EVALUATION OF MATERIAL ACCUMULATION OF INFRASTRUCTURES IN VIETNAM

ĐÁNH GIÁ LƯỢNG VẬT LIỆU XÂY DỰNG TÍCH LŨY TRONG HẠ TẦNG GIAO THÔNG VIỆT NAM

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Abstract - In the attempt to support the development of sustainable transport in Vietnam, this study investigates the material stocks of road and railroad network. A long-term preference for transport development (especially road and railroads network) has led to approximately 40% of Vietnam's annual consumption of construction materials to be for expanding and maintaining its network, causing stress on natural resources and the environment. Materials stocked in the railroad was stable while in road doubled from 2003 to 2012. We identified a co-dependency of physical infrastructure development and economic development. The outcomes of this research are intended to assist the future development strategies, particularly the Green Growth Strategy in Vietnam.

Key words - Material stock analysis; construction minerals; waste management; infrastructure

Tóm tắt - Với nỗ lực nhằm hướng tới sự phát triển giao thông vận tải bền vững, nghiên cứu này tập trung vào sự tiêu thụ và tích lũy vật liệu xây dựng trong mạng lưới đường bộ và đường sắt. Việc ưu tiên phát triển mạng lưới giao thông (đường bộ và đường sắt) trong thời gian dài đã dẫn đến khoảng 40% lượng tiêu thụ vật liệu xây dựng hàng năm của Việt Nam dành cho việc mở rộng và duy trì mạng lưới này, gây căng thẳng cho tài nguyên và môi trường. Vật liệu dự trữ trong mạng lưới đường bộ đã tăng gấp đôi từ năm 2003 đến năm 2012, và hầu như không thay đổi ở mạng lưới đường sắt. Kết quả nghiên cứu giúp các nhà quản lý hoạch định được các chính sách cho chiến lược phát triển Tăng trưởng Xanh của Việt Nam.

Từ khóa - Phân tích tích lũy vật liệu; vật liệu xây dựng; quản lý chất thải; cơ sở hạ tầng

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 to a stock based one by utilizing the infrastructures in an efficient and effective way. There is no direct and concrete solutions for a 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 a country to go to a sustainable society. This research tries to a make a parallel study of material flow and stock of roads and also uses some indicators.

As regards the outcomes of previous works related to material stocks, mainly they are materials quantities through historical periods, not much special attention paying on the socioeconomic driving factors as well as efficient utilization of those stocks. Of visible studies dealing with those challenges, Fishman et al. [1] have done for whole Japan while Huang et al. [2] only carried out for three big cities in China. Earlier additional research mention about those issues is Müller [3] with the dynamic stock model using the living space in square meters to be an indicator of effective service performance for building stocks in Netherland. The additional case of developing countries with early development patterns of such developed countries deserved considerations.

As above mention, data issue is recognized as a primary challenge for accounting material flows and stocks, entailing in various comprehensive approaches have been approved. In methodology perspective, top-down and bottom-up approaches are used more popularly to quality accumulation of materials. Besides, offering to analyze the dynamic change and distribution of material stocks effectively, some well spatial tools such as GIS and Remote Sensing are new members of stock measurements family [4]. By employing domestic data and using bottom-up method that tends to provide comprehensive results, this study takes Vietnam as a case study for nation-wide material stock accounts, aiming to add to body of knowledge of Vietnam about:

- The size and composition of material stock in roads and railroads, as well as the annual materials, are required for expansion and maintenance of the road network in Vietnam.

- The interaction between road stocks and socio-economic background in Vietnam.

2. Data and Methodology

2.1. Material Flow and Stock Accounts

This study is based on the Material Flow Analysis (MFA) approach, allowing account the volume of materials during their transitions into and out of the defined systems regarding time and space. The system boundary with the study framework for four types of infrastructure, under the scope of this research framework, is illustrated in Figure 1. As we showed in above diagram, we defined system boundary between prefectures and between infrastructures. In addition, as our main objectives lie around tracing the respective amounts of increase and decrease in stocks and flows of specific infrastructure, the environmental impacts (including resource usage and pollutant emissions), recyclable amounts within respective infrastructures, possible routes of waste flow outside, and so on, are not evaluated in this study.

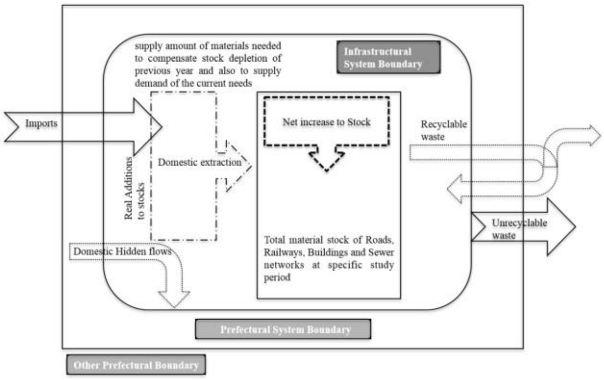

Figure 1. *Simplified scheme to evaluate NAS and GAS in well-defined system boundaries of material flow and stocks*

2.2. Material Stock of Roads

2.2.1. Material Stock of Roads

To quantify in physical terms of road infrastructure, this study used data regarding the total lengths of roadways derived from reliable national data sources [5] for the year 2017, at provincial level. The detail flow of estimation of material stock for roadways is shown in Figure 2.

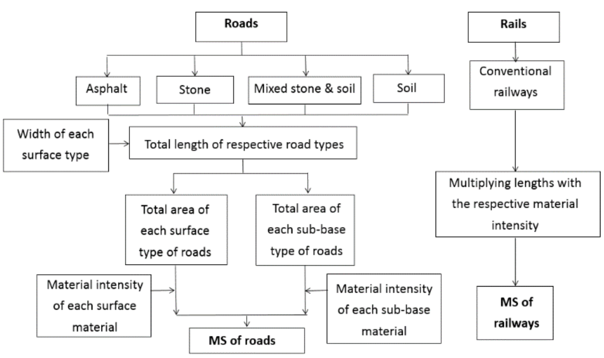

Figure 2. *Flowchart for the Estimation of the Material Stock of Railroads and Roadways*

After categorizing roads, the total accumulated materials in road infrastructure are evaluated using the following equation 1.

$$\mathrm{MS}_{i,j}\ (t) = \mathrm{A}_j(t) \times \mathrm{I}_{i,j} \qquad \text{(Eq. 1)}$$

Where:

$\mathrm{A}_j(t)$ is the total area of specific road category j at year t.

$\mathrm{I}_{i,j}\ (t)$ is the material intensity of material i in specific road category j. The material intensities for the above-mention road categories are estimated based on the Standard Specifications for Construction which is provided by Vietnamese Ministry of Construction in 2007 [6]. Due to the lack of reliable material intensity data for the previous years of 2007, it is assumed there is no change of this data over the studied period.

Table 1. *Material Intensities of Roadways*

No.	Paving type	Material intensity (kg/m^2) for roads in Vietnam					
		Surface layer			Base layer		
		Stone	Sand	Asphalt	Stone	Sand	Cement
1	Asphalt	210		5		1,530	97
2	Stone	330	40		1,800		
3	Mixed stone and soil	215	74		2,070		
4	Soil					1,680	

2.2.2. GAS and NAS of roads

The yearly quantities of materials that are required for expanding and maintaining the road network have been calculated from Eq. 2. As regard expansion material inflows of road network, they are defined by the net increase of stock extent. For maintenance material inflows, they are those materials required to keep the stock extent, entailing in providing stock' services. Thus, we make the assumption that: maintenance activity is the renewable of upper road layer, and it depends on the lifetime of a road.

$$GAS\ (t) = \mathrm{MI}_{expansion}(t) + \mathrm{MI}_{maintenance}\ (t)$$
$$= \left[\mathrm{A}_j(t) - \mathrm{A}_j(t-1)\right] \times \mathrm{I}_{i,j} + A^*{}_j(t) \times \frac{1}{\mathrm{T}_{i,j}} \times \mathrm{I}_{i,j} \qquad \text{(Eq.2)}$$

In which:

$\mathrm{A}_j(t)$ is the total area of specific road category j at year t.

$\mathrm{A}_j(t-1)$ is the total area of specific road category j at year t-1.

$A^*{}_j(t)$ is the total surface area of specific road category j at year t.

$\mathrm{T}_{i,j}$ is the road lifetime.

$\mathrm{MI}_{expansion}(t)$ is the material inputs for the expansion of road network in the year t. If the $\left[\mathrm{A}_j(t) - \mathrm{A}_j(t-1)\right] < 0$, it indicates that there is a stock decline in the year t.

$\mathrm{MI}_{maintenance}\ (t)$ is the material inputs for the maintenance of road network in the year t.

Material outflows are estimated as the sum of the amount road stocks out of use and lost that need to maintain.

$$\mathrm{RS}_{i,j}\ (t) = \mathrm{MI}_{decline}\ (t) + \mathrm{MI}_{maintenance}\ (t) \qquad \text{(Eq.3)}$$

There is a lack of reliable literature regarding the recycling rate of construction materials in Vietnam. It is a major challenge for evaluating the proportions of those materials would be returned to use in society. Hence, we assume that the recycling rate of construction and demolition waste of road is 0.

NAS is classified as balancing indicator and is equivalent to the amount of GAS and demolished stocks in the given year.

2.3. Material Stock of Railroads and their GAS and NAS

2.3.1. Material Stock of Railroads

Similarly, the bottom-up method is used for estimating the in-used stocks of railroad. Only conventional railway category is considered in this study (Figure 2).

The total material stocks of this type of railways can be calculated using this Eq. 2 equation:

$$MS_{railway\ k}\ (t) = L(t) \times r_p \times I_{p,m}\ (t) \quad \text{(Eq.4)}$$

Where:

$MS_{railway\ k}\ (t)$ is the quantity of material k stock in conventional railways in year t.

$L(t)$ is the length of conventional railways in year t.

r_p is the percentage of sleeper p by type of material. Concrete, steel and wood are the three specific types of sleeper using in conventional railway system in Vietnam. According to the assumption of Vietnam Railway Authority, the usage percentage of concrete sleeper, steel sleeper and wood sleeper is 55,5%, 32,5% and 12% respectively [7]. Due to considering only non-metallic materials, this study does not consider the amount of steel and wood.

$I_{p,m}\ (t)$ (unit in tonnes/km) is the material intensity of railways by the type of sleeper p and ballast m. Because French Government built the Vietnamese conventional railway system during the colonial period, there are difficulties in estimating the material intensity of railroad construction in Vietnam. Therefore, the Specific Standard for Construction which is provided by MOC in 2007 [8] is also used as the material intensity of railroad in this study.

Table 2. *Material Intensities of Railroads*

Type	Material intensity (ton/km)	
	Stone, Sand, Gravel	**Concrete**
Main railroads	3,375	77

2.3.2. GAS and NAS of railroads

NAS could be found by evaluating annual change in stock, which points to the fact that finding the difference in stock between two-study periods and finding average value amounts to evaluating NAS of roadways. In addition, total length altered for the new extension and maintenance parts of the railway was used for multiplying with material intensity of respective category of railways to obtain the GAS of the specific year.

3. Results and Discussions

3.1. Material Stock of Roads and Railroads

Figure 3 shows the results for the main stocked materials with respect to their constituents in road in Vietnam. There is a considerable expansion of the total road stock over the period studied, from 1,321 Mt in 2003 to 2,660 Mt in 2019, corresponding to the rapid extension of road lengths from 126 thousand to 217 thousand kilometers, respectively. Although the asphalt-paved type has been accounted the large share of such total road length' extension, there is an insignificant change regarding the share of materials, especially bitumen. The quantity of bitumen is always accounted less than 1% of total stocks due to its low density compared with other materials in road constituent. Meanwhile, stone and gravel, and sand always represent significant proportions. Using the bottom-up method of calculation, the quantity of materials that are stocked in railways is 8 Mt.

Considering GAS as the material inputs flows, this study shows 183 Mt of materials, or 39% of overall DMC of construction minerals, is used for expansion and maintenance road stocks in Vietnam on average from 2003 to 2019. The rest of DMC of construction minerals are used for other types of infrastructure stocks such as buildings, bridges and underground networks.

Figure 3 also raises the contribution of recycled flows that could be the potential material inputs flows into stocks. Despite the government has recently introduced the collective recycling rate target by 2020 at 30% to national law [9], the Construction and Demolition (C&D) waste in Vietnam is not clearly known concerning its pathways for the possible C&D recycling rates for constituent construction materials.

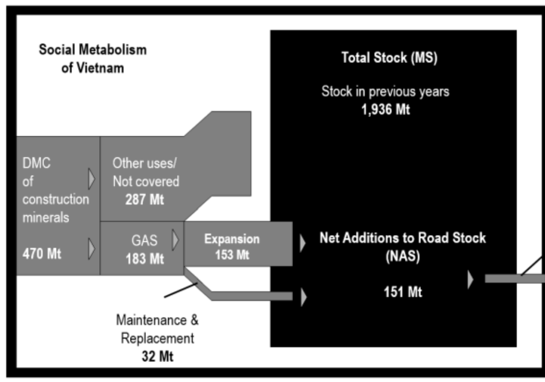

Figure 3. *DMC and Material Stocks on average*

3.2. Driving forces of road stock accumulation

We assume that the change in the material stock accumulation in Vietnam from 2003 to 2019 was driven by the growth of vehicle. With the opened market economy since 2000, there has been an increasing significantly the cheap vehicles (motorbikes and cars) that are imported from China to Vietnam [10]. For the affluence, with the annual growth rate of GDP and population in Vietnam from 2003 to 2019 was 6.4% (IMF reports) and 1.12% (World Bank) respectively, the GDP per capita has a growth factor of 2.5 in 2003 to 2019, this explains the higher ability to afford vehicles. Figure 4 shows the number of vehicle growth in Vietnam in the studied period.

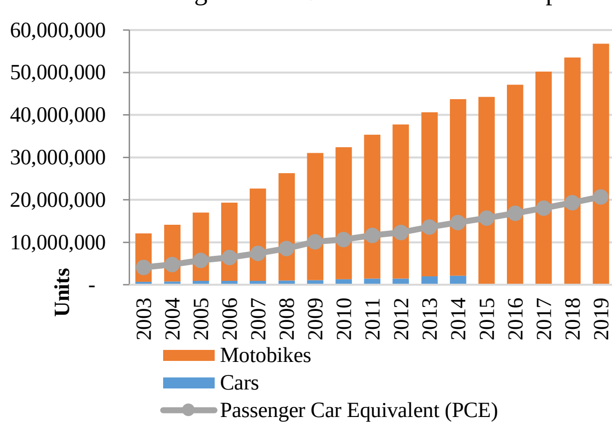

Figure 4. *Vehicle Growth over time*

Of the additional indicator that contributed negatively to material stock accumulation through the periods, the number of persons per vehicles (or inverse of vehicle ownership) accounted the high share impact to materials stocked in road. As per-capita incomes increase, private vehicles, especially private cars, become more affordable, thus increase the level of personal vehicle ownership in both motorbikes and automobiles in Vietnam. These consumption patterns of vehicles, especially the growth in automobiles impacts to the road available capacity. Hence, the road networks in urban areas have been expanded and improved to sustain increasing loads and travel speed, but new issues such as increasing traffic congestion and acceleration of deterioration of pavements [11].

3.3. Policy Implication

In this section, we derive some policy options that aim to reduce the resource consumptions and improve the efficiency of transportation stock utilization, meeting the national target of sustainable development. In Vietnam, the main material inputs to stocks such as sand, gravel, and stone are mainly domestic extracted sources. Such significant accumulation of transport infrastructure stocks, to meet the demands of socioeconomic development, posing enormous consequences on environmental impacts. With the uneven distribution and the finite supply of natural construction minerals, the government should put efforts in the effective management and the efficient utilization of such resources.

Also, the government should carefully look into the strategies to the develop transport infrastructure, especially roadways in each prefecture. Well-developed infrastructure should be utilized effectively with respect to obtaining maximum services from a certain amount of stocked materials. The lifespan of existing infrastructure would be shorter with such huge volume of commuting, leading to the material consumption and environmental impacts in the near future. Therefore, there are some solutions related to material stocks and flows field as the following: (i) Developing other infrastructures such as railways to suppress the volume of passenger flows from roads. (ii) Good maintenance the current road stocks to last longer their lifespans.

4. Conclusion

We have been enjoying mass extraction of construction materials and mass production and it means that we are in the material flow type society. As a result, significant impacts on environment are attained. However, it is time to change our society from material flow type to a sustainable stock type society where effective and efficient utilization of material stock are coupled with high socioeconomic outcomes reducing construction materials as much as we could. This study assessed the material stocks related to construction the infrastructure (roads and railroads) in Vietnam for year 2019. The central aim of this research is to assist in policy measures for Vietnam to move to a sustainable stock type society, by helping more understanding on stocking and utilization of construction materials by analysing with different socio-economic indicators and regional disparity. The outcomes of this research are intended to assist the future development strategies, particularly the Green Growth Strategy in Vietnam.

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