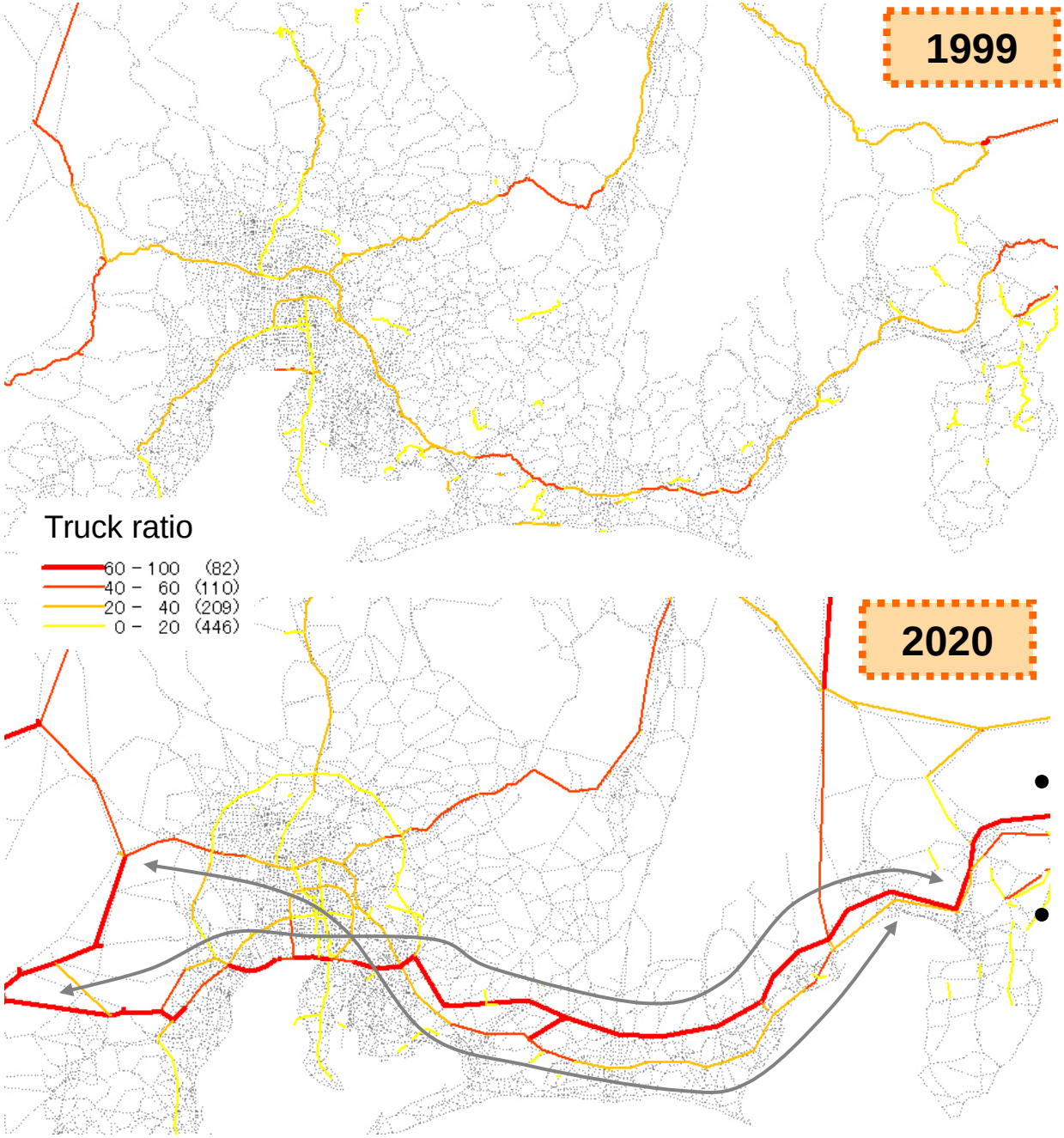
Operation at on/off ramp is not considered in simulation

Scenarios

Scenarios for New Tomei-Meishin Expressway

	Normal lanes		Truck automated lanes	
	Lanes	Speed limit	Lanes	Speed
Base	4～6	100km/h	--	--
Case 1	6	100km/h	--	--
Case 2	6	120km/h	--	--
Case 3	4	100km/h	2	100km/h

Truck ratio at base case

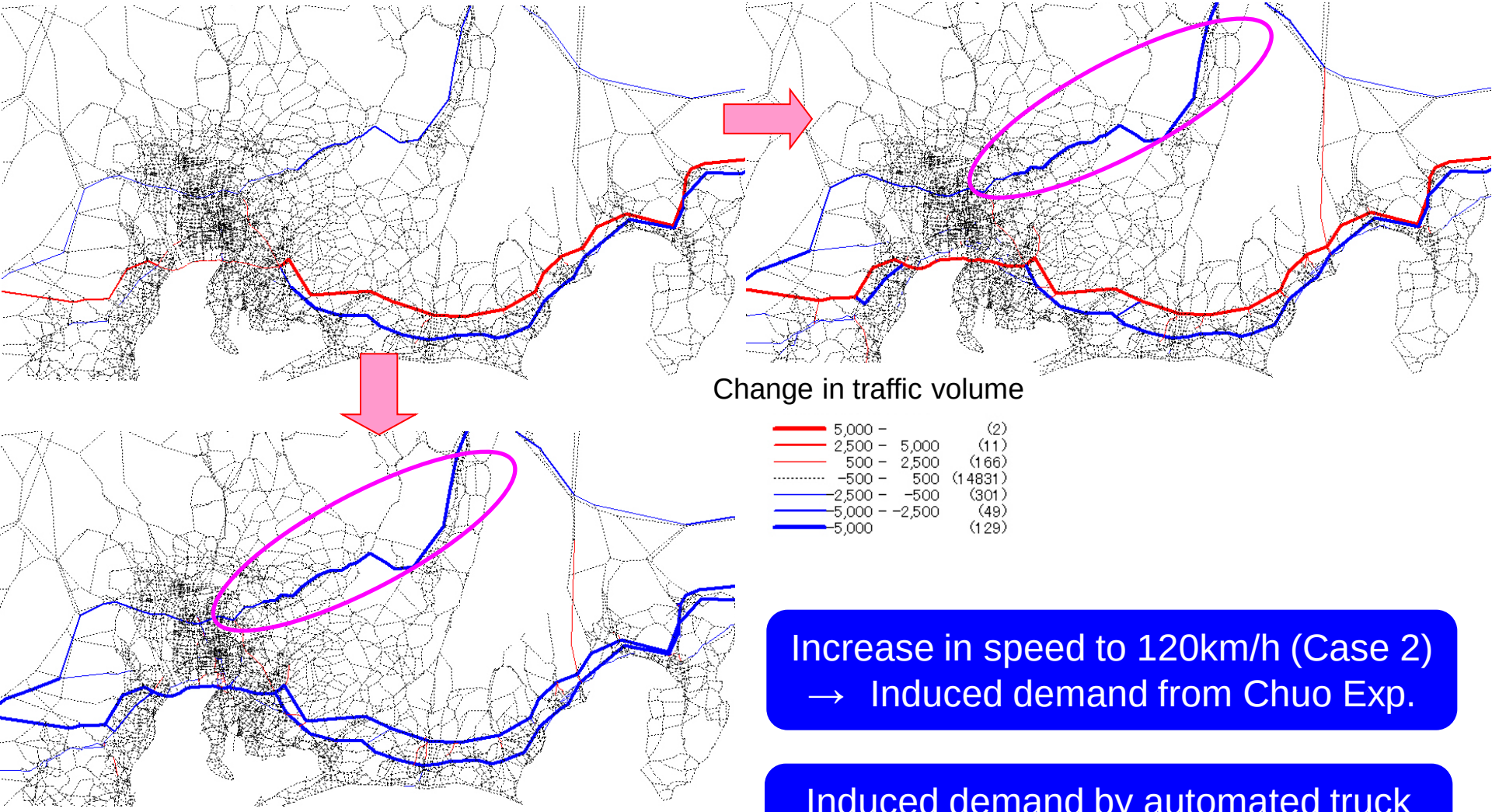


- High truck ratio at New Tomei-Meishin Exp.
- Change in Old Tomei-Meishin Exp. is small

Change in traffic volume compared to base case

Case 1：6 lanes 100km/h

Case 2：6 lanes 120km/h



Case 4：4 lanes 100km/h＋2 truck automated lanes

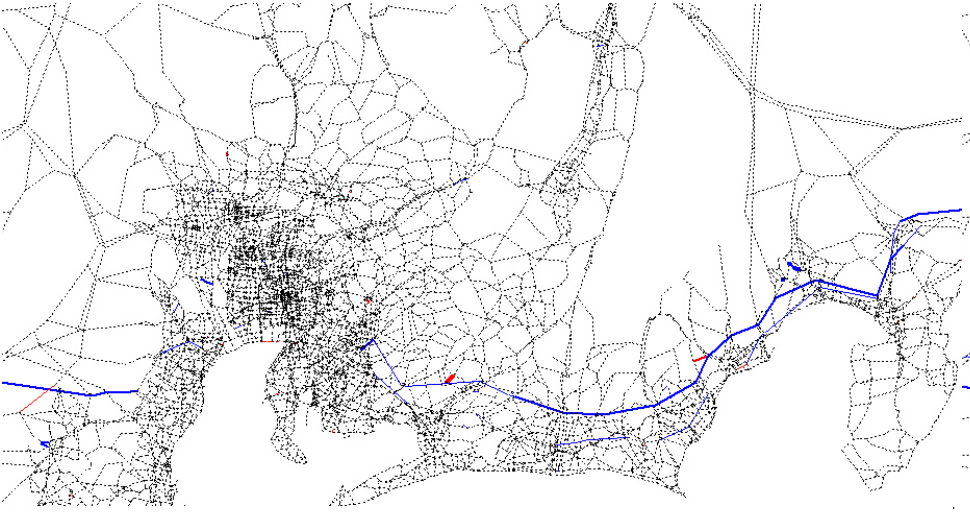
※Normal lanes are shown for New Tomei-Meishin exp. in figure

Increase in speed to 120km/h (Case 2)
→ Induced demand from Chuo Exp.

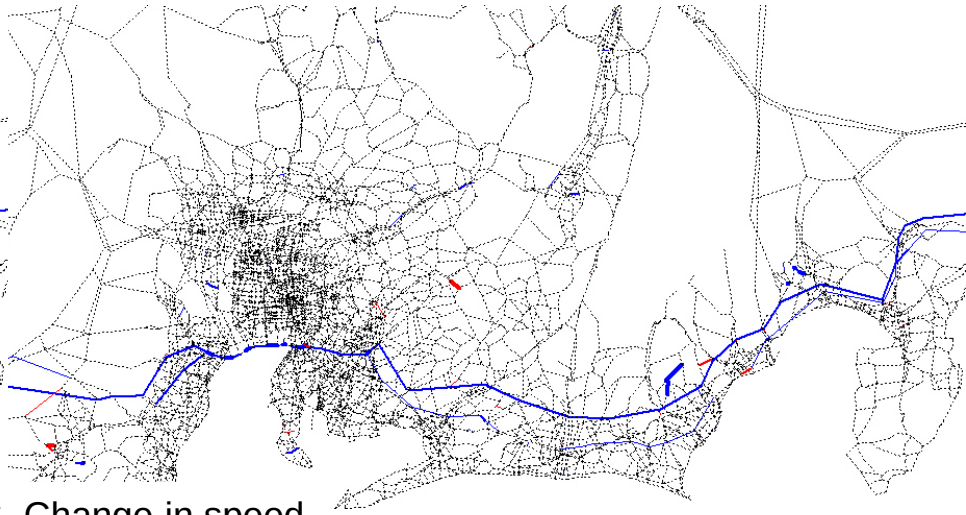
Induced demand by automated truck lanes at the same level

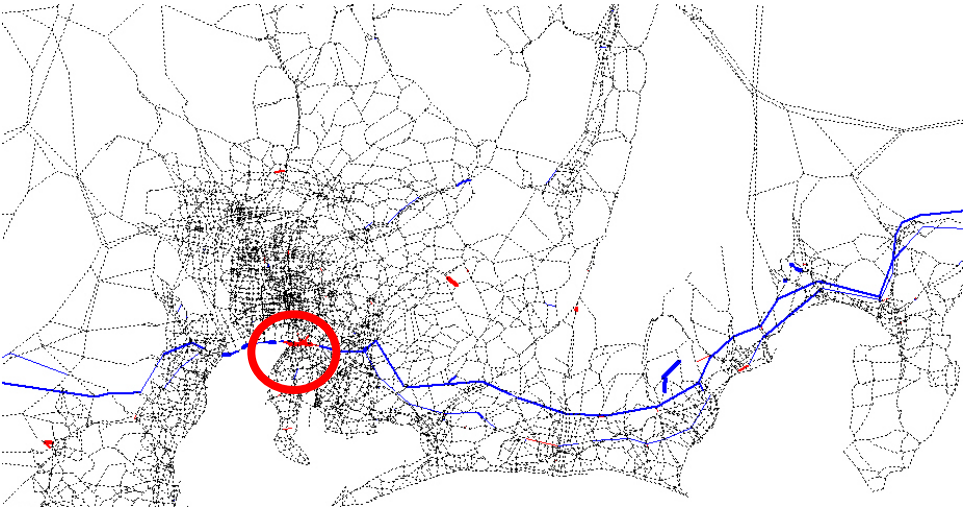
Change in speed compared to base case

Case 1：6 lanes 100km/h



Case 2：6 lanes 120km/h





Case 3：4lanes 100km/h＋2 automated truck lanes

※Normal lanes are shown for New Tomei-Meishin exp. in figure

Change in speed

10	– 100	(30)
2.5	– 10	(30)
1	– 2.5	(3)
−1	– 1	(20)
−2.5	– −1	(6)
−10	– −2.5	(9)
−100	– −10	(7)

Increase in speed on other links is not significant

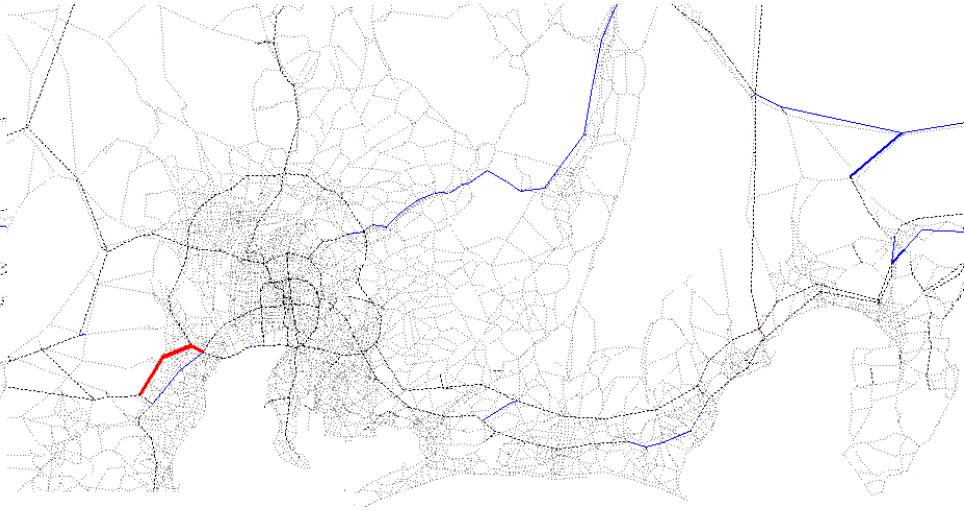
Case 2 & 3 have the same speed increase for passenger car

Nagoya JCT has speed decrease because of increased truck volume

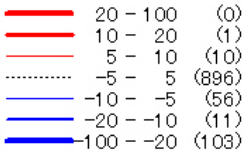
Change in truck ratio compared to base case

Case 1：6 lanes 100km/h

Case 2：6 lanes 120km/h



Change in truck ratio



Significant decrease in truck ratio at normal lanes in Case 3

Case 3：4lanes 100km/h＋2 automated truck lanes

*Normal lanes are shown for New Tomei-Meishin exp. in figure
*Only expressways are shown in figures

Comparison of vehicle-hours and benefit

＜Vehicle-hours＞

※Unit：1000 veh. hour

	Total		Tomei–Meishin		New Tomei–Meishin		Other	
Base case	6094	--	319	--	356	--	5419	--
Case 1（6 lanes 100km/h）	6075	-19	289	-30	384	+28	5704	-17
Case 2（6 lanes 120km/h）	6044	-50	261	-58	411	+55	5662	-48
Case 3（4 lanes＋2 truck automated lanes）	6055	-39	256	-63	413	+57	5670	-34

・The size of decrease in veh.-hrs. is Case 2 > Case 3 > Case 1

・Decrease in veh.-hrs. is significant at routes other than New Tomei-Meishin Exp.

＜Benefit＞

	Travel time decrease (100MJPY/Yr.)
Case 1（6 lanes 100km/h）	340
Case 2（6 lanes 120km/h）	884
Case 3（4 lanes＋2 truck automated lanes）	706

Automated truck lanes doubles the benefit

Conclusion

- Introducing truck automated lanes has a better effect than mixed use of lanes in terms of veh.-hrs.
- Introducing truck automated lanes into New Tomei-Meishin Exp. causes significant flow change in whole networks
  → Assumption of fixed demand was not realistic

Future tasks

- Estimation of different speed in mixed traffic for each vehicle class
- Improvement of simulator including realistic route choice
- Estimation of CO2 reduction considering platoon effect