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A Study for Measuring Repercussive Pollution Arising from the Location of Manufacturing Industries on the Large-Scale Industrial Development

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Abstract

This paper reports the estimate of the repercussive pollution by the method based on the Interregional Input-Output Model and also the estimate of the environmental pollution control investment by the method based on the System Dynamics Simulations Model arising from the location of manufacturing industries such as Petrochemicals, Petroleum, Steel manufacturing, Non-ferrous metal manufacturing and Transportation manufacturing in the Tomakomai-Tobu Industrial Development.

Key Words: Repercussive pollution, Interregional input-output model, System Dynamics, Large-scale industrial development.

1. Introduction

The possibility of integrating economic and environmental models has been recognized by at least seven scholars such as Ayres and Kneese, Victor, Cumberland, Daly, Isard and Leontief. Ayres, Kneese and Victor have made the Cassel general equilibrium model based on the Walras. Cumberland, Daly, Isard and Leontief have each suggested that input-output models can be adapted to environmental sectors.

In this paper, we try to investigate the method for measuring the repercussive pollution based on the interregional input-output model, and measure the impact arising from the location of manufacturing industries in the Tomakomai-Tobu Industrial Development, and also evaluate the impact of the redistribution of manufacturing industries between Hokkaido region and Kanto region. Furthermore, we try to investigate the method for measuring the investment of environmental pollution control based on the System Dynamics model.

2. The Method for Measuring the Repercussive Pollution

This chapter presents the mathematical formation of the method for measuring the repercussive pollution arising from the location of manufacturing industries.

First, we shall consider the following conditions to formulate the method for measuring the repercussive pollution.

(1) It is necessary to measure the repercussive pollution by the industries and scales.

(2) We can make to be clear the differences of the impact of repercussive pollutions arising from the location of manufacturing industries.

(3) It is necessary to measure the impact of pollutions not only for the direct repercussive effects but also for the indirect repercussive effects.

(4) We must measure the indirect repercussive pollution not only for the locational region but also for the other region.

We shall represent the method for measuring the repercussive pollution arising from the location of manufacturing industries satisfied the four conditions mentioned above.

We define the notations of the partitioned matrices as follows.

A: interregional input coefficients matrix by regions.

I: identity matrix.

S: matrix having the values of inputs from other industries to locaitonal industry along the main diagonal (the diagonal running upper left to lower right) and zero elsewhere.

P: matrix having the values of inputs of locational industry along the column and zero elsewhere.

R: emission factors.

N: number of regions.

M: number of industries.

X represents the matrix of the total repercussive pollution and satisfies the following equations.

$$\begin{aligned} X &= D \otimes R + A \cdot S \otimes R + A^2 \cdot S \otimes R + \cdots \\ &= D \otimes R + [I + A + \cdots] \cdot A \cdot S \otimes R \\ &= D \otimes R + [I - A]^{-1} \cdot A \cdot S \otimes R \end{aligned}$$

where, $D \otimes R$ is the direct repercussive pollution and $[I-A]^{-1} \cdot A \cdot S \otimes R$ is the indirect one.

The relation of matrices S and D is as follows.

$$d_{ij}^{k'k} = s_j^{k'} \qquad (k=k_0,\ j=j_0)$$

$$d_{ij}^{k'k} = 0 \qquad \text{other} \begin{pmatrix} i,\ j=1, 2, \cdots, N \\ k',\ k=1, 2, \cdots, M \end{pmatrix}$$

(k_0 is the locational industry and j_0 is the locational region).

where, $\otimes$ multiplication presents the next formation.

$$X_i^{k'} = \sum_{k=1}^{M} d_{ij}^{k'k} \cdot r_i^{k'} + \sum_{k=1}^{M} s_j^{k'} \cdot a_{ij}^{k'k} \cdot r_i^{k'}$$

$(i,\ j=1, 2, \cdots, N,\ k,\ k'=1, 2, \cdots, M)$

$$[I-A]^{-1} \cdot A = [a_{ij}^{k'k}]\,, \qquad S=[s_{ij}^{k'k}]\,, \qquad s_{ij}^{k'k} = s_i^k \begin{pmatrix} k=k' \\ i=j \end{pmatrix}$$

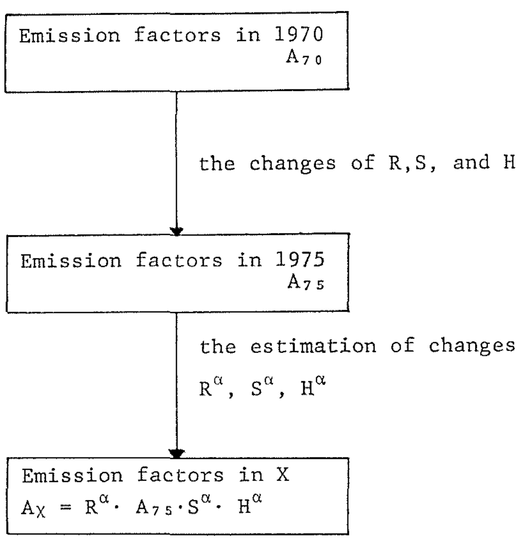
$$D=[d_{ij}^{k'k}] \qquad\qquad s_{ij}^{k'k} = 0 \text{ other}$$

To apply the method, it is necessary to estimate the future target values of interregional input coefficients and emission factors. We have shown the method to estimate the future target values of interregional input coefficients. Then, we shall present the improvement RAS method in order to estimate the future target values of emission factors. The emission factors are the rate at which products are emitted from the burning or processing of a given quantity of material.

Figure 1 presents the flow in order to estimate the future target values of emission factors.

We shall adopt the interregional input-output tables using the Isard's Model with 9 regions having 25 by 25 sectors in 1960, 1965, 1970 and 1975 in which the ministry of International Trade and Industry has prepared.

The classifications of regions and sectors are shown in Table 1 and 2.



R: substitute change coefficients

S: processing change coefficients

H: relative change coefficients

α = (X-1975)/ 5

Figure 1. Estimate of Emission Factors by The Improvement RAS Method.

Table 1. The Classifications of 9 Regions

Regions	Prefectures
Hokkaido	Hokkaido
Tohoku	Aomori, Iwate, Miyagi, Akita, Yamagata, Fukushima
Kanto	Niigata, Ibaragi, Tochigi, Gumma, Saitama, Chiba Tokyo, Kanagawa, Yamanashi, Nagano, Shizuoka
Tokai	Gifu, Aichi, Mie
Hokuriku	Toyama, Ishikawa
Kinki	Fukui, Shiga, Kyoto, Osaka, Hyogo, Nara, Wakayama
Chugoku	Tottori, Shimane, Okayama, Hiroshima, Yamaguchi
Shikoku	Tokushima, Kagawa, Ehime, Kochi
Kyushu	Fukuoka, Saga, Nagasaki, Kumamoto, Oita, Miyazaki, Kagoshima

Table 2. The Classification of 25 Sectors

Number	Sectors	Number	Sectors
01	Agriculture forestry & fisheries	14	Metal products
02	Coal & lignite mining	15	Machinery (n.e.c)
03	Mining (except 02)	16	Electric machinery
04	Food & kindred products	17	Transportation equipment
05	Textile products	18	Precision machinery
06	Lumber & wood products	19	Miscellaneous manufacturing
07	Pulp, paper & paper products	20	Construction
08	Leather, leather products & rubber products	21	Electricity, gas, water & sanitary services
09	Chemicals	22	Wholesale & retail trade
10	Petroleum & coal products	23	Finance, real estates & other service
11	Ceramic, clay & stone products	24	Transportation & warehousing
12	Primary iron & steel manufacturing	25	Unallocated
13	Primary nonferrous metal manufacturing		

3. The Estimate of the Repercussive Pollution Arising from the Industrial Locations in the Tomakomai-Tobu Large Industrial Development

The Tomakomai-Tobu Large Industrial Development is not merely the growth of an existing industrial situation but rather a fundamental change in the economic complex of Hokkaido region.

The main locational industries are the international competitive industries such as Steel manufacturing, Petroleum, Petrochemicals, Non-ferrous metal manufacturing, Transportation manufacturing and Relative industries.

The output of main locational industries on the master plan (MP) and the reconsidered plan (RP) are estimated in Table 3. The reconsidered plan is the plan that the master plan was re-evaluated by the possibility of location of industries and the environmental pollution problem.

The total, repercussive pollution are measured by two project plans.

(1) From the facts presented in the project plans, the total repercussive pollution of the master plan increases more than the ones of the reconsidered plan.

(2) The regional total repercussive pollution by the emission sectors such as Sulfur Oxide (SOX), Chemical Oxygen Demand (COD), Suspended Solid (SS) and Industrial Waste Disposal (IWD) are shown in Table 4. From the facts presented in Table 4, the sum of the regional total repercussive pollution of other regions except Hokkaido region is larger than the ones of Hokkaido region. The remarkable feature is the expansion of the regional total repercussive pollution in Kanto region

Table 3. The Outputs of the Locational Industries

Sector \ plan	Master plan	Reconsidered plan
Petrochemicals	3,200	2,420
Petroleum	2,150	2,150
Steel manufacturing	4,300	4,300
Non-ferrous metal manufacturing	2,550	1,100
Transportation manufacturing	1,250	1,250
Relative industies	3,050	2,550
Total	16,500	13,770

(Outputs: Million dollars)

Table 4. Distribution Percentages of Regional Total Repercussive Pollution (by Industrial Sectors) (%)

Emission Sector	SOX		COD		SS		IWP	
Region \ Plan	MP	RP	MP	RP	MP	RP	MP	RP
Hokkaido	39.8	41.4	49.1	49.1	34.7	36.9	23.1	26.9
Tohoku	9.5	9.0	6.7	6.3	13.8	13.0	31.0	28.2
Kanto	35.7	33.3	30.4	30.2	32.6	28.2	30.7	27.1
Tokai	2.4	2.9	2.1	2.4	1.8	2.2	2.0	2.6
Hokuriku	0.8	0.8	0.5	0.5	0.6	0.7	2.0	2.1
Kinki	4.8	5.2	5.3	5.4	8.7	10.2	7.1	7.7
Chugogu	4.4	4.7	2.6	2.8	5.6	6.5	2.0	2.6
Shikoku	1.5	1.6	1.5	1.5	0.8	0.8	1.7	2.2
Kyushu	1.1	1.1	1.8	1.8	1.4	1.5	0.4	0.5

Table 5. Distribution Percentages of Total Repercussive Pollution (by Industrial) (%)

Emission Sector / Plan / Sector	SOX MP	SOX RP	COD MP	COD RP	SS MP	SS RP	IWP MP	IWP RP
01	0.5	0.5	3.3	3.3	0.8	0.8	0.0	0.0
02	1.5	1.6	0.4	0.5	16.9	18.2	0.0	0.0
03	6.0	5.8	3.2	3.1	20.9	20.8	0.0	0.0
04	1.3	1.3	7.9	7.8	4.5	4.5	5.1	5.8
05	0.2	0.2	0.4	0.4	0.0	0.1	0.3	0.4
06	0.0	0.0	0.1	0.1	0.0	0.0	0.2	0.3
07	4.7	4.8	32.6	32.6	9.4	9.9	1.3	1.5
08	0.2	0.3	0.9	1.2	0.3	0.4	0.1	0.2
09	17.2	17.3	13.8	13.6	6.5	6.7	8.6	9.6
10	3.6	4.1	2.2	2.4	0.5	0.6	2.5	3.2
11	6.2	6.8	0.3	0.3	3.3	3.7	6.3	7.5
12	6.7	8.4	2.3	2.9	7.4	9.5	6.7	9.4
13	11.3	7.2	1.1	0.8	15.0	9.5	50.6	0.8
14	0.3	0.3	0.1	0.1	0.2	0.2	0.8	1.1
15	0.3	0.4	0.0	0.0	0.0	0.0	0.3	0.4
16	0.2	0.2	0.0	0.0	0.0	0.0	0.7	0.9
17	0.2	0.2	0.4	0.5	0.1	0.2	0.8	1.1
18	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1
19	0.1	0.1	0.4	0.5	0.2	0.2	0.4	0.5
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	34.9	35.5	25.2	24.4	10.9	11.3	15.0	17.2
22	1.1	1.2	0.4	0.5	0.0	0.0	0.0	0.0
23	0.5	0.5	1.5	1.6	2.3	2.6	0.0	0.0
24	3.0	3.2	3.2	3.3	0.5	0.6	0.0	0.0

Table 6. Distribution Percentages of Regional Total Repercussive Pollution (by Backward Linkage Effects) (%)

Emission Sector / Plan / Region	SOX MP	SOX RP	COD MP	COD RP	SS MP	SS RP	IWD MP	IWD RP
Hokkaido	47.5	48.2	58.2	57.7	41.8	42.8	37.1	38.3
Tohoku	10.6	9.9	6.8	6.5	14.9	13.8	15.3	17.9
Kanto	24.6	23.3	20.1	20.4	21.8	19.1	24.8	20.4
Tokai	2.8	3.3	2.3	2.6	2.1	2.4	3.0	3.4
Hokuriku	0.9	1.0	0.6	0.6	0.7	0.8	3.0	2.9
Kinki	5.6	5.9	5.7	5.8	10.0	11.4	10.4	10.1
Chugoku	5.0	5.3	2.8	3.0	6.3	7.2	3.3	3.5
Shikoku	1.7	1.8	1.6	1.6	0.8	0.9	2.4	2.9
Kyushu	1.3	1.3	1.9	1.0	1.5	1.6	0.6	0.6

advanced industrially.

(3) The distribution percentages of total repercussive pollution by industries are shown in Table 5. From the facts presented in Table 5, Electricity, gas, waste & sanitary services (21), Chemicals (09) and Primary nonferrous metal manufacturing (13) have high level on Sulfur Oxide (SOX), Pulp, paper & paper products (07), Electricity, gas, waste & sanitary services (21) and Chemicals (09) on Chemical Oxygen Demand (COD), Mining (Except (02)) (03), Coal & lignite mining (02), and Primary nonferrous metal manufacturing (13) on Suspended Solid (SS), and Primary nonferrous metal manufacturing (13), Electricity, gas, waste & sanitary services (21) and Chemicals (09) on Industrial Waste Disposal (IWD).

The distribution percentage of Primary nonferrous metal manufacturing on reconcidered plan has lower level than the ones on master plan.

(4) The method of backward linkage effects is to increase the interregional input coefficients of Hokkaido region. In this case, especially the intraregional input coefficients of locational industries such as Machinary, Metal and Other industries in Hokkaido region increase 50% than the before values of intraregional input coefficients. And this increase values are subtracted from the intraregional input coefficients of Kanto region advanced industrially. Distribution percentages of regional total repercussive pollution by backward linkage effects are shown in Table 6. From the facts presented in Table 6, the distribution percentages of Kanto region by four sectors such as SOX, COD, SS and IWD represent lower level about 10% than the ones without backward linkage effects in Table 4.

4. The Estimate of the Environmental Pollution Control Investments by the Locational Industries.

This chapter investigates the estimate of the environmental pollution control investment of the locaitonal industries by using System Dynamics Simulation Model.

The method of System Dynamics is very effective in analysing dynamically such a complex and intangible system as the estimate of the environmental pollution control investment.

The procedure of model building by System Dynamics is as follows:

(1) The sphere of systems surrounding the pollution is expressed when a problem is clarified. The causal factors within the system sphere gave both input and output characters. The system is influenced by the external factors of the system.

(2) When the sphere of system is decided, the factors composing the system are observed as System Observation. In this case, interrelations among causal factors are recognized as positive or negative combinations and are connected as an information feed back loop.

(3) The equations are formulated on the basis of these interrelations and are calculated with a computer. In order to recognize the dynamic state of the system, two specific variables we found, which are Level variable and Rate variable. The Lebel variable is the accumulation of the flow of the variable and its value exists in a time cross section. The Rate variable is arranged sequentially and gave rise

to changes in the Level variables. These variables are also known as decision making functions.

The decision making functions are determined by human decision making or other system structures.

(4) After the model building is finished, the simulation analysis is implemented by two methods. One is the method which is the translation of the FORTRAN language directly, and the other uses particular languages, which are Dynamo, DSMP and so on. In the case of the former language, the analyst describes the model as much detail as he can. On the contrary, in the case of the latter language, the analyst represents the problems with a simulation language and the computer translates and calculates the alternative. It is easy to analyse the model by using the simulation language.

The flow of environmental pollution control investment model is shown in Figure 2.

The environmental pollution control investment model is consisted of eight sectors such as Investment planning, Production ability, Production output, Total repercussive pollution, Emission standards, Reductive ability of pollution by facilities, Reductive pollution, and Environmental pollution control investment.

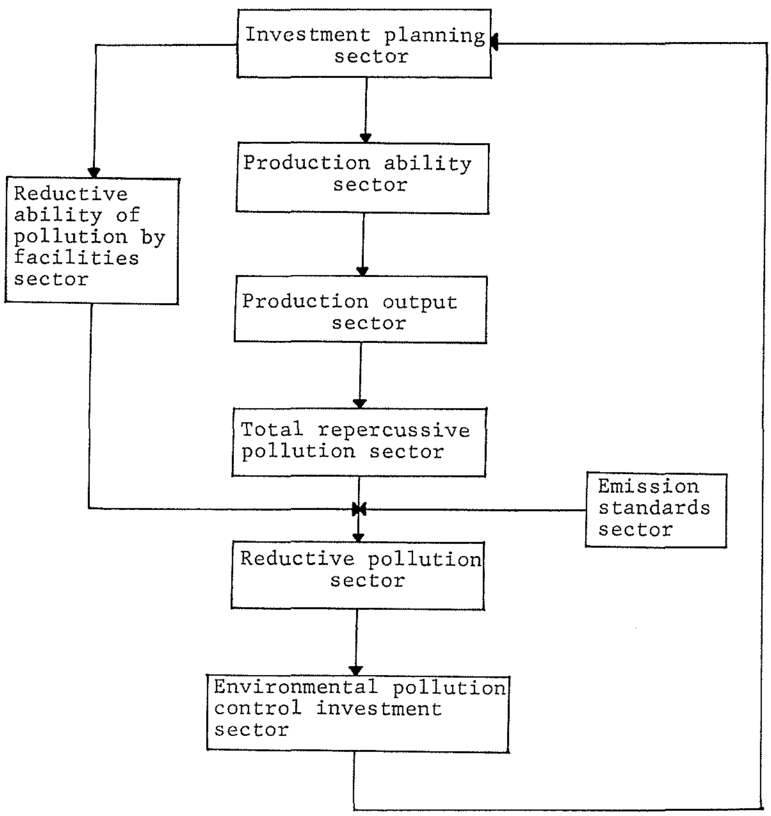


Figure 2. Flow is Simulation model.

Table 7. Environmental Pollution Control Investments by Locational Industries

Investment plan \ Locational industries		Chemicals	Petroleum	Steel manufacturing	Non-ferrous metal manufacturing	Transportation manufacturing	Total
Investments with repercussive effects	MP	196.6	43.8	277.6	431.8	16.2	966.0
	RP	143.5	43.8	277.6	164.8	16.2	645.9
Investments without repercussive effects	MP	146.2	38.6	247.4	418.7	12.8	863.7
	RP	108.0	38.6	247.4	161.2	12.8	568.0

(Million dollars).

We shall consider four estimates of the environmental pollution control investments by the locational industries such as Chemicals, Petroleum, Steel manufacturing, Nonferrous metal manufacturing and Transportation manufacturing.

Table 7 represents the estimates of environmental pollution control investments by the locational industries. From the facts presented in Table 7, the investments of Non-ferrous metal manufacturing, Steel manufacturing and Chemicals have high level and the ones of Petroleum and Transportation manufacturing have low level to control the pollution. And the investments of the master plan increase more than the ones of the reconsidered plan from the facts presented in the project plans.

Furthermore, the investments with repercussive effects increase more than the ones without repercussive effects. Then, it is very important to estimate the repercussive effects by the locational industries.

5. Environmental Impact Assessment of Tomakomai-Tobu Large Industrial Development

The Hokkaido government carried out fact-finding surveys regarding pollutions and established preventive measures in regard to water pollution and air pollution and presented a bill of "Regulation on Environmental Assessment of Hokkaido" to the Hokkaido Assembly in March, 1978, which was passed by the July Session of the Assembly and was to be enforced in January, 1979.

This regulation aims at securing a good environment in order to contribute to the welfare of the people and to the development of Hokkaido, by establishing procedures which assure adequate assessment of influence on the environment by certain development projects which may seriously affect the environment, together with other measures to prevent public nuisance such as pollution and maintain natural environment.

In Figure 3, the regulation does not restrict development itself, but tries to prevent the distruction of environment, which might accompany the development

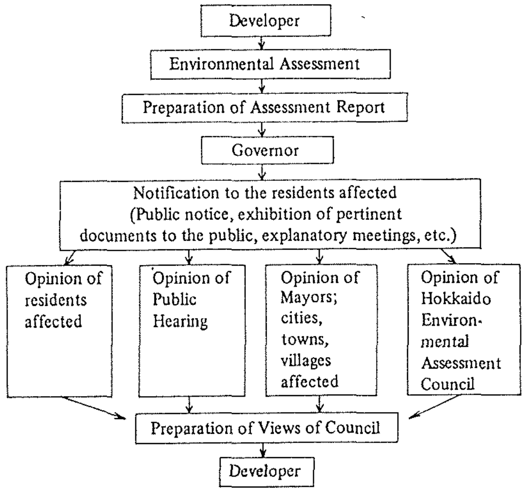


Figure 3. Assessment Process.

by making public the pertinent data on the influences that the development may have on the environment and by trying to encourage the opinions of the people in the area relative to the development plan. If this is done, the governor can form his own opinion on the possible effect on the environment or to the person has obtained the approval for development.

According to the Regulation, there are 8 kinds of construction and/or development which would be covered ; a dam over a certain scale, a new rail-road, trunk line, an airport, a power generation station, an industrial estate, a housing complex, the construction or development of overall recreation facilities.

5.1 First stage plan

The output of locational industries of the first stage plan are estimated such as Petroleum (650 million dollars), Petrochemicals (700 million dollars), Transportation manufacturing (450 million dollars), Relative industries (350 million dollars) and Electric power (0.35 million KW).

5.2 Environmental pollution control plan

The environmental pollution control plan is considered to pollution impact of not only Tomakomai-Tobu industrial development but also Tomakomai-Seibu industrial development.

(1) Air pollution

a) Sulfur dioxide (SO_2)

The environmental standards of sulfur dioxide are below 0.1 ppm on hour value, 0.04 ppm on the daily average value and 0.015 ppm on the annual average value.

The exhaust volume of sulfur dioxide is estimated at 0.009 ppm (annual average value) of the maximum landing density based on the exhaust volumes of sulfur dioxide of 2000 Nm^3/h (Tomakomai-Seibu) and 530 Nm^3/h (Tomakomai-Tobu) by using Bosanquet-Sutton method.

The target value of the exhaust volumes of sulfur dioxide of Tomakomai-Seibu is aimed at 1600 Nm^3/h for safety, because the additive value of living pollution sensity is 0.006 ppm (annual average value) and the sum of pollution densities approach to the environmental standard 0.015 ppm (annual average value).

Then, it is necessary to equip with the sulfur removing equipment and conserve the energy.

b) Nitrogen dioxide (NO_2)

The environmental standard of nitrogen dioxide is below 0.02 ppm on the daily average value.

The exhaust volume of nitrogen dioxide is estimate at 0.036 ppm (daily average value) based on the exhaust volumes of nitrogen dioxide of 1180 Nm^3/h (Tomakomai-Seibu). The target value of the exhaust volumes of nitrogen dioxide is aimed at 700 Nm^3/h for safety. Then, it is necessary to equip with the nitrogen removing equipment and conserve the energy.

c) Suspended solid (SS)

The environmental standard of suspended solid are below 0.2 mg/m^3 on hour value and 0.1 mg/m^3 on the daily average value.

The exhaust volume of suspended solid is estimate at 0.13 mg/m^3 (daily average value) based on the exhaust volumes of suspended solid of 570 kg/h (Tomakomai-Seibu) and 950 kg/h (Tomakoami-Tobu).

The target value of the exhaust volumes of suspended solid are aimed at 370 kg/h (Tomakomai-Seibu) and 475 kg/h (Tomakomai-Tobu). Then, it is necessary to equip with the suspended solid removing equipment and green belt for buffer zone.

(2) Water pollution

The environmental standard of COD is below 2 ppm on the daily average value.

The exhaust volume of COD is estimated at 17 ppm based on the exhaust volumes of 3180 kg/day from the locational industries. The value of COD at sea district is estimated at 2.3 ppm. Then, it is necessary to equip with the sewage treatment with the activated sludge process and coagulating sedimentation.

(3) Industrial waste disposal

The industrial waste disposal is estimated at 190 thousand ton. Then, the treatment of industrial waste disposal is necessary to bill in the common treatment district by the concentration of attention with strict fairness.

(4) Conservational planning of natural environment

It is necessary to maintain the proper land use and green belt for the natural environment conservation and human environment conservation.

a) Evaluation of the present condition

The present conditions of natural environment are evaluated from points of view such as the scientific value, ecological succession, landscape value and caltural deposite assets.

b) Establishment of conservational district

Each district is ranked according to the conservational value of natural environment. Then, the conservational districts are selected among many district by high evaluation of natural conservation.

c) Buffer green belt planning

The buffer green belt are selected among many green zones for the separation of industrial estate and residential area. Then, the buffer green belt are wider than the conservational districts. And the. industrial estate is enclosed with the buffer green belt presented in Figure 4.

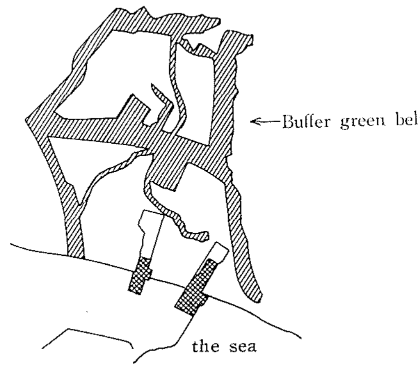


Figure 4. Buffer greenbelt planning.

6. Conclusion

We have investigated the method for measuring the repercussive pollution based on the interregional input-output model and also the method for measuring the investment of environmental pollution control based on the System Dynamics Model. From the both method mentioned above, we have estimated the repercussive pollution and the investment of environmental pollution control arising from the location of manufacturing industries in the Tomakomai-Tobu Industrial Development.

The main results as follows :

(1) From the facts presented in the project plans, the total repercussive pollution of the master plan increases more than the ones of the reconsidered plan.

(2) The sum of the regional total repercussive pollution of other regions except Hokkaido region is larger than the ones of Hokkaido region. The remarkable feature is the expansion of the regional total repercussive pollution in Kanto region advanced industrially.

(3) The distrubution percentages of total repercussive pollution by Electricity, gas, waste & sanitary services, Chemicals and Primary nonferrous metal manufacturing have high level on Sulfur Oxide, Pulp, paper & paper products, Electricity, gas, waste & sanitary services and Chemicals on Chemical Oxygen Demand, Mining (except (02)) Coal & lignite mining and Primary nonferrous metal manufacturing on Suspended Solid, and Primary nonferrous metal manufacturing, Electricity, gas, waste & sanitary services and Chemicals on Industrial Wate Disposal.

(4) The distribution percentages of regional total repercussive pollution such as four sectors (SOX, COD, SS and IWD) of Kanto region by backward linkage effects represent lower level about 10% than the ones without backward linkage effects.

(5) The investments of environmental pollution control of Nonferrous metal manufacturing, Steel manufacturing and Chemicals have high level and the ones of Petroleum and Transportation manufacturing have low level to control the pollution.

And also, the investments with repercussive effects increase more than the ones without repercussive effects.

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