Environmental Impacts of the Road and Building Construction Industry in Japan

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ABSTRACT: Construction of infrastructure facilities such as buildings and roads are very useful for society. There are, however, externalities that we need to consider in the construction of these facilities. The environmental evaluation of the construction system is studied in this paper. It focuses on the assessment of the environmental impacts of the road and building construction industry in Japan. Moreover, the Input-Output Approach is used to analyze the impacts of road and building construction to the environment. Results show that significant amounts of nitrogen oxide, sulfur dioxide and carbon dioxide pollutants are emitted from construction alone. Compared to road construction, the building construction industry spewed off lower pollutant emissions. With the detrimental effects of pollutants to urban areas, tradeoffs are necessary to balance the amount of emissions and construction of new facilities.

INTRODUCTION

The effects of environmental pollutants such as carbon dioxide (CO_2), nitrogen oxides (NOx) and sulfur oxides (SOx) are known to be detrimental to human, health, nature and to the air. It is, therefore, important to appraise the environmental loads of these pollutants brought about by the manufacture of a product, process and of systems. Life cycle assessment is a method for analyzing and evaluating environmental performance of products, processes or services throughout its entire life cycle. Currently, there are several approaches in performing LCA, one is the conventional method and the other is the economic input-output approach (EIO-LCA). The similarities and differences of the two methods are shown in Gerilla and Inamura, 1999. The Input-Output (I-O) Approach is used to analyze the impacts of road and building construction to the environment. The input-output (I-O) model is a quantitative framework within which one can describe and explain the economic significance of the operations of a particular activity in relation to all other activities in the system. It is usually used to explain the interrelationships among various sectors of an economic system (Leontief, 1986). The input-output model has been directly applied to the environmental LCA and the result is the economic input-output life cycle assessment (EIO-LCA) (Horvath and Hendrickson, 1998). It makes use of input-output tables as data requirement in analyzing the environmental effects of a particular product or service.

The study seeks to evaluate the environmental burdens created by the building and road construction industries in Japan. The study also compares the environmental impacts and energy consumption between the building construction and road construction. In the following section, the I-O framework used in the study is explained further.

The empirical application of Japan's input-output tables is shown in the next section. A set of conclusions completes the paper.

METHODOLOGY

The supply chain of any construction process is depicted in Figure 1. The life cycle model starts from mining of raw material, processing, usage of end user and final disposal. The system boundary of the study is from the mining of raw materials until the usage of the raw materials. The model here will not calculate the emissions from the use of the building or road and its final disposal.

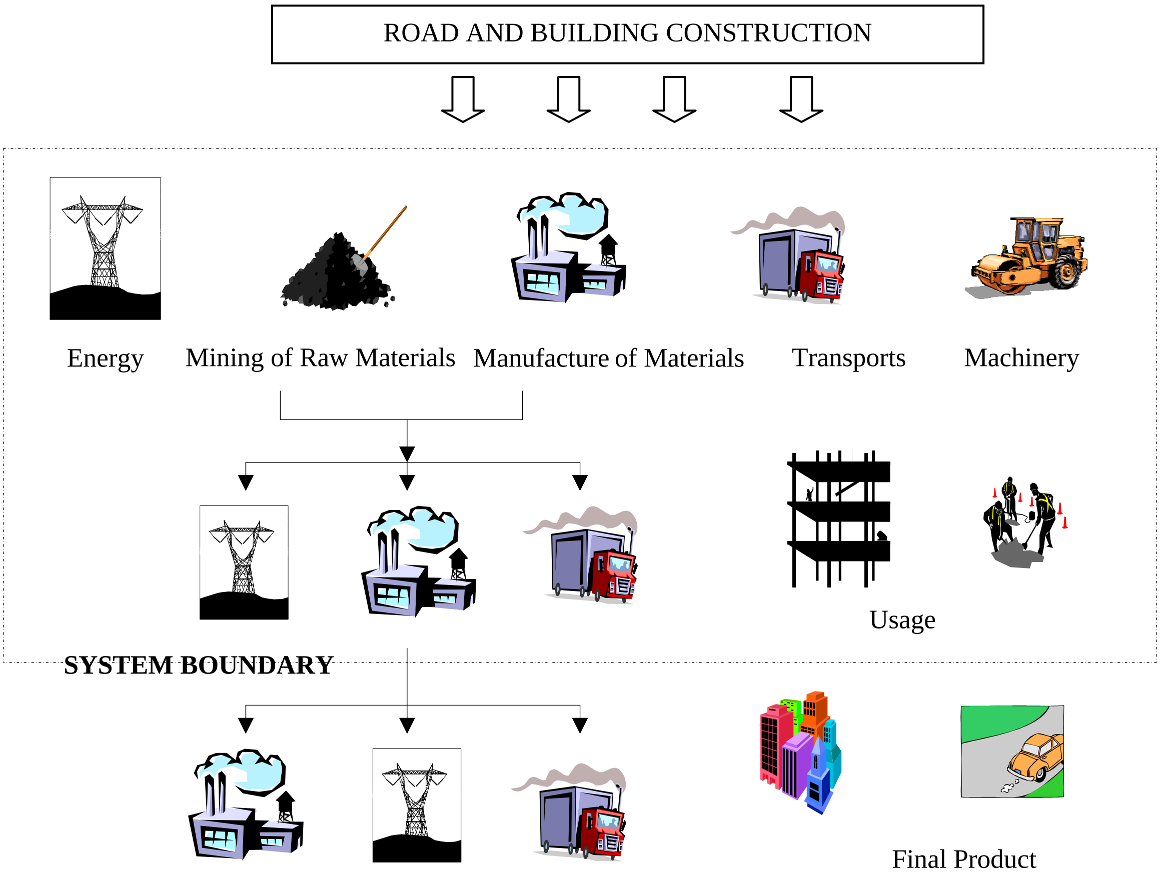

Figure 1. The Model of the Construction Process

Interactions of the industries in the economy are very crucial in the use of the I-O method. Direct and indirect effects in the economy as incorporated in the model are important in getting the amount of pollutant emissions. The amounts of various pollutants produced by an industry may be considered proportional to the primary output of that industry. A very straightforward approach to accounting for pollution generation associated with inter-industry activity is to first assume a matrix of pollution output or direct impact coefficients, $v = [v_{kj}]$. Each element of the vector is the amount of pollutant type k generated per dollar's worth of industry j's output (Miller and Blair, 1985). The level of pollution associated with a given vector of total outputs can be expressed as:

$$\mathbf{v^* = v\ X} \qquad \textbf{[1]}$$

where:

v* = the total emission vector of the environmental pollutant;
v = the vector of emission coefficient of the environmental pollutant (kg/'000yen);
X = total vector of output changes in industry.

Hence, by adding the traditional Leontief model, we can compute v* as a function of final demand, that is, the total pollution of each type generated by the economy directly and indirectly in supporting that final demand:

$$\mathbf{v^* = [v\,(I - A_{ij})^{-1}\,Y]} \qquad [2]$$

where:

A_{ij} = n x n technical coefficient matrix;

Y = n x 1 matrix of final demand;

I = n x n identity matrix.

The 1990 Input-Output Tables with a total of 405 by 405-economic sectors in Japan were used for the analysis.

RESULTS AND DISCUSSION

The pollutants in the air affect nature and humans all over whether it is global, regional or local. In urban areas and rural areas, industrial facilities and mines are located which contribute to the large volume of air pollutants. Three major pollutants to cities are discussed in the paper, namely: carbon dioxide, nitrogen oxides and sulfur oxides. Carbon dioxide, a global pollutant is a major contributor to global warming. Sulfur dioxide, SO_2 and nitrogen oxides are two of the pollutants, which cause acidification when mixed with water in the air. Acid rain is one effect of acidification, which causes plants to wither and buildings to be corroded. Nitrogen oxides (NOx) causes eutrophication, which causes the nutrients of the soil to be depleted, thereby decrease agricultural productivity. NOx when inhaled affects the respiratory system and it increases susceptibility to infections among others, SOx, likewise affects the lungs. The serious effects of these pollutants have led to the study of their amount and their causes in the construction industry.

The volume of the three pollutants discussed in this section is based on the material movement and economic movement in the construction industry. The scenario of the pollutants in the building construction and road construction industries in Japan is shown in the following sections.

Environmental Impacts from Building Construction `

The building construction industry in Japan is very robust. With the growing construction industry, environmental burdens are not far behind because of the use of resources and the emission of pollutants, which affect society in general. Building construction as used here are the construction of wooden and non-wooden houses and wooden and non-wooden non-residential construction.

The highest CO_2 inducing sectors relevant for the building construction industry are crude petroleum, coal products, and hot rolled steel, petroleum refinery products, cement and metal products for construction.

Similarly, it is interesting to note that the iron and steel industry, cement and concrete product industry, transport services as well as the petroleum industry are the highest contributors of NOx emission in building construction. Moreover, sulfur oxides generated in the building construction industry are mainly due to the iron and steel industry, aluminum industry, transport services, petroleum and power generation industry. Industries that are directly involved in contributing the noxious emissions to air are mainly the steel and aluminum industries.

The industries, which use up so much energy in the building construction industry, are the ready mixed concrete industry, transport services, iron and steel industry and petroleum industry. For the direct and indirect sectors involved in energy consumption, it can be seen that crude petroleum, which is a non-renewable resource, is the most resource used in the building construction industry. But for direct energy consumption, metals for construction use up much energy, followed by the ready mixed concrete industry.

Table 1 shows the total sector coefficients for building construction. The emission and energy coefficients are expressed in units per 1000 yen of output of the building industry. Total discharges or energy consumption can be calculated by multiplying the output of the industry in this case the building construction industry by the pollutant or energy coefficient. The coefficients mean that for every 1000 yen of construction, the amount of pollutant is emitted or the amount of energy is consumed. The table also shows the amount of pollution and energy consumed for a 100 million-construction cost for a building. It shows that nitrogen oxide emissions are more than 3 billion grams with a 100 million building construction project.

Table 1. Pollution Emission and Energy Consumption for Japan's Building Construction Industry

	Total sector coefficient (units/'000 yen)	Average Discharge per total sector output	Average Discharge per 100 M output
Sulfur Dioxide [g]	19.52	1.027E+12	1.95B
Carbon Dioxide [kg]	12.67	6.62E+11	1.27B
Nitrogen Oxide [g]	32.10	1.68E+12	3.21B
Energy Consumption, [MJ]	288.78	1.514E+13	28.88B

Environmental Impacts from Road Construction

The basic I-O table aggregates the road construction work into one sector, therefore it is a bit difficult to get the final demand of road construction work by sector. Moreover, the road construction industry is divided into several categories namely: earthworks, pavement work, bridge works and other works involved in the road construction. The supply chain of direct and indirect inputs is the commodity inputs into the road construction sectors. The inputs are shown in million yen of purchases. Based on the amount of purchases in the supply chain, the input coefficient for final demand was calculated by dividing the purchases by the total domestic production or gross outputs as shown in the equation 3 (Piantanakulchai, 1999).

$$c_{ij} = \frac{C_{ij}}{\sum_i C_{ij}} \qquad \textbf{[3]}$$

where:

c_{ij} = input coefficient from sector i for the construction sector j
C_{ij} = cost of input from sector i to the construction sector j

These input coefficients could be multiplied to the cost of construction to get the final demand of the particular sector.

The four components of road construction in general are earthworks, bridge works, pavement works, and other works. Other works include construction of guideposts, traffic signs and markings, etc. Tables 2-5 show the total and direct coefficients for each type of category.

These coefficients elucidate the effect of 1 unit of production on the three pollutants for each economic activity.

Table 2. Total and direct emission and energy coefficient for the earthworks

	Total sector coefficient	Direct sector coefficient
Sulfur Dioxide [g/'000 yen]	19.07	10.23
Carbon Dioxide [kg/'000 yen]	16.11	8.19
Nitrogen Oxide [g/'000 yen]	37.25	23.93
Energy Consumption, [MJ/'000 yen]	214.32	104.47

Table 3. Total and direct emission and energy coefficient for the pavement works

	Total sector coefficient	Direct sector coefficient
Sulfur Dioxide [g/'000 yen]	22.55	11.22
Carbon Dioxide [kg/'000 yen]	20.37	9.34
Nitrogen Oxide [g/'000 yen]	43.10	27.04
Energy Consumption, [MJ/'000 yen]	282.01	128.41

Table 4. Total and direct emission and energy coefficient for the bridge works

	Total sector coefficient	Direct sector coefficient
Sulfur Dioxide [g/'000 yen]	24.53	10.91
Carbon Dioxide [kg/'000 yen]	17.23	9.03
Nitrogen Oxide [g/'000 yen]	44.74	25.52
Energy Consumption, [MJ/'000 yen]	217.70	107.70

Table 5. Total and direct emission and energy coefficient for the other works

	Total sector coefficient	Direct sector coefficient
Sulfur Dioxide [g/'000 yen]	21.27	10.43
Carbon Dioxide [kg/'000 yen]	16.20	8.20
Nitrogen Oxide [g/'000 yen]	38.25	22.42
Energy Consumption, [MJ/'000 yen]	216.50	106.48

It can be seen from the tables above that the total sector is almost twice that of direct sector coefficient. It shows that the embedded emissions from other industries not directly related to the 4 categories are also a huge amount thereby, indirect effects can not be ignored. The values in Tables 2-5 when multiplied with the construction component cost of a road facility then the eventual outcome will be the total discharge for the environmental pollutants together with the energy consumption for constructing the road facility.

The reduction of nitrogen oxides is very important especially in urban areas where the concentration of this pollutant is high. Sulfur oxide emissions were highest for bridge works, which is mainly caused by transport activities, and heavy use of steel. A huge amount of carbon dioxide pollutants are emitted as well for road and building construction therefore, it is also important to focus on this pollutant for it contributes to the phenomena called global warming.

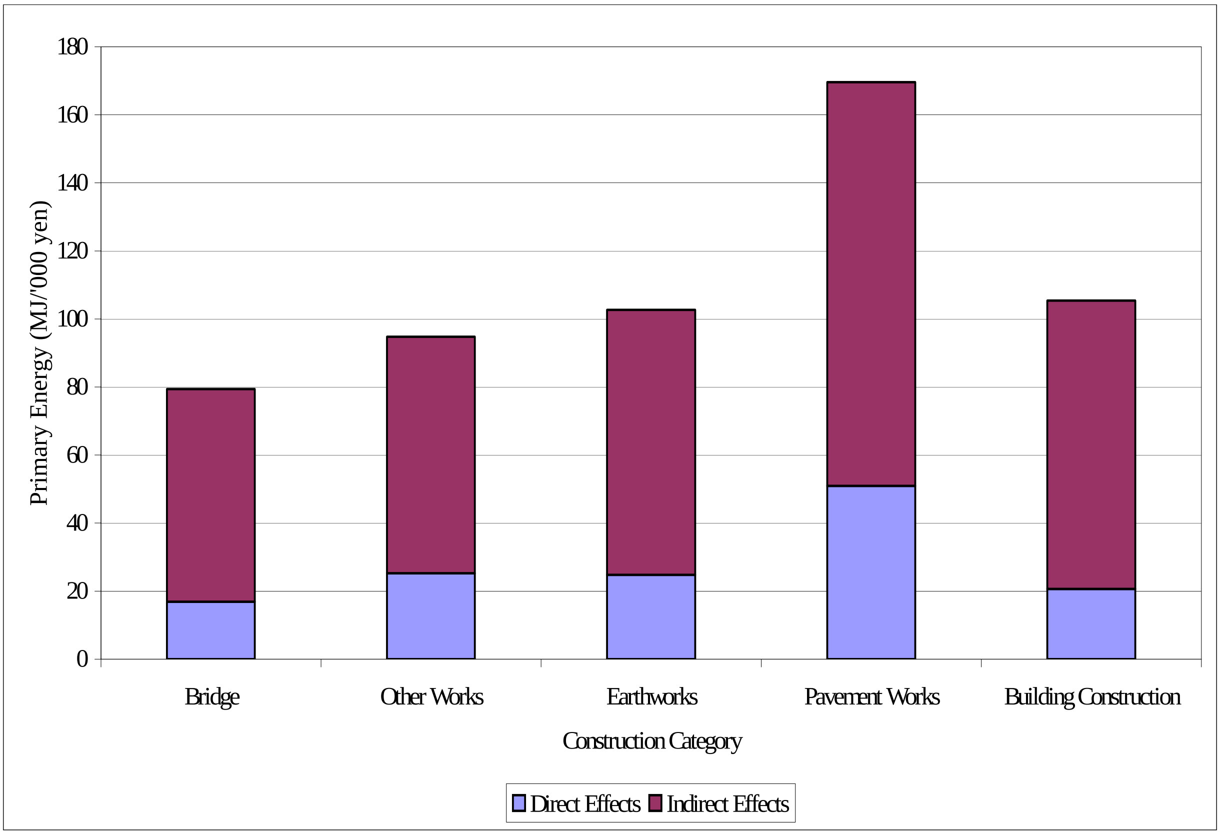

Figure 2. Primary Energy used for different construction types

Figure 2 shows the primary energy intensity for different construction types. The primary energy as defined in this report is composed of coal, natural gas, crude oil, petroleum refined products, and gas supply. It is interesting to note that pavement works use more primary energy compared to building construction. It may be due to the initial processing of raw materials in pavement works, as in asphalt production, which require higher amounts of primary energy. Since pavement works require more primary energy, carbon dioxide emissions for this particular component is the highest among other components.

A great dependence on primary energy sources which are non-renewable are not a very efficient and environment friendly way to build road facilities. It is best to find new sources of energy for usage in the construction industry. New types of materials as well can be developed to lessen the dependence on raw materials, which use up a huge amount of energy.

CONCLUSIONS

Construction of a building or road is a system in itself, which if the conventional life cycle inventory were used would require tremendous amounts of data. The methodology used in this research, the Environmental Input-Output- Life Cycle Assessment (EIO-LCA), is very appropriate to calculate environmental loads for complex systems. The methodology used here is a fresh and easy way to analyze environmental burdens of infrastructure facilities because the amount of data needed is very much available through statistics. Aside from easy data collection methods, the methodology is also reproducible because of the model used. The supply chain of system can also be traced. With the emission coefficients for the three types of pollutants already calculated, by simply knowing the projected construction cost of a particular project the environmental loads for future construction projects could be assessed.

The results show that carbon dioxide and sulfur dioxide emissions in Japan are mainly due to the manufacture and use of petroleum refinery products, crude petroleum and coal products. Moreover, nitrogen oxide emissions are due to transportation services, steel production and manufacture and use of petroleum and coal products. Looking into the building construction industry, the carbon dioxide emissions mainly come from the use and production of coal products, steel and metal products and cement. Nitrogen and sulfur oxide emissions, on the other hand, are due to the use of transport services, the use and manufacture of steel, steel and concrete products. Road construction, on the average, emits more pollutants as compared to building construction. It is mainly due to the excessive consumption of primary energy. The movements in the economy as a result of the production processes of industries cause the pollutant emissions. The impact to the environment are not only due to the direct effect of the particular manufacturing plant of a particular product or material but indirect contributions of other industries affect the pollutant emissions. The indirect pollutant effects constitute almost half of the total environmental load of a particular pollutant. This just shows the relationship of the movements in the economy to the amount of pollutants released.

Construction of infrastructure facilities such as buildings and roads are very useful for society. The proliferation of these structures mean progress to any city as it increases the quality of life of the person as well as enhances the economy of a city or nation. There are, however, externalities that we need to consider and can not be ignored because of the magnitude of the amount of pollutants emitted. Tradeoffs are, therefore, necessary to balance the pollutant emissions and construction of new facilities. The significant amount of emissions to air and the dependence on primary energy sources should be restrained. One way might be recycling of some industrial wastes for use as materials in the construction industry. Another way is the reduction of the dependence in the primary energy sources and find other sources of energy.

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