ESTIMATION OF LIFE CYCLE EMISSION IN ROAD DEVELOPMENT PROJECTS

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Abstract: A project of infrastructure such as a road generates huge volumes of emissions in each stage of its construction, and thereafter due to maintenance and repairs. The amount of emissions, therefore, should be estimated for the totality of its project's life cycle. In order to develop a basic model to estimate total emissions, the activities of recycling, collection of by-products or wastes and disposal of wastes are added to the SNA style Input-Output table. In this table, a process of recycling resources between activities is explicitly included. This model is applied to an actual project of a Japanese national highway to estimate the amount of emissions generated by alternate plans of roads that differ in the lengths of elevated parts, cut/fill parts and tunnel parts respectively. A plan that is estimated to generate the minimum emissions in all the economic activities is not necessarily equal to a plan that is directly estimated in a road project.

Key words: Life Cycle Cost, I-O Analysis, Emission

1. INTRODUCTION

A project of infrastructure such as a road requires as an input huge volume of resources, and in turn generates large amounts of by-products in each stage of its construction, and thereafter due to maintenance and repairs. Therefore, it influences environment of surrounding areas and also to each stage of its construction, maintenance and repairs. The amount of emissions, which is not only pertaining to the air but also to solid and liquid, should be estimated for the totality of life cycles for a society of few emissions.

Furthermore, influences of emissions are not limited to industries directly related to a road project, but extend to all economic activities through input-output process. Assuming that an issue of selecting a road line with the lowest level of emissions, there is possibility that the answer will be different if emissions are estimated taking into consideration all the industries as opposed to estimating only the road project in question. Clearly, it is necessary to consider all the industries for an issue about emissions. It is conceivable that an input-output table is now the most useful method to this issue. However, the existing input-output table is not capable of estimating such emissions. There is then the need to improve a model.

The purpose of this paper is to develop a basic model capable of estimating total amount of emissions by adding a resource circulation process into a conventional input-output table.

This paper consists of 5 sections.

In section 1, purposes and a structure of this paper are expressed. In Section 2, three new activities, namely recycling, collection of by-products or wastes and disposal of wastes, are added to the SNA style Input-Output table. The model is capable of estimating influences to all economic activities on amounts of material basis. This model is specified to a project of a road in Section 3 by considering that the road is composed of 3 structural elements: elevated parts, cut/fill parts and tunnel parts respectively. In section 4, this model is applied to the problem of selecting a minimum-emissions road line from a set of alternatives that differ in the lengths of elevated parts, cut/fill parts and tunnel parts respectively. It is shown that amount of emission estimated with all the industries is different from the one estimated with only the project of the roads even when their structures are simple. In section 5, we conclude some results of the estimations.

Many attempts to study the environmental problem and to expand the IO table in the field of environment have been done. Leontief (1970) added an activity of recovering pollution in IO table and quantitatively estimated the influence to other economic activities by the prevention activity of the pollution by pollutant such as scrapped material. Rose (1983) also evaluated a prevention activity of environmental pollution from the economic standpoint in consideration of interdependence relation of technology coefficient and production coefficient in IO table. Miyata *et al.* (2000) added a regional aspect to the analysis and Moriguchi *et al.* (1996) applied an actual transportation project. Although many other subsequent papers examine the issue, very few develop a framework of the influence through all the industries of a project of infrastructure considering economic activities respectively regarding recycling.

In addition, a brief explanation in Japanese of the method proposed in this paper was included as a subsystem in a forecasting system of aggregates discharged in construction projects in Kuroda *et al.* (2001)

2. DEVELOPMENT OF ESTIMATION MODEL

Figure 1 shows a flow of emissions of an infrastructure project. The SNA style Input-Output table is used to measure influences of all activities. Existing table, however, cannot be used to sufficiently express circulation process and discard process of emissions. For example, it summarizes by-products and recycling goods and represents them as by-products and wastes. This summarization does not consider the process of collection and recycling explicitly.

Input and output of by-products and wastes are usually represented as negative values. Therefore, they are not described as transactions of goods but as services. The present paper proposes a SNA style IO table that takes the recycling process as shown in table 1, to express resources circulation process between activities.

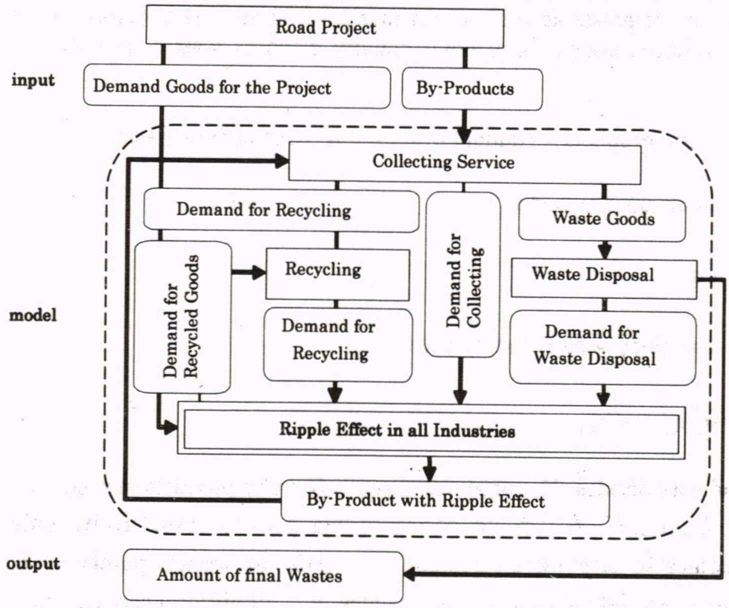

Figure 1. Model Flow of Estimating Life Cycle Emission

Table 1. SNA Style IO Table Considering Recycling Process

	General Goods v	Recycled Goods r	Collecting Service z	Disposal Service w	General Industry v	Recycling Industry r	Collecting Industry z	Disposal Industry w	Final Demand	Total
General Goods v					U_{vv}	U_{vr}	U_{vz}	U_{vw}	f_v	q_v
Recycled Goods r					U_{rv}	U_{rr}	U_{rz}	U_{rw}	f_r	q_r
Collecting Service z					U_{zv}	U_{zr}	U_{zz}	U_{zw}	f_z	q_z
Disposal Service w							U_{wz}			q_w
General Industry v	V_{vv}									g_v
Recycling Industry r		V_{rr}								g_r
Collecting Industry z			V_{zz}							g_z
Disposal Industry w				V_{ww}						g_w
Value Added					y_v	y_r	y_z	y_w		
Total	q_v	q_r	q_z	q_w	g_v	g_r	g_z	g_w		

V_{VV} of general goods and service is produced from general activities and is inputted $U_{vv}, U_{vr}, U_{vz}, U_{vw}, f_v$ respectively to normal activities, recycling activity, collecting activity, waste disposal activity and final demand. In other words, each activity that produces by-products and final demands purchases $U_{vv}, U_{vr}, U_{vz}, U_{vw}, f_v$ of service of collecting them respectively. Then collecting service produces V_{zz}.

A collection activity is a service of collecting by-products. A portion of total of by-products is defined as recycle goods according to demand, while the rest is defined as waste. A recycle activity reproduces goods. A disposal activity disposes wastes, in other words, generates emissions.

$$\text{Amount of by-products} = \text{Amount of recycling} + \text{Amount of waste} \tag{1}$$

Define $\mathbf{q}$ as an amount vector.

$$\mathbf{q}_z = \mathbf{q}_r + \mathbf{q}_w \tag{2}$$

Define $\mathbf{p}$ as a price vector, and then we have

$$\hat{\mathbf{p}}_z^{-1}\mathbf{q}_z = \hat{\mathbf{p}}_r^{-1}\mathbf{q}_r + \hat{\mathbf{p}}_w^{-1}\mathbf{q}_w \,. \tag{3}$$

Recycle industry divides V_{rr} of recycled goods from by-products in accordance with demand and input $U_{rv}, U_{rr}, U_{rz}, U_{rw}, f_r$ to corresponding activity respectively. Collecting industry which becomes to disposal the remaining material as wastes, purchases U_{wz} of disposal service. Then disposal industry, which provides V_{ww} of disposal service, disposes wastes.

Define coefficient vectors $\mathbf{B}, \mathbf{D}$ as follows.

$$\mathbf{B} \equiv \mathbf{U}\hat{\mathbf{g}}^{-1} \tag{4}$$
$$\mathbf{D} \equiv \mathbf{V}\hat{\mathbf{q}}^{-1} \tag{5}$$

$\mathbf{q}^{(1)}$ is a vector of total influenced outputs in terms of the 1st stage goods or services, excluding those influenced by disposal of wastes. Then equations of demand balance are (6) and (7).

$$\begin{pmatrix} \mathbf{B}_{vv} & \mathbf{B}_{vr} & \mathbf{B}_{vz} \\ \mathbf{B}_{rv} & \mathbf{B}_{rr} & \mathbf{B}_{rz} \\ \mathbf{B}_{zv} & \mathbf{B}_{zr} & \mathbf{B}_{zz} \end{pmatrix} \begin{pmatrix} \mathbf{g}_v^{(1)} \\ \mathbf{g}_r^{(1)} \\ \mathbf{g}_z^{(1)} \end{pmatrix} + \begin{pmatrix} \mathbf{f}_v \\ \mathbf{f}_r \\ \mathbf{f}_z \end{pmatrix} = \begin{pmatrix} \mathbf{q}_v^{(1)} \\ \mathbf{q}_r^{(1)} \\ \mathbf{q}_z^{(1)} \end{pmatrix} \tag{6}$$

$$\begin{pmatrix} \mathbf{D}_{vv} & 0 & 0 \\ 0 & \mathbf{D}_{rr} & 0 \\ 0 & 0 & \mathbf{D}_{zz} \end{pmatrix} \begin{pmatrix} \mathbf{q}_v^{(1)} \\ \mathbf{q}_r^{(1)} \\ \mathbf{q}_z^{(1)} \end{pmatrix} = \begin{pmatrix} \mathbf{g}_v^{(1)} \\ \mathbf{g}_r^{(1)} \\ \mathbf{g}_z^{(1)} \end{pmatrix} \tag{7}$$

Substituting (7) into (6) yields

$$\begin{pmatrix} \mathbf{q}_v^{(1)} \\ \mathbf{q}_r^{(1)} \\ \mathbf{q}_z^{(1)} \end{pmatrix} = \left(\mathbf{I} - \begin{pmatrix} \mathbf{B}_{vv} & \mathbf{B}_{vr} & \mathbf{B}_{vz} \\ \mathbf{B}_{rv} & \mathbf{B}_{rr} & \mathbf{B}_{rz} \\ \mathbf{B}_{zv} & \mathbf{B}_{zr} & \mathbf{B}_{zz} \end{pmatrix} \begin{pmatrix} \mathbf{D}_{vv} & 0 & 0 \\ 0 & \mathbf{D}_{rr} & 0 \\ 0 & 0 & \mathbf{D}_{zz} \end{pmatrix} \right)^{-1} \begin{pmatrix} \mathbf{f}_v \\ \mathbf{f}_r \\ \mathbf{f}_z \end{pmatrix} \tag{8}$$

Defining $G = (I - BD)^{-1}$ for simplicity, the above can be expressed as:

$$\begin{pmatrix} q_v^{(1)} \\ q_r^{(1)} \\ q_z^{(1)} \end{pmatrix} = \begin{pmatrix} G_{vv} & G_{vr} & G_{vz} \\ G_{rv} & G_{rr} & G_{rz} \\ G_{zv} & G_{zr} & G_{zz} \end{pmatrix} \begin{pmatrix} f_v \\ f_r \\ f_z \end{pmatrix} \tag{9}$$

From equation (3), the total influenced outputs by disposal service on the 1st stage, $\mathbf{q}_w^{(1)}$:

$$q_w^{(1)} = \hat{p}_w \left(\hat{p}_z^{-1} q_z^{(1)} - \hat{p}_r^{-1} q_r^{(1)} \right) \tag{10}$$

Then substituting (9) into (10) yields

$$q_w^{(1)} = \hat{p}_w \hat{p}_z^{-1} q_z^{(1)} - \hat{p}_w \hat{p}_r^{-1} q_r^{(1)}$$

$$\left(\hat{p}_w \hat{p}_z^{-1} G_{zv} - \hat{p}_w \hat{p}_r^{-1} G_{rv} \quad \hat{p}_w \hat{p}_z^{-1} G_{zr} - \hat{p}_w \hat{p}_r^{-1} G_{rr} \quad \hat{p}_w \hat{p}_z^{-1} G_{zz} - \hat{p}_w \hat{p}_r^{-1} G_{rz} \right) \begin{pmatrix} f_v \\ f_r \\ f_z \end{pmatrix}$$

$$= \left(\mathbf{H}_v \quad \mathbf{H}_r \quad \mathbf{H}_z \right) \begin{pmatrix} \mathbf{f}_v \\ \mathbf{f}_r \\ \mathbf{f}_z \end{pmatrix} \tag{11}$$

Where $\left(\mathbf{H}_v \quad \mathbf{H}_r \quad \mathbf{H}_z \right)$ is defined for simplicity.

Intermediate goods are inputted to a disposal activity for $\mathbf{q}_w^{(1)}$ of disposal service and influence effect reaches other activities. Then define $\mathbf{q}^{(2)}$ as influenced outputs on the 2nd stage of general activities, recycle activity and collecting activity and service which is newly produced by $\mathbf{q}_w^{(1)}$.

$$\begin{pmatrix} q_v^{(2)} \\ q_r^{(2)} \\ q_z^{(2)} \end{pmatrix} = \begin{pmatrix} G_{vv} & G_{vr} & G_{vz} \\ G_{rv} & G_{rr} & G_{rz} \\ G_{zv} & G_{zr} & G_{zz} \end{pmatrix} \begin{pmatrix} B_{vw} \\ B_{rw} \\ B_{zw} \end{pmatrix} D_{ww} q_w^{(1)} \tag{12}$$

Furthermore, the total influenced outputs by disposal service on the 2nd stage, $\mathbf{q}_w^{(2)}$ is calculated from equation (11),

$$q_w^{(2)} = \hat{p}_w \hat{p}_z^{-1} q_z^{(2)} - \hat{p}_w \hat{p}_r^{-1} q_r^{(2)} = \left(H_v \quad H_r \quad H_z \right) \begin{pmatrix} B_{vw} \\ B_{rw} \\ B_{zw} \end{pmatrix} D_{ww} q_w^{(1)}$$

$$= \left(H_v \quad H_r \quad H_z \right) \begin{pmatrix} B_{vw} \\ B_{rw} \\ B_{zw} \end{pmatrix} D_{ww} \left(H_v \quad H_r \quad H_z \right) \begin{pmatrix} f_v \\ f_r \\ f_z \end{pmatrix} \tag{13}$$

Then, $\mathbf{q}^{(3)}$ which is newly produced by $\mathbf{q}_w^{(2)}$ as influenced outputs on the 3rd stage of general activities, recycle activity and collecting activity and service is calculated similar to the equation (12).

$$\begin{pmatrix} q_v^{(3)} \\ q_r^{(3)} \\ q_z^{(3)} \end{pmatrix} = \begin{pmatrix} G_{vv} & G_{vr} & G_{vz} \\ G_{rv} & G_{rr} & G_{rz} \\ G_{zv} & G_{zr} & G_{zz} \end{pmatrix} \begin{pmatrix} B_{vw} \\ B_{rw} \\ B_{zw} \end{pmatrix} D_{ww} q_w^{(2)} \tag{14}$$

And we have

$$q_{w\cdot}^{(3)} = \hat{p}_w \hat{p}_z^{-1} q_z^{(3)} - \hat{p}_w \hat{p}_r^{-1} q_r^{(3)} = \begin{pmatrix} H_v & H_r & H_z \end{pmatrix} \begin{pmatrix} B_{vw} \\ B_{rw} \\ B_{zw} \end{pmatrix} D_{ww} q_w^{(2)}$$

$$= \left\{ \begin{pmatrix} H_v & H_r & H_z \end{pmatrix} \begin{pmatrix} B_{vw} \\ B_{rw} \\ B_{zw} \end{pmatrix} D_{ww} \right\}^2 \begin{pmatrix} H_v & H_r & H_z \end{pmatrix} \begin{pmatrix} f_v \\ f_r \\ f_z \end{pmatrix} \tag{15}$$

Define $\mathbf{q}_w$ as the final outputs of disposal service at the end of the influence that continues infinitely. (11), (13) and (15) yields

$$q_w = \sum_{i=1}^{\infty} q_w^{(i)} = \sum_{j=0}^{\infty} \left\{ \begin{pmatrix} H_v & H_r & H_z \end{pmatrix} \begin{pmatrix} B_{vw} \\ B_{rw} \\ B_{zw} \end{pmatrix} D_{ww} \right\}^j \begin{pmatrix} H_v & H_r & H_z \end{pmatrix} \begin{pmatrix} f_v \\ f_r \\ f_z \end{pmatrix}$$

$$= \left(I - \begin{pmatrix} H_v & H_r & H_z \end{pmatrix} \begin{pmatrix} B_{vw} \\ B_{rw} \\ B_{rw} \end{pmatrix} D_{ww} \right)^{-1} \begin{pmatrix} H_v & H_r & H_z \end{pmatrix} \begin{pmatrix} f_v \\ f_r \\ f_r \end{pmatrix} \tag{16}$$

On the other hand, the final influenced outputs $\mathbf{q}$ of other activities and services are calculated from (9), (12) and (14)

$$\begin{pmatrix} q_v \\ q_r \\ q_z \end{pmatrix} = \sum_{j=1}^{\infty} \begin{pmatrix} q_v^{(j)} \\ q_r^{(j)} \\ q_z^{(j)} \end{pmatrix}$$

$$= \begin{pmatrix} G_{vv} & G_{vr} & G_{vz} \\ G_{rv} & G_{rr} & G_{rz} \\ G_{zv} & G_{zr} & G_{zz} \end{pmatrix} \begin{pmatrix} f_v \\ f_r \\ f_z \end{pmatrix} + \begin{pmatrix} G_{vv} & G_{vr} & G_{vz} \\ G_{rv} & G_{rr} & G_{rz} \\ G_{zv} & G_{zr} & G_{zz} \end{pmatrix} \begin{pmatrix} B_{vw} \\ B_{rw} \\ B_{zw} \end{pmatrix} D_{ww} \sum_{j=1}^{\infty} q_w^{(j)}$$

$$
= \begin{pmatrix} G_{vv} & G_{vr} & G_{vz} \\ G_{rv} & G_{rr} & G_{rz} \\ G_{zv} & G_{zr} & G_{zz} \end{pmatrix} \begin{pmatrix} f_v \\ f_r \\ f_z \end{pmatrix} + \begin{pmatrix} G_{vv} & G_{vr} & G_{vz} \\ G_{rv} & G_{rr} & G_{rz} \\ G_{zv} & G_{zr} & G_{zz} \end{pmatrix} \begin{pmatrix} B_{vw} \\ B_{rw} \\ B_{zw} \end{pmatrix} D_{ww} q_w
$$

$$
= \begin{pmatrix} G_{vv} & G_{vr} & G_{vz} \\ G_{rv} & G_{rr} & G_{rz} \\ G_{zv} & G_{zr} & G_{zz} \end{pmatrix} \begin{pmatrix} f_v \\ f_r \\ f_z \end{pmatrix} + \begin{pmatrix} G_{vv} & G_{vr} & G_{vz} \\ G_{rv} & G_{rr} & G_{rz} \\ G_{zv} & G_{zr} & G_{zz} \end{pmatrix} \begin{pmatrix} B_{vw} \\ B_{rw} \\ B_{rw} \end{pmatrix} D_{ww}
$$

$$
\left(I - \begin{pmatrix} H_v & H_r & H_z \end{pmatrix} \begin{pmatrix} B_{vw} \\ B_{rw} \\ B_{rw} \end{pmatrix} D_{ww} \right)^{-1} \begin{pmatrix} H_v & H_r & H_z \end{pmatrix} \begin{pmatrix} f_v \\ f_r \\ f_r \end{pmatrix}
$$

$$
= \begin{pmatrix} G_{vv} & G_{vr} & G_{vz} \\ G_{rv} & G_{rr} & G_{rz} \\ G_{zv} & G_{zr} & G_{zz} \end{pmatrix} \left\{ I + \begin{pmatrix} B_{vw} \\ B_{rw} \\ B_{rw} \end{pmatrix} D_{ww} \right.
$$

$$
\left. \left(I - \begin{pmatrix} H_v & H_r & H_z \end{pmatrix} \begin{pmatrix} B_{vw} \\ B_{rw} \\ B_{rw} \end{pmatrix} D_{ww} \right)^{-1} \begin{pmatrix} H_v & H_r & H_z \end{pmatrix} \right\} \begin{pmatrix} f_v \\ f_r \\ f_r \end{pmatrix} \tag{17}
$$

Then we have the influenced total outputs by disposal service from equation (17) similar to (11) as follows.

$$
q_w = \hat{p}_w \left(\hat{p}_z^{-1} q_z - \hat{p}_r^{-1} q_r \right) \tag{18}
$$

$\mathbf{q_w}$ from the equation (16) should be equal to $\mathbf{q_w}$ from the equation (18).

3. ESTIMATION OF EMISSION FROM A ROAD PROJECT

Suppose that a road in this section consists of 3 structural elements, namely elevated parts, cut/fill parts and tunnel parts, and assume that amount of demand goods and by-products by constructing every part is proportional to the length of each structure. Demand goods correspond to general goods and recycled goods as noted in the previous section and amount of by-products correspond to the demand of collection service of them.

Procedure of estimation is as shown in figure 2. Define $\mathbf{l}$ as a vector of a road structure consisting of the length of each part and $\mathbf{S}$ the amount of demand per 1 km of each part, in other words, amount of general goods, recycle goods and by-products per unit. Then we have the total demand in terms of goods or service, where,

$$
\begin{pmatrix} \underline{f_v} \\ \underline{f_r} \\ \underline{f_z} \end{pmatrix} = \begin{pmatrix} S_v \\ S_r \\ S_z \end{pmatrix} l \tag{19}
$$

The total demand with the unit of amount is multiplied by price vector $\mathbf{p}$. Then we have the total demand with the unit of price, where,

$$\begin{pmatrix} f_v \\ f_r \\ f_z \end{pmatrix} = \begin{pmatrix} \hat{p}_v \underline{f_v} \\ \hat{p}_r \underline{f_r} \\ \hat{p}_z \underline{f_z} \end{pmatrix} = \begin{pmatrix} \hat{p}_v S_v \\ \hat{p}_r S_r \\ \hat{p}_z S_z \end{pmatrix} 1 \tag{20}$$

Substituting this into the equation (16), we have influenced total output by a disposal activity, $\mathbf{q}_w$.

$$q_w = \left(I - \begin{pmatrix} H_v & H_r & H_z \end{pmatrix} \begin{pmatrix} B_{vw} \\ B_{rw} \\ B_{rw} \end{pmatrix} D_{ww} \right)^{-1} \begin{pmatrix} H_v & H_r & H_z \end{pmatrix} \begin{pmatrix} \hat{p}_v S_v \\ \hat{p}_r S_r \\ \hat{p}_z S_z \end{pmatrix} 1 \tag{21}$$

The influenced total output with the unit of price is multiplied by the inverse of price vector $\mathbf{p}^{-1}$. Then we have the influenced total output with the unit of amount, in other words, total disposal wastes.

$$\underline{\mathbf{q}_w} = \hat{\mathbf{p}}_w^{-1} \left(\mathbf{I} - \begin{pmatrix} \mathbf{H}_v & \mathbf{H}_r & \mathbf{H}_z \end{pmatrix} \begin{pmatrix} \mathbf{B}_{vw} \\ \mathbf{B}_{rw} \\ \mathbf{B}_{rw} \end{pmatrix} \mathbf{D}_{ww} \right)^{-1} \begin{pmatrix} \mathbf{H}_v & \mathbf{H}_r & \mathbf{H}_z \end{pmatrix} \begin{pmatrix} \hat{\mathbf{p}}_v \mathbf{S}_v \\ \hat{\mathbf{p}}_r \mathbf{S}_r \\ \hat{\mathbf{p}}_z \mathbf{S}_z \end{pmatrix} \mathbf{1} \tag{22}$$

This is the amount of disposal wastes before disposal activities take place. The final amount of disposal wastes is reduced by disposal activity. Multiplying $\underline{\mathbf{q}_w}$ and a reduction vector, $\hat{\mathbf{W}}$, together, we have,

$$\underline{\mathbf{q}_{wend}} = \hat{\mathbf{w}} \hat{\mathbf{p}}_w^{-1} \left(\mathbf{I} - \begin{pmatrix} \mathbf{H}_v & \mathbf{H}_r & \mathbf{H}_z \end{pmatrix} \begin{pmatrix} \mathbf{B}_{vw} \\ \mathbf{B}_{rw} \\ \mathbf{B}_{rw} \end{pmatrix} \mathbf{D}_{ww} \right)^{-1} \begin{pmatrix} \mathbf{H}_v & \mathbf{H}_r & \mathbf{H}_z \end{pmatrix} \begin{pmatrix} \hat{\mathbf{p}}_v \mathbf{S}_v \\ \hat{\mathbf{p}}_r \mathbf{S}_r \\ \hat{\mathbf{p}}_z \mathbf{S}_z \end{pmatrix} \mathbf{1} \tag{23}$$

Figure 2 summarizes these steps of estimation. In model box in this figure, equation (16) is described as the most important equation. After that $\underline{\mathbf{q}_w}$ is transformed by price vector $\mathbf{p}$. Finally, a reduction vector is multiplied and the total influenced amount of disposal is obtained.

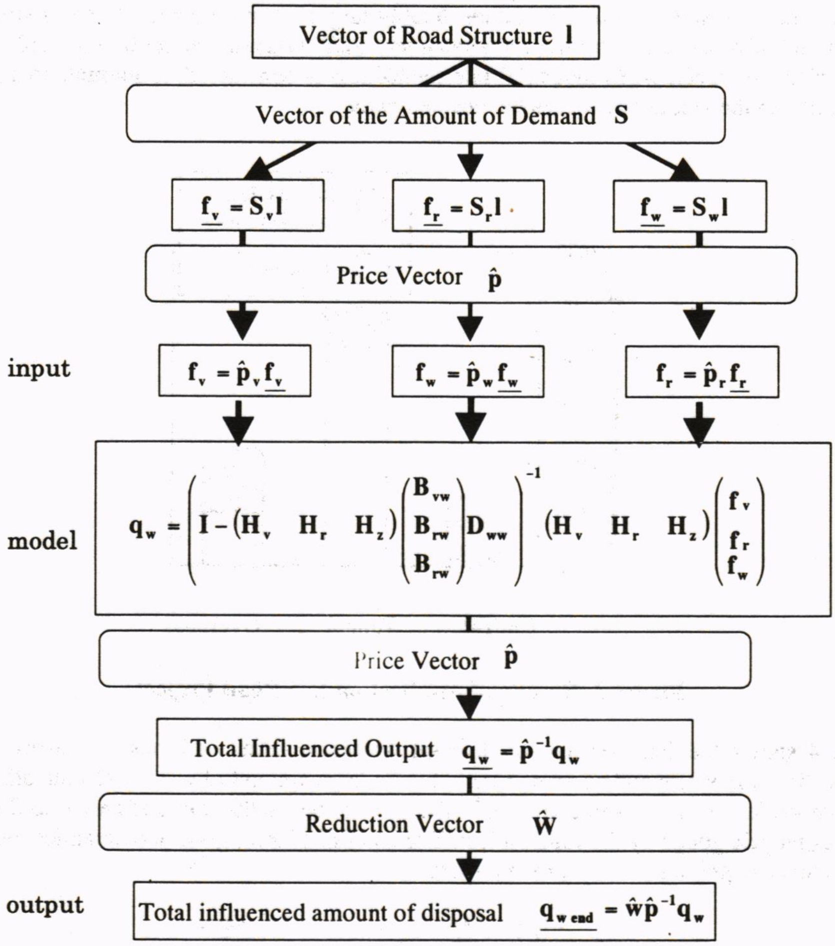

Figure 2. Estimation of Total Emission in terms of a Road Structure

4. APPLICATION OF THE MODEL

The model is applied to an actual project of a Japanese national highway. Since the project is carried out in Tohoku area where are many mountains and rivers, the highway route is including many elevated parts and tunnel parts. Structure of roads, therefore, should be considered very carefully. The model estimates the amount of emissions of the alternate plans of roads that differ in the lengths of elevated parts, cut/fill parts and tunnel parts.

The application is carried out using real data of amount of demand to every the unit of length in terms of road structures of an actual national highway project. Figure 3 shows the estimated value of the final amount of disposal wastes excluding sludge in terms of road structures. Ripple effect in the figure means emission estimated through the influence process. It is clear that the amount of emission, which we estimate only to a road project, is quite different from the one of emission, which we do through the influence process. This highlights the importance of considering all activities for the issue of emissions.

The amount of wastes by a tunnel is considerably larger when compared to other structures. The amount of wastes by a cut/fill part is relatively small when the effect in other industries is disregarded. However, when industrial interrelatedness is considered, it amounts to a volume comparable to the amount of wastes by elevated parts.

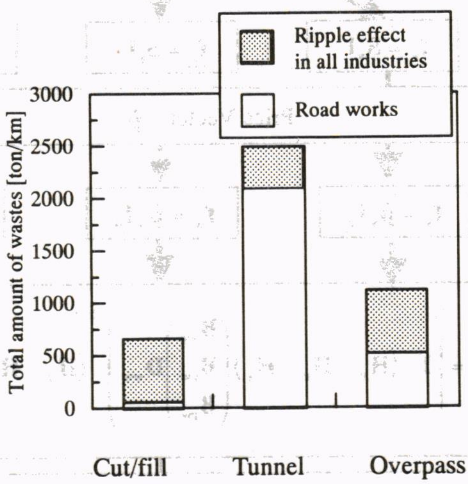

Figure 3. Results of Application to a Road Project

Figure 4 shows the final amount of disposal wastes in terms of kinds of wastes. Sludge, construction mix waste and concrete turn out to be large amount of wastes. On the other hand, negative values result for some kinds of wastes. This means that there is an induced demand effect as recycle goods by the road project. The amount of iron, glass and ceramics, which are easily recycled, are reduced by a road project.

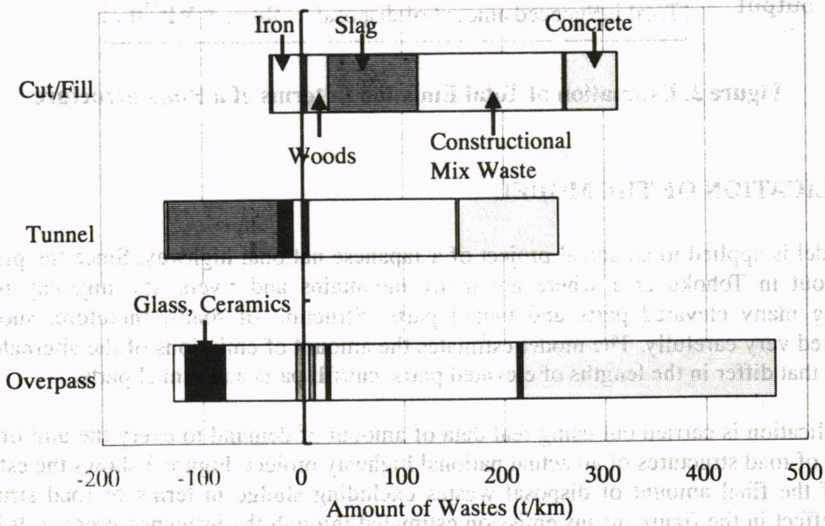

Figure 4. Result of Estimation in Terms of Kinds of Wastes

5. CONCLUDING REMARKS

From the analysis in this paper we were able to confirm that,

(1) The amount of emissions estimated in all the economic activities is considerably larger than the emissions directly estimated in a road project.
(2) Elevated roads do not necessarily generate more amounts of emissions than other types of roads from the perspective of economy as a whole, although they generate overwhelmingly larger amounts of emissions in the case that we consider only a road project. Therefore, the difference of quantity of emissions by road structures should be considered, when we select road structures.
(3) We confirm the ability to decrease emissions by using many recycle resources. On the other hand, if recycling is promoted only in a road project, the emissions including the influences to all the economic activities do not decrease substantially.

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