ENERGY CONSUMPTION AND AIR EMISSION INVENTORY FOR TRANSPORTATION SECTORS OF VIETNAM

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ABSTRACT

Aiming to clarify the environmental impact caused by transportation activities in sectors of Vietnam, this study uses the Input-Output (IO) model to assess energy consumptions and air emissions from railway, road traffic, waterway, transport service as well as aviation vehicles in 2016. The data is based on the 2012 IO table updated for 2016. All sectors of the original IO table are aggregated into 38 sectors where the transport service sectors are kept intact for the deeper analysis. The energy consumptions of transport activities are determined based on the net contribution rate of fuels to each product/service sector and the calorific value of each fuel type. Then multiplying with the corresponding emission factors of CO₂, NOₓ and SO₂, the respective emissions from above sectors are calculated. The results show the contribution of transport activities in total emissions of each product/service sector and compare these numbers among all the sectors. Additionally, the study evidences that among transportation service sectors, the road traffic occupies the highest rate in term of energy consumptions and air emissions as well.

Keywords: IO table, energy consumption, transportation, CO₂, NOₓ and SO₂ emissions.

1. INTRODUCTION

IO tables have been applied to estimate the energy consumption and air emissions of product and service sectors in a couple of countries included USA, ECs, Japan, Singapore and India [1, 2, 3]. In Viet Nam, since IO tables were firstly published in 2000, the number of IO table-based researches is very limited. In fields of energy and environment, energy productivity as well as hidden energy flows of 50 product and service sectors has been evaluated using IO table [4, 5]. However, its further analysis in transportation sectors is still new idea.

This study aims to clarify environmental impacts caused by transportation activities in sectors of Vietnam. The study uses IO model to inventory energy consumption and CO₂, NOₓ, and SO₂ emission from railway, road traffic, waterway, aviation vehicles and other some transportation services in 2016.
2. METHODS

The study methodology is illustrated in Figure 1. After updating and aggregating IO table, energy consumption of a sector is determined based on the net contribution rate of fuels and its calorific value. Then, multiplying with air emission factors, the respective emissions are estimated.

Figure 1. Diagram of inventory method.

2.1. Structure of an IO table

The IO table presents the relations among economic sectors (Table 1). Interrelationships of the providing and demanding sectors are balanced, as seen in equations (1) and (2).

Table 1. Structure of the IO table [2].

<table>
<thead>
<tr>
<th>Goods sectors</th>
<th>Product/service sectors</th>
<th>Intermediate demand</th>
<th>Final demand</th>
<th>Total output (X)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td>…</td>
</tr>
<tr>
<td>Intermediate</td>
<td></td>
<td>z_{11}</td>
<td>z_{12}</td>
<td>…</td>
</tr>
<tr>
<td>providing</td>
<td></td>
<td>z_{21}</td>
<td>z_{22}</td>
<td>…</td>
</tr>
<tr>
<td></td>
<td></td>
<td>…</td>
<td>…</td>
<td>…</td>
</tr>
<tr>
<td>n</td>
<td></td>
<td>z_{n1}</td>
<td>z_{n2}</td>
<td>…</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>\sum_{i=1}^{n}z_{i1}</td>
<td>\sum_{i=1}^{n}z_{i2}</td>
<td>\ldots</td>
</tr>
<tr>
<td>Value added</td>
<td></td>
<td>V_{1}</td>
<td>V_{2}</td>
<td>…</td>
</tr>
<tr>
<td>Total input (X)</td>
<td></td>
<td>X_{1}</td>
<td>X_{2}</td>
<td>…</td>
</tr>
</tbody>
</table>
Balance by rows and columns:

\[ X_i = \sum_{j=1}^{n} z_{ij} + Y_i \quad (i = 1, \ldots, n) \]  
\[ X_j = \sum_{i=1}^{n} z_{ij} + V_j \quad (j = 1, \ldots, n) \]  

where: \( n \): number of economic sectors; \( z_{ij} \): inter-industry sales by sector \( i \) to sectors \( j \) (million VND); \( X_i \): total output of sector \( i \) (million VND); \( Y_i \): final demand of sector \( i \) (million VND); \( V_j \): value added of sector \( j \) (million VND).

In the study, the original 2012 IO table is updated for 2016 using standard RAS method [3]. All product sectors of the updated IO table are aggregated into 38 sectors based on the Decision No. 10/2007/NĐ-CP [6], where the transport service sectors are kept intact for deeper analyses.

### 2.2. Estimation of energy consumption and air emissions

Energy consumption (\( ED_i \)) and air emissions (\( E_i \)) of sector \( i \) are defined as following [7]:

\[ ED_i = \sum_n ED_{i,n} = \sum_n q_n r_{i,n} m_{i,n} \]  
\[ E_i = \sum_n EF_n \cdot ED_{i,n} \]  

where: \( ED_{i,n} \) is energy consumption of fuel \( n \) in sector \( i \); \( r_{i,n} \) is net contribution rate of fuel \( n \) in sector \( i \); \( m_{i,n} \) is amount of fuel \( n \) consumed in sector \( i \); \( q_n \) is calorific value of fuel \( n \); \( EF_n \) is emission factors of fuel \( n \).

The IO tables have been compiled in currency unit and based on the producer’s price. In order to get \( m_{i,n} \), the updated IO table is then converted into the table of hybrid units in which primary energy sectors are compiled in physical units. In this calculation process, price of fuels in 2016 are determined as the follows: price of hard coal and lignite is averaged according to the General Statistical Office; price of crude oil, price of natural gas and LPG as well as price of gasoline and lubricants are respectively averaged according to Petrolimex. In this study, toe (tons of oil equivalents) is used as standard unit for energy consumption. Emission factors \( EF_n \) are determined from valuable sources [7, 8]. Energy production sectors use primary energy sources as main input materials, therefore the sectors are not appeared in the corresponding calculation in order to avoid double counting.

### 3. RESULTS DISCUSSION

#### 3.1. Energy consumption in sectors

As the results, energy consumption of 38 product and service sectors is described in Figure 2. It’s seen that among the sectors, transport sectors (N27-N35), fishery and aquacululture sector (N3) and communication and tourism sector (N36) were the highest energy consumers with 15.90 Mtoe, occupied about 40.93 % of total energy consumption of Vietnam in 2016. These sectors use gasoline and DO as main energy sources for their transportation activities. Other biggest energy consumers are building materials sector (N15), basic chemicals sector (N14) and electrical production and delivery sector (N21). Those sectors use hard coal and natural/LPG gas as main energy sources in their production processes.
Energy consumption and air emission inventory for transportation sectors of Viet Nam

Figure 2. Energy consumption inventory for 38 sectors in 2016.

Note: N1: Agriculture and its services; N2: Forestry and its services; N3: Fishery and aquaculture; N4: Hard coal and lignite; N5: Crude oil; N6: Natural gas or LPG; N7: Extractive; N8: Food process; N9: Fashion manufacture; N10: Paper and its service; N11: Coking coal; N12: Gasoline and lubricants; N13: Other oil mining; N14: Basic chemicals; N15: Building materials; N16: Electronic, electric equipment; N18: Equipment and tool production; N19: Transport mean production; N20: Medical equipment; N21: Electrical production and delivery; N22: Gas and services; N23: Water; N24: Waste treatment; N25: Construction; N26: Trading, repairing services of automobiles, motorcycles and motors; N27: Railway passenger services; N28: Railway freight services; N29: Bus transport services, other road passenger transport services; N30: Transport services by road, pipeline; N31: Coastal shipping passenger services; N32: Coastal shipping freight services; N33: Aviation passenger services; N34: Aviation freight services; N35: Warehouse services and other services of transport activities; N36: Telecommunications and tourism services; N37: Insurance service; N38: Other services.

3.2. Air emissions from transportation activities

In term of air emissions, its results are described in Figure 3 and the emission data extraction of transport activities are listed in Table 2. CO₂, NOₓ emissions of building materials sector are very large due to using the high hard coal as mentioned above. Total CO₂ emission from transport sectors (N27÷N35), fishery and aquaculture sector (N3) and telecommunications and tourism sector (N36) were also the highest with amount of 44.20 Mt (39.05 % of total emission). This means that these sectors are contributed mainly into GHG emission. Then, their NOₓ emission is the high ratio of 168.83 kt (62.06 % of total emission). In case of calculating for transport activities (N27÷N35) is about 142.86 kt, occupied 52.51 % due to the high mobile sources emission factors. Similarly, SO₂ emission of three sector groups is also eliminated the amount of 49.41 kt, equivalent of 37.22 % in comparison with the total emission. In fact, NOₓ and SO₂ are not GHGs but their presence in the atmosphere may influence directly to human health and the global environmental problems.

Table 2. Air emissions data of transport sectors.

<table>
<thead>
<tr>
<th>Code</th>
<th>N27</th>
<th>N28</th>
<th>N29</th>
<th>N30</th>
<th>N31</th>
<th>N32</th>
<th>N33</th>
<th>N34</th>
<th>N35</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ (kt)</td>
<td>71.48</td>
<td>63.23</td>
<td>3670.72</td>
<td>8613.43</td>
<td>362.37</td>
<td>3679.39</td>
<td>3630.89</td>
<td>657.41</td>
<td>988.28</td>
</tr>
<tr>
<td>NOₓ (kt)</td>
<td>0.71</td>
<td>0.63</td>
<td>21.38</td>
<td>56.82</td>
<td>4.48</td>
<td>82.73</td>
<td>8.99</td>
<td>1.63</td>
<td>1.11</td>
</tr>
<tr>
<td>SO₂ (kt)</td>
<td>0.10</td>
<td>0.09</td>
<td>3.39</td>
<td>12.65</td>
<td>0.53</td>
<td>6.39</td>
<td>5.33</td>
<td>0.97</td>
<td>0.86</td>
</tr>
</tbody>
</table>
Figure 3. Air emissions inventory for 38 sectors in 2016.

Figure 4 presents CO\textsubscript{2}, NO\textsubscript{x} and SO\textsubscript{2} emissions from transport activities in fishery and aquaculture sector (N3), telecommunications and tourism sector (N36) and transportation sectors included railway (N27+N28), road (N29+N30), coastal shipping (N31+N32), aviation (N33+N34) and other services (N35).

As seen in the figure, CO\textsubscript{2}, NO\textsubscript{x} and SO\textsubscript{2} emitted from road transport activities (N29+N30, N36) were highest and the next contributors were shipping transport activities (N3, N31+N32). Among each product and service sectors, CO\textsubscript{2} and SO\textsubscript{2} emissions from fishery and aquaculture sector (N3) and telecommunications and tourism sector (N36) contributed significantly to total corresponding emission from transport activities. CO\textsubscript{2} emission of N3 and N36 occupied 26.91\% and 23.91\% of the total, respectively. SO\textsubscript{2} emission of N3 and N36 occupied 20.86\% and 16.76\% of the total, respectively. NO\textsubscript{x} emissions from road transportation sectors (N29+N30) was highest.

It is also seen that that CO\textsubscript{2}, NO\textsubscript{x} and SO\textsubscript{2} emissions from passenger transport service of railway and aviation are larger than their freight services. Meanwhile the emissions of road freight transport, coastal shipping freight service are higher than their passenger services.

As the results, the transport activities have been the largest GHG generator in Vietnam. It is necessary to replace the fuels by alternative sources such as biofuels. As published by FAO, using 1 MJ of E5 instead of 1 MJ of gasoline would save 37-39\% of GHG emission in life cycle of the product [9].
4. CONCLUSION

As calculated in Vietnam 2016, total energy consumption and CO₂ emission of N3, N27÷N35, N36 are 15.90 Mtoe and 44.20 Mt, respectively. The results show the biggest contribution of transport activities in term of energy consumption and air emissions of Vietnamese economy. The study also evidences that among transportation service sectors, the road traffic occupies the highest share. Therefore, it is necessary to have the solution in order to reduce the burdens. One of the priorities should be the environmental friendly fuel replace. This paper can be used as a scientific basis for air pollution control in transportation sectors in particular and for air quality management in Vietnam.

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