AN EVALUATION OF TRAFFIC MANAGEMENT AND AIR QUALITY FOR WIDE AREA NETWORK USING MICROSCOPIC SIMULATION

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ミクロシミュレーションを用いた交通と大気環境の広域的な評価

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首都圏において，SPM や Nox 等の大気汚染物質は，環境基準の達成率が依然として低く，交通渋滞・環境対策を，今後いかに行っていくべきかを検討することが，引き続き重要な政策課題である。しかし，広域に影響を及ぼす大気汚染物質低減のための各種政策に関しては，社会実験等によっても，その影響を評価することが困難である。そこで，本研究では，道路環境，運転状況を詳細に記述することが可能な交通ミクロシミュレータを活用し，東京南部・川崎・横浜を対象とした現状の交通システムに近いネットワークデータを構築し、OD 交通量の精度を向上させ、実データに基づいた信号入力を行い、シミュレーションに組み込むことで交通流の現況再現性の評価を行った。構築したシステムを用いて環境関連の各種 ITS 施策をシミュレートした結果、交通状況及び大気環境の状況が改善する可能性があることが確認された。

1. Introduction

In Tokyo, it is still important to examine the traffic congestion and their impacts on air quality, including emissions and the corresponding ambient concentrations of NOx (nitrogen oxide) and SPM (suspended particulate matter). The ambient air quality standard is strict (*e.g.*, for SPM the daily average for hourly values should not exceed 0.10 μg/m^3, and hourly values should not exceed 0.20 μg/m^3) and therefore, regulatory authorities have to implement policies leading to better air quality. To effectively implement traffic and air pollution control strategies, an improved method of evaluating vehicle emissions and analysis of spatio-temporal dispersion patterns of emission are needed to be done.

In this paper, the microscopic road traffic simulation of the highly dense road network in the Tokyo Metropolitan Area is implemented to evaluate ITS (Intelligent Transportation System)-related policies aiming at mitigating traffic congestion and air pollution. Although this is a continuing research from Goto et al. (2002) and Shirahama et al. (2004), two major improvements of the micro-simulation system were done. First, the actual data of the traffic signal phasing was encoded in the simulation system. Second, the time-of-day O-D (origin-destination) tables classified according to four types of vehicles were created using traffic census data. Both of these were aimed to improve the reproducibility of the traffic volume. Moreover, the modification of O-D tables was conducted by using modifier model developed by Shirahama et al. (2004). Finally, the actuated signal system for priority of truck traffic and the route guidance of trucks combined with road pricing and the construction of new toll road are evaluated in terms of the reduction in PM emissions.

2. Literature Review

Simulation modeling is becoming increasingly popular and effective tool for analyzing transportation policies. In the field of traffic simulation, there seems to be general agreement that a computational resolution down to the level of individual travelers, is now a viable alternative and may be the answer to questions arising from a wide variety of problems. Recent advancements in computer technology have led to the development of a variety of microscopic simulation models. For example, microscopic traffic simulation softwares that are widely used include PARAMICS, VISSIM, SOUNDS and DeBNets.

There are already systems integrating microscopic traffic simulation with assessment of the air quality. For example, Park (2001) integrated microscopic traffic simulator VISSIM with the CO_2 instantaneous emission model and Gaussian dispersion model and applied the integrated model to the area of Kent Maidstone, England. In this paper, the ITS policies in the study area are examined in detail. As Ishida (2003) pointed out, the necessity of policies for reducing traffic congestion caused by trucks is increasing. Ishida also observed the phenomena where trucks pass through narrow streets to avoid the congestion along trunk roads. Such traffic situation is undesirable. The appropriate distribution of trucks in the network would be conducted through the implementation of route guidance system or TDM (Travel Demand Management) measures.

3. Encoding of the Road Network of Southern Tokyo, Kawasaki, and Yokohama

3.1 Study Area

The road network of the study area, which covers southern Tokyo, Kawasaki and Yokohama, was encoded with more detail to better approximate the actual road network. The base network was built by Goto *et al.* (2003), as shown in Figure 1.

The study area has a radius of about 30km and is divided into 122 internal zones. The number of nodes in the network is 10,802 and the number of links is 20,636 with a total length of 4,815 km. The snapshot of the network is shown in Figure 1.

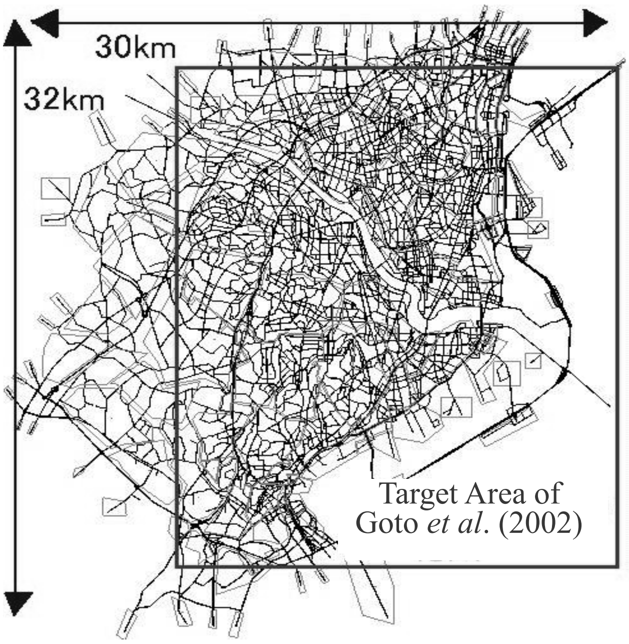

Figure 1: Study Area

3.2 Outline of Network Building

The strategy for enhancing the detail of the road network is shown in Figure 2. First, to reproduce the realistic network, the preceding studies, Goto et al. (2003) and Shirahama et al. (2004), inputted the actual data of the number of lanes and maximum speed using actual data derived from MLIT (Ministry of Land, Infrastructure and Transport of Japan). The characteristics of roads, including the geometry of junctions and interchanges and the nodes of the network were coordinated with the DRM (Digital Road Map) data. In this study, the physical conditions of the road network in Shibuya Ward and Minato Ward in the Southern Tokyo Area, were encoded with more detail.

Second, the actual signal data was inputted and time-of-day O-D tables were created. The data of traffic signals was derived from Metropolitan Police Department, and the number of traffic signals inputted was about 1,000.

Finally, 4 types of O-D tables including the fix route of BUS were created based on the data collected by the MLIT in 1999. In the process of model calibration, the modifier model of O-D tables was applied to adjust the simulated and observed traffic counts iteratively. The trial-and-error method based on engineering experience is also employed for calibration especially at the bottleneck intersections.

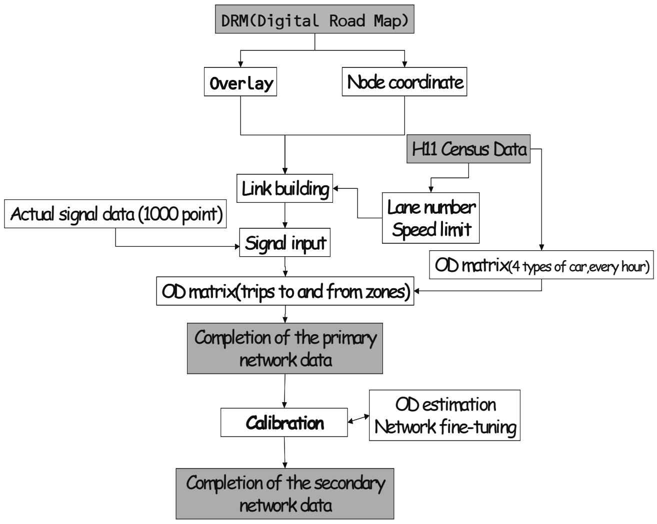

Figure 2: Task sequence for the network building

3.3 Setting of Traffic Signals

To represent a more realistic network, traffic signal data (split, cycle, phase, etc.) must be encoded in the simulation. There are about 3,000 traffic signals in the study area, which means that a substantial amount of effort would be required to encode signal phasing and cycle lengths into the simulation system. For about 2,500 locations, signal cycle-length data provided by Tokyo

Metropolitan Police and Kanagawa Prefectural Police were manually inputted into the network. For the rest of the signalized intersections, the average signal cycle length was inputted as a proxy value. The average cycle length in the network is about 100 seconds. We selected this value according to actual observations of cycle length in Tokyo.

3.4 Zoning Design

Traffic zones were subdivided into new conventional zones based on the zones in Goto et al. (2002). The new zoning design follows the zoning system of Japan's road traffic census. The total number of zones was thus changed from 64 to 122.

Of the 122 zones, 71 are internal zones within the study area; the other 51 are external zones. External O-D zones are established so that traffic from outside of the study area is represented by arterial roads linked to the external regions. Furthermore, the derived external O-D traffic is assigned to each arterial road outside the study area, based on the large-scale traffic assignment model of the whole Kanto Region. For these zone settings, a daily O-D matrix was created.

3.5 Building Time-of-Day O-D Tables Using Traffic Census Data

In order to decompose the daily O-D tables into hourly (time-of-day) tables, the 1999 road traffic census data was used. Conversion to O-D traffic classified according to four types of vehicles (Car, OGV [ordinary goods vehicle] and LGV [light goods vehicle] Bus-fixed route) was conducted. Detailed information on the arrival and departure time of trips for every vehicle type and for all O-D zonal pairs was acquired from census data. The data also provided traffic share by time period for every O-D pair.

3.6 Modification of Time-of-Day O-D Tables Using Microscopic Simulation

It is quite difficult to reproduce actual hourly variation in traffic volume for all possible links in the network since the original input of O-D data is in terms of daily volumes. Moreover, the accuracy of the converted time-of-day O-D traffic volume is very low, and it should be improved for reliable simulations.

This study develops a method of improving the reproducibility of time-dependent traffic volume by revising O-D matrix for each time period. The conventional method of the O-D estimation is adopted from Shirahama et al. (2004).

The 270 detectors, which count the traffic volume, are configured in the network and the output of simulated traffic counts and simulated average vehicle speed for each observational point were extracted for every time period. When the deviation between the simulated and the observed traffic counts is relatively large, the generalized cost of the target link is modified manually to improve the reproducibility of vehicle speed and/or traffic volume of the target link. Thirdly, the O-D modifier model is applied so that the simulated and the observed traffic counts will be in good agreement. A simulation run again carried out with the revised O-D matrix as an input data for microscopic simulation improving the reproducibility of present condition, and volume is repeated for all time periods. That is, the proposed method has a recursive process in the sense that the revised time-of-day O-D matrix is employed as an input to the next step.

3.7 Calibration Results

The calibration involves checking the simulated results versus the observed data and adjusting parameters until the calibrated results attain a high accuracy. The traffic count data was classified by four types of vehicles (Small car, LGV, OGV, BUS), which was obtained from MLIT. The comparison results of the observed and the simulated traffic volume after implementing the O-D modification are shown in Figure 3, Figure 4 and Figure 5 for each vehicle type, respectively. There are 270 observation points in the whole network.

The simulated traffic volume, which was initially underestimated, was improved after O-D modification. Table 1 below shows the value of calibration results of traffic counts.

Traffic counts of all types of the vehicles at 8-10 AM and 15-18 PM showed good validation with the O-D modification. The correlation coefficient of OGV (Ordinary Goods Vehicles) has dramatically improved since OGV has a fixed route. However, the correlation coefficient of car has not improved even after the O-D modification. The car driver may change the route according to his activity. The primary O-D matrix of car may have more error than that of the truck.

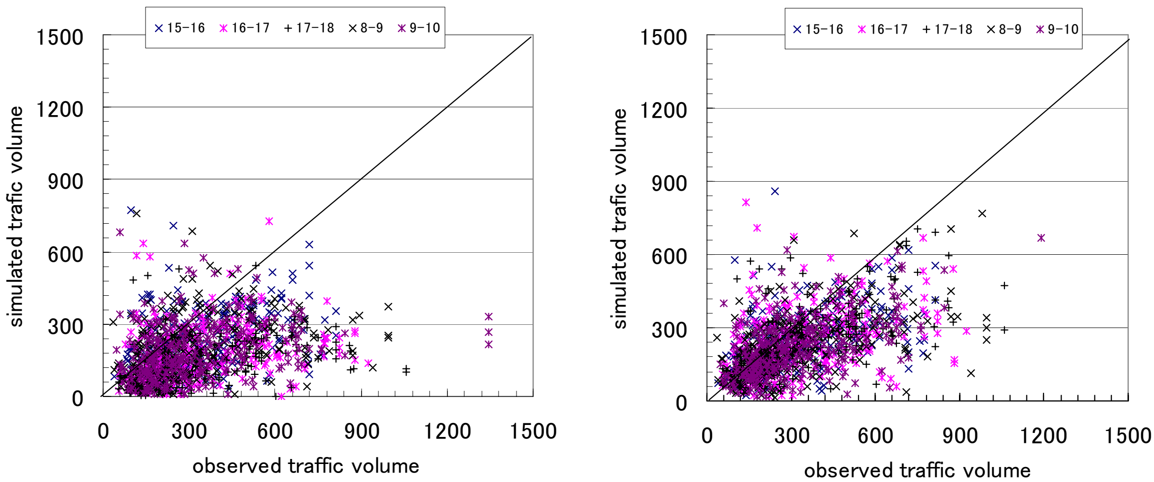

Figure 3. Comparison of observed and simulated traffic volume (Small Car)

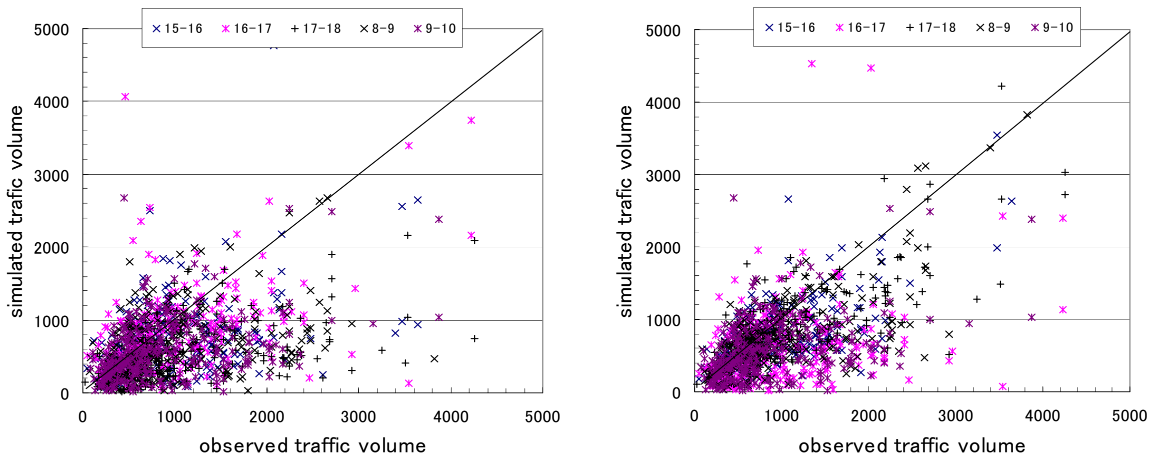

Figure 4, Comparison of observed and simulated traffic volume (OGV)

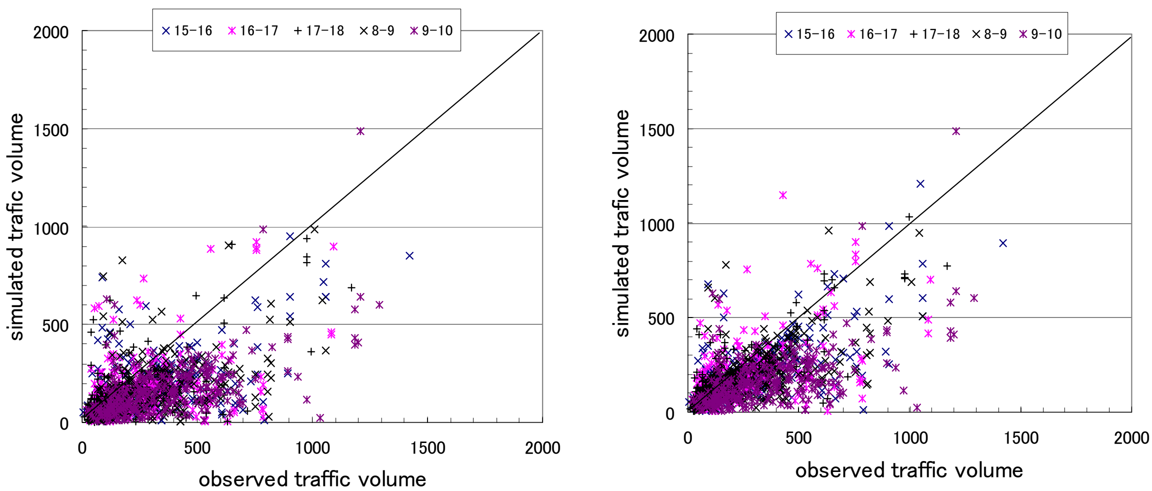

Figure 5. Comparison of observed and simulated traffic volume (LGV)

Table 1. Calibration results of traffic counts during congested hours (8-10 AM and 15-18 PM)

times of OD modification	0		1	2	3	
Car	Corre.Coe	RMSE	Corre.Coe	Corre.Coe	Corre.Coe	RMSE
8:00-9:00	0.42	364.6	0.56	0.60	0.57	310.9
9:00-10:00	0.41	348.8	0.51	0.62	0.64	302.0
15:00-16:00	0.33	359.8	0.39	0.41	0.44	300.5
16:00-17:00	0.40	374.9	0.55	0.53	0.54	316.7
17:00-18:00	0.46	408.3	0.53	0.62	0.56	340.3
Lignt Goods Vehicle						
8:00-9:00	0.38	209.2	0.44	0.48	0.53	189.3
9:00-10:00	0.31	217.4	0.40	0.44	0.44	190.9
15:00-16:00	0.49	200.3	0.51	0.53	0.57	185.9
16:00-17:00	0.35	223.9	0.45	0.54	0.51	189.7
17:00-18:00	0.40	235.6	0.37	0.49	0.48	190.1
Ordinary Goods Vehicle						
8:00-9:00	0.45	217.4	0.49	0.50	0.53	192.5
9:00-10:00	0.46	243.6	0.58	0.60	0.58	214.2
15:00-16:00	0.59	203.5	0.68	0.66	0.71	181.0
16:00-17:00	0.60	193.4	0.72	0.75	0.76	164.7
17:00-18:00	0.59	176.4	0.47	0.70	0.70	146.6

RMSE(veh/h/point)

3.8 Outline of Microscopic PM Emission Model

In this study, the PM emission model, developed by Shirahama et al. (2004), was adopted for the simulation. This model incorporates acceleration, velocity and slope.

The data used for estimating unknown parameters were collected by IBS (Institute of Behavioral Sciences, Japan) from an experiment using the chassis dynamometer along the Tomei Expressway near the Yokohama-Aoba Interchange in October 2002. The type of the vehicle used for the experiment was a sprinkler truck (Isuzu “Forward” manufactured in 1994). The tank of the sprinkler was emptied. The PM emission, speed, acceleration and other important items were measured. These items were recorded every 0.1 second and the total number of samples amounted to 26,471. We randomly selected 2,000 samples and used them for the calibration of the model.

4. Impact Analysis of ITS-Related Transportation Policies

The improvements of the traffic conditions are still needed in the study area. Recently, truck traffic is one of the most serious problems in the Tokyo metropolitan area because there are still no significant countermeasures formulated. There is a high volume of trucks which emit PM in Tokyo resulting to traffic congestion and air pollution. Sangyo Road, a major road in the Kanagawa prefecture, is one of with the highest share of truck traffic in the metropolitan area because it is located in the Keihin industrial areas in the south. However, there are many residential areas located in the north of Sangyo Road. In this study, we mainly focus on the Sangyo Road and its surroundings. Two policies related to the ITS to alleviate the traffic problem and air pollution are proposed below:

・Actuated signal system for prioritization of truck traffic
・Route guidance of truck combined with the construction of new toll road and road pricing.

In the analysis, the input data of the modified O-D matrix is used. The target simulation period selected was the morning peak period (8-10 AM)

4.1 Actuated Signal System for Truck Traffic Priority

Traffic congestion at intersections had always been a problem in recent years. Actuated signal system is one means to reduce traffic congestion. In this study, in order to reduce the frequent stopping of trucks, an actuated signal control is implemented where it extends the green time when trucks approaching the intersection are detected.

The study set an extension of the green time of 10 seconds with reference to the bus priority signal already in use. The actuated signal system for truck is set up on exclusive truck lanes.

This actuated signal system is set up at 29 intersections

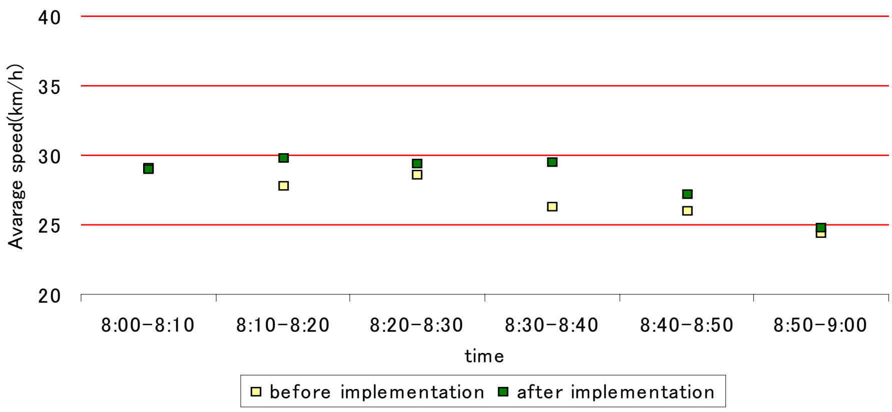

Figure 6. Impact of actuated signal system for trucks on the average traffic speed at the Sangyo Road

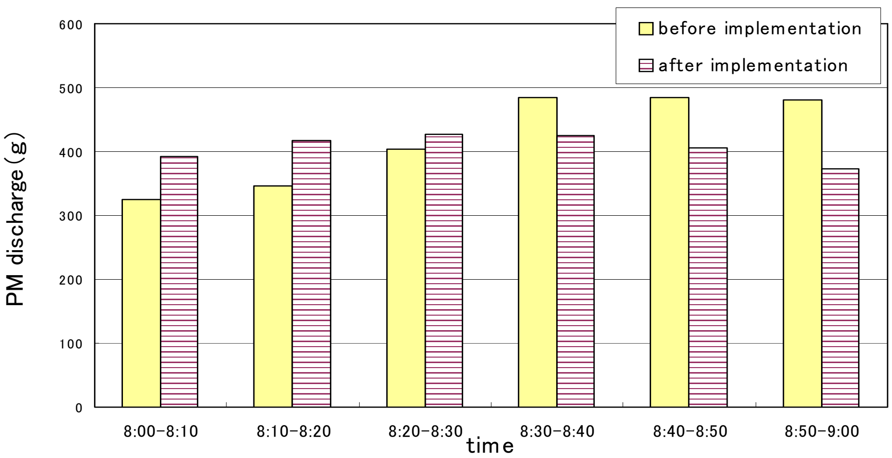

Figure 7. Impacts of actuated signal system for trucks on the PM emissions at the Sangyo Road

in the Sangyo Road.

The impacts of the actuated signal system for trucks on average traffic speed and PM emissions at the Sangyo Road are shown in Figure 6 and Figure 7, respectively. Overall, the average speed rose by 4.6% and of the total PM emissions decreased by 4% for the Sangyo Road, confirming that the actuated signal system for trucks could improve air quality. However, there are cases where intersection throughput is reduced.

4.2 Route Guidance for Trucks Combined with Construction of New Toll Road and Road Pricing

With the institution of route guidance for trucks, the truck toll at the Yoga Toll Plaza of the Tokyo Metropolitan Expressway is raised by 43% at the morning peak period. A new road is constructed which connects Tomei Expressway to the Bayshore Line via the Third Keihin Expressway and the Yokohane Expressway. Moreover, since the study is focused on the vehicles which pass through the metropolitan area, the inbound traffic and the through traffic were analyzed. The change in traffic volumes is shown in Figure 8. The figure indicates that traffic volume in the Bayshore Line and the Oguro Line increased while it decreased in the Shibuya Line. In the coastal area, it is interesting to note that the traffic of trucks decreased in spite of the increase of car traffic in the Sangyo Road.

Traffic volume also increased in the Ichigao and Futakobashi segments in Route No. 246 which is a national highway. The traffic volume increased because trucks travel in the national road just before the starting time of implementation of higher truck tolls. Changes in the amount of PM emissions after implementing the policies are aggregated for every link in Sangyo Road, as shown in Figure 9.

Overall, PM emissions in Sangyo Road decreased by

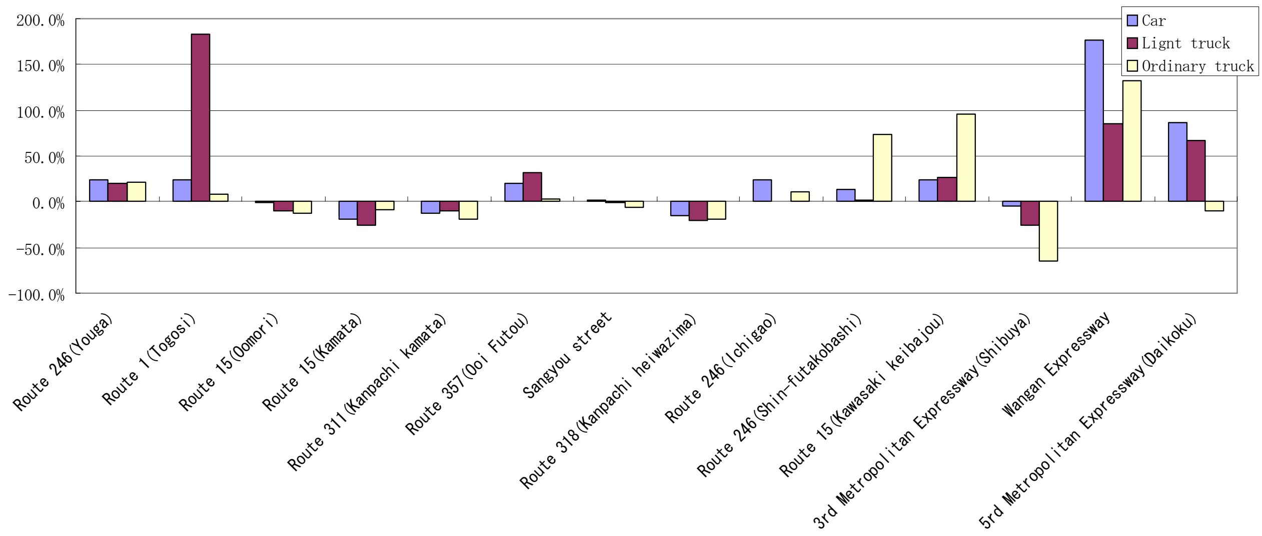

Figure 8. Impact on traffic volume of the combined policy of route guidance for trucks, construction of new toll road and road pricing

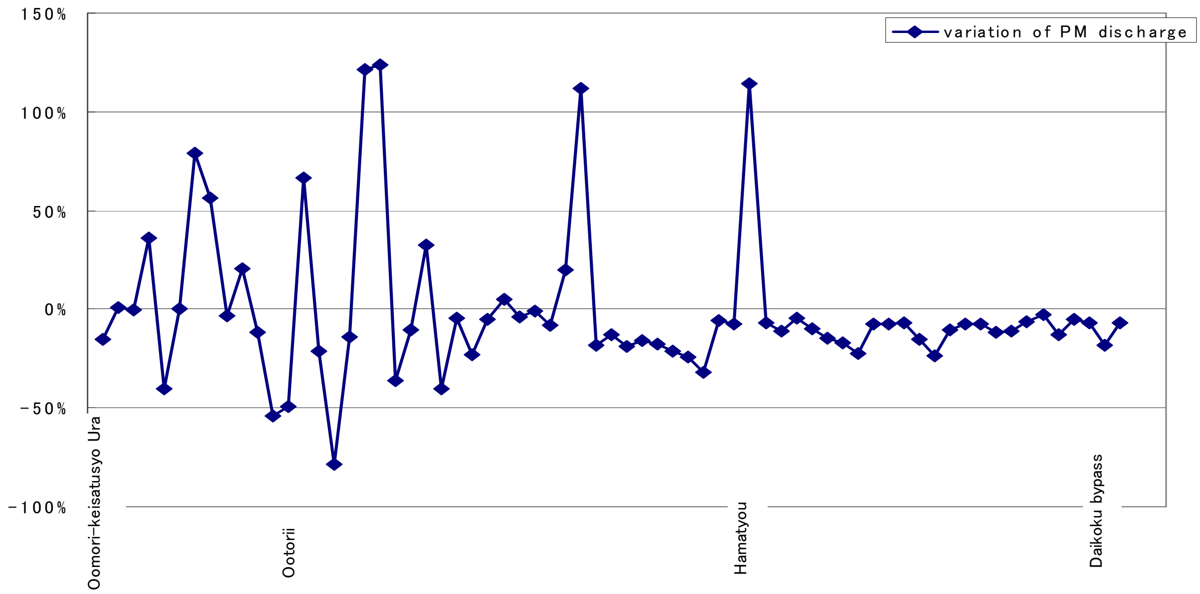

Figure 9. Changes in the link-level PM emissions in the Sangyo Road after implementation of the combined policy

7.7% after implementation of the combined policy. Air quality could be improved in Sangyo Road with the implementation of this combined policy measure.

Although the overall PM emissions decreased, there were links where the PM emissions increased.

5. Conclusions and Future Research Directions

The actual traffic signal phasing was incorporated in the simulation system. Four types of time-of-day OD tables by time period utilizing Census data were developed. These inputs were improved in order to create a more realistic traffic network.

All types of the vehicles during the 8-10 AM and 3-6 PM time periods showed good validation with the O-D modification.

The effectiveness of the ITS-related policies to improve traffic conditions and air quality are evaluated. In this study, the actuated signal system for trucks and the route guidance of trucks combined with the construction of new toll road and road pricing are implemented in the improved simulation system. It was confirmed that the proposed actuated signal system for trucks may improve air quality. The combined policy resulted to overall improvement in air quality with some of the traffic diverted to national highways and bayside expressway lines.

Reproducibility is necessary to be increased by creating the bus O-D matrix in the future system. It is also important to decide on which of the parameters of the traffic assignment should be calibrated.

There is a need for the assessment of other policies to improve air quality, such as environmental road pricing, in addition to the ITS policy measures. Using the PARAMICS, there is a need to simulate various environmental policies and ITS-related measures or their combinations.

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