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A Study on Land-Use Air Pollution Appraisal Model for Tokyo Metropolitan Area

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Abstract

One of the major consequences of rapid economic growth in a modern society is the aggravation of environmental problems. To lessen the impact of such problems, various economies have adopted various environmental protection measures in the form of environmental standards.

In Japan, an environmental standard for NO_2 (nitrogen dioxide), one of the majorosources of air pollution, was adopted in May 1973 and its control mechanisms were immediately enforced. The various countermeasures related to the source of generation, traffic volume control, the rescheduling of routes etc were instituted as a means of controlling the exhaust fumes of motor vehicles. However, both at home and abroad, several environmentalists have questioned the effectiveness of these control measures. This controversy stems from the fact that various studies have shown that the air pollution standards adopted for NO_2 is too low to cause any health hapzard to people. However the cost of meeting, this standard is enormous and unreasonable.

Aganist this background of controversy and the need for a re-examination of the entire air pollution control measures, an air pollution regulatory model has been constructed in this study for the 23 districts(ku) of Tokyo. Based on radical countermeasures like population-rearrangement, industrial restructuring etc it is aimed at helping to estimate variations in air pollution. This, it is hoped, would help appraise constantly the regulation effectiveness of air pollution standards over the time.

Key Words: Air Pollution, Nitrogen oxides (NO_x), Ligth Duty Truck, Heavy Duty Truck, Metropolitan Tokyo, Population-Rearrangement, Industrial Restructuring, Regulation Effectiveness, Environmental Indexe, Density of Emission, Degree of Damage.

1. Introduction

The phenonmenon of urban concentration, like its politics, its economy as well as the culture of a contemporary society, is based on industrialization. The current advances in the technological field seems to accelerate the pace of increasing hypertrophy of urban regions with the results that Metropolitan Areas are presently characterized by rapid and excessive concentration of people and industry.

in the past, the concentration of Metropolitan Areas promoted simultaneously mass production-consumer and information-oriented society. The accompanying effect was an increase in the volume of freight generation by means of the diffusion, the behaviour and the diversification of the various human activitious. The transition in freight volume to a much greater extent, depicted a close connection between urban structure and urban function. Stated differently, the increase in intraurban freight volume was the function of areal converage and long-distance haul of freight volume. Subsequently therefore, these two factors have assumed primary responsibility for the increase in vehicular movements in Metropolitan Areas ever-since.

The relationship existing between land-use and environmental pollution has been an area of intense research activity with most of the researchers corroborating on the correlation between these two variables. For example (Nishioka 1985) concluded that a strong correlation exists between expansion in urban land use and the increase in the level of NO_2 concentration. To put it more succintly, an increase in the appropriation of urban land uses, result in an increase in vehicular attractions into the area. Since land uses generate their own traffic under this circumstances, there is the tendency for the levels of NO_2 concentration to increase thereby enhancing the possibility of atmospheric air pollution. Thus the air pollution problem can be tackled by making readjustments in land uses and population concentration levels within the urban environment.

In this paper therefore, an attempt has been made to grasp the status quo of air pollution generated by vehicles in the Tokyo Metropolitan Area. radical countermeasures like variations in the land use and freight volume patterns have been employed in developing an air pollution estimation model for the city region. As a case study, the model is used to analyse the regulation effectiveness of air pollution for nitrogen oxides (NO_x) within the study area.

2. The Research Target

(1) *The Target-Air Pollution*

The cause of air pollution is attributed to a variety of gases. Under this

Table 1. Classification of Vehicles according to Loading Capacity

Vehicular Classification	Loading Capacity
Light Freight Carriers *(40–49)	Light Duty Truck
Small Freight Carriers *(4, 40–49) *(6, 60–69)	
Freight-Customer Carriers (Light Van, Van etc) *(4, 40–49)	
Ordinary Freight Trucks *(1, 10–19)	Heavy Duty Truck
Special Trucks *(8, 80–89)	

*; Vehicular Classification Number for Different Size and Loading Capacity followed in Japan

study however, the target 'gas' is NO_2 (nitrogen dioxide). This is because NO_2 constitutes 69% of all exhaust gases discharged by vehicles in the Tokyo Metropolitan Area and exceeds the standard set up in the existing Environmental Control Act.

(2) *The Target-Traffic*

The vehicular type considered under this Traffic Survey is the motor truck (light duty truck, heavy duty truck) because exhaust fumes emitted by motor trucks amounted to 66% of all vehicular emitted gases in 1980 in the 23 ku (distructs) of Tokyo. The estimated value of motor truck emitted gases for the same area for 1985 was 74%. Thus a countermeasure against exhaust fumes emitted by motor trucks is strongly desired at the present time.

(3) *The Target-Area*

The target area under study was characterised as A, B, C, depending on its measured distance from the CBD of Tokyo as shown in Figure 1. Region A took up approximately 23-ku (district) of the Tokyo metropolis covering a circumferential area of about 20 km from the CBD of Tokyo. Region B covered the circumferential area lying between a distance of 20 km and 50 km from the center of the

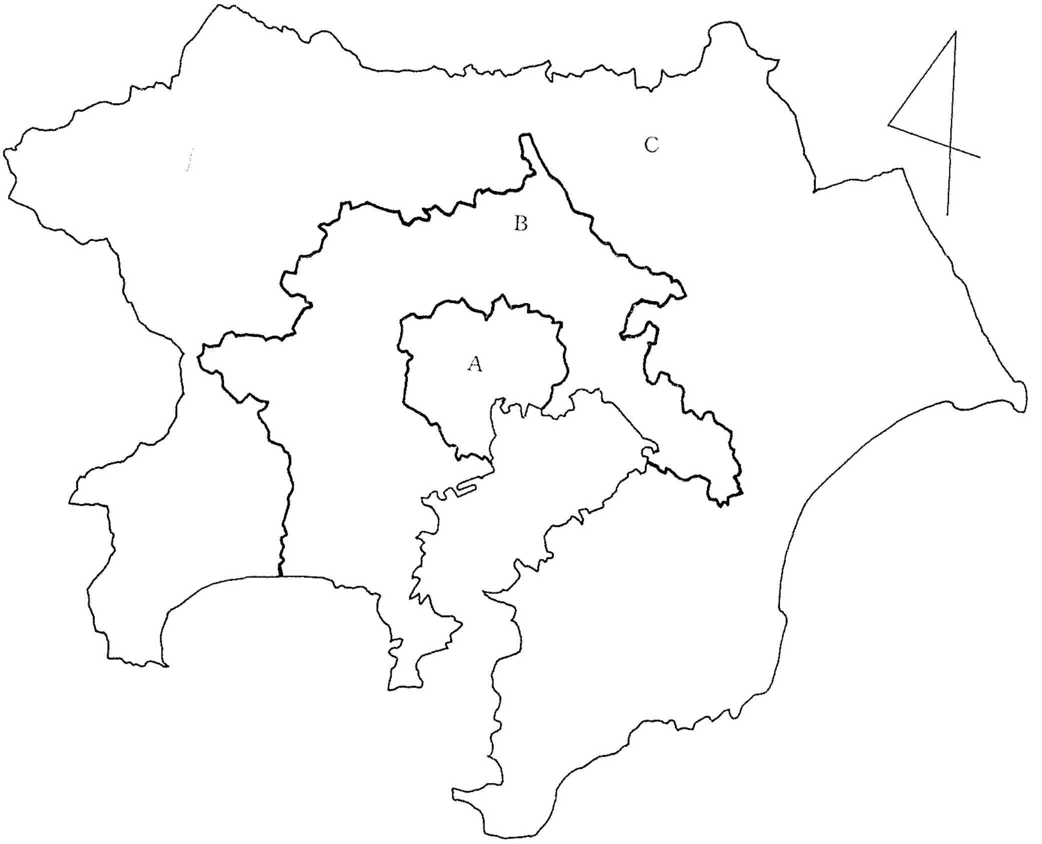

Figure 1. A Map of the Study Area showing the 3 designated Regions.

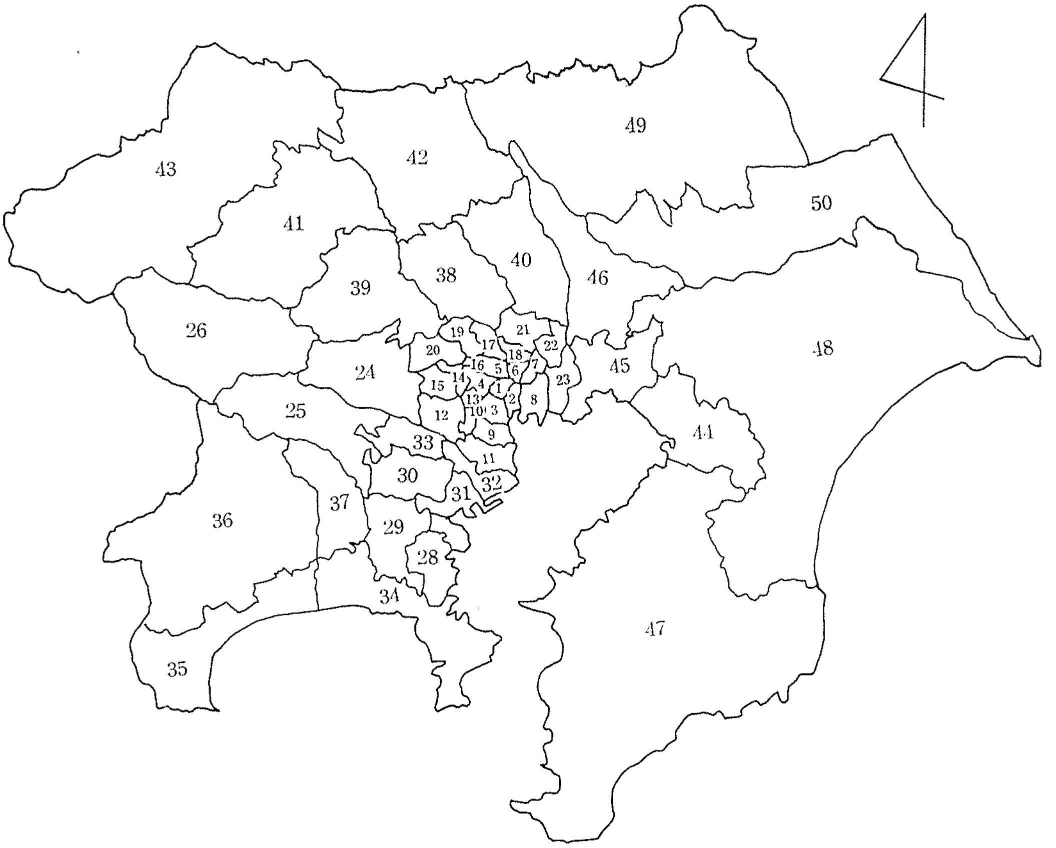

Figure 2. A Map of the Study Area showing the 50 zonal Divisions

city. Region C which was the exterior region took up a circumferential area lying between a distance of 50 km and 80 km from the CBD.

For convenience sake, the study area was demarcated so that it represented a total of 50 zones with each zone representing one ku or district. Region A took up 23 zones, region B 17 zones and region C, 10 zones depending on the degree of measured pollution in these areas.

3. The Method of Study

A model for estimating air pollution levels using traffic demand forecast was constructed. The forecasting of the traffic demand was based on the Origin and Destination Table of the Traffic Situation Survey Conducted on Japanese Road in 1980. The flowchart illustrating the estimation procedures is shown in Figure 3.

Next, a set of policy variable and policy allternatives were set up in order to effect changes in the present land use pattern.

(1) *The Policy Variables were*

1) Resident Population ie people who stay in the area

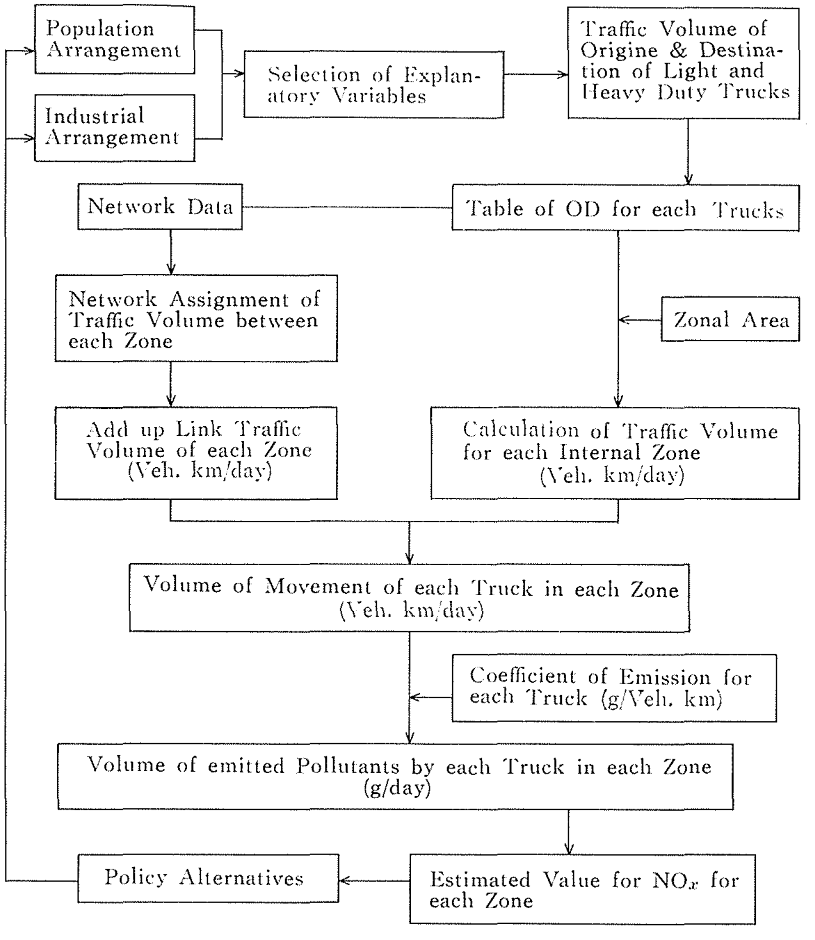

Figure 3. Flow Chart for the Estimation of Air Pollution.

2) Industrial Population ie people who are employed in the area. This includes non-residents, who commute daily to work in the area

3) Resident Population+Industrial Population (1+2) as above

(2) *The policy-alternatives*

In order to ensure a deconcentration of population and land use activity as a means to reducing air pollution levels in region A the following policy alternatives were simulated.

1) An objective of reducing the aggregate of the previously stated policy variables (ie. resident population, industrial population and resident+industrial population) by 10% through a policy of dispersing them into the outlying B and C regions equally and alternatively. That is initially the 10% of region A population is distributed equally among regions B and C. Next, the 10% population is dispersed or concentrated in region B alone and secondly, region C and its consequences on traffic attraction and therefore air pollution levels recorded.

Table 2. Explanation of Policy Measures

	Resident Population+Industrial Population					
	Industrial Population					
Variable	Resident Population					
Classification	1	2	3	4	5	6
Region A	Redistribution of 10% of Region A's Population (take equally from each Zone in Region A)	Redistribution of 10% of Region A's Population (take equally from each Zone in Region A)	Redistribution of 10% of Region A's Population (take equally from each Zone in Region A)	Redistribution of 50% of Region A's Population (take equally from each Zone in Region A)	Redistribution of 50% of Region A's Population (take equally from each Zone in Region A)	Redistribution of 50% of Region A's Population (take equally from each Zone in Region A)
Region B	Assigning 5% of the Population from Region A equally among Zones	Assigning 10% of the Population from Region A equally among Zones	Unchanged	Assigning 25% of the Population from Region A equally among Zones	Assigning 50% of the Population from Region A equally among Zones	Unchanged
Region C	Assigning 5% of the Population from Region A equally among Zones	Unchanged	Assigning 10% of the Population from Region A equally among Zones	Assigning 25% of the Population from Region A equally among Zones	Unchanged	Assigning 50% of the Population from Region A equally among Zones

2) Another objective of reducing the aggregate population in region A by 50% using the same method of population dispersal into region B and C as was done in 1) above.

This deconcentration arrangement resulted in 18 cases ($3\times2\times3$) of policy alternatives as shown in Table 1. An estimation model of air pollution was derived from a 3 step method of traffic demand forecast. From this model, the traffic and emission volumes, the degree of damage etc were also derived. The objective of this analysis was to effect a change in the land use pattern and therefore the present levels of air pollution in the 3 regions and analysis the regulation effectiveness of the model.

(3) *Environmental Index*

A framework of environmental indexes was constructed as a medium of appraisal of the levels of the environmental standards in the metropolis as Table 3.

The emphasis here was laid on the fact that traffic, distributed by roads, originates and concentrates on the various social-economic human activities. The mechanism for appraising the impact of traffic generated air pollution on people consists of 2 models.

(a) appraisal model which estimates traffic volume according to the aforementioned policy alternatives and

(b) also an environmental model that evalu ates the environmentalquality.

1) Relationship between traffic volume and volume of emitted pollutants.

Table 3. Judgement indexes for Preventive Policy of Transport Exhaust Pollition in Metropolitan Area

Social Activity (principal)		Social Activity		Environmental Load		Environmental status		Social Impact
Industrial Activity, Industrial Rearrangement Population Rearrangement	Traffic Assignment	Transportation	Intensity of Emission	Volume of Emission	Diffusion	Density of Emission	Population Rearrangement	Impact to Health
Value of Industrial Output Index Indicating the degree of Population and Industrial rearrangement (Policy of this Study), Road Network Density Population Density		(1) Ratio of Distances covered by Trucks in the 3 Regions, Ratio of Heavy Trucks/all other Vehicles in the 3 Regions, Average Distance covered per Truck in the 3 Regions Industrial Energe Consumption in the 3 Regions, Density of Traffic in the 3 Regions (2) Degree of Congestion in the 3 region	Calculation of Emission Factor	(3) Volume of total emission (4) Volume of Emission of Internal traffic (5) Volume of Emission from Light Duty Trucks (6) Volume of Emission from Heavy Duty Trucks	Model of diffusion	(7) Volume of Emission per Area (8) Volume of Emission per km Ratio of Emission Densities between Regions A, B and C		(9) Emission Density × Population (Degree of Damage to Population in Regions A, B and C) (10) Emission Density × Industrial Population (Degree of Damage to Industrial Population Difference in Damages to Population in Regions A, B and C)

The prediction of the variations in the environmental load was done by varying the regulation effectiveness of the undermentioned traffic-volume related variables in line with policy measures and effectiveness judgement as in table 3.

(a) Total Veh. × km ((Veh. × km) × 10^3)

(d) Degree of congestion

(c) Volume of total emission (ton/day)

(b) Volume of emission for traffic in region A (ton/day)

(e) Volume of emission for light duty truck (ton/day)

(f) Volume of emission for heavy duty truck (ton/day)

2) Social impact of the air pollution

Variations in emission volume of pollutants as already stated, bear some relationships with traffic vlume and levels of concentration of pollution which directly affect the health of people. To capture the effect of this relationship, a regulation effectness of air pollution was done by assessing the impact of the policy measures on these 4 indexes/variables.

(a) Density (kg/km^2)

(b) Volume of emission for 1 km of road length (kg/km)

(c) Degree of damage on resident population ((kg/km^2)×persons)

(d) Degree of damage on industrial population (kg/km^2)

In a sum therefore, the regulation effectiveness of air pollution was appraised by the investigating the reaction of the three (3) policy measures on the 10 indexes mentioned above.

4. The Target Region-Some Considerations

(1) *Characteristics of the Target Region*

As shown in table 4, the population of region A is about four (4) times that of region B. It is also more densely populated as compare to region C despite the latter's larger area of coverage. In terms of the size of industrial population among regions, the order is as follows, C has the largest followed by B and then A. The length of road network in region A which is the shortest and the most congested

Table 4. Some Characteristics of the Target Region

Regional Property \ Regional Classification	Region A	Region B	Region C	Judgement
Area (km^2)	592	3410	11545	A<B<C
Density of Population (person/km^2)	14107	4435	519	A>B>C
Population (person)	8351893	15123499	5997547	B>A>C
Total Industrial Population (person)	6234048	5069302	2741647	A>B>C
Resident Population+Industrial Population (person)	10292276	17040433	6924758	B>A>C
Road Length (km)	479.9	917	940.5	C>B>A
Trip Generation Voume of Light Duty Trucks	1548749	2120989	1424231	B>A>C
Trip Generation Volume of Large Duty Trucks	338655	463893	238168	B>A>C

Table 5. The Nature of Air Pollution in Target Region

Regional Classification \ Environmental Index	Degree of Damage (kg/km^2) person	Density of Emission (kg/km^2)	Degree of Congestion	Volume of Total Emission (kg)	Total Veh. km (1000 Veh. km)
Region A	980256	117	11.1	69	20228
Region B	950151	38	0.85	129	40185
Region C	66273	11	0.52	128	42421
Judgement	A>B>C	A>B>C	A>B>C	B>C>A	C>B>A

Table 6. The Impact of Variation of the Land Use Pattern on Fright Volume in Region A

A Curtailment Appraisal Index of Air Pollution in Region A		Total Veh. km ((Veh.×km)×10³)			Degree of Congestion		
The Value of Status Quo of Air Pollution in Region A		20.228			1.11		
The curtail-ment-measures	The Rate of Movement / Movement-Policy of Resident and Industrial Population	To have A divided equally among to Regions B and C	To have A concentrated only in Region B	To have A concentrated only in Region C	To have A divided equally among to Regions B and C	To have A concentrated only in Region B	To have A concentrated only in Region C
I The Curtailment-Effectiveness at the Time of Movement of Population in Region A	10%	19,517 (−3.5%)	19,641 (−2.9%)	19,401 (−4.1%)	1.07 (−3.6%)	1.08 (−2.7%)	1.07 (−3.6%)
	50%	16,739 (−17.2%)	17,093 (−15.5%)	16,105 (−20.0%)	0.92 (−17.1%)	0.95 (−14.4%)	0.89 (−19.8%)
II The Curtailment-Effectiveness at the Time of Movement of Industrial Population in Region A	10%	19,388 (−4.2%)	19,562 (−3.3%)	19,194 (−5.1%)	1.07 (−3.6%)	1.08 (−2.7%)	1.06 (−4.5%)
	50%	16,018 (−20.8%)	16,512 (−18.4%)	15,313 (−24.5%)	0.89 (−19.8%)	0.92 (−17.1%)	0.86 (−22.5%)
III The Curtailment-Effectiveness at the Time of Movement of Resident+Industrial Population in Region A	10%	18,674 (−7.7%)	18,912 (−6.5%)	18,394 (−9.1%)	1.03 (−7.2%)	1.04 (−6.3%)	1.01 (−9.0%)
	50%	12,628 (−37.6%)	13,344 (−34.0%)	11,573 (−42.8%)	0.71 (−36.0%)	0.76 (−31.5%)	0.66 (−40.5%)

among the 3 regions is 479.9 km. In terms of the traffic generated by both light and heavy duty trucks, region B ranks as the highest followed by regions A and C in that order. From the above analysis, the problems associated with region A's environment has been clarified. This in turn calls for appropriate measures to help improve the general situation of he area.

(2) *Air pollution in target region*

Table 4 gives an account of the various indexes associated with the measurement of air pollution in the 3 regions of the 5 indexes under discussion, the rank of region is the highest for the degree of damage to people, density/concentration of emissions and the degree of congestion. Region B with the highest concentration of industrial activities and therefore with the greatest attraction for light and heavy duty trucks have the largest volume of total emissions. But considering the peculiar characteristics of region A ie small size in comparison to region B the pollution problem is greater in region A than in region B ie level of concentration. The same argument can be applied to the relationship between the volume of emissions in region A and C. That the pollution problem is much severer in

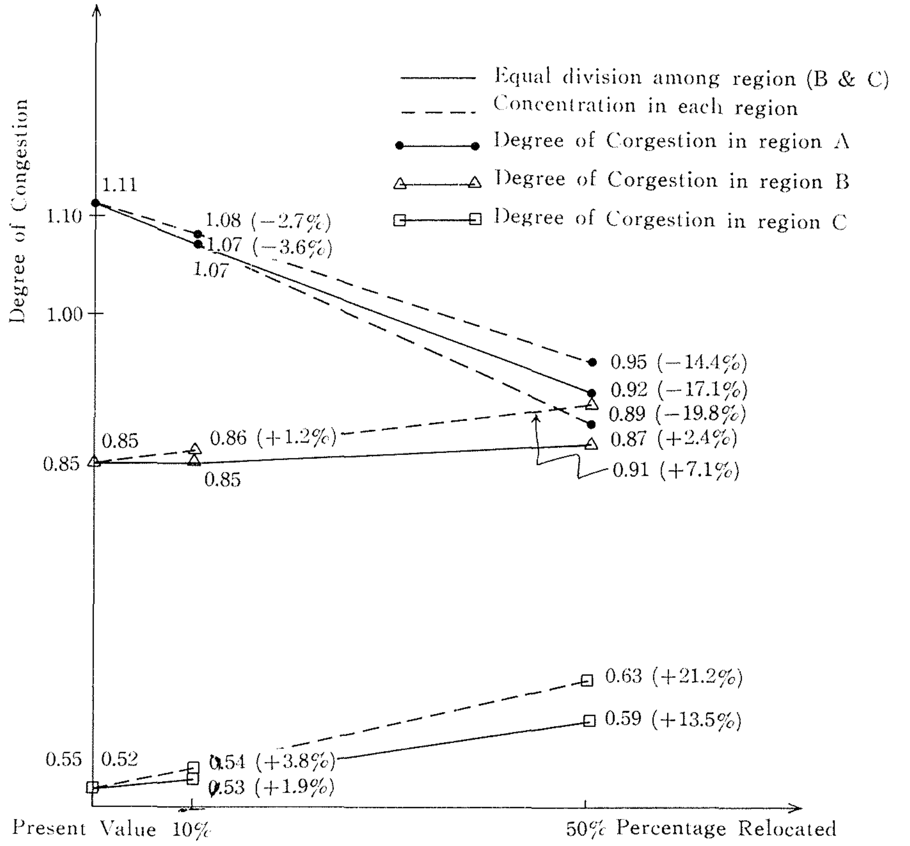

Figure 4. The Degree of Congestion in each region after the Relocation of Resident Population from Region A.

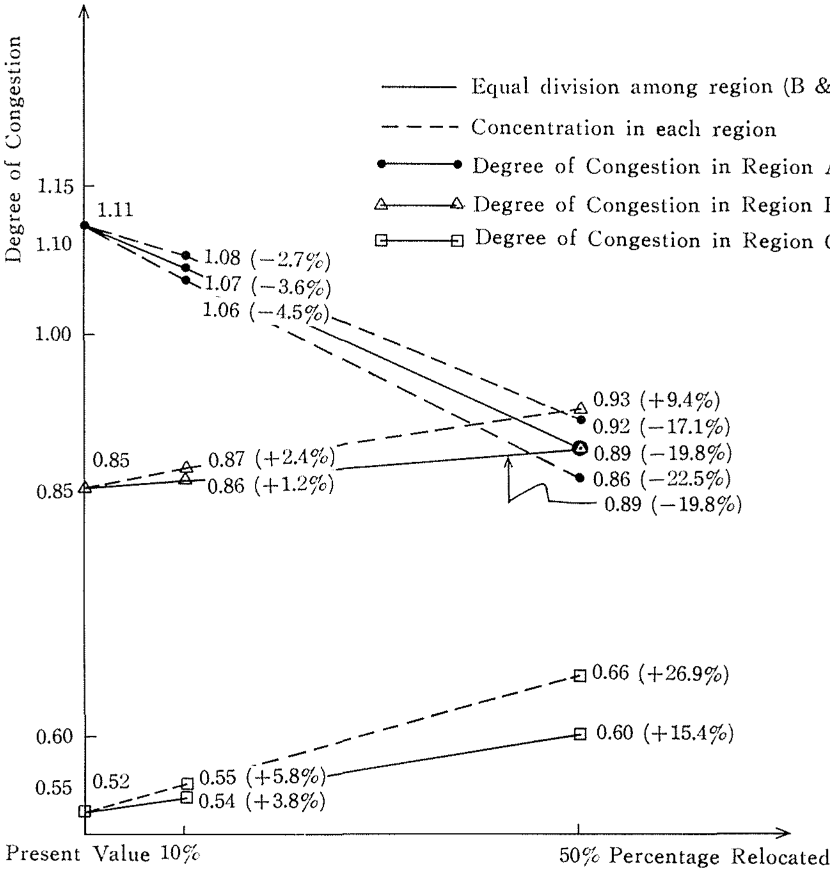

Figure 5. The Degree of Congestion in each region after the Relocation of Industrial population from Region A.

region A than in region C. The last index, traffic volume portray a similar pattern. Even though absolute figures indicate that C has the highest traffic volume followed B and then A. But in practice, because of smaller area, the impact of traffic volume ie degree of congestion is much felt in region A than in the other regions.

(3) *The analysis of the regulation-effectiveness of air pollution in 23 ku of Tokyo*

This analysis which is done in stages is as follows; First, the regulation-effectiveness of air pollution in region A is assessed by population and industrial arrangement variations from region A into regions B and C.

Second, based on the 10 environmental indexes previously defined, the effectiveness of policy measures on transforming air pollution from region A into region B and C are appraised using a movement-variation from region A method.

Third, the most desirable choice of policy among the policy measures for regulating air pollution is made.

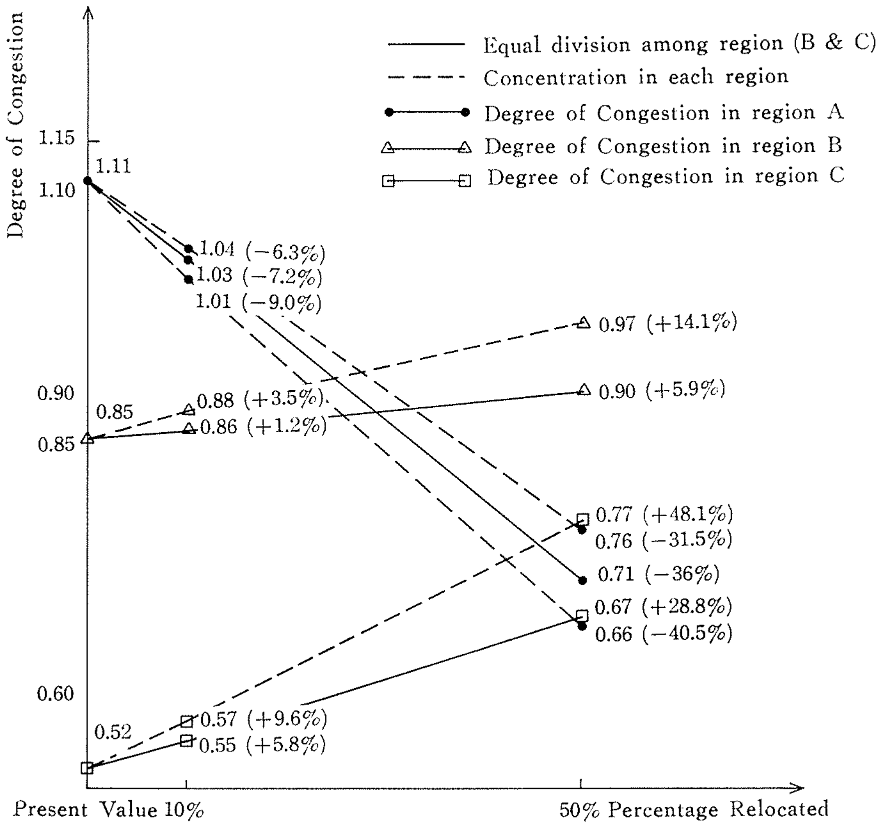

Figure 6. The Degree of Congestion in each region after the Relocation of Resident and Industrial Population from Region A.

In order to ensure a workable framework for all the 3 regions the relevance of the model will not be limited to region A alone but also region B and C. As a result an analysis of variationsin air pollution in region B and C will be considered. It is expected that the model would be able to forecast future sair pollution levels with changes in the pattern of land use.

1) Total Veh. km

The impact or the regulation-effectiveness of the movement of 10% of the resident population from region A shows a variation of between 2.9% to 4.1%. In terms of the movement of 10% of the industrial population out of the region, the regulation-effectiveness varies from 3.3% to 3.5% by moving 10% of the population (that is resident+industrial) the regulation effectiveness shows a variation of between 6.5% to 9.1%. The simulation also showed that the regulation-effectiveness was higher when 10% of the resident+industrial population from region A were relocated in region C as compared to relocating this population equally among regions B and C or only in region B. It is however worst in the last relocation policy ie in region B only. In comparison of the regulation-effectiveness of either moving 10% or 50% of the resident population out of region A, it was found that they

Table 7. The Impact of Variations in Environmental Load in Region A by Variations in the Land Use Pattern

A Curtailment Appraisal Index of Air Pollution in Region A		Volume of Total Emission (ton/day)			Volume of Emission of Internal traffic (ton/day)		
The Value of Status Quo of Air Pollution in Region A		69			6.5		
The curtail-ment-measures \ The Rate of Movement \ Movement-Policy of Resident and Industrial Population		To have A divided equally among to Regions B and C	To have A concentrated only in Region B	To have A concentrated only in Region C	To have A divided equally among to Regions B and C	To have A concentrated only in Region B	To have A concentrated only in Region C
I The Curtailment-Effectiveness at the Time of Movement of Population in Region A	0%	67 (−2.9%)	68 (−1.4%)	67 (−2.9%)	6.1 (−6.2%)	6.1 (−6.2%)	6.0 (−7.7%)
	50%	58 (−15.9%)	60 (−13.0%)	60 (−18.8%)	4.5 (−30.8%)	4.5 (−30.8%)	4.3 (−33.8%)
II The Curtailment-Effectiveness at the Time of Movement of Industrial Population in Region A	10%	67 (−2.9%)	67 (−2.9%)	66 (−4.3%)	6.1 (−6.2%)	6.1 (−6.2%)	6.0 (−7.7%)
	50%	55 (−20.3%)	57 (−17.4%)	53 (−23.2%)	4.5 (−30.8%)	4.5 (−30.8%)	4.3 (−33.8%)
III The Curtailment-Effect tiveness at the Time of Movement of Resident+Industrial Population in Region A	10%	64 (−7.2%)	65 (−5.8%)	64 (−7.2%)	5.7 (−12.3%)	5.7 (−12.3%)	5.6 (−13.8%)
	50%	44 (−36.0%)	47 (−31.9%)	41 (−40.6%)	2.6 (−60.0%)	2.6 (−60.0%)	2.5 (−61.5%)

Table 8. Impact of Variations in Environmental Load in Region A by Variations in the Land Use Pattern

A Curtailment Appraisal Index of Air Pollution in Region A		Volume of Emission for Light Duty Truck (ton/day)			Volume of Emission for Heavy Duty Truck (ton/day)		
The Value of Status Quo of Air Pollution in Region A		35.5			27.5		
The curtail-ment-measures (Movement-Policy of Resident and Industrial Population)	The Rate of Movement	To have A divided equally among to Regions B and C	To have A concentrated only in Region B	To have A concentrated only in Region C	To have A divided equally among to Regions B and C	To have A concentrated only in Region B	To have A concentrated only in Region C
I The Curtailment-Effectiveness at the Time of Movement of Population in Region A	10%	34.3 (−3.4%)	34.5 (−2.8%)	34.0 (−4.2%)	27.0 (−1.8%)	27.1 (−1.5%)	26.8 (−2.5%)
	50%	29.3 (−17.5%)	30.2 (−14.9%)	28.0 (−21.1%)	24.7 (−10.2%)	24.9 (−9.5%)	24.1 (−12.4%)
II The Curtailment-Effectiveness at the Time of Movement of Industrial Population in Region A	10%	34.0 (−4.2%)	34.4 (−3.1%)	33.6 (−5.9%)	26.6 (−3.3%)	26.8 (−2.5%)	26.3 (−4.4%)
	50%	28.0 (−21.1%)	29.0 (−18.3%)	26.6 (−25.1%)	22.9 (−16.7%)	23.5 (−14.5%)	22.0 (−20.0%)
III The Curtailment-Effectiveness at the Time of Movement of Resident+Industrial Population in Region A	10%	32.8 (−7.6%)	33.3 (−6.2%)	32.2 (−9.3%)	26.0 (−5.5%)	26.3 (−4.4%)	25.7 (−6.5%)
	50%	21.9 (−38.3%)	23.4 (−34.1%)	19.8 (−44.2%)	20.0 (−27.3%)	20.9 (−24.0%)	18.7 (−32.0%)

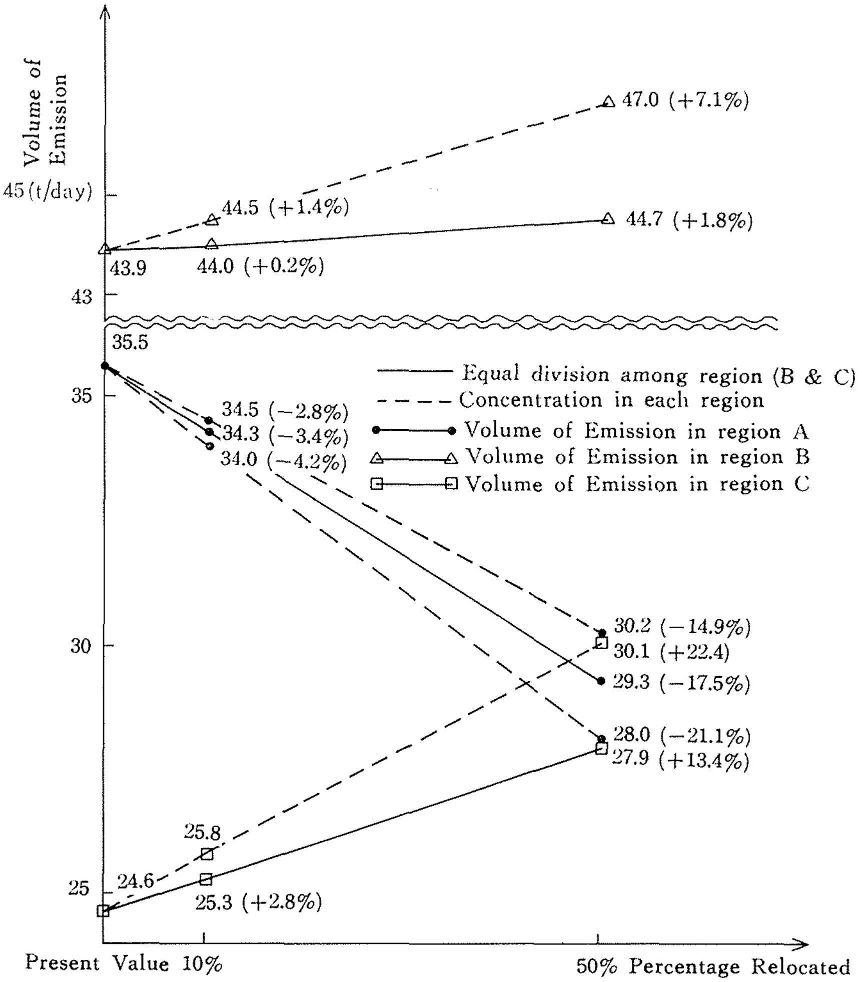

Figure 7. The Volume of Emission by Light Duty Trucks in each region after the relocation of Resident Population from Region A.

both tend to give similar results. This is shown in Table 6 below.

2) The Degree of Congestion

The analysis revealed a regulation effectiveness of 27% on congestion in region A as a result of relocating 10% of the region's resident population in region B. However the regulation effectiveness was 3.6% when it was divided equally among region B and C. Moving 10% of the industrial population in region A to region B alone result in a regulation effectiveness of 2.7% in the region's degree of congestion. However when the same population is distributed equally among regions B and C or is moved solely to region C, the regulation effectiveness on congestion is 3.6% and 4.5% respectively. This indicates that the movement of both the resident and the industrial population from region A to either region B or C or to both results in varying impacts on the regulation effectiveness of congestion in region A.

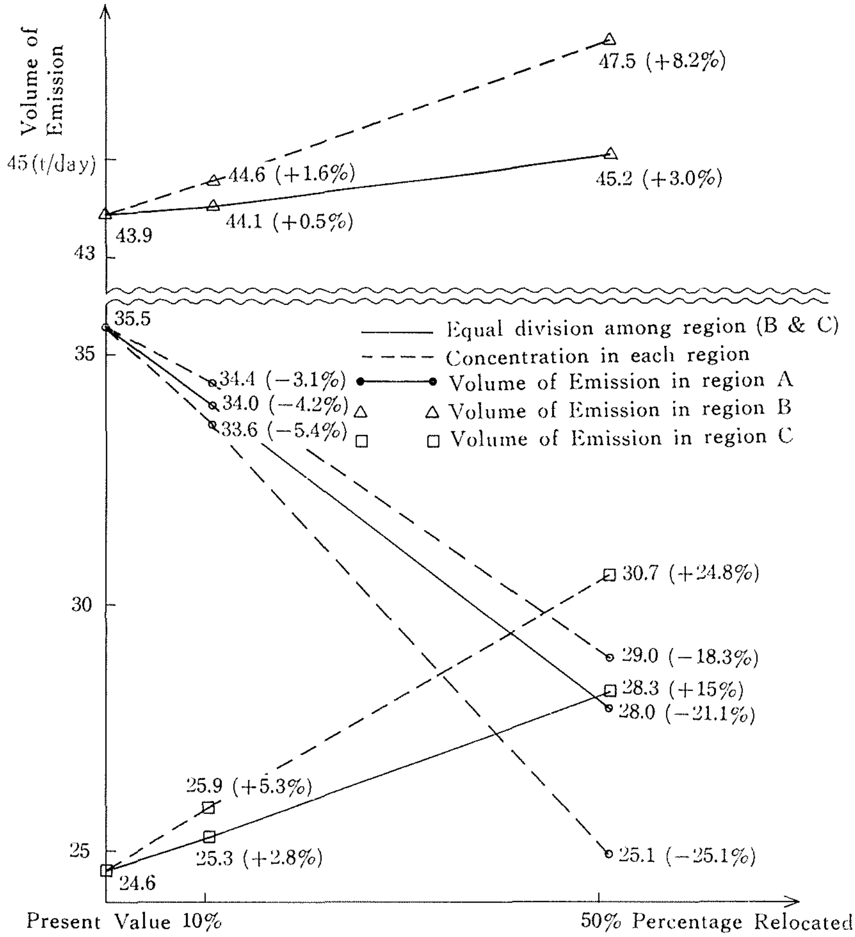

Figure 8. The Volume of Emission by Light Duty Trucks in each region after the Relocation of Resident Population from Region A.

As shown in table 6 above, a 50% movement of region A's population on the 3 policy variables ie resident population, industrial population and both result in a high level of concentration in region B, followed by an equal division among regions B and C and lastly region C.

Table 7 shows the impact of variations in environmental load on variations in land use pattern among regions A, B, C due to population movements from region A.

3) Volume of Total Emission (ton/day)

The impact (regulation effectiveness) of a movement of 10% of region A's resident population on the volume of total emission in region A is neglegible for all the 3 policy variables.

On the other hand however, a 50% movement of region A's resident population to region B alone results in a regulation effectiveness of 13.0% in the volume

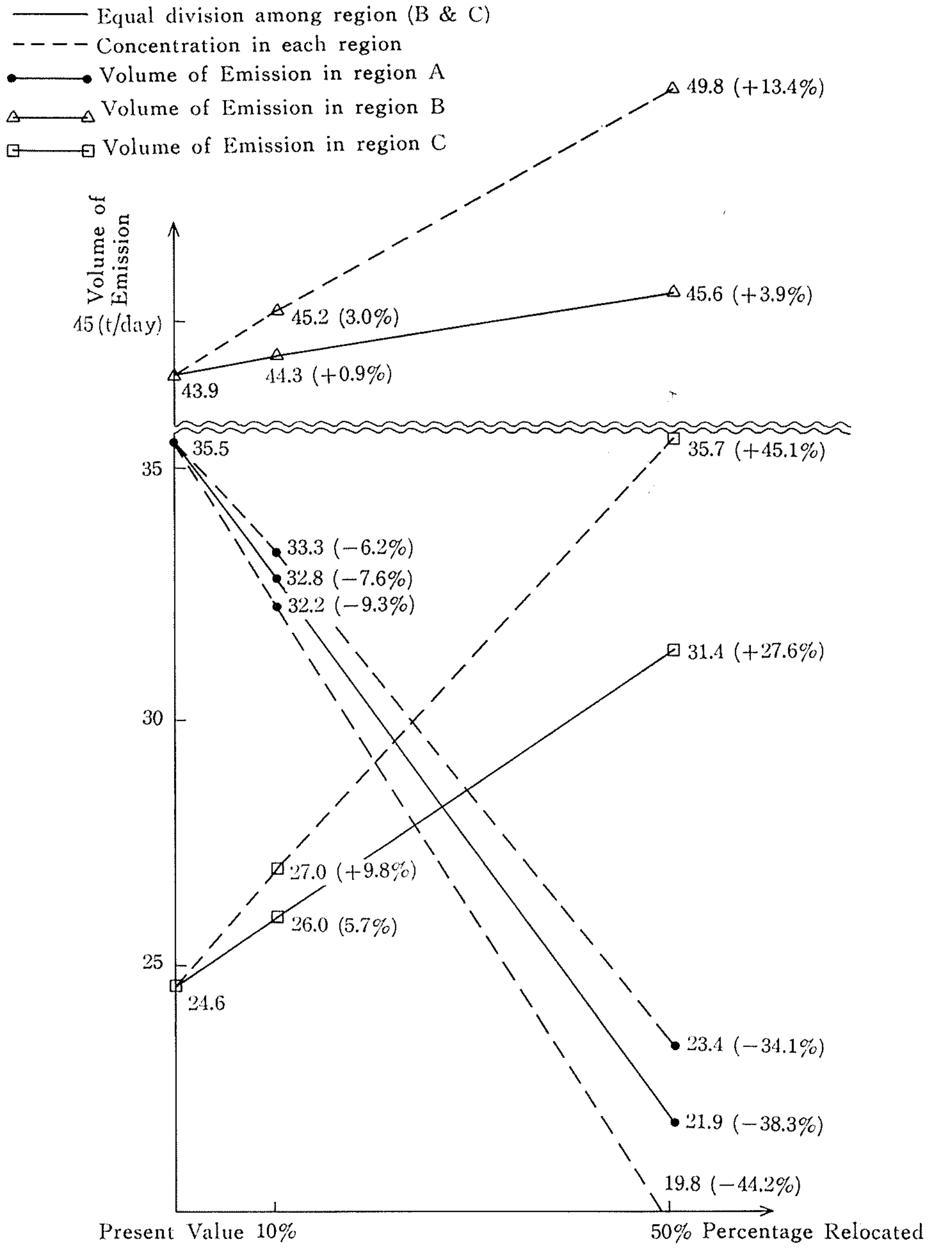

Figure 9. The Volume Emission by Heavy Duty Trucks in each region after the relocation of resident Population from region A.

Table 9. Curtailment Effectiess of Variations in Environmental Conditionin Region A through Variations in the Land Use Pattern

A Curtailment Appraisal Index of Air Pollution in Region A		Density of Emission (kg/km²)			Density of Emission per 1 km of Road Length (kg/km²)		
The Value of Status Quo of Air Pollution in Region A		117			111.1		
The curtail-ment-measures (Movement-Policy of Resident and Industrial Population)	The Rate of Movement	To have A divided equally among to Regions B and C	To have A concentrated only in Region B	To have A concentrated only in Region C	To have A divided equally among to Regions B and C	To have A concentrated only in Region B	To have A concentrated only in Region C
I The Curtailment-Effectiveness at the Time of Movement of Population in Region A	10%	114 (−2.6%)	114 (−2.6%)	113 (−3.4%)	107.5 (−3.2%)	108.2 (−2.6%)	106.9 (−3.8%)
	50%	99 (−15.4%)	101 (−13.7%)	95 (−18.8%)	93.4 (−15.9%)	95.3 (−14.2%)	90.2 (−18.8%)
II The Curtailment-Effectiveness at the Time of Movement of Industrial Population in Region A	10%	113 (−3.4%)	114 (−2.6%)	112 (−4.3%)	106.6 (−4.1%)	107.5 (−3.2%)	105.5 (−50.%)
	50%	93 (−20.5%)	96 (−17.9%)	89 (−23.9%)	88.5 (−20.3%)	91.2 (−17.9%)	84.6 (−23.9%)
III The Curtailment-Effectiveness at the Time of Movement of Resident+Industrial Population in Region A	10%	109 (−6.8%)	110 (−6.0%)	107 (−8.5%)	103.1 (−7.2%)	104.3 (−6.1%)	101.5 (−8.6%)
	50%	75 (−35.9%)	79 (−32.5%)	69 (−41.0%)	71.2 (−35.9%)	75.1 (−32.4%)	65.5 (−41.0%)

total emissions in the region. It is however 18.8% when the movement is concentrated in region C alone and 15.9% when divided equally between region B and C.

A movement of 10% of the industrial population in region A results in a higher regulation effectiveness on the volume of total emissions as compared to a movement of 10% of the resident population in same region. However the regulation effectiveness of having all the population concentrated in either region B alone or in region C or having it divided equally between regions B and C gives the same results of 2.9%. The regulation effectiveness of the movement of 10% of an aggregation of the resident and industrial populations to region C alone or having it divided equally between regions B and C is equal and the highest among the other alternatives.

4) Volume of Emission of Internal traffic (ton/day)

The regulation effectiveness of the movement of 10% of region A's resident population on the volume of total emissions emanating from region A is higher when the relocated population is concentrated solely in region C. When the moved population is concentrated either in region B or it is divided equally between regions

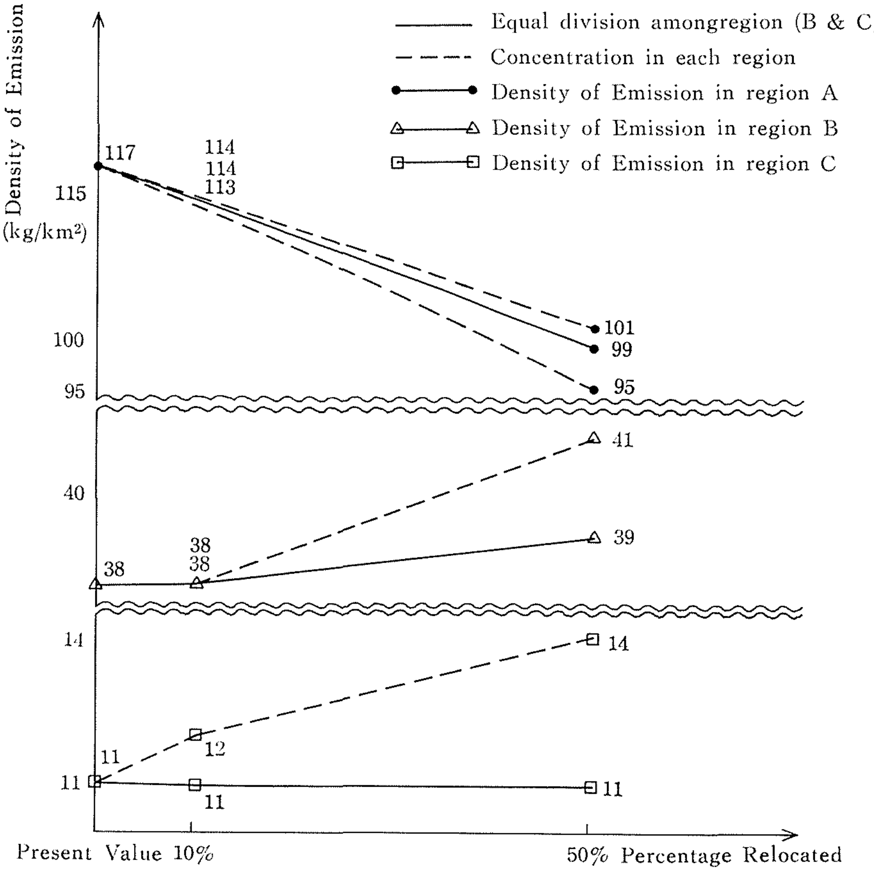

Figure 10. The Density of Emission in each region after the Relocation of Resident Population from Region A.

B and C the result is the same but lower.

A 10% movement of either the residential population or the industrial population from A to the other regions result in an equal regulation effectiveness figure for the volume of total emissions from region A. However a 10% movement of both residential and industrial population from region A gives a 12.3% regulation effectiveness on the volume of total emission in region A.

5) Volume of Emission from Light Duty Trucks (ton/day)

Table 8 shows the regulation effectiveness of policy values 1), 2), 3) on the volume of emissions by light duty trucks in the various regions. The hightest

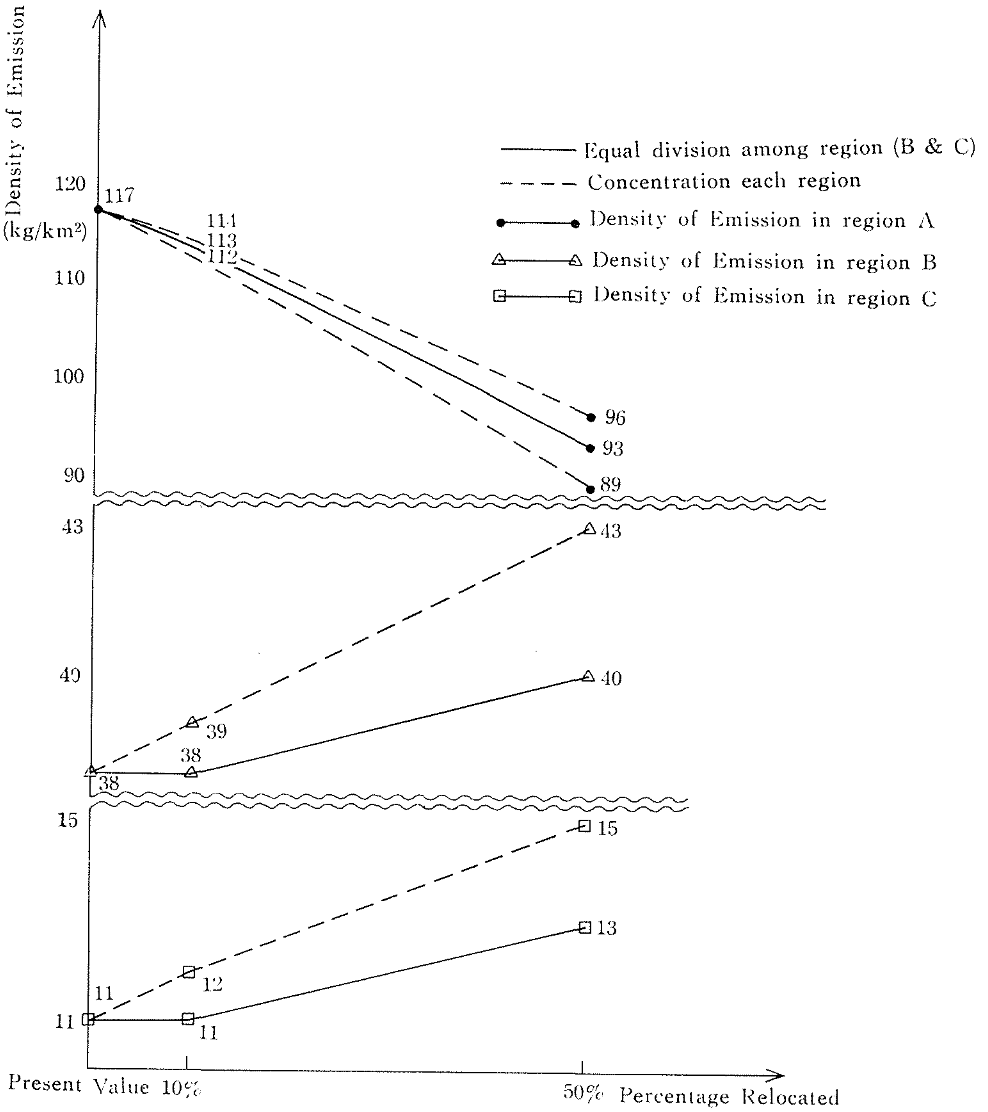

Figure 11. The Density of Emission in each region after the Relocation of Industrial Population from Region A.

level of concentration of emission was in region B, followed by regions B and C together and finally region C. A movement of 10% of the residential population from region A results in a regulation effectiveness of between 2.8% and 4.2% on the other hand when a 10% industrial population is moved out, the regulation effectiveness is between 3.1% and 5.4%.

6) Volume of Emission from Heavy Duty Trucks (ton/day)

The regulation effectiveness of emission volume by heavy duty trucks is lower than light duty trucks as a result of population movements from region A. The regulation effectiveness of a 10% movement of industrial population on the volume of emission of heavy duty trucks in region A is equal to the impact of a movement

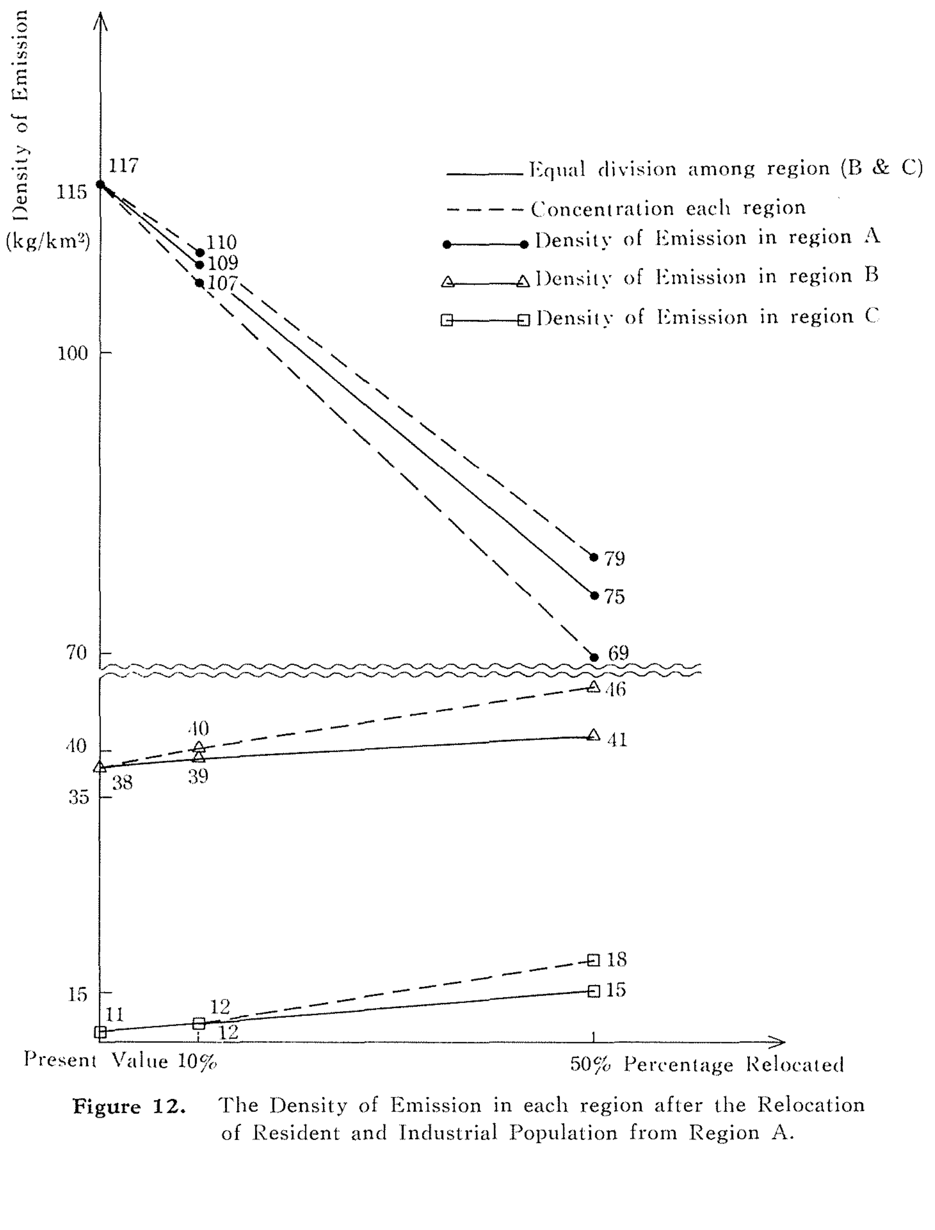

Figure 12. The Density of Emission in each region after the Relocation of Resident and Industrial Population from Region A.

Table 10. Rlationship between Variations in hte Social Impacts in Region A and Variations in the Land Use Pattern

A Curtailment Appraisal Index of Air Pollution in Region A		Degree of Damage of the Residential Population ((kg/km^2) person)			Degree of Damage of the Industrial Population ((kg/km^2) person)		
The Value of Status Quo of Air Pollution in Region A		980.256			731.686		
The curtail-ment-measures	Movement-Policy of Resident and Industrial Population / The Rate of Movement	To have A divided equally among to Regions B and C	To have A concentrated only in Reg-ion B	To have A concentrated only in Reg-ion C	To have A divided equally among to Regions B and C	To have A concentrated only in Reg-ion B	To have A concentrated only in Reg-ion C
I The Curtailment-Effec-tiveness at the Time of Movement of Population in Region A	10%	854,169 (−12.9%)	859,468 (−12.3%)	849,396 (−13.3%)	708,413 (−3.2%)	712,806 (−2.6%)	704,455 (−3.7%)
	50%	412,358 (−57.9%)	420,484 (−57.1%)	397,939 (−59.4%)	615,587 (−15.9%)	627,719 (−14.2%)	594,063 (−18.8%)
II The Curtailment-Effec-tiveness at the Time of Movement of Industrial Population in Region A	10%	940,704 (−4.0%)	949,122 (−3.2%)	931,316 (−5.0%)	680,308 (−7.0%)	686,397 (−6.2%)	673,518 (−7.9%)
	50%	780.859 (−20.3%)	805,017 (−17.9%)	746,930 (−23.8%)	492,143 (−32.7%)	507,369 (−35.7%)	470,759 (−35.7%)
III The Curtailment-Effec-tiveness at the Time of Movement of Resident+ Industrial Population in Region A	10%	811,629 (−16.5%)	828,768 (−15.5%)	806,529 (−17.7%)	657,805 (−10.1%)	665,952 (−9.0%)	648,083 (−11.4%)
	50%	314,276 (−67.9%)	331,577 (−66.2%)	288,949 (−70.5%)	396,150 (−42.9%)	417,960 (−42.9%)	364,225 (−50.2%)

of 10% residential population on the volume of emission by light duty trucks in the sauce region. The movement of 10% of the residential population from region A result in a regulation effectiveness ranging from 1.5% to 2.5% on the volume of emissions by heavy duty trucks while a 10% movement of industrial population from the same region result in a regulation effectiveness of between 2.5% and 4.4%.

7) Level of Concentration (Density) of Emissions (kg/km²)

A 10% movement of the residential population in region A results in an equal regulation effectiveness on the level of concentration of emissions in region A when the moved population was relocated either in region B solely or were divided equally between regions B and C. But by concentrating all the moved population in region

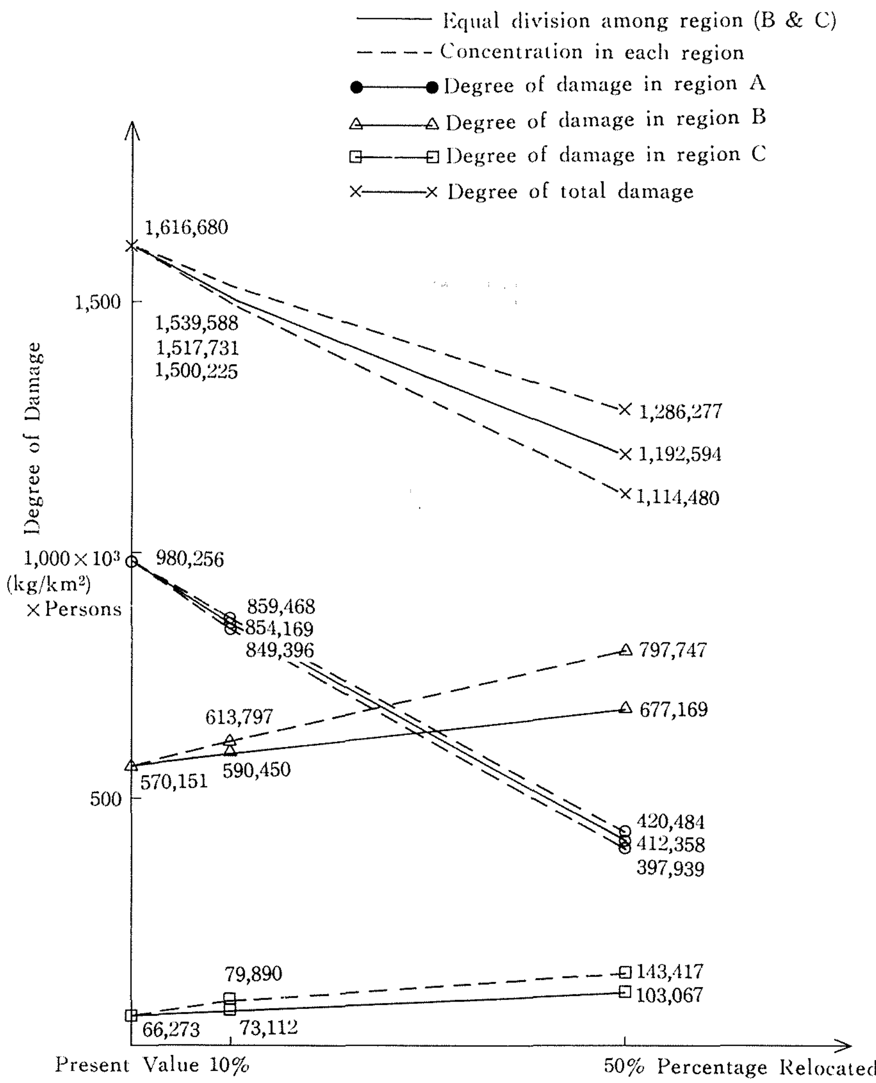

Figure 13. The Degree of Damage on the Resident Population in each region when resident population from Region A is relocated.

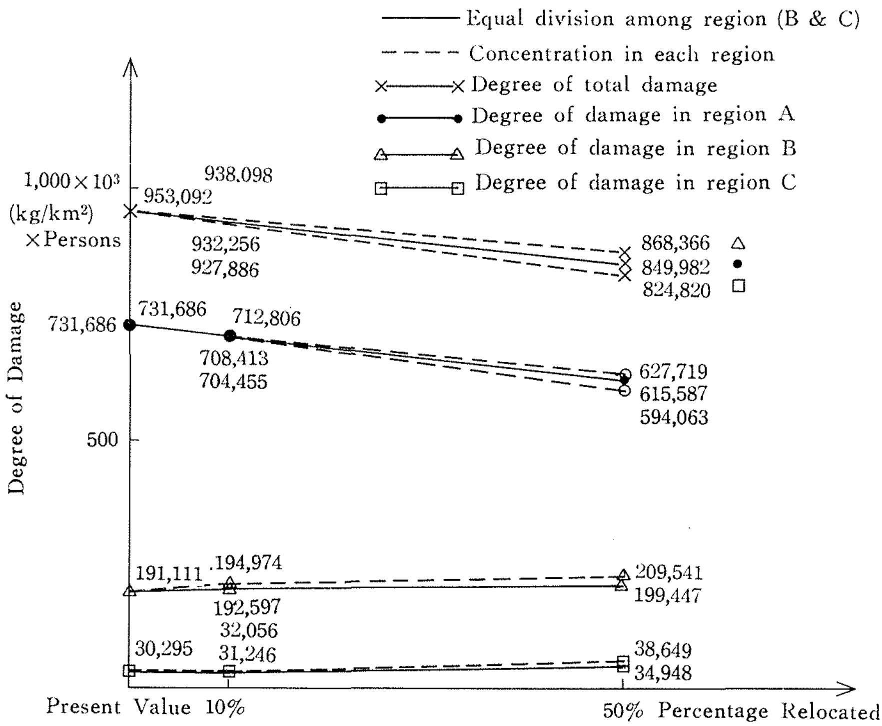

Figure 14. The Degree of Damage on the Industrial Population in each region when Resident Population from Region A is relocated.

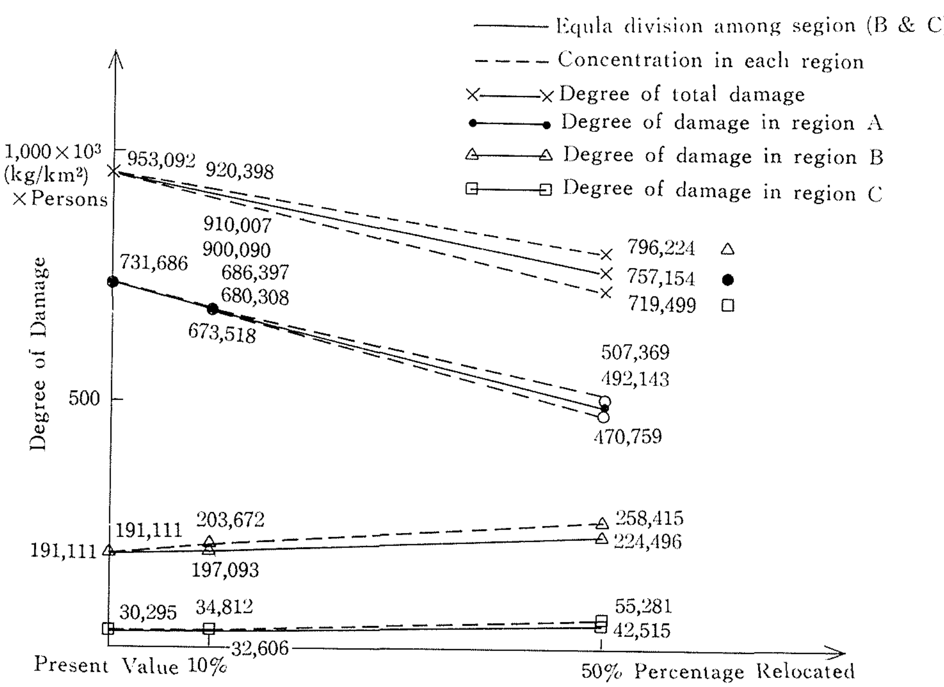

Figure 15. The Degree of Damage on the Industrial Population in each region when Industrial Population from region A is relocated.

C result in a regulation effectiveness of 3.4%.

However, a 50% movement of residential population from region A to either region C alone or shared equally between regions B and C result in a regulation effectiveness that is 5 times higher than a movement of 10% of the above population from the same region. However, concentrating this population in region B alone gives a lower value.

The regulation effectiveness of a movement of 10% of the residential population from region A gives an impact ranging from 2.6% to 3.4% while for industrial population it is between 2.6% and 4.3%. A higher regulation effectiveness ranging from 6.0% to 8,5% is obtained by a 10% movement of both residential and industrial population from region A.

8) Level of Concentration of Emission per 1 km of Road Length (kg/km)

The regulation effectiveness of concentration of emissions per 1 kilometer of road length is highest in this order, concentration of 10% of the residential

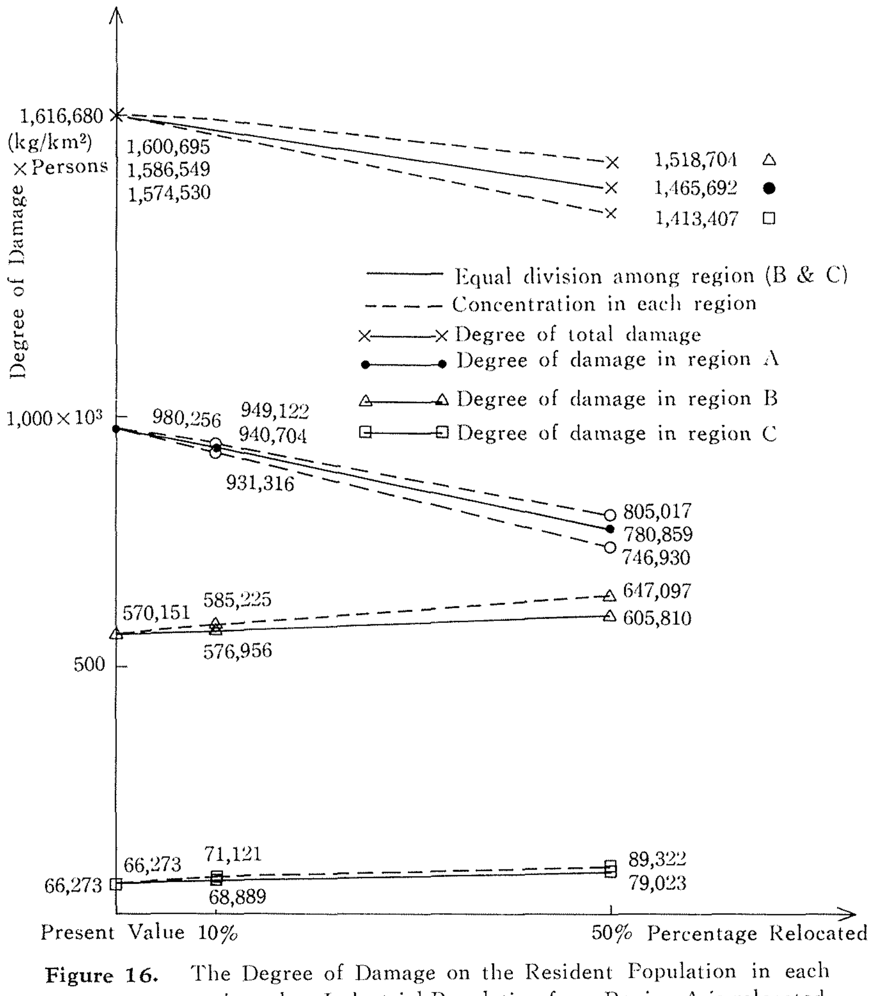

Figure 16. The Degree of Damage on the Resident Population in each region when Industrial Population from Region A is relocated.

population in region B alone, concentration of this residential population in equal proportions in regions B and C, concentration in region C alone. The degree of the regulation effectiveness of a 10% movement of residential population from region A ranges from 2.6% to 3.8% while a movement of the same percentage of industrial population from region A yields a regulation effectiveness of between 3.2% and 5.0%. A movement of 50% of the residential population on the other hand yields a regulation effectiveness of between 14.2% and 18.8% while the same figure for the movement of equal numbers of industrial population is between 17.9% and 23.9%. The previous analyses have centered on the impact of land use changes on the general levels of air pollution in the three regions. In the next analysis, an examination of the degree of air pollution damage on human health has being tackled by using 10 social impact indexes to appraise the regulation effectiveness of the model on human health.

9) Degree of Damage of the Residential Population ((kg/km²) × person)

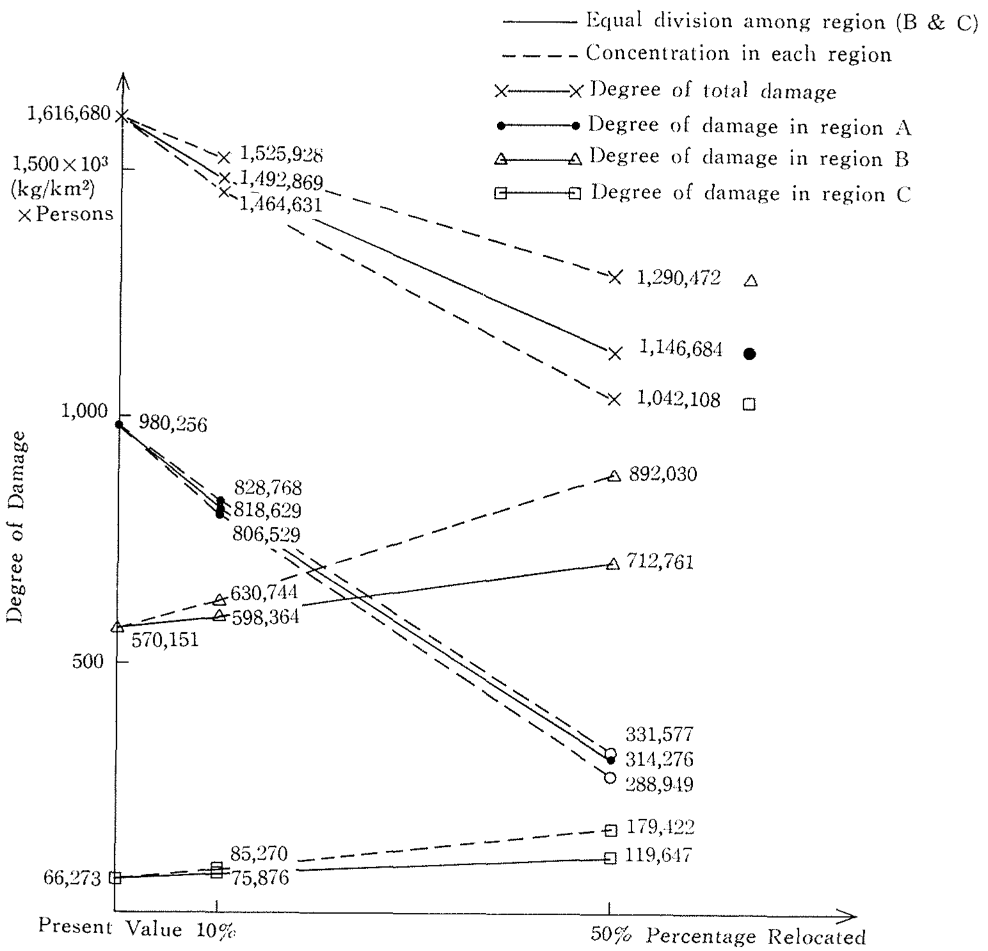

Figure 17. The Degree on the Resident Population in each region when Resident and Industrial Population from RegionA are relocated.

An analysis of the effectiveness of the regulation measures 1), 2), 3) on the degree of air pollution damage on region A's resident population indicates that concentration of population in only region C gives the best results followed by concentrating the population in both regions B and C and lastly in only region B. The degree of damage index, it must be emphasized, is not the same as the other indexes and the regulation effectiveness is almost proportional to the rate of population regulation. Stated differently, the regulation effectiveness is higher.

A 10% movement of the residential population from region A results in a regulation effectiveness in the degree of damage to vary from 12.3% to 13.3% whilst for a 50% movement of residential population from region A the result is between 57.1% to 59,4%. the regulation effectiveness for a 10% movement of both residential and industrial population result in a degree of damage ranging from 15.5% to 17.7% while the same degree of famage of the movement of 50% of population in the above category vary from 66.2% to 70.5%.

10) Degree of Damage of Industrial Population ((kg/km²)×person)

For the regulation effectiveness on the degree of damage to the industrial population as a result of the movement of 10% of the residential population from region A the result vary from 2.6% to 3.7% for a 10% movement of industrial population from region, the regulation effectiveness ranges between 6.2% and 7.9.

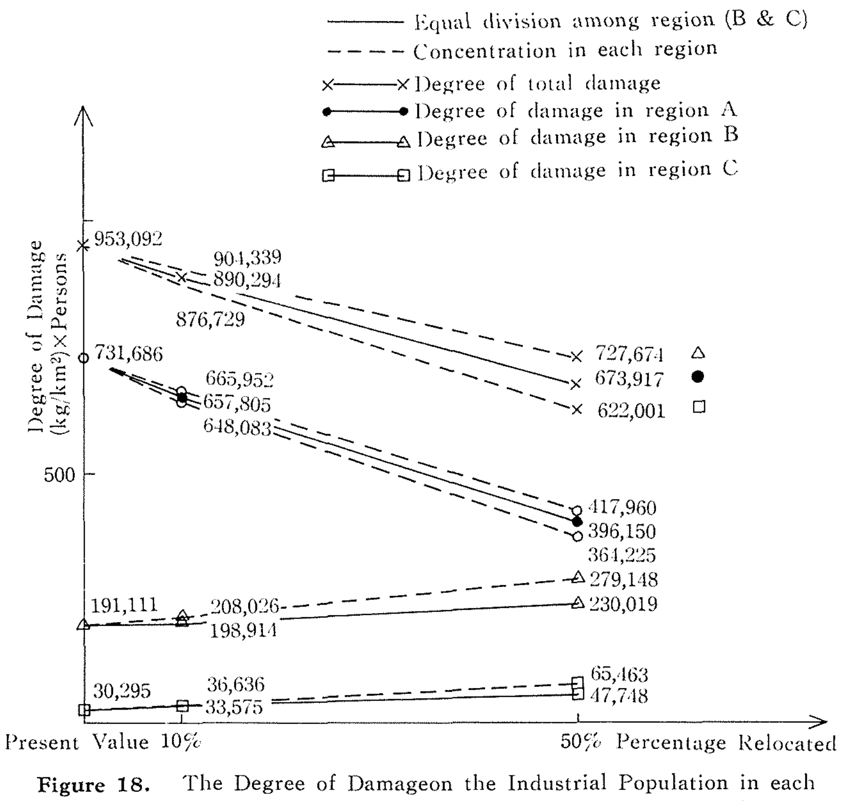

Figure 18. The Degree of Damageon the Industrial Population in each region when resident population from region A are relocated.

Table 11. Rlationship between Variations in the Social

A Curtailment Appraisal Index of Air Pollution in Region A		Total Veh. km ((Veh. km)×10^3)	Degree of Congestion	Volume of Total Emission (ton/day)	Volume of Emission of Internal Traffic
Status Quo of Air Pollution in Region A / The Rate of Movement / The curtail-ment-measures		20,228	11.1	69	6.5
I The Curtailment-Effectiveness at the Time of Movement of Population in Region A	10%	19,417 (−3.5%)	1.07 (−3.6%)	67 (−2.9%)	6.1 (−6.2%)
	50%	16,739 (−17.2%)	0.92 (−17.1%)	58 (−15.9%)	4.5 (−30.8%)
II The Curtailment-Effectiveness at the Time of Movement of Industrial Population in Region A	10%	19,388 (−4.2%)	1.07 (−3.6%)	67 (−2.9%)	6.1 (−6.2%)
	50%	16,018 (−20.8%)	0.89 (−19.8%)	55 (−20.3%)	4.5 (−30.8%)
III The Curtailment-Effectiveness at the Time of Movement of Resident+Industrial Population in Region A	10%	18,674 (−7.7%)	1.03 (−7.2%)	64 (−7.2%)	5.7 (−12.3%)
	50%	12,628 (−37.6%)	0.71 (−36.0%)	44 (−36.0%)	2.6 (−60.0%)

This implies that the regulation effectiveness of industrial population is greater.

A comprehensive summary of results for the regulation effectiveness of air pollution for the 10 indexes examined under the air pollution-appraisal model in this study is provided in table 11 below.

5. Conclusion

This study has examined the various countermeasures relevant for reducing the levels of air pollution (nitrogen oxides) in the Tokyo Metropolitan in the form of policy variables and policy alternatives. After grasping the 'status quo' of air pollution in the metropolis and its relationships with the urban structure, the problem was tackled through radical policy measures like population and industrial rearrangements, traffic management decisions.

A summary of the results are as follows

(1) A land use-traffic model that measures the regulation effectiveness of air pollution (nitrogen oxides) by the variation of the land use pattern (population and industrial rearrangement) and which is functionally operative.

(2) The regulation effectiveness of air pollution at the time of the movement

Impacts in Region A and Variations in the Land Use Pattern

Volume of Emission for Light Duty Truck (ton/day)	Volume of Emission for Heavy Duty Truck (ton/day)	Density of Emission (kg/km²)	Density of Emission per 1 km of Road Length (kg/km²)	Degree of Damage of the Residential Population ((kg/km² person)	Degree of Damage of the Industrial Population ((kg/km² person)
35.5	27.5	117	111.1	980,256	731,686
34.3 (−3.4%)	27.0 (−1.8%)	114 (−2.6%)	107.5 (−3.2%)	854,169 (−12.9%)	808,413 (−3.2%)
29.3 (−17.5%)	24.7 (−10.2%)	99 (−15.4%)	93.4 (−15.9%)	412,358 (−57.9%)	615,587 (−15.9%)
34.0 (−4.2%)	26.6 (−3.3%)	113 (−3.4%)	106.6 (−4.1%)	940,704 (−4.0%)	680,308 (−7.0%)
28.0 (−21.1%)	22.9 (−16.7%)	93 (−20.5%)	88.5 (−20.3%)	780,859 (−20.3%)	492,143 (−31.7%)
32.8 (−7.6%)	26.0 (−5.5%)	109 (−6.5%)	103.1 (−7.2%)	818,629 (−16.5%)	657,805 (−10.1%)
21.9 (−38.3%)	20.0 (−27.3%)	75 (−35.9%)	71.2 (−35.9%)	314,276 (−67.9%)	396,150 (−45.9%)

of

1) Residential Population
2) Industrial Population
3) Residential Population+Industrial Population

which were used as policy variables of the land use pattern. In terms of a choice among the 3 policy variables it is relevant to stress that the regulation effectiveness of the movement of the industrial population was the most rational and the regulation effectiveness of the movement of residential+industrial population was the lest. The simulation indicated that this policy variable was 2.5 times more effective that the other alternatives.

Finally from the three (3) cases established ie

1) having the policy variables concentrate only in region B
2) having the policy variables concentrate only in region C
3) having the policy variables divided equally between region B and C

it became clear that the choice of regulation effectiveness policy for air pollution in the study area was in this order of 1), 3), 2) in terms of desirability.

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