

## **Towards a Carbon Neutral Economy in Vietnam: Modal Shifting in Transportation Sector**

**Nguyen Hoang LAN<sup>1</sup>, Nguyen Thi Thu THUY<sup>2\*</sup> and Nguyen Thi Nhu VAN<sup>3</sup>**

<sup>1</sup> Department of Industrial Economics, School of Economics and Management, Hanoi University of Science and Technology, Hanoi, Vietnam

<sup>2</sup> Department of Economics, School of Economics and Management, Hanoi University of Science and Technology, Hanoi, Vietnam

<sup>3</sup> Industrial and Energy Management Faculty, Electric Power University, Hanoi, Vietnam

\*Corresponding author: [thuy.nguyenthithu@hust.edu.vn](mailto:thuy.nguyenthithu@hust.edu.vn)

### **Abstract**

*Transportation is one of the largest energy users and carbon emitters. The carbon intensity differs between sub-sectors such as road, rail, and water. Therefore, modal shifting will have significant effect on carbon emission of the overall sector. In the study, the effect of modal shifting is considered as a factor for carbon dioxide emission reduction. Rail transportation emits less gas than road and air transportation. Therefore, shifting from road and air transport to rail transport will reduce carbon dioxide emission. Using linear optimization model TIMES, the authors will analyze the effects of modal shifting on final energy, primary energy, and carbon dioxide emission reduction. The result shows that the total carbon dioxide emission can be reduced by up to 14.5% in 2050 when applying modal shifting. Besides, modal shifting can cause a decline in final energy consumption and primary consumption as well. Energy intensity can be reduced by up to 50% in passenger transportation with modal shifting. The emission reduction in big emitter like transportation plays an important role in the roadmap to a carbon neutral economy in Vietnam*

#### **Research purpose:**

*Analyzing the effects of modal shifting in transportation on final energy, primary energy, and carbon dioxide emission reduction towards a carbon neutral economy in Vietnam.*

#### **Research motivation:**

*Transportation is one of the largest energy users and carbon emitters. The carbon intensity differs between sub-sectors such as road, rail, water. Therefore, modal shifting will have significant effect on carbon emission of the overall sector. In the study, the effect of modal shifting is considered as a factor for carbon dioxide emission reduction. Rail transportation emits less gas than road and air transportation. Therefore, shifting from road and air transport to rail transport will reduce carbon dioxide emission.*

#### **Research design, approach and method:**

*The study uses TIMES model developed for Vietnam case. The TIMES model represents the entire energy system including primary energy supply, energy conversion, and energy users which are transport, industry, agriculture, residential and commercial sectors. The scenarios developed in the research to test the effect of modal shifting to overall system include a baseline scenario (PD) and three alternative scenarios including modal shifting for passenger (TRN1), modal shifting for freight (TRN2), and modal shifting for both passenger and freight (TRN3).*

#### **Main findings:**

*The modal shift has a significant effect on carbon dioxide emission, leading to reduction of the transportation sector with the reduction by up to 14.5 % in carbon dioxide emission in TRN3 scenario. Furthermore, modal shifting leads to the decline of final energy consumption by transportation as well as energy intensity of freight transport by 36% and passenger transport by 50% in 2050. In terms of cost, modal shifting will help reduce the overall cost of the sector.*

#### **Practical/managerial implications:**

*The role of modal shifting is significant in the process of reducing carbon dioxide emission, setting the steps towards carbon neutrality for the whole economy. It is necessary to have mechanisms to enable investment sharing between private and governmental source to promote development of metro and high-speed rail in the future.*

**Keywords:** Carbon neutral economy, transportation, TIMES, modal shifting

## 1. INTRODUCTION

Vietnam is a country located in the South-East Asia region with a population of 97.58 million (2020), and its area is 329.3 thousand km<sup>2</sup>. Vietnam's gross domestic product (GDP) average growth rate is 6.6 percent in 2015 - 2019 and decreases to 2.91 percent in 2020 due to the effect of COVID19 pandemic (GSO, 2021). In the future, the economy of Vietnam is forecasted to recover and continue growing quickly at the rate of around 6.8% until 2025 and reduce to around 5.4 % percent thereafter up to 2050. Additionally, the population is expected to increase to 108.4 million in 2050 (IE, 2021b).

With the high growth rate of the economy and the development of population, the energy demand becomes more and more important as an issue to Vietnam. During the 2011 and 2019 period, the total primary energy rises at the rate of 6 percent (IE, 2021a).

The high demand in the future for energy supply, especially from fossil fuels, forces Vietnam to face with the environmental issues. The environmental issues related to energy using are considered the global problem. The impact of Greenhouse gas (GHG) emission can become serious in this century with the forecast of rising in global temperature by 2.9 degree. Therefore, the consequence is relative huge; for example, the potential damages from the increase of sea level to individual countries including Vietnam can reach ten billion US due to the destruction to the coastal areas' infrastructure. At present, although emission in developing countries is lower compared to developed countries, it is expected to grow much faster in the future. Thus, if actions are taken earlier, the consequences will be reduced. Realizing the environmental problems, Vietnam had taken actions such as signing the United Nations Framework Convention on Climate Change (UNFCCC) in 1994, signing the Kyoto Protocol and approving it on September 25, 2002. Vietnam also joined Paris Agreement with the commitment of reducing carbon emission by 9% and up to 27% with international aid (GOV, 2020).

Recently, the international community's effort to achieve carbon neutrality by 2050 has been pushing actions and co-operation among countries in the world (Korea, 2020; António Guterres, 2021).

“Carbon neutrality describes a state in which the GHG emissions released to the atmosphere by a stakeholder (individual, organization, company, country, etc.) have been reduced or avoided and the remaining ones are compensated with carbon credits” (UNFCCC, 2020). From the point of view of a country, carbon neutral economy can be reached by reducing carbon emissions from all sectors or buying the carbon credits from other countries. The later one requires the existing of international carbon market which is currently not available. Therefore, emissions reduction is a good way

for a country like Vietnam to meet its target.

To use energy in a way that protects the environment, carbon neutrality is the aim of Vietnam's development. Reaching the goal requires long-term vision, with plans for the next four or five decades instead of a single decade.

Transportation is one of the main energy users in the economy. The share of transportation in final energy consumption is 23% in total final energy. The energy consumption of roadway is about 83% of final energy consumption of the whole sector (IE, 2021a). The transportation sector continues to play an important role in the economy. Higher incomes and economic growth have led to rapid mechanization in Vietnam, along with a sharp increase in the number of cars, which are replacing motorbikes, especially in big cities. The use of public transport remains low, due to the low level of public infrastructure development, and the convenience and lesser cost of motorbikes. In freight transport, economic development and rapid integration with world trade in recent years help with the development of waterways based on the long coastline and the extensive network of inland waterways. Railway use is quite low compared to the other modes of transport. The share of roadway for freight is 22.3% of total freight demand, while the share of railway is 2.0%. The roadway still dominates passenger transportation. In 2020, the share of roadway is 94.0% of total passenger demand, while railway is only 1.3% (GSO, 2021). The railway of Vietnam is quite outdated; it has been 140 years since its infrastructure was built, but it has only been maintained with limited fund, and has not been renovated and upgraded. Air, road, and waterway transport are assigned to enterprises for both investment and operation, while with railways, the enterprise is the representative for the government only in managing and operating the system. This arrangement restricts the source of investment funds. From the environmental perspective, rail transportation emits less gas than road and airway transportation (EEA, 2021). Therefore, shifting transportation demand from high emission modal (like roadway and airway) to low emission modal (like rail) is the way to reduce emissions towards carbon neutrality for transportation and the whole economy.

To model carbon scenarios, using a dynamic linear programming model which minimizes the discounted cost under socioeconomic hypothesis and technical constraints is an effective approach (ShuZang, 2020; Jacopo T., 2018).

In the study of China, China-TIMES is built to test the different scenarios towards carbon neutrality. Transportation will contribute the larger share in reducing carbon emissions from 2030 with 85% of vehicles be electric (ShuZang, 2020). In the case of Denmark, based on TIMES-DK model, the study shows that model shift brings the big opportunity for decarbonisation in transportation sector and helps Denmark on the way to achieving carbon neutrality in

2050 (Jacopo T., 2018)

In Vietnam, under the Nationally Determined Contributions (NDC) roadmap context, the transportation sector was modelled using the Energy (Forecasting Framework and Emissions Consensus Tool) EFFECT model (DecisionWare Group LLC, 2020). EFFECT model is an economic – technology and simulation model in which the transportation was simulated by a bottom-up approach. However, this model did not take into account the transport sector in the intergration with other sectors in the economy (Ministry of Transportation, 2015).

In this study, the authors use TIMES-Vietnam as an effective tool to develop the scenarios of energy system during the 2020 and 2050 periods. The analysis will be taken to see the effects of modal shifting in the transportation sector on energy use (primary energy supply, final energy consumption, energy intensity), carbon dioxide emission reduction (total emission reduction, contribution of sectors to emission reduction) in association with the entire energy sector .

The paper includes: section 2 describing the methodology used for analysis; section 3 presenting the results and discussion on the effects of modal shifting in the transportation sector to energy use, carbon emission, carbon intensity; and section 4 concluding with main findings in the study.

**2. METHODOLOGY**

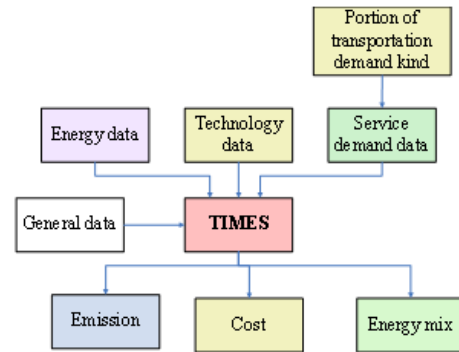
**2.1 TIMES-Vietnam Model**

The study uses TIMES developed for Vietnam case. The TIMES model represents the entire energy system including primary energy supply, energy conversion, and energy users which are transport, industry, agriculture, residential and commercial sectors. The objective is to analyse the effects of modal shifting of transportation on energy system and CO2 emission.

The methodology is illustrated in Figure 1. Data after construction will be the input of TIMES model. After having run the model, the output data including fuel mix and emission obtained will be analysed to find the trend in the 2020 and 2050 period. The shift from high emission modes (roadway and airway) to lesser emission mode (railway) of transport will reduce emission. The data for transportation service demand from 2020 to 2050 will be the input for service demand data. The output will be analysed to identify the changes in energy intensity, energy consumption, CO2 emission.

Transport includes freight and passenger transport, which are divided into road, rail, water, and air transportation. Road passenger transport includes car and motorbikes, grouped as private road vehicles, and bus and coach, grouped as non-private road vehicles. The demand data in 2020 – 2050 is taken from the Ministry of Transport of Vietnam. The main fuels used for transportation are petroleum products like diesel,

gasoline, jet fuel, LPG. Electricity is also promoted to use for transportation.



**Fig 1.** Flow chart of methodology

**2.2 Scenarios Description**

In TIMES models, the whole sector comprises multiple technologies that compete to fulfill exogenous demands. The TIME model implementation for the Vietnam transport sector includes commodity and process definitions as always. This model includes the following commodities:

- Fossil fuel which includes Gasoline, Jet Fuel, Diesel, Fuel Oil, Electricity, and Natural Gas
- Demands (in billion passenger-kilometers traveled or billion-ton kilometers traveled)
- Emissions of CO2 (in kilos ton)

The model also includes the following technologies:

- Cars: Five different types of car are simulated: Compact, mini-compact, large SUV, small – SUV, and Fullsize
- Scooter and Motorbike: Electric Scooter and Gasoline Motorbike
- Buses: Two types of buses are included, diesel bus and CNG bus
- Light Commercial Vehicles: Five different vehicles are simulated for passenger and goods transport
- Heavy Commercial Vehicles:
- Railway: There are two kinds of railway in the model. The first one is the traditional railway that is simulated as existing technology and the second is the high-speed railway that is considered as the future technology
- Waterways: Four different vehicles are modeled for passenger and freight transport purpose by coastal and inland waterways
- Airway: Only domestic airway is simulated in the model

The existing processes are characterized by their existing installed capacity (STOCK) in thousands of car units (000\_units) as indicated above. The stock values correspond to the amount of fuel consumption (e.g. TRNOILGSL) required to produce the transportation demand (TPLD) as given by the energy balance and taking into account the efficiency (EFF), the annual

availability factor (AFA), and the conversion between capacity unit and activity unit (CAP2ACT).

The efficiency (EFF) is specified in terms of billions of vehicle kilometers per petajoule (BVkm/PJ) and can be interpreted as the number of kilometers a vehicle can travel with 1 PJ of energy

The annual availability factor (AFA) represents the average thousand kilometres ('000 km) a car is traveling each year.

The lifetime (LIFE) is specified in number of years as for the other processes.

The conversion factor between capacity unit and activity unit (CAP2ACT) is translating mvkm into bvkm

The demand for transportation by cars is updated and declared in the right units and correspond to the sum of billion passengers-kilometres (Bpass\*km) for all types of cars

$$\text{Demand(Bpass*km)} = \text{STOCK(000\_units)} * \text{AFA(000\_vehiclekm/unit)} * \text{ACTFLO(Passengers/vehicle)} * \text{CAP2ACT(0.001bvkm/mvkm)}$$

The scenarios developed in the research include a base

scenario (PD) and three alternative scenarios including modal shifting for passenger (TRN1), modal shifting for freight (TRN2), and modal shifting for both passenger and freight (TRN3).

PD: Policy direction. This scenario uses assumptions on all sectors based on the current policy of the government

TRN1: modal shifting from road to railway for passenger using passenger high-speed railway.

In this scenario, we assume that from 2030 demand of rail will constitute 11% of total passenger demand and increase to 15% in 2050. This growth comes from road demand and domestic airway demand.

TRN2: modal shifting from road and airway for freight using freight high-speed railway

In this scenario, the share of freight demand served by railway increases from 5% in 2025 to 35% in 2050. This demand is shifted from road and airway to high-speed railway.

TRN3: modal shifting for both freight and passenger to high-speed railway.

This scenario combines both assumptions of TRN1 and TRN2 scenarios.

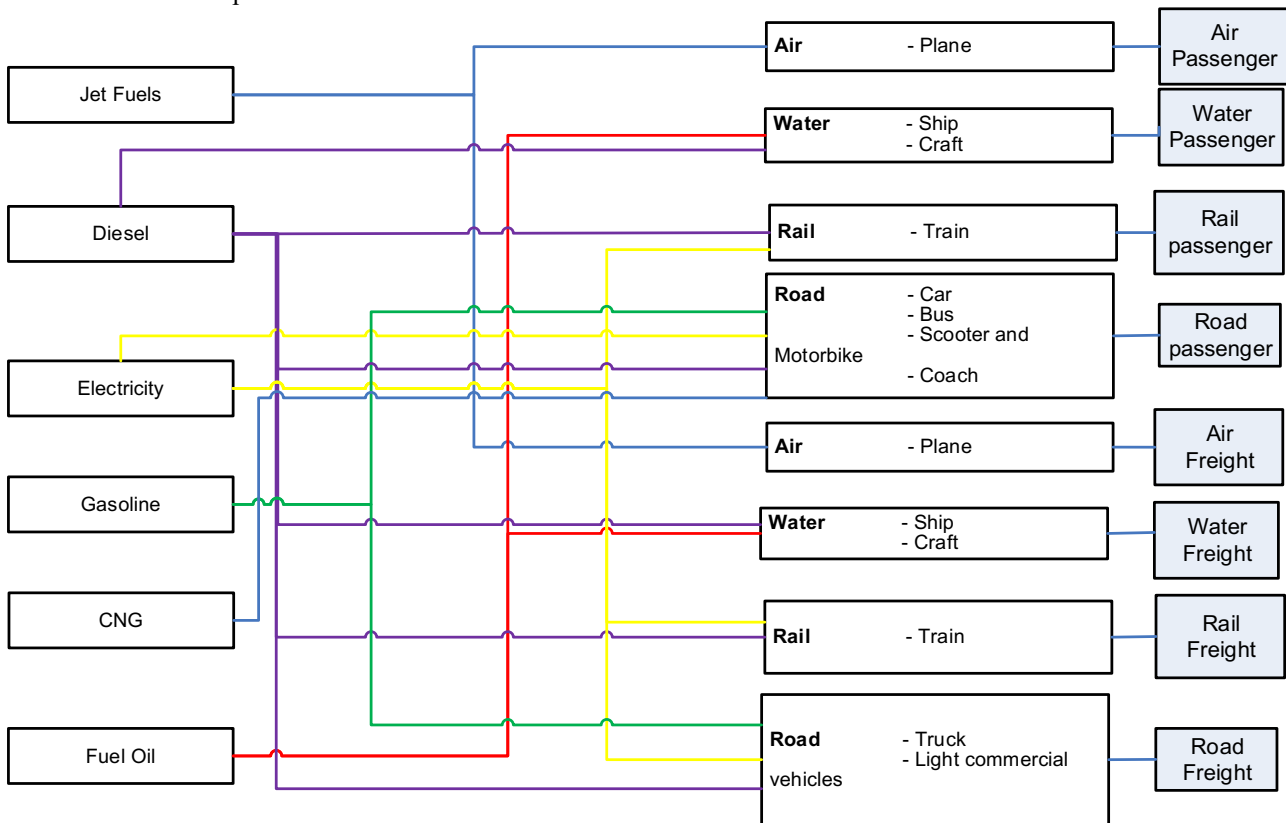


Fig 2: Transportation Model

### 3. RESULTS AND DISCUSSION

#### 3.1 Effects on energy use in the transportation sector

##### Total final energy use

Table 1: Total final energy use (PJ)

|      | PD   | TRN1 | TRN2 | TRN3 |
|------|------|------|------|------|
| 2020 | 553  | 554  | 554  | 554  |
| 2030 | 719  | 694  | 669  | 649  |
| 2040 | 1160 | 1103 | 1049 | 1030 |
| 2050 | 1712 | 1644 | 1487 | 1434 |

The final energy consumption in transportation reduces when shifting from roadway (non-private vehicles) and airway to railway (high-speed railway and metro) in all three alternative scenarios. In 2050, the final energy consumption is 1644 PJ and 1487PJ in the TRN1 and TRN2 case respectively compared to 1712 PJ in the base case. The reduction is much more when applying modal shifting in both freight and passenger transport (table 1) in TRN3 scenario.

Roadway, especially private transportation, still dominates final energy consumption. Road transportation accounts for 82% in 2020 and tends to decrease in the following period, to 68% in 2030, 62% in 2040, and 58% in 2050. With the transportation demand shift from roadway to railway, in 2040, the share in final energy consumption of railway increases from 0.59% in PD scenarios to 2.21%, 3.12%, and 5.19% in TRN1, TRN2, TRN3 scenarios respectively. Remarkably, in 2050, the share in final energy is 7.65% for TRN3 scenario (figure 2).

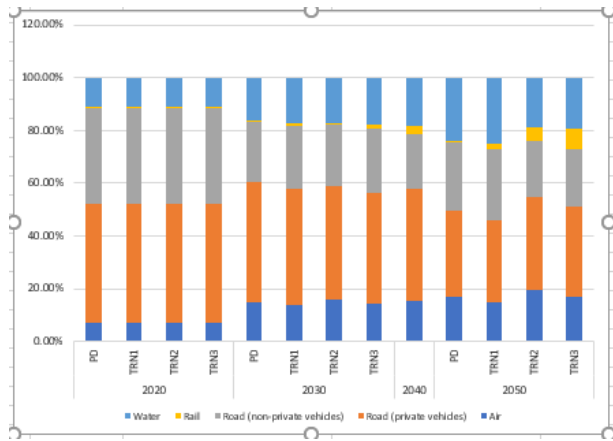


Fig. 2: Share of transportation modal in final energy consumption (%)

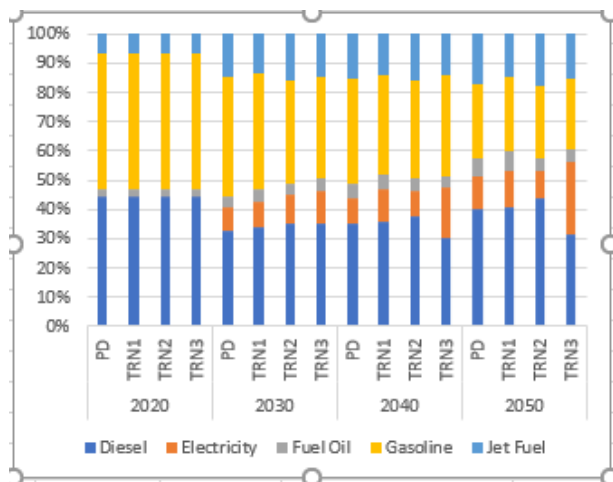


Fig. 3: Fuel mix in final energy consumption (%)

In the fuel mix, oil products still dominate over 2020 – 2050 period in all scenarios. The electricity share tends to increase when shifting from road and air to railway

scenarios (figure 3).

Energy intensity

Energy intensity is presented in term of final energy consumption (PJ) for a billion tonne-kilometre (freight)/passenger-kilometre (passenger), abbreviated as btkm/bpkm.



Fig. 4: Energy Intensity in freight transportation (PJ/btkm)

Energy intensity in freight transportation decreases over the time period, from 0.45PJ/btkm to 0.36 PJ/btkm in PD scenario, and from 0.45PJ/btkm to 0.24PJ/btkm in TRN2 scenario. When there is a shift from the road transportation to rail transportation, the energy intensity reduces significantly, about 4% in 2030 to 36% in 2050 compared to the PD case (figure 4).

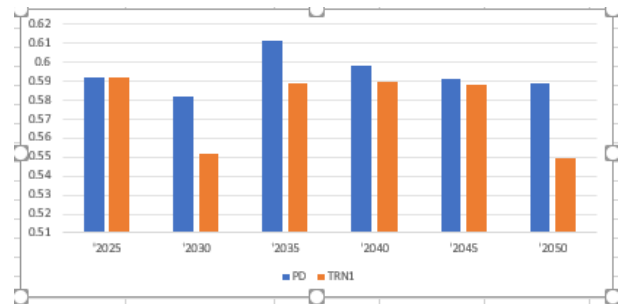


Fig. 5: Energy Intensity in passenger transportation (PJ/bpkm)

In passenger transportation, the shift from road transportation to rail transportation causes the dramatic decrease of more than 50% in energy intensity (Figure 5). This reflects the trend of moving from high-energy intensity means (roadway and airway) to low energy intensity mean (railway). Therefore, shifting to rail transportation is a good suggestion to reduce energy consumption as well as energy intensity of the transportation sector.

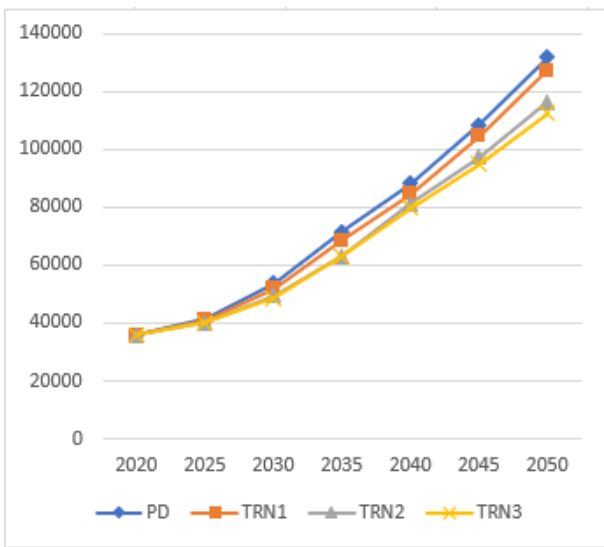
3.2 Effects on total primary energy use at national level



**Fig 6:** Total primary energy supply at national level (PJ)

Total primary energy supply (PES) increases in average 4% annually in PD scenario from 4212PJ in 2020 to 13623PJ in 2050. After applying modal shifting, PES is reduced by between 0.4% to 0.6% in TRN1 scenario, 5.8% to 3.2% in TRN2 scenarios and 6% to 3.5% in TRN3 scenario. It is apparent that modal shifting will be helpful to reduce PEC at national level.

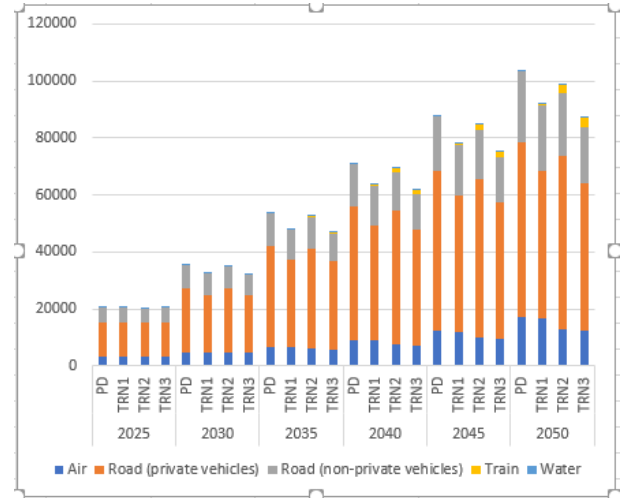
### 3.3 Effects on carbon dioxide emission in transportation sector



**Fig. 7:** Carbon dioxide emission in transportation sector (kt CO2eq)

The carbon emission of transportation sector increases by 3.5% annually in PD scenario, from 39727 kt CO2eq in 2020 to 110611 kt CO2eq in 2050. In 2030, modal shifting helps to reduce the carbon emission by 0.63% in TRN1, 2.4% in TRN2, 2.4% in TRN3 compared to PD scenario. In 2050, the reduction in carbon emission is 4.27%, 11.6%, and 14.5% in TRN1, TRN2, TRN3 respectively compared to PD scenario. Therefore, modal shifting will help transportation sector account to the emission reduction target of Vietnam.

### 3.4 Effects on cost of transportation sector



**Fig. 8:** Transport annual cost (Million Euro)

During 2025 – 2050 period, the annual cost increases by 6.7% annually due to the higher transportation demand in PD scenario. The share of roadway is bigger than all other type of transportation, around 86% in PD scenario. The airway ranks second, accounting for 13% to 17% in total annual cost. With the shift of transportation demand from roadway and airway to railway, the annual cost decreases by 11% in TRN1, 5% in TRN2, 16% in TRN3 scenario in 2050. The modal shift in passenger transportation demand (TRN1 scenario) causes the increase of the annual cost for railway by 393 million Euro in 2050, and only accounts for 0.45% in total annual cost. In TRN2, when shifting part of roadway and airway demand to high-speed rail, the annual cost for high-speed rail only increases by 2795 million Euro in 2050. With the combination of higher share in both passenger demand and freight demand of railway (TRN3 scenario), the share of railway accounts for 3.54% in total annual cost in 2050.

### 4. CONCLUSION

The modal shift has a significant effect on carbon dioxide emission reduction of the transportation sector with the decrease is up to 14.5 % in carbon dioxide emission in TRN3 scenario.

Furthermore, modal shifting leads to the decline of final energy consumption by transportation as well as energy intensity of freight transport by 36% and passenger transport by 50% in 2050. The dramatic change causes the drop in total primary energy supply. Through that, the role of modal shifting is significant in the process of reducing carbon dioxide emission, setting the step towards to carbon neutrality for the whole economy.

In terms of cost, modal shifting will help reduce the overall cost of the sector. Therefore, it is necessary to have mechanisms to enable investment sharing between private and governmental source to promote development of metro and high-speed rail in the future.

However, it is well-known that, emissions in the transport sector are influenced not only by modal choice but also technical efficiency and lifestyle, especially with EV transition trend. These matters will be taken into account as new scenarios in a low-carbon energy path to achieve the neutral carbon target.

TIMES is a powerful tool in modeling. In this study, Vietnam transport sector is modelled based on the types of current vehicles and also takes into account future technology. However, the bottom-up approach in such kind of model does not allow investigation of the relationship between the behavior of consumers and the system.

## 7. REFERENCES

- [1] António Guterres (2021), “Carbon neutrality by 2050: the world’s most urgent mission”, *retrieved from United Nations website on 15 June, 2021*.
- [2] European Environment Agency EEA (2021), “Rail and waterborne – best for low-carbon motorized transport”.
- [3] DecisionWare Group LLC (2020), “NDC Pathways Analysis Energy Sector Report” Prepare for Worldbank and ministry of industry and Trade Vietnam.
- [4] General Statistics Office of Vietnam, “Statistical data for Vietnam”.
- [5] Institute of Energy IE, Ministry of Industry and Trade MOIT (2021a), “Vietnam energy statistic 2019”
- [6] Institute of Energy IE, Ministry of Industry and Trade MOIT (2021a), Forecasted data for 2020 – 2050.
- [7] Jacopo Tattini, Maurizio Gargiulo, Kenneth Karlsson (2018), “Reaching carbon neutral transport sector in Denmark – Evidence from the incorporation of modal shift into the TIMES energy system modeling framework”, *Energy Policy*, 113, 571-583.
- [8] Ministry of Transport of Vietnam (2015), “Tracking Sustainable Transport in Vietnam: Data and Policy Review for Energy Efficiency and Climate Change 2015”.
- [9] Ministry of Transport of Vietnam (2021), “Forecasted data for transportation”.
- [10] ShuZang (2020), Modeling the Rapid Development of Electric Vehicles and Energy Storage Technology Under China Carbon Neutral Scenario Based on China-TIMES Model, *Proceeding of 12th International Conference on Applied Energy*, ISBN 978-91-986738-0-7 Volume 10.
- [11] The Government of the Republic of Korea (2020), “2050 carbon neutral strategy of the Republic of Korea towards a sustainable and green society”.
- [12] The Government of Vietnam (2020), “Updated nationally determined contribution (NDC)”.
- [13] UNFCCC (2020), “Climate neutral now: Guideline for participation”.