Sustainability Indicators based on Material and Waste Flow Analysis

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ABSTRACT

This study analyzed the mass-flow of material and waste (total of the industrial and municipal) in individual industrial regions to evaluate a material flow model encompassing the larger industrial area. The regions included 40 Japanese prefectures in 1994. We used the emission rate of total or industrial waste as an environmental loading item, in order to create an index capable of evaluating regional sustainability. Generation of industrial waste was also compared in each industrial category. The relationships between total waste volume and the total material input of the objected prefectures imply that total waste corresponds to nearly 10% of the total material input generated in every prefecture.

INTRODUCTION

In order to develop a sustainable society, an index that relates the understanding of the present state of urban metabolism to social activity is required. There is research which investigates the amount of material required based on social activity, such as material flow accounting [1] as well as the macroscopic analysis of specific categories of material distributed among industries in Japan. Our study compares the flow of material and waste (total of the industrial and municipal) in Japanese prefectures (40 of 47, selected by the waste data availability) by analyzing material flow on a comparatively smaller scale. Some sustainable indicators are extracted from the following equation.

$$waste = \frac{waste}{flow} \times \frac{flow}{GDP} \times GDP$$

in which, *waste*: total waste emission
flow: total material input or total material flow
GDP: gross domestic product (economic value)

This is a kind of identity of the material and waste flow in regional economic system. Waste reduction with economic growth (increasing GDP) should need a remarkable reduction of "*waste*/*flow*" and "*flow*/*GDP*" as advanced sustainable indicators.

DATA AND METHODS

Based on the national physical distribution census (NPD)[2], we calculated the mass of materials transported inside the prefecture. Some NPD features are: data handled in NPD is net transport data, it is suitable for the study of materials of interest, and it represents the cargo flow

at the shipping site (since it is investigated at the shipping site). Also, data on industrial waste is based on technical reports [3] of the industrial waste in each prefecture; these technical reports are for management decision making on the future of the industry. In investigating material flow, the research on mass balance by Morita *et. al.* [4] was a necessary reference. We did not consider export or import volumes in this study.

RESULTS AND DISCUSSION

The relationships between waste volume (total emission of the industrial and municipal waste) and the TMI (total material input) of the 40 prefectures in Japan are shown in Figure 1. The gradient of the regression line in Figure 1 is nearly 0.1 or 9%. This regression line implies that total waste corresponds to 9% of the TMI thrown in every prefecture. Noteworthy are the generation ratios of waste to TMI in some prefectures, which are higher than those of other prefectures are. On the other hand, the hybrid ratio of waste to TMI is smaller in some other specified prefectures than in other prefectures.

The relationships between waste volume and the GDP (gross domestic product in each prefecture) of the 40 prefectures in Japan are shown in Figure 2. The gradient of the regression line in Figure 2 implies that total waste corresponds to 1g of the 1YEN of GDP generated in every prefecture. Noteworthy are the difference between 0.2g/YEN and more than 4g/YEN for the "*waste*/*GDP*" in 40 prefectures. The relationships between TMI and GDP of the 40 prefectures in Japan are shown in Figure 3. Noteworthy are the difference between 3g/YEN and more than 43g/YEN for the "*flow*/*GDP*" in 40 prefectures.

Such variations of all three ratios may represent various environmental efficiencies related to many types of regional and industrial characteristics. The relationships between the ratio of municipal waste emission to GDP "*municipal waste*/*GDP*" and the ratio of service or commercial workers to the total workers of the 40 prefectures in Japan are shown in Figure 4. Activity of the service or

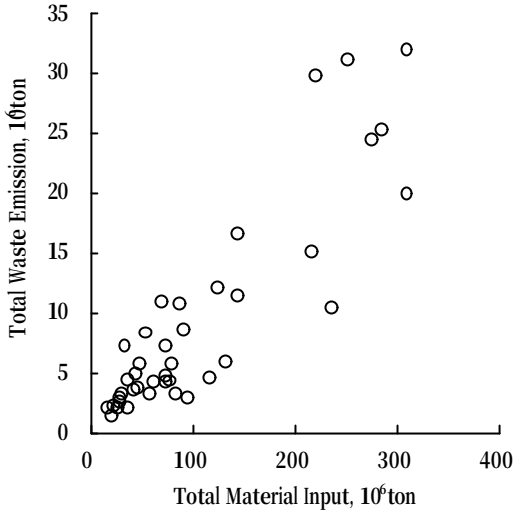

Figure 1 Relationships between waste volume (total emission of the industrial and municipal waste) and the TMI (total material input) of the 40 prefectures in Japan

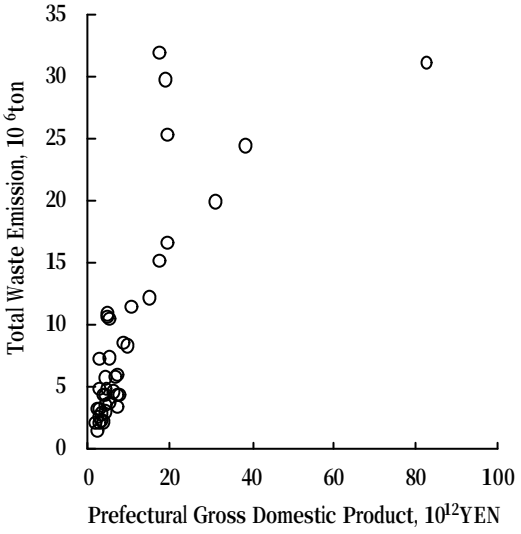

Figure 2 Relationships between waste volume (total emission of the industrial and municipal waste) and the GDP (gross domestic product in each prefecture) of the 40 prefectures in Japan

commercial industries should promote high ratios of municipal waste emission to regional economy. In this way, simple ratios mentioned above could be utilized as sustainable indicators that evaluate environmental efficiencies of several regions or industrial sectors.

NEXT STEPS

In this study, the volume of waste (industrial and municipal waste emission) was considered a principal environmental loading item. In the future, it will be necessary to evaluate overall waste flows taking into consideration the weight and volume reduction of waste, resource recycling and disposal volume, as well as generation of waste. Import and export volumes and water resources must also be incorporated into the total material balance. Furthermore, it is essential to consider waste that is transferred to other prefectures. This can be done by analyzing material and waste interactions between multiple prefectures.

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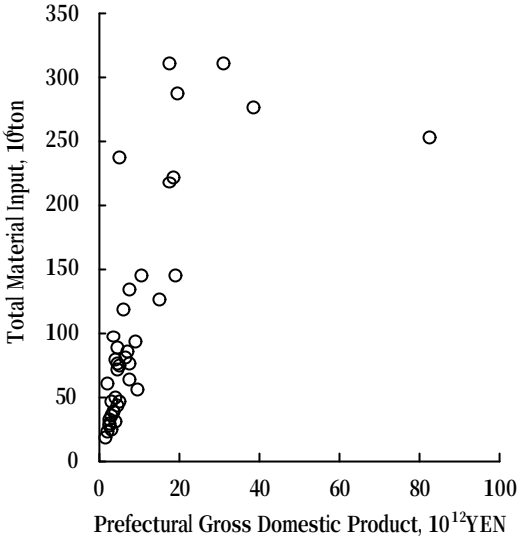

Figure 3 Relationships between TMI (total material input) and the GDP (gross domestic product in each prefecture) of the 40 prefectures in Japan

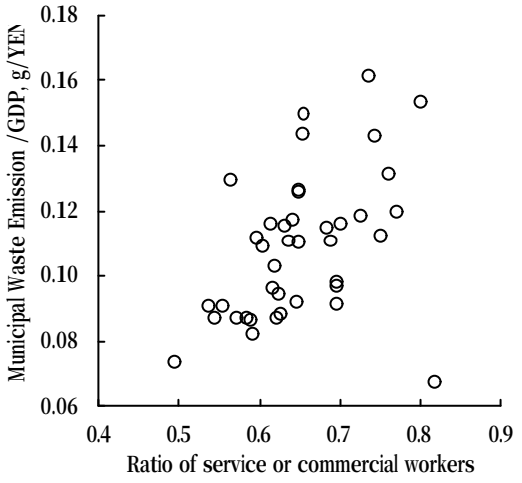

Figure 4 Relationships between the ratio of municipal waste emission to GDP "municipal waste/GDP" and the ratio of service or commercial workers to the total workers of the 40 prefectures in Japan

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