Development of Material Flow Account and Evaluation of the Regional Eco-Efficiency in Shiga Prefecture, Japan

Takaaki Niren[1], Research Center for Socioecological Systems, The University of Shiga Prefecture
Amane Hayashi[2], Research Center for Socioecological Systems, Shiga Industrial Support Plaza
Tohru Yoshida[3], Research Center for Socioecological Systems, Shiga Industrial Support Plaza

1. Overview

In Japan, conversion into a society to recycle resources has become a national goal, and the system of individual laws has been maintained along the "Basic Law for Establishing a Recycling-based Society" in 2003. Technical, managerial and political efforts have been made by the government and industrial society at the levels of business establishments, corporations, industries and regions as well as at the national level, to realize a recycling-oriented society. The purpose of this legislative system is to reduce wastes and at the same time to promote their utilization in a circulative manner. Globally, sustainable development, proposed in 1987 by the World Commission on Environment and Development has now become a common goal in the world, through the Rio Summit and the Johannesburg Summit. It has been a long time since effective and fair utilization of limited resources beyond generations as well as actions to convert into a kind of industry or society that does not cause environmental destruction became challenges. Most of all, the Kyoto Protocol adopted at COP3 in 1997 in regards to the increase of greenhouse gas concentration including ambient carbon dioxide that causes various risks resulting from climate changes was finally agreed to in 2005. During the first commitment period from 2008 to 2012, major industrialized countries are obliged to reduce emission by 5% to 10% compared with the year 1990, and discussions for next step emission reduction have already begun.

However, there is no database that enables integrated treatment of material flow as well as energy flow in regards to industrial and household wastes, resource utilization, energy utilization, carbon dioxide emission and burdens of water pollution. The material flow at the national level has begun to be developed since the 1993 issue of "White Paper on the Environment." It is currently succeeded by the "White Paper on Recycling-oriented Society," but only the material flow at the national level is described, which is not more than the flow of the total physical volume. Therefore, the research group by Moriguchi, et al. of the National Institute of Environmental Studies prepared the Physical Input-Output Tables (PIOT) including wastes, to apply them to material flow analyses (Moriguchi, 2005). Studies by Nakamura, et al., in regards to waste input-output tables (WIOT) also propose the model to connect IOT with waste generation, treatment and recycling (Nakamura, 2000; Nakamura and Kondo, 2002). Such series of studies in Japan indicate that input-output analyses are useful for the study of industrial ecology. Fujie et al. and Goto et al. developed material flow data and presented model for zero emission network in a certain region by applying regional IOT (Fujie and Goto,2000, Goto et al, 2001). IOT can express not only transactions among industries and households in

[1] niren@ses.usp.ac.jp
[2] hayashi.a@office.usp.ac.jp
[3] yoshida.to@office.usp.ac.jp

terms of quantity of money but also in the physical volume, providing not only a framework to express the flow of resources, energy and wastes among industries and households but also a framework to analyze them in an integrated manner (Duchin 1992; Suh and Kagawa, 2005).

In Europe, preparation of PIOT has progressed since 1990 by incorporating utilization of resources and energy, waste generation, and the emission volume of environmental burden into IOT. In countries such as Holland, Denmark, Germany and Finland, PIOT were prepared for 1990 and 1995. In the most detailed table for 1995 in Germany, PIOT were developed for substances, energy and water in regards to 60 industrial sectors (Hoekstra and Bergh, J., 2006). Additionally, Applications of PIOT to regional sustainability analysis and its comparison have been developed in Europe (Wiedman et al., 2006).

In this study, POIT were prepared based on IOT for 1995 and 2000 in Shiga Prefecture in order to conduct the analysis of industrial ecology pertinent to the actual condition of Shiga Prefecture, and at the same time the industrial ecology was analyzed by using PIOT.

The paper is structured as follows:

In the following section, the framework of PIOT in Shiga Prefecture is presented. We show the data developed and make brief examination. Section 3 explains the preparation of physical input-output table of Shiga prefecture in Japan. Section 4 discusses the factors that influenced the structural changes in industries in Shiga Prefecture 1995-2000. Finally, conclusion remarks and future tasks are described in Section 5.

2. Framework of Physical Input-Output Table

2.1 Framework of IOT for environmental analyses

To prepare PIOT corresponding to MIOT that covers both economic and environmental territories, the vast amount of data, which has not been organized in the past, has to be processed. It is necessary to review the framework from the viewpoint of data availability. We also need to consider the framework from the viewpoint of how to utilize it. The starting point of this study was database development to evaluate industrial technologies that have less environmental loads in Shiga Prefecture. Reduction of environmental burdens by industries is an area targeted by industrial ecology, and dematerialization of industries and economy is a common issue. Although there are various aspects of dematerialization, the purpose of this study is to develop a database to evaluate it. One method of dematerialization is to reduce resources injected into industries, in order to conduct production activities with fewer resources. In this case, development of a framework that enables evaluation of productivity of resources by industries becomes a challenge. Another method is to reduce residuals discharged from industries, in order to recycle residuals from one industry to be used as resources for another industry. This promotes recycling. Since recycling requires additional input of resources and energy, it is not worthwhile to evaluate the high recycling rate only. It is necessary to provide a framework that enables comparison and estimation between reduction of environmental loads by additional input of resources and energy and by recycling. In addition, incineration is conducted in order to reduce the volume of residuals discharged from industries so that wastes ultimately disposed into the environment can be reduced. This cannot be evaluated either simply because of the reduction of final disposal amount, since incineration reduces the disposal volume of solid wastes but increases the emission volume of carbon dioxide. A framework that compares loss and profit for recycling is necessary here as well. Finally, changes in consumption structure as well as in lifestyle change the structure and amount of necessary commodities and services. This requires a framework that enables analysis on how the change in final demand structure influences production, input of resources and discharge of residuals.

In order to conduct analyses in regards to the above industrial ecology on the premise of constraints of available data,

1) Not only industrial sectors covered by MIOT but also sectors disposing residuals such as the industrial waste treatment sector, general waste treatment sector, and sewer system sector were also established. In regards to treatment sectors, since the input for treatment is different depending on treatment methods, sectors were established in accordance with treatment methods.

2) The matrices and vectors that have both physical and money include intermediate input matrix X_{ij}, final demand vector $X^F{}_i$, by-product input matrix Y_{mj} and output matrix U_{mj}. Other matrices and vectors as well as scalar quantity are indicated in physical term only.

3) Intermediate treatment for residuals is slightly complicated.

The intermediate treatment sector brings to the treatment sector the industrial waste in matrix W_{lj} (the type l industrial wastes from the sector j) and the municipal waste with vector $W^F{}_l$ discharged from the final demand sector, are brought into the intermediate treatment sectors. These treated wastes, indicated in T_{lk} (the type l wastes are disposed at the treatment sector k), are converted into recycled

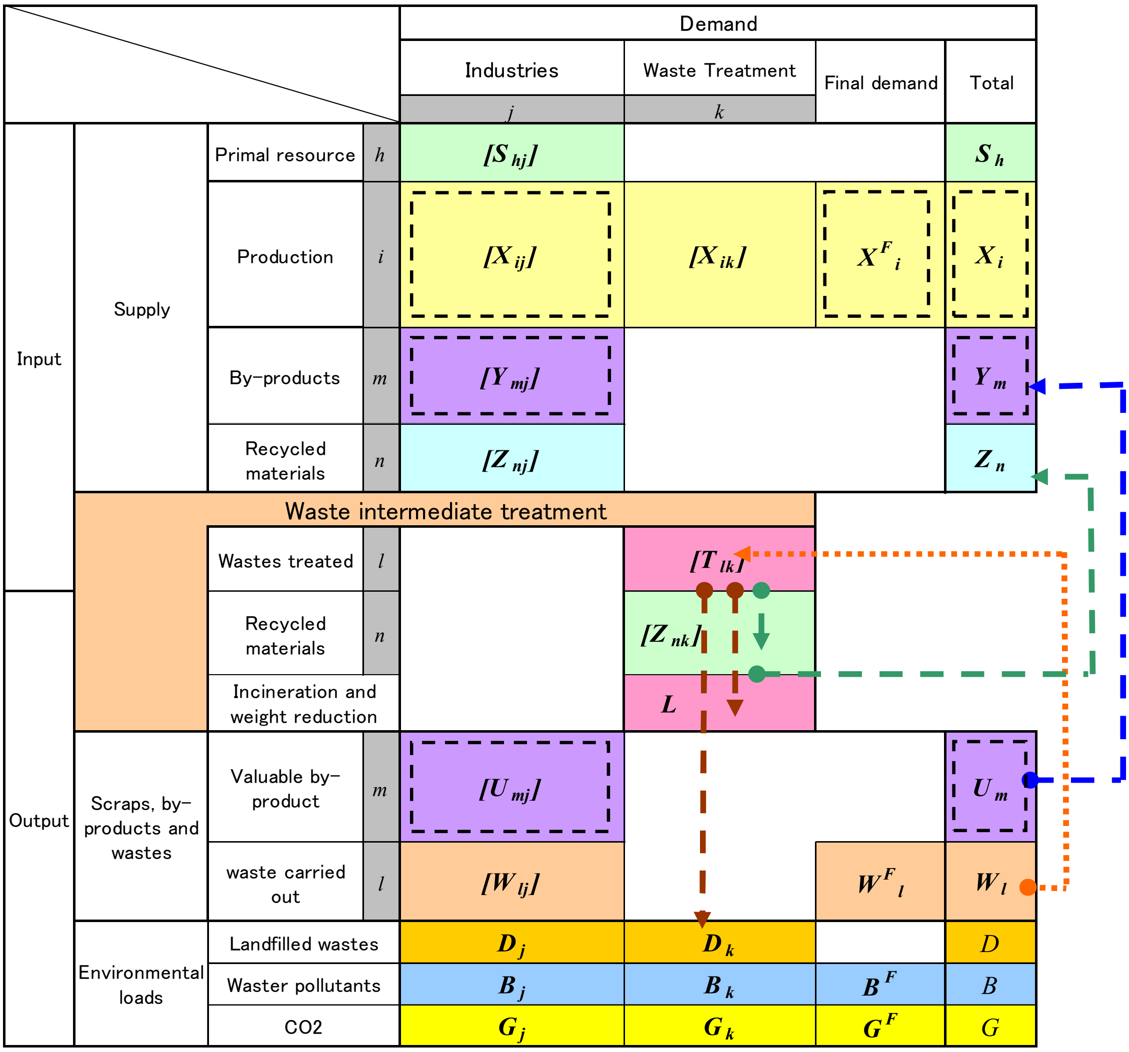

Figure 1. Structure of Environmental Input-Output Table

commodities in matrix Z_n(the type n recycled commodities), the reduction of waste volume L and the final disposal volume in matrix D_k (the disposal volume generated due to treatment of the type k).
The recycled commodities Z_n are input into industrial sectors, which are shown as matrix Z_{nj} (type n recycled commodities to the sector j).

4) Extraction of resources from the environment is in matrix S_{hj} (the type h natural resources are injected into the sector j), and it is assumed that resource extraction from the environment does not exist in the final demand sector. In reality, direct resource utilization exists such as fishing, but we did not take it into account since the size is negligibly small.

5) The scale of impact on the environment cased by residual discharge to environment from the economy was evaluated in accordance with the final disposal of solid waste D, water pollutant B (indicated with nitrogen, phosphorus and COD/BOD index), and carbon dioxide emission amounts into the air G.

3. Preparation of industrial input-output tables for environmental analyses

3.1. Structure of material flow database

In this study, material throughput was projected for each industrial sector based on IOT in Shiga Prefecture, and at the same time, the waste treatment sector was established as an independent sector, separate from industrial sectors. In industrial sectors, raw materials with positive economic value were input to produce products with positive economic value and wastes with negative economic value, while the waste treatment sector produces recycled materials with positive economic value and discharges wastes with negative value into the environment, using products with positive value (such as energy and chemicals) and wastes with negative value from industrial sectors. The difference between industrial sectors and the waste treatment sector is that the latter takes wastes with negative value as input.

In reality, material flow with no positive value is not treated adequately in the economic statistics, while raw materials and products with positive value are the main target of data collection. However, the material flow in the present industrial society cannot always be understood by covering industrial sectors only, and the waste treatment sector also influences significantly to the material flow. For reference, the waste treatment volume handled by the waste treatment sector in Shiga Prefecture is approximately 33% of the volume discharged.

Secondly, IOT is the most related to the material flow between industrial sectors. It covers the flow of raw materials and products based on money. It has been regularly prepared nationally, by prefectures and by major cities. Therefore, in order to analyze environmental burdens from industries, data availability in analysis will increase dramatically by developing data in a way that linkage with IOT is possible.

The data of industrial sectors are estimated using "minor consolidated sector classification" in which there are 186 industrial sectors in 1995 and 188 sectors in 2000.

The waste treatment sectors are comprised of sectors where sewer system and waste treatment businesses are divided in accordance with treatment methods in Shiga prefecture.

3.2. Preparation of physical input-output tables

The following steps were taken as a method to project regional material flow (Figure 2). The database prepared at this point is a table with physical volume corresponding to monetary IOT made by Shiga prefecture statistical administration. The method to prepare a table with physical volume is explained as follows, using the 1995 IOT for Shiga Prefecture.

3.3. Output/Input table for scraps and by-products

In national IOT in Japan, the output and input of scrap and by-products traded with economic value is recorded in currency in the attached "Table on Scrap and By-Products" that makes it possible to distinguish the flow of scrap and by-products.

However, IOT in Shiga Prefecture does not have a table on scrap and by-products as in national IOT, So except for iron scraps and nonferrous metal scraps, scraps and by-products value are usually in competitive commodities row (equivalent to "paper and pulp in the case of scrap paper for example). For the database in this study, we extracted output and input value (monetary) for scraps and by-products from IOT and converted them into physical value.

3.4 Preparation of waste database

In accordance with surveys on industrial waste in Shiga Prefecture (conducted every 4-5 years) and with research on industrial waste treatment (conducted every year), the physical volume of valuables, generation of waste, discharged waste, self-treated waste in industries, recycled waste, consigned waste and final disposal for 1995 are projected and integrated in accordance with minor consolidated sector classification.

This data enables analyses that were not possible in the past, by dividing it into classification of IOT sectors. For example, comparison between the generation volume and commodity production volume by industry and by waste type enables inspection of productivity of resources.

3.5 Preparation of water pollutants database [P_i]

We are provided with data on water pollutant discharge from business establishments, which prefectural government has collected and used as the supporting data for preparing Plan for Conservation of Lake Water Quality. The data of business enterprises targeted in 1995 is split into minor consolidated sector classification of IOT and added up by sector. The water pollutant emission unit by sector is obtained by dividing these sectoral pollutant loads data with value of sectoral production in the same year.

3.6 CO_2 database [G_i]

At present, a CO2 database for each sector in minor consolidated sector classification of IOT covered cannot be developed from the data maintained by Shiga Prefecture as well as from generally available materials. At the present stage, the emission unit (t-C/million Yen) prepared by the National Institute for Environmental Studies is utilized in this study as a temporary value.

3.7 Database for intermediate waste treatment sector [T_{kj}]

Activities by the intermediate treatment sector also consume commodities and energy.

In the minor consolidated sector classification of IOT Shiga Prefecture, industrial waste and general waste treatments are integrated in the "waste treatment" sector. They were separated in this study, and the industrial waste treatment sector was also divided into representative treatment methods (ex. incineration, more than 30 sectors) operated in relevant year in Shiga Prefecture. The waste volume consigned by each treatment sector is also projected based on questionnaires on the processors, the treatment stations, treatment equipment manufacturers, etc.

4. Change in Industrial Structure and Material Flow

4.1 Change in industrial structure

The industrial structure in Shiga Prefecture has characteristics specific to the secondary sector of industry, especially to the manufacturing industry. Table 1, proportion of regional gross production by economic activity, suggests that although the proportion of manufacturing industry in the total production has been decreasing but still maintains the high proportion, i.e., 40%. Although Shiga Prefecture maintains one of the highest statuses as the inland industrial area in Japan, the structure of manufacturing industry has been changing.

The proportion of electric machinery in the gross production peaked in 1991 (17.8%) then continued to decrease, i.e., 8.8% in 2003. The proportion of other inland-type manufacturing has been decreasing gradually. The proportion of transport machinery has been growing during the last decade, but is still at 4.6%. The proportions for ceramic, stone and clay industry have been decreasing as well. The industrial structure might be changing from the catch-up type or the growth-type that specializes in especially outstanding industries to the mature-type.

What are then qualifications of mature-type industrial structure? In Table 2, the rate of change in value-added production by industries in Shiga Prefecture was compared using the 1995 and 2000 IOT as well as tables with physical volume prepared here. Since extreme economic change did not occurred from 1995 to 2000, this kind of comparison will not be accepted. The industrial sector with increased value added from 1995 to 2000 includes petroleum and coal products (1.45 times, the highest), followed by precision instruments, transportation equipment, general machinery, pulp, paper, wooden products, and then iron and steel. On the other hand, industries with decreased value added include textile products (0.59 times; the lowest), followed by the mining, ceramic, stone and clay products, construction, foods, and then chemical products. The factors that caused increase of added value are obtained in the following equation:

$$V = \frac{V}{P_M} \cdot \frac{P_M}{P_P} \cdot P_P \qquad \cdots\cdots (3)$$

V : value added
P_M : production value
P_P : physical volume of production,

The first term $\frac{V}{P_M}$ represents the value-added per production value. The larger is V, the more labor-intensive and capital-intensive the production is. It also means that an industry has more potential for the improvement driven by the change in final consumption and capital formation rather than the effect to induce production in other industries, i.e., the characteristics of a mature economy drawn by the final demand are strengthened. The second term $\frac{P_M}{P_P}$ represents the production value for one physical production unit, i.e., price for physical product volume. When this value is high, products with higher value are being produced. This also indicates the characteristics of a mature industry. Finally, the third term P_P represents the physical production volume, and its growth means an increase of the value-added. However, this is not growing in any industries other than precision instruments, transportation instruments and pulp, paper and wooden products, which implies the industries' direction toward dematerialization. Based on the above, it seems that the direction of industrial change in Shiga is moving toward maturization.

4.2 Industrial structure and material flow

Although we prepared IOT for environmental analyses as minor consolidated sector classification (186 sectors, 1995) and intermediate consolidated sector classification (104 sectors; 2000) with the 1995 and 2000 IOT for Shiga Prefecture as basic data, they include massive data and therefore are integrated into the major consolidated sector classifications (32 sectors) for the purpose of easy viewing here. Since the data shown in the major consolidated sector classification is still hard to look at, the overview is illustrated in Figure 3 as regional material flow.

Although the emission amount of carbon dioxide in industries is decreasing, it is probably reflecting the shutdown of one of the major cement plants. In reality, the emission volume is rather increasing in other sectors, reflecting difficulty in reduction of carbon dioxide emissions.

The water pollutant load has also decreased by half during the last five years. In regards to industrial wastes as well as water pollutant load, industries in Shiga Prefecture dramatically reduced environmental loads. This can be considered as structural change, which can also be learned from Figure 3. In regards to emission reduction of carbon dioxide, the way out to more reduction of CO2 has not been found at the present stage.

4.3 Environmental loads in industrial sectors

Using the same method as 4.1, we broke down and investigated the factor to determine the change of the final disposal volume of wastes, the change of water pollutant such as COD and T-N, and the change of the emission volume of carbon dioxide.

First of all, the factor to determine the final disposal volume of wastes was broken down as follows:

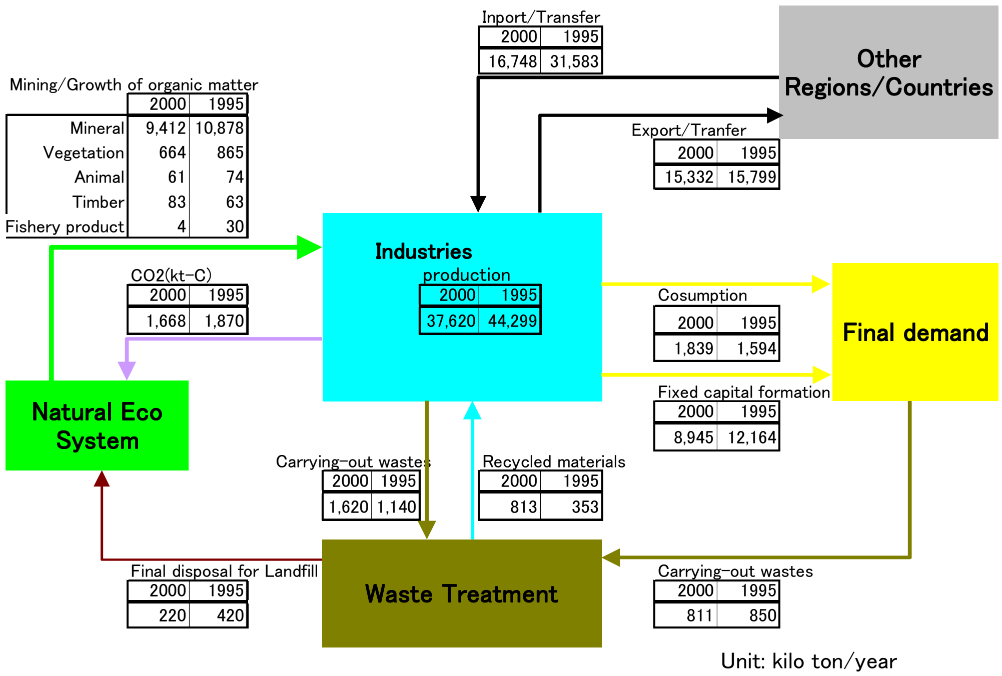

Figure 3. Material Flow in Shiga Prefecture in 1995 and 2000

$$D = \frac{D}{W} \cdot \frac{W}{M} \cdot \frac{M}{P} \cdot P \quad \cdots\cdots (4)$$

D : Volume of final disposal wastes
W : volume of discharged wastes
M : volume of input resources and materials
P : physical production volume

When B represents of water pollutant load (COD or T-N), the factor to determine the burdens of water pollutant can be broken down as follows:

$$B = \frac{B}{P} \cdot P \quad \cdots\cdots (5)$$

Furthermore, the emission volume of carbon dioxide G is broken down as follows in a similar way:

$$G = \frac{G}{P} \cdot P \quad \cdots\cdots (6)$$

The result is shown in Table 3. The volume of final disposal wastes is determined by the four factors, D/W, W/M, M/P and P, The industry with increased production volume does not always increase the final disposal volume of wastes and the opposite can be true for some industries. The influential factors on ⊿D are the second and third terms, i.e., the factor to increase the final disposal waste volume from the discharged waste amount, and a factor to decrease the wastes relative to the input of raw materials. The former is to thoroughly implement waste treatment, and the latter is to use raw materials as effectively as possible in the production process. Industries that are making efforts in both of them can be observed in the group of machinery industry. This indicates that the final disposal waste volume can be reduced regardless of the increase or decrease of production volume.

Secondly in regards to reduction of water pollutant load BOD and T-N, the volume of burden from the industrial sector reduced to half in reality, buy what could this result from? Table 3 shows that the volume of pollutant load per production volume is decreased regardless of the increase or decrease of production volume. It is considered that improvement of production process, establishment of wastewater treatment facility, and the connection of plants to sewer system contributed to such effect. The effect of reduction of pollutant load in the group of machinery industry is significant here as well.

Table 3. Factorization analysis on rate of change in environmental load 1995-2000 (physical basis) 32-sector classification

Industries	⊿D	Factor				⊿B (BOD)	Factor		⊿B (T-N)	Factor		⊿G	Factor	
		D/W	W/M	M/P	P		B/P	P		B/P	P		G/P	P
Agriculture, forestry and fishery	4.79	2.86	1.63	1.26	0.81			0.81			0.81	0.79	0.98	0.81
Mining						0.93	1.14		0.59	0.73		0.84	1.03	
Foods	0.24	0.10	1.63	1.60	0.90	0.42	0.47	0.90	0.44	0.49	0.90	0.93	1.04	0.90
Textile products	2.10	1.39	2.09	1.41	0.51	0.45	0.87	0.51	0.69	1.35	0.51	0.59	1.15	0.51
Pulp, paper and wooden products	0.63	0.56	0.77	0.97	1.48	0.89	0.60	1.48	0.66	0.45	1.48	1.09	0.74	1.48
Chemical products	0.97	1.15	0.53	1.71	0.93	0.68	0.73	0.93	0.48	0.51	0.93	1.04	1.12	0.93
Petroleum and coal products			2.14	1.02	0.87	2.96	3.42	0.87	1.94	2.23	0.87	0.78	0.90	0.87
Ceramic, stone and clay products	8.08	4.89	1.40	1.44	0.82	0.36	0.43	0.82	0.42	0.51	0.82	0.71	0.87	0.82
Metal products	0.67	1.04	0.50	1.67	0.77	0.50	0.64	0.77	0.47	0.60	0.77	1.13	1.46	0.77
General Machinery	0.22	0.30	0.45	1.48	1.12	0.41	0.37	1.12	0.48	0.42	1.12	1.52	1.35	1.12
Electrical Machinery	0.85	0.86	0.55	1.76	1.02	0.80	0.79	1.02	0.75	0.74	1.02	1.62	1.59	1.02
Transportation equipment	0.19	0.28	0.36	1.38	1.33	0.49	0.37	1.33	0.72	0.54	1.33	1.64	1.24	1.33
Precision instrument	0.86	0.97	0.46	1.28	1.50	0.56	0.37	1.50	0.30	0.20	1.50	1.82	1.22	1.50
Miscellaneous manufacturing products	1.00	1.25	0.56	1.62	0.89	0.61	0.69	0.89	0.81	0.91	0.89	1.24	1.40	0.89
Construction	0.17	0.10	1.55	1.47	0.73			0.73			0.73	0.87	1.18	0.73

The blank columns are due to the lack or absence of data

Finally, the group of machinery industry rather increased the carbon dioxide emission ⊿G, while other industrial groups decreased it. In regards to industries that contributed to decrease, reduction of their industrial size, i.e., results from production volume reduction, led to reduction of carbon dioxide emission, which does not seem to be the results of efforts in production process. In the group of machinery industry, both the production volume and the emission of carbon dioxide per production volume increased, and improvement has not been observed at least from the tendency from 1995 to 2000. Despite the fact that machinery industries largely contribute to the reduction of final disposal volume of industrial wastes and emission of water pollutant load, it seems it is not easy to reduce carbon dioxide emission in industrial sectors.

Factor analyses were conducted in regards to CO2 emission, final disposal of industrial wastes and COD in the same way as the intermediate consolidated sector classification (93 sectors in 1995, 104 sectors in 2000). The results were indicated in Table 4.

It should be noticed here that the industrial sectors are lined up in the order that has the higher reduction rate of CO2 emission volume from 1995 to 2000. CO2 emission is factorized here as follows:

$$G = \frac{G}{M_{aux}} \cdot \frac{M_{aux}}{P} \cdot P \qquad (7)$$

Table 4. Factorization analysis on rate of change in environmental load
1995-2000 (physical basis)

	Categories of industries	⊿G	Factor			⊿D	Factor				⊿B COD	Factor	
			G/Maux	Maux/P	P		D/W	W/M	M/P	P		B/P	P
61	Other transportation equipment and repair of transportation equipment	0.03	9.16	0.34	0.01			2.22	1.01	0.01		64.27	0.01
15	Wearing apparel and other textile products	0.30	0.80	1.27	0.29	1.02	1.26	2.20	1.27	0.29	0.15	0.52	0.29
40	Cast and forged steel products	0.52	0.31	2.23	0.76	0.93	0.66	1.56	1.19	0.76	1.59	2.08	0.76
35	Cement and cement products	0.58	1.21	0.62	0.76	2.14	0.96	2.89	1.01	0.76	0.40	0.52	0.76
14	Textile products	0.61	0.94	1.17	0.56	2.33	1.38	2.71	1.12	0.56	0.46	0.82	0.56
25	Synthetic resins	0.64	0.71	1.72	0.52	250.56	290.99	1.58	1.05	0.52	0.17	0.33	0.52
11	Beverage	0.71	0.70	1.12	0.90	2.83	0.53	3.42	1.73	0.90	0.37	0.41	0.90
34	Glass and glass products	0.73	0.99	0.77	0.96	0.33	0.28	1.23	0.99	0.96	0.32	0.33	0.96
17	Furniture and fixtures	0.82	0.90	1.12	0.81	1.27	1.82	0.80	1.08	0.81	0.79	0.96	0.81
64	Buiding construction	0.86	0.39	2.34	0.93	0.17	0.10	1.86	0.99	0.93	0.00	0.00	0.93
44	Metal products for construction and architecture	0.94	0.77	1.48	0.82	0.64	1.14	0.67	1.02	0.82	0.48	0.59	0.82
37	Other ceramic, stone and clay products	1.00	1.16	1.29	0.67	140.07	125.23	1.35	1.23	0.67	0.36	0.54	0.67
51	Electronic computing equipment and accessory equipment	1.01	1.07	0.36	2.64			0.61	0.48	2.64	3.37	1.28	2.64
56	Heavy electrical equipment	1.02	1.29	1.24	0.64	0.12	0.05	3.47	1.00	0.64	0.53	0.83	0.64
22	Basic inorganic chemical products	1.03	1.00	0.81	1.28	0.00	0.00	0.14	2.03	1.28	0.67	0.53	1.28
42	Non-ferrous metals	1.05	1.21	1.19	0.73	7.80	5.30	1.80	1.12	0.73	0.33	0.45	0.73
26	Synthetic fibers	1.07	0.57	1.11	1.70	0.00	0.00	0.46	0.88	1.70	0.35	0.21	1.70
19	Paper products	1.07	0.82	1.25	1.05	0.70	0.54	1.20	1.03	1.05	0.16	0.15	1.05
32	Rubber products	1.11	1.08	0.82	1.25	0.64	0.87	0.61	0.96	1.25	0.27	0.22	1.25
16	Timber and wooden products	1.11	1.55	0.68	1.05	0.80	0.73	1.04	1.01	1.05	0.99	0.94	1.05
18	Pulp, paper, paperboard, building paper	1.14	5.62	0.17	1.16	0.45	0.49	0.81	0.98	1.16	0.94	0.82	1.16
50	Household electronic and electric appliances	1.19	1.17	1.39	0.73	0.55	1.22	0.65	0.95	0.73	0.85	1.17	0.73
28	Final chemical products, n.e.c.	1.25	1.46	1.06	0.80	0.12	0.12	1.26	0.97	0.80	0.82	1.03	0.80
43	Non-ferrous metal products	1.26	1.14	1.44	0.77	5.62	8.60	0.86	0.99	0.77	0.60	0.78	0.77
10	Foods	1.26	1.13	1.32	0.84	0.24	0.20	1.65	0.87	0.84	0.46	0.54	0.84
48	Other general machines	1.27	1.19	1.07	1.00	0.13	0.11	1.29	0.98	1.00	0.76	0.76	1.00
47	Special industrial machinery	1.28	1.30	1.14	0.86	0.21	0.42	0.62	0.93	0.86	0.84	0.98	0.86
31	Plastic products	1.31	1.80	0.88	0.83	2.55	3.17	1.01	0.97	0.83	0.65	0.78	0.83
20	Publishing, printing	1.33	1.50	1.11	0.80	0.89	1.04	1.03	1.03	0.80	0.77	0.96	0.80
45	Other metal products	1.34	1.49	1.26	0.71	0.86	1.20	1.05	0.96	0.71	0.50	0.70	0.71
60	Ships and repair of ships	1.38	1.05	1.02	1.29	0.00	0.00	0.72	0.88	1.29	2.50	1.94	1.29
29	Petroleum refinery products	1.42	0.05	18.13	1.44	0.00	0.00	0.74	1.54	1.44	5.09	3.54	1.44
55	Electronic components	1.49	1.26	0.46	2.58	0.69	0.59	0.73	0.63	2.58	0.66	0.26	2.58
27	Medicaments	1.61	1.38	1.05	1.11	0.50	0.36	1.21	1.02	1.11	0.53	0.48	1.11
24	Organic chemical products	1.66	0.96	1.42	1.22	0.00	0.00	0.58	0.96	1.22	0.38	0.31	1.22
53	Applied electronic equipment and electric measuring instruments	1.74	1.46	0.86	1.37			0.92	1.05	1.37	0.00	0.00	1.37
36	Pottery, china and earthenware	1.74	1.15	0.81	1.87	3.13	2.38	0.70	1.00	1.87	0.35	0.19	1.87
59	Other cars	1.78	1.95	0.68	1.34	0.24	2.17	0.10	0.84	1.34	0.32	0.24	1.34
62	Precision instruments	1.82	1.57	0.77	1.50	0.86	0.97	0.68	0.88	1.50	0.56	0.37	1.50
46	General industrial machinery	1.94	1.26	1.05	1.46	0.55	0.73	0.51	1.00	1.46	0.28	0.19	1.46
57	Other electrical equipment	1.95	1.44	1.40	0.97	3.77	3.77	1.08	0.96	0.97	0.38	0.39	0.97
49	Machinery for office and service industry	2.26	1.39	0.75	2.16	0.00	0.00	0.43	1.01	2.16	0.06	0.03	2.16
12	Feeds and organic fertilizer, n.e.c.	2.95	0.48	2.59	2.38			0.94	1.18	2.38	0.60	0.25	2.38
54	Semiconductor devices and integrated circuits	3.45	0.99	0.97	3.59	1.08	0.73	0.48	0.87	3.59	0.74	0.21	3.59
52	Communication equipment	3.49	1.37	1.41	1.81	10.67	3.13	1.73	1.09	1.81			1.81
58	Passenger motor cars	3.51	2.74	0.36	3.54	0.00	0.00	0.94	1.04	3.54	0.54	0.15	3.54

*The categories of industries are assorted in line with intermediate consolidated classification in IOT
*The blank columns are due to the lack or absence of data

M_{aux}, newly introduced here, and they include raw materials consumed in the production process among intermediate material input in the industry and most of them belong to fuel for energy sources in most industries, while there are raw materials that will be embodied in products. The first term therefore represents the emission unit of CO2 from fuel input used in the production process, and the second term represents use efficiency of fuel materials. Sector group with codes 61 to 44 that decreased the CO2 emission decreased the production volume on one hand, at the same time, improvement is observed in both the first term and the second term. In the second group (codes 37 to 18), the CO2 emission slightly increased but improvement is observed in either the first term or the second term. In regards to the third group (codes 50 to 45), although the production decreased, the first and second terms worsened and the emission increased by 20% to 30%. In the fourth group (code 29 to 58), the first and second terms improved; however the emission is far from reduction but increased to a significant extent, due to increase of production. They mainly include machinery industry, electronic industry and chemical industry, many of which make efforts to enhance use efficiency of auxiliary materials and fuel, and it is necessary for them to make further efforts.

5. Conclusion

We presented framework of material flow database for Shiga Prefecture and explained the procedure of the development of database. The main feature of this database is that the physical production data of industrial sector is estimated by accumulating regional production and business statistics and that sector aggregation of basic database is more intimate than the other similar studies.

The comparative analysis on eco-efficiency in manufacturing industries, it was found that high value-added economy and increase in production was realized in 1995-2000. Decomposition analyses are conducted regarding the interaction of production, material input and environmental loads. The key findings in this paper are that: a) the dematerialization and maturing of local economy had been proceeding. b) Machinery industry cluster enhanced material use in production and reduced final disposal waste and emission of environmental loads. c) Reduction of CO2 in manufacturing industries was not made. d) PIOT in this paper is useful for the analyses of industrial ecology in the most detailed sector aggregation.

As the future tasks, we are recollecting and refining production data and environmental loads data for future scenario analyses, which are expected to contribute the plan or policy of sustainable production and consumption in this region. The future scenarios will be needed to consist of possible technology changes of production in the future such as improvement of material use efficiency, environmental loads emission, substitution of input materials etc.

Some parts of database, CO_2 emission and input-output data of municipal solid waste treatment, which are tentative in this paper, should be finished.

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