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Comparing Gross and Net Additions to Material Stock for Roadways in Japan

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ABSTRACT

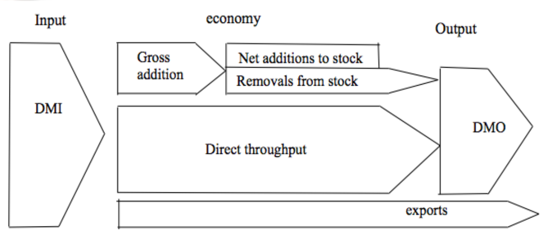
The overall material stock of the Japanese economy is growing. Large portion of the stock is invested in construction materials such as asphalt, cement, sand and gravel, crushed stone, and other aggregates. The transport sector, particularly roadways, accounts for a large proportion of the construction material stock. This paper evaulates the Gross Additions to Stock (GAS) and Net Additions to Stock (NAS) in Japan's roadways using novel measures derived directly from stock. Consistent with previous studies, Economy-Wide Material Flow Accounting (EW-MFA) is used as the conceptual framework. Annual GAS is estimated from data on the improvement, maintenance and new extension of roads and pavements, excluding highways. NAS is alternatively estimated on a five year average using total stock. Calculations show that in 2005, GAS for roadways in Japan is 61m tons, while NAS was approximately half of this amount (33m tons). The results of this paper show that while annual GAS and NAS have reduced, total roadway stock has increased over the study period from 754 million tons to 2 billion tons (1970-2005). The implications of these results and the use of GAS and NAS as indicators of sustainability are discussed.

Keywords **–** Gross additions to stock, material stock; net additions to stock; sustainable material society; Economy-Wide Material Flow Accounting (EW-MFA).

1. INTRODUCTION

Resources that used for development are never endless. Material flow society does have a variety of benefits. However, too much movement of materials and correlated energy consumption has also caused giant influences on the nature. Therefore, it is necessary for us to transfer our society from a material flow based society to a stock based one by utilizing the infrastructures in an efficient and effective way. There is no direct and concrete solution for every country to measure the effectiveness and efficiency of material usages in infrastructure and so, it needs some possible findings for relations and dependencies of material stock and flows to convey ways for each country to lead to a sustainable society. Infrastructure is recognized as a crucial input for economic development but defining it can be difficult. The Merriam-Webster dictionary (11th Edition) defines the infrastructure as the underlying foundation or basic framework (as of a system or organization), the system of public works of a country, state or region and also the resources (as building or equipment) required for an activity. The term infrastructure typically refers to the technical structures that support a society, such as roads, water supply, sewers, electrical grids, telecommunications, and so forth, and can be defined as the physical components of interrelated systems providing commodities and services essential to enable, sustain, or enhance societal living conditions. Among the infrastructures, this study will focus on roadways excluding highway in relation to their Gross Additions to Stock (GAS) and Net Additions to Stock (NAS). The study considers all the 47 prefectures in Japan over the period 1970 to 2005. GAS and NAS are indicators based on Economy Wide Material Flow Accounting (EW-MFA). EWMFA is a framework system which can be used to calculate and provides an important database with which to calculate a variety of indicators for Gross additions to stock mean the additional stock in every year to compensate the stock loss of the previous year and to support the demand of the present year. Decommissioned materials, if not recycled, are accounted for in "domestic processed output" (DPO).

Figure 1. Position of GAS and NAS indicator in EW-MFA [1]



Net additions to stock are therefore determined by balancing additions to stock and stock depletion. NAS measures the 'physical growth of the economy', i.e. the quantity (weight) of new construction materials used in buildings and other infrastructure and of materials incorporated into new durable goods such as cars, industrial machinery, and household appliances [2]. Figure 1 describes position of GAS and NAS in the EW-MFA where DMI is Direct Material Input and DMO stands for Direct Material Output. The national data available in Japan allows us to estimate GAS and NAS for Japan's road network for the first time. Two additional features make this analysis distinct:

- This study develops of an alternative method for NAS calculation.
- This study makes a clear distinction between NAS and GAS (gross additions to stock/ real additions to stock) in an economy.

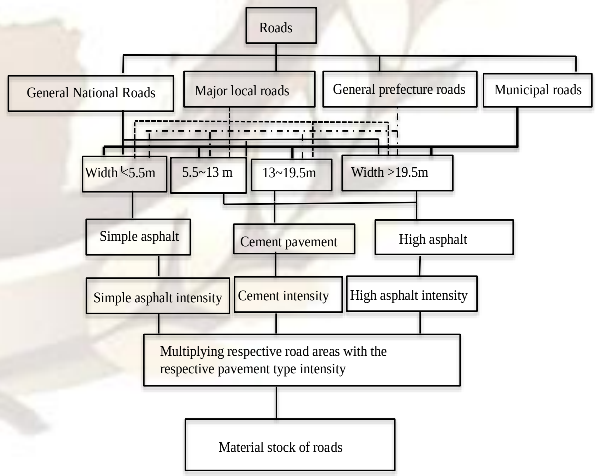
NAS and total stock can be used for estimating future waste flows, as all infrastructure and products we will use become wastes at some time in the future [3]. Although there are two general types for calculation of NAS: direct method and indirect one, in this research, we tried to calculate NAS by alternative method which will be discussed in methodology part. All methods for calculation of NAS are proxy measures for built-up area, because stocks also occupy some space. As the area of the Earth is finite, the cessation in growth of NAS can be perceived as a pre-requisite for long-term sustainability [4]. Since NAS is the quantity of materials put annually into buildings and other infrastructure and materials contained in new durable goods, a sustainable economy would be characterized by zero NAS, i.e. flow equilibrium between inputs and outputs of the material flow balance. As negative loads to environment due to huge material consumption become a more concerning factor, it is critical time to think about effective and efficient usage of existing infrastructure (the minimum required amount of physical infrastructure) with the usage of less amount of materials from natural resources but producing more economic outcomes based on existing infrastructure to a certain extent. It is a point to ponder for a country that aims to a sustainable society. Japan has already calculated GAS and NAS for overall infrastructure by using indirect method but still it misses accuracy and those indicators for specific types of infrastructure. This research tried to fill this gap by finding NAS based on each specific infrastructure's stock used as alternative method. In other words, we are trying to penetrate directly on each infrastructure stock to know its NAS with the aid of statistical data availability in Japan. All methods for calculation of NAS are proxy measures for built-up area, because stocks also occupy some space. According to the Ministry of Environment, Japan, White paper 2011 [5], increase of net addition to stock shows an approximately constant ratio of the amount of resources input. That is one reason of NAS for being taken as a good indicator for a country to show its total material flow and stock condition related to natural resources.

As another important indicator, we estimate materials added to the economy's stock each year (Gross additions to stock).Old materials are eradicated from stock as buildings are demolished and durable goods disposed of (removals). Thus, GAS means the additional stock in every year to compensate the stock loss of the previous year and also to support the demand of the present year. Concerning consumption, these data were rather sparse and unreliable currently, so that we directly tried to find GAS from amount of materials needed for new construction or maintenance of existing infrastructure. In all, this research tries to solve the following for each type of infrastructure:

- How much amount of materials added to the economy's stock each year i.e. GAS ?
- What is the balance amount between added materials and stock depletion i.e. NAS?
- How much is total amount of roadway stock ?

Figure 2.The flow chart for calculation of material stock of roads

2. BACKGROUND LITERATURE REVIEW



Previous studies tried to calculate NAS in indirect method which was applied in Economy-wide material flow accounts EW-MFA [6] shown as equation 1:

DMI means direct material inputs and DPO stands for direct processed output. According to this concept, experts calculated NAS for Austria, Germany, Japan, and the Netherland. To get NAS, from sum of annual flow of materials that enter the economy (direct material inputs) and air inputs (e.g. for oxidation process), sum of domestic processed output, water vapor and export needs to be subtracted. Only a few studies have calculated NAS

$$NAS = DMI - DPO - Exports \qquad (1)$$

directly by subtracting sum of material outputs of decommissioned building materials (as construction and demolition wastes), disposed durable goods and material recycled from gross additions to stock [6]. One more thing for US to use direct model to estimate outflows is lack of good industrial waste statistics. In general, there are two methods to calculate NAS as the following:

A.) Indirect method calculation: a simple difference between all input and output flows.

B.) Direct method: It involves

(i) measuring the amounts of material added to particular categories of physical stock and

(ii) the amount of waste flows from these stocks. Nevertheless, as an alternative method, this study tries to evaluate NAS directly from stock. Moreover, GAS will be also directly calculated from all new construction part and maintenance part of roads and pavements which will be later deliberated in methodology part.

3. METHODOLOGY

There are two steps included in methodology part: calculation of total material stock for roadways, and evaluating GAS and NAS of roads. As the pioneer step of this research, in evaluating GAS and NAS part, we could only focus on roads excluding high ways for which important data for calculation are still missing. Future research of evaluating GAS and NAS will take many types of infrastructure in the country including highways, railways, buildings, etc. into consideration.

3.1 Evaluating material stock of roads

Figure 2 shows flow chart for calculation of material stock of roads. Generally, the material stock of infrastructure can be estimated by using the following equation 2:

Where $MS_{i,j(t)}$ is the stock amount of material i stocked in structure j in year t, and $Aj(t)$ is the total amount of physical data for structure j in year t. $I_{i,j(t)}$ is intensity of material i in structure j in year t.

$$MS_t = \sum_i \sum_j (W_{i,j,w,t} \times L_{i,j,w,t} \times MI_{i,j,w,t}) \qquad (3)$$

Stock calculation for specific type of roadways categorized by width can be done by using the equation 3 above where:

$$MS_{i,j(t)} = A_{j(t)} \times I_{i,j(t)} \qquad (2)$$

MS_t = Material stock MS at year t (tons)

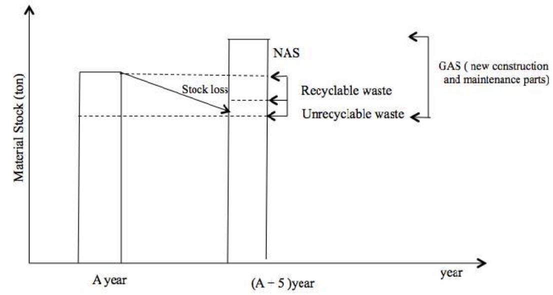
$W_{i,j,w,t}$ = Average width W of specific category w of categorized road type i of specific pavement type j at year t (km)

$L_{i,j,w,t}$ = Length of road L with specific road category w of categorized road type i of specific pavement j at year t (km)

$MI_{i,j,w,t}$ = Material intensity MI of specific width category w of categorized road type i of specific pavement type j at year t (ton/km^2)[7]

3.2 Calculation NAS and GAS for roads

Figure 3. Evaluating estimated GAS and NAS for specific type of infrastructure



As described above, generally, there are two methods to evaluate NAS which are indirect method and direct one. Indirect method for calculating NAS has some demerits such as much less accuracy, not recognizing the main material components of the stock changes, risk of double counting (e.g., waste which is incinerated, may be included under waste disposal, as well as under emissions to air), broad need of data and huge uncertainties due to inclusion of variety of factors. If direct method is applied, it needs to know the exact amount of wastes which could be recyclable and unrecyclable. Nevertheless, exact amount of recycle data is not easy to be calculated. Moreover recycling flows are not part of the material balance (they are neither counted as input nor outputs, except as part of imports or exports or the net additions to stock). Separate recording of recycling and the derivation of indicators (e.g. ratio of recycled materials to material inputs or outputs) may be interesting but it does also pose problems. First, data on material recycled within statistical units are not normally available. Second, the definition and measurement of recycling flows is difficult. Further work on recycling may be useful but it is not recommended making recycling amounts part of a standard set of economy wide MFA at present [8]. Due to above reasons, in our calculation, we tried to calculate NAS by using an alternative method which is mainly based on stock data. Figure 3 represents our understanding on evaluating NAS and GAS for every 5 year. According this understanding, annual average NAS could be evaluated by the following equation 4 where MS_A stands for total material stock at year A and MS_{A+5} is total material stock at year A + 5 :

$$Avg.Annual\ NAS = (MS_{A+5} - MS_A)/5 \qquad (4)$$

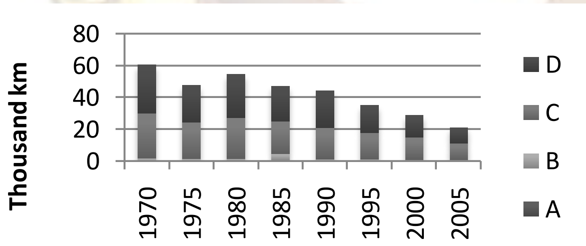
Demolished data of roads could not be found exactly and so, for this case, direct calculation for gross additions to stock is done by using historical data of extension of road and pavement repair from 1970 to 2005. In other words, GAS of roads was directly evaluated by calculation of all new construction parts and maintenance parts of roads and pavements. Although our study period is from 1970 to 2005, we try to evaluate GAS and NAS for every 5 year study period. The NAS in the figure 3 shows NAS value for 5-year study period. E.g. the shown NAS value at 1985 means the NAS between 1980 and 1985 and NAS at 1990 stands for NAS between 1985 and 1990, etc. Therefore, to get average annual result of NAS, 5-year NAS value has to be divided by 5.

In contrast, shown GAS in figure only represents the GAS at specific year. e.g., GAS shown at 1985 stands only for GAS at 1985. Since materials are added to the economy's stock every year denotes to GAS, in this research, GAS of roads was directly evaluated by calculation of material consumption for all new construction part and maintenance part of roads and pavements by using the following Eq. 5.

$$MI_{ia}(t) = C_a(t) \times \partial_{ia}(t) \qquad (5)$$

where $MI_{ia(t)}$ is the amount of material i which is input to infrastructure type a in year t, $C_a(t)$ is the amount of infrastructure type a in year t and $\partial_{ia}(t)$ is the input rate of material i per construction infrastructure type a in year t.

Figure 4. Length of roads categorized by its specific road width - A: width over 19.5 m, B: width between 13m and 19.5 m, C: width between 5.5 m and 13 m, D: width less than or equal 5.5m used for



GAS

Figure 5. Total material stock of categorized roadways (1970-2005)

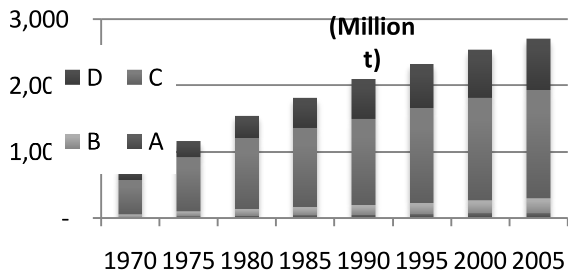


Figure 6. Cumulative GAS of categorized road types in million ton per year

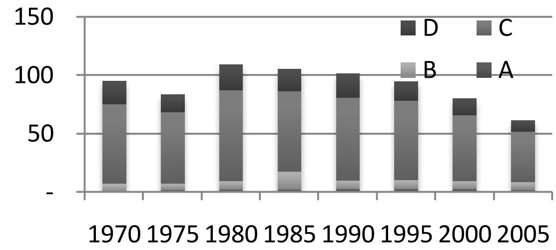


Figure 7. Comparison of GAS (amount of materials added to economy each year) and NAS (Average annual yearly change) for roads (excluding high ways) in Japan

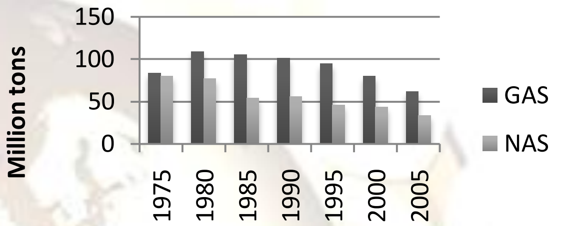
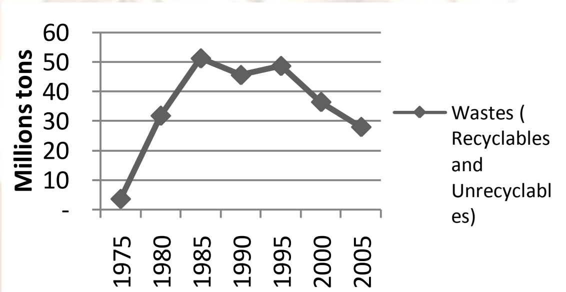


Figure 8. Amount of waste trend in Japan (Wastes: recyclables and unrecyclables)



We assume that calculation directly GAS by using maintenance and new construction parts is more common and more appropriate method. Firstly, depending on data availability, roads are categorized as general national roads, major local roads, general prefecture roads and municipal roads. After categorizing roads, respective GAS of improvement of roads, new pavement and pavement repairs were calculated by multiplying respective material intensities and their areas for respective years.

Figure 4 describes total length of new construction and maintenance of specific roads and pavements at respective years. Figure Before this research, there are no complete or partial statistical surveys using statistical calculation methods for new construction and maintenance parts of roads and pavements. So, for calculation of this part, we collected data from Annual Statistical yearbook of Roads from the Ministry of Transport from Japan manually [9]. Unfortunately, we identified apparently wrong typing errors in them and so, cross checks were done in handling data in order to get the most reliable results for the whole study period (1970-2005).

4. RESULTS AND DISCUSSION

4.1 Time series variation of infrastructure stock

Total material stock for the study period is presented in figure 5. It has been increasing- 754million tons in 1970 but over 2 billion tons but by capturing the national overall trend, variation of the growth rate of the infrastructure stock for the whole country was found in decreasing trend.

4.2 GAS and NAS for categorized roads

Figure 6 shows cumulative GAS of categorized road types with their specific construction types in million ton per year. E.g. the total GAS of categorized roads in 1970 was 94 million tons but in 2005, it was 61 million tons. Construction activities in Japan are decreasing and so reasonably, GAS of roads in Japan becomes less and less.

The values of NAS indicate that the disposal of waste will show a rising tendency in the study period and also that the pressures exerted on land (or, broadly, speaking, space) are growing or decreasing. This is most evident in the study period at 1975 and the least in the case at 2005. Comparison of GAS and NAS is shown in figure 7.

It is observed that GAS and NAS become less starting from 1980 while total stock has been increasing. In spite of increasing stock, stock growth rate decreased. These conditions are very attractive for anticipating a sustainable society. According to our results, we tried to analyze the background reasons for GAS condition: Economic conditions and recycling laws. Due to two oil crises (1973 and 1979) in the 1970s, construction investment turned sluggish and the share of construction investment in GNP decreased gradually. Although economic crisis happened in 1990, Japanese government did huge amount of investment in infrastructure at that time. Thanks to enforcement of recycling laws in Japan in 1995, total newly amount of material added to economy became less. Construction activities in Japan are decreasing and so reasonably, GAS in Japan becomes less and less. If we look on NAS as a good indicator related with natural resource usage, it is very impressive to see decreased NAS in Japan. Moreover, two factors could be concluded from NAS results: (i) It shows the rising tendency of disposal waste from demolished structures as shown in figure 8. (ii) A decrease in the national budget of civil engineering projects (e.g. roadway construction).

5. CONCLUSIONS

The study described in this article made available the NAS data for the roads in Japan expressing that calculation of NAS using an alternative method is possible in this country, with respect to data availability. Moreover, this study also emphasizes on evaluation of GAS or real additions to stock amount and shows it could not be the same in amount with NAS in practical way in a country. Not only for sole aim on this research, we think that evaluating of material stock of developed country like Japan is a very big start to think for developing countries and generally, we could imagine in mind that average stock of infrastructure stock condition in developed countries could be the peak material accumulation in developing countries in the future.

The future work will focus in detail on other types of infrastructure in Japan and will analyze more what NAS and GAS are good for and how they can be used in policies, planning, etc. to establish a sustainable material consumption society in Japan. Moreover, this research innovatively tried to capture material stock and flow together to convey some points to ponder for going towards a sustainable society because as examples, stock and flows look like rocks and water. In nature, the rocks shape the water in the short term, but in the long-term, it is the water that shapes the rocks. So, this research which focuses on both of material flow indicators and stock condition of one type of infrastructure to anticipate not only for short term but also for long term.

The ultimate goal of this research is to show a balance that is a state in which material flow inputs into the economy equal material output plus net additions to net changes in physical stocks of the all types of infrastructure such as telecommunication lines, homogenous group of stocks including roads, parking lots, and airports. The pending objective is elaboration and application of the same methodology applied in this research for developing countries not only in roads but also for other types of infrastructure.

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REFERENCES

[1] Economy-wide material flow accounts and derived indicators: A methodological guide. Luxembourg: Euorstat, 2001.

[2] Economy-wide material flow accounts and derived indicators: A methodological guide. Luxembourg: Euorstat, 2009.

[3] Bringezu, S., H. Schutz, and S. Moll. Rationale for and interpretation of economy-wide material flow analysis and derived indicators. *Journal of Industrial Ecology 7(2)*, 2003, 43–64.

[4] Bringezu, S. *Materializing policies for sustainable use and economy-wide management of re- sources: Biophysical perspectives, socio-economic options and a dual approach for the European Union* (Wuppertal Institute for Climate, Environment and Energy, 2006).

[5] White Paper on a Sound Material-Cycle Society 20011, Ministry of the Environment of Japan, Gyosei, Tokyo.

[6] Emily Matthews, et.al *The Weight of Nations (Material Outflows from Industrial Economies)* (World Resource Institute, Washington, DC, 2000).

[7] Nagaoka, K., Tanikawa, H., Yoshida, N., Higashi, O., Onishi, A., Feng, S., Imura, H.: Study of Accumulation/ Distribution tendency to the Material Stock of Construction Sector in All Prefectures and Mega cities in Japan, *Papers on Environmental Science, No.23,* 2009, 83-88.(in Japanese)

[8] Economy-wide material flow accounts and derived indicators: A methodological guide. Luxembourg: Euorstat, 2000.

[9] Annual Reports of Road and Railway Statistics in Japan, Ministry of Land, Infrastructure and Transport of Japan, 1975-2000.

[10] Bringezu, S., Schutz, H., Moll, S., Rationale for and interpretation of economy-wide materials flow analysisand derived indicators, *Journal of Industrial Ecology, 7(2),* 2003, 43–64.

[11] Adriaanse, A., Bringezu, S., Hammond, A., Moriguchi, Y., Rodenburg, E., Rogich, D., Schutz, H., *Resource Flows: The Material Basis of Industrial Economies* (World Resource Institute, Washington, DC, USA, 1997).

[12] Cherry Myo Lwin et.al., Study on the Correlation between Material stock of Roadways and Industrial Structure Change in Japan, *Proceedings of the Thirteenth International Summer Symposium,* JSCE, Vol. 13, 2011, 305-308.

[13] White Paper on a Sound Material-Cycle Society 2003, Ministry of the Environment of Japan, Gyosei, Tokyo.

[14] Hashimoto, S., Tanikawa, H., Moriguchi Y.: Where will large amount of materials accumulated within the economy go? – A material flow analysis of construction minerals for Japan, Paper on Science Direct, *Waste Management 27*, 2007, 1725-1738.

[15] Tanikawa, H., Hashimoto, S.: Urban stock over time: spatial material stock analysis using 4d-GIS, *Building research & Information, 37(5-6)*, 2009, 483-502.

Note: Reference 1 to 9 is main references and the rest are supporting idea ones.