Monitoring Greenhouse Gas Emissions in Thailand's Transport Sector

Towards a measurement, reporting, and verification system for the land transport sector

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The Project Context

The GIZ Programme on Cities, Environment and Transport (CET) in ASEAN seeks to reduce emissions from transport and industry by providing co-benefits for local and global environmental protection. The CET Project ‘Energy Efficiency and Climate Change Mitigation in the Land Transport Sector in the ASEAN region’ (Transport and Climate Change (TCC) www.TransportandClimateChange.org) aims to develop strategies and action plans for more sustainable transport.

As presented to the ASEAN Land Transport Working Group, TCC’s regional activities are in the area of fuel efficiency, strategy development, green freight, and Nationally Appropriate Mitigation Actions in the transport sector. At the national level the project supports relevant transport and environment government bodies in the Philippines, Thailand, Vietnam, Malaysia and Indonesia, for the development of national action plans and improvement of policy monitoring systems. The project is funded by the German Federal Ministry for Economic Cooperation and Development.

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List of abbreviations

2 / 3 W	two / three-wheelers
BMA	Bangkok Metropolitan Authority
BEM	Bangkok Expressway and Metro public company limited
BMTA	Bangkok Mass Transit Authority
BTS	Bangkok Mass Transit Public Company Limited
BUR	Biennial Update Reports
CFS	Commodity Flow Survey
CNG	Compressed Natural Gas
DEDE	Department of Alternative Energy Development and Efficiency
DLT	Department of Land Transport
DOEB	Department of Energy Business
DOH	Department of Highways
DPT	Department of Public Works and Town & Country Planning
DRR	Department of Rural Roads
eBUM	extended Bangkok Urban Area Model
EF	Emission Factor
EPPO	Energy Policy and Planning Office
EXAT	Expressway Authority of Thailand
GHG	Greenhouse Gas
HCV	Heavy Commercial Vehicle
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
LCV	Light Commercial Vehicle
LPG	Liquefied Petroleum Gas
MAC	Marginal Abatement Cost
MICT	Ministry of Information and Communication Technologies
MRT	Mass Rapid Transit
MRV	Measurement, Reporting and Verification
MTOE	Million Tonnes of oil equivalent
NCV	Net Calorific Value
NG	Natural Gas
NGV	Natural Gas Vehicle

NLTS	National Land Transport System
OD	Origin - Destination
OTP	Office of Transport and Traffic Policy and Planning
PCD	Pollution Control Department
PKT (also p-km)	Passenger-Kilometre Travelled
SFC	Specific Fuel Consumption
SLCP	Short-Lived Climate Pollutants
SRT	State Railway of Thailand
TEEMP	Transport Emission Evaluation Model for Projects
TAI	Thailand Automotive Institute
TGO	Thailand Greenhouse Gas Management Organisation (Public Organisation)
TKT (also t-km)	Tonne-Kilometre Travelled
UNFCCC	United National Framework Convention on Climate Change

Executive summary

Monitoring of greenhouse gas emissions has gained importance in the context of international climate policy and the UNFCCC, particularly for Intended Nationally Determined Contributions (climate change action plans submitted in 2015), Nationally Appropriate Mitigation Actions, and Biennial Update Reports. Given its diversity of modes, vehicles, fuels, and links to behaviour and multiple societal interests, the transport sector is known for its complexity for measurement, reporting and verification of emissions and emission reductions. Improving data and monitoring systems will not only assist climate change policy, it will also enhance capacity to plan and monitor sustainable transport policies. **This report therefore aims to assist in developing an MRV system for the national land transport sector in Thailand by gathering and analysing existing data and the institutional setup of data collection and reporting. All data gathered are included in the accompanying Excel database. This report also includes an initial analysis of first steps to be taken by several organisations to improve transport data.**

Generally, GHG emission could be estimated by two approaches; top-down and bottom-up. In the top-down approach, for historical emission estimates based on fuel sales, there appear to be uncertainties related to diesel consumption, particularly in the allocation of activities to the transport sector versus other sectors. The bottom-up approach uses more data inputs, including vehicle-km travelled (VKT), vehicle fleet, and specific fuel consumption. In addition, transport demand, trip patterns, vehicle speeds, occupancy rates, modal split data are also needed.

The study of existing Thailand transport sector data shows that the statistics for vehicle registration for all vehicle types, including by age and fuel type, are readily available. However, other data, notably specific fuel consumption, vehicle speed patterns, occupancy rate, modal split and trip patterns need to be improved.

To address such barriers and improve transport MRV step-by-step, we propose the improvement of data collection through type approval testing and real-life measurements, household surveys, traffic counts, existing data of public transport operators and other surveys. To illustrate, the general population and housing census, as well as the annual socio-economic survey, could be expanded with one or multiple transport questions related to daily commuting; collection of odometer data to support VKT data can be improved. Another issue of data collection relates to vehicle classification, which should be adjusted so as to strike a balance between comprehensiveness and practicality.

In addition, the study identifies a need to set up a Transport MRV Joint Working Group, in which all related agencies participate to coordinate data collection, reporting and verification. One key task of the working group is to agree on data gathering methodologies in order to ensure high data quality. Templates for common reporting of key data are required, as well as more technical knowledge. Further coordination between various government organisations is recommended in order to ensure consistency in reported data.

In summary, there are the needs for support to setting up and implementing MRV land transport sector for Thailand. It is apparent that, cooperation between agencies is essential to setting up a sustainable MRV system. In many cases, multiple organisations have been gathering similar data, mostly in a project-based approach. In addition, data is often not publicly available and thereby may go unnoticed. Timely sharing and online publication of data is sometimes obstructed by regulations: such barriers should be removed and data sharing between organisations and to the public further promoted. Moreover, there needs to be top-down regulation, that emphasises the importance of MRV for climate change and transport planning purposes, and that asks related organisations to collect data e.g. vehicle kilometres travelled.

Financial resources are also required for setting up and implementing the MRV system. It may partially come from (existing) domestic sources, as this will improve the quality of transport policy and planning. International climate finance could also play role, e.g. through internationally supported NAMAs.

Some key fact found in this report:

- Thailand classifies 23 passenger and freight vehicle categories (and a myriad of sub-types) which is too diverse. To match the need of data usage especially for GHG emission calculation, regrouping the types of data are recommended.
- From 2004 to 2014, the number of cars and pick-ups increased by over 10% and 6% respectively, and trucks and two-wheelers by approximately 4% each.
- Annual mileage of private vehicles appears to be decreasing (note: more analysis required).
- About 50% of pick-ups, buses and trucks are older than 10 years, and approximately 20% are older than 20 years.
- Natural gas consumption in the transport sector has increased 10-fold in the period 2007 to 2012.

1. Introduction

Measurement, Reporting and Verification (MRV) in the context of climate change mitigation covers various issues including greenhouse inventory development of baseline and mitigation scenarios, and ex-post monitoring of policies and measures. As of 2016, there is no 'Gold Standard' for MRV in transport, even though experiences from other countries can be helpful in design a country's monitoring system. For Thailand, the approach is therefore to start from existing material, and design a process to improve data availability, monitoring methodologies and capacity. This is in line with international thinking on MRV of Nationally Appropriate Mitigation Actions and Biennial Update Reports[1] as part of reporting to the UNFCCC on climate change. The transport sector covers both passenger and freight, urban and inter-urban, all modes, but excludes international transport. Of the greenhouse gases, CO_2 is the most important, but others, notably methane and nitrous oxide, may be considered.

An MRV system, even if not precisely defined, would consist of necessary data, statistical methods, calculation methodologies, modelling tools, monitoring approaches, a reporting mechanism, verification mechanism, and an organisational structure with responsible organisations. The forthcoming 'Reference Document on Monitoring Systems for the Transport Sector' and the 'MRV Blueprints'[2] give extensive guidance related to such MRV systems and in this report we make use of many concepts discussed there.

It is important to note that a transport MRV system will not only serve climate change objectives, but also helps to improve the knowledge base and capacity to design, implement and monitor sustainable transport policies and plans.

However, since MRV for transport sector is an unprecedented system in Thailand. The assessment of data availability and gap should be the primary action. Therefore, this report aims to support the development of a system for measuring and monitoring the GHG emission of Thailand's national land transport sector. It consequently focuses mainly on the "M" or measuring or monitoring of GHG emission reductions. Information sources are international and national literature, existing data from databases and statistics in Thailand, national and international expert input, and a few own calculations. The draft report; December 2015, was discussed at the MRV Stakeholder Workshop held on 25 April 2016, in which 63 participants from relevant government organisations and related stakeholders participated (see Annex I for a workshop summary). Oral and written feedback was gathered at this workshop and afterwards, and included in this final report.

The report is divided into the following chapters. Chapter 2 starts with an overview of Thailand's national land transport system and provides an overall framework for the methodology of GHG emission estimation for the national land transport system. Chapter 3 presents an inventory and gaps in existing data, based on both the top-down and bottom-up approaches for emission estimations. Based on this Chapter 4 analyses which stakeholders could play a role in improving the MRV system and which immediate issues need to be addressed. In addition, Annex V discusses the technique of marginal abatement cost (MAC) analysis, with an illustration for non-motorised transport.

[1] http://unfccc.int/national_reports/non-annex_i_natcom/items/2716.php
[2] http://transport-namas.org/measuring-reporting-and-verification-mrv-expert-group/

2. Methodology for monitoring GHG of national land transport sector

This chapter outlines the approach and methodology for developing the MRV system, particularly the necessary data. Chapter 3 will apply these concepts and go into the details of the data.

2.1. General approach

There are two, related but distinct, aspects of MRV of transport emissions:

- Estimating total emissions in the sector (mainly 'mega level' in Figure 2-1)
- Estimating emission reductions (ex-ante or ex-post) as a result of mitigation actions (mainly 'macro' and 'micro level' in Figure 2-1, with more explanation in Annex IV)

Figure 2-1 Overall monitoring framework (Grütter, 2015)

This report deals predominantly with the data needed to apply the mega and macro level approaches, and to some extent the micro level. However the data at the higher levels is often helpful and essential as well in the micro level, and data consistency between the levels also needs to be ensured.

We focus on greenhouse gases covered by the Intergovernmental Panel on Climate Change (IPCC), and predominantly on CO_2. It should be noted that in addition to these substances, the transport sector causes considerable emissions of short-lived climate pollutants (SLCP) such as particulate matter and ozone precursors. The reduction of SLCP emissions often contributes to climate change mitigation, in addition to health benefits.

2.2. National land transport system

In view of the overall energy use within the various sectors in Thailand, energy use by transport is comparable to that of the industrial sector, with their respective percentages recorded at 35.4% and 35.9%. Within the transport sector, road transport has the highest CO_2 emissions, amounting to 97% of the total transport emissions (see Figure 2-2).

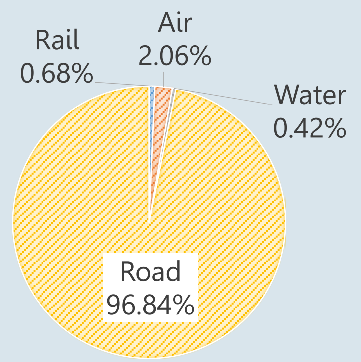


Figure 2-2 Shares of greenhouse gas released by Thailand's transport sector (Source: OTP, 2012)

From the previous statistics, it is shown that the transport by road and rail account for almost 97% of the entire transport system (Figure 2-2). Hence, this report is concentrated on the land transport activities which included road transportation and rail transportation. The term NLTS (National Land Transport System) will be used in the report which, again, includes activities for both road and rail transportation. The system is classified into the movement of both passengers and freight in both city and intercity area, followings by types of vehicle in those separate areas. Figure 2-3 presents the system characteristics of the NLTS that will be used for developing the methodology of GHG emission estimation.

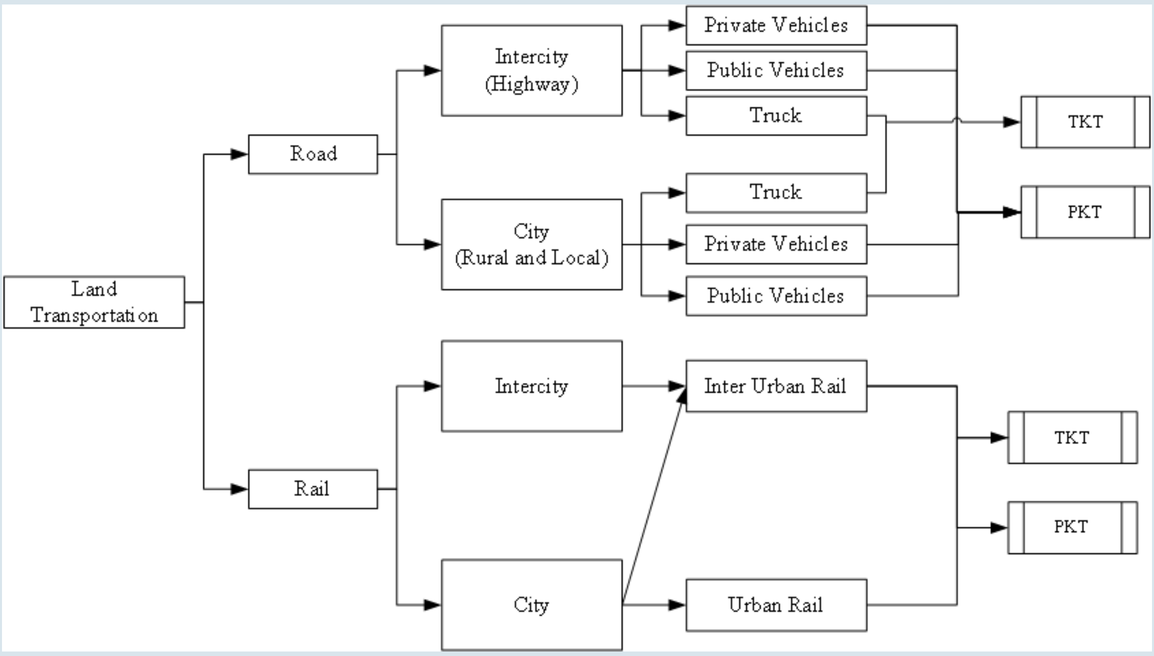


Figure 2-3 Overview of the national land transport system (Source: Authors)

The characteristics of road transport can be classified into passenger (passenger-km travelled, PKT) and freight travel (ton-km travelled, TKT). Both passengers and freight can also be classified into intercity and intra-city (inside the city) travel. The inter-city movements refer to passengers and freight on highway/railway, while the city movements are passengers and freight moving on the arterial, urban street, or local roads. This report will consider three types of vehicle group including private vehicles, public vehicles, and trucks. Private vehicles include passenger car less than 7 passengers (PC<7 or sedan), passenger car more than 7 passengers (PC>7 or microbus & van), and pickup, as well as motor-tricycle taxi, motorcycle, and motorcycle-taxi. For public vehicles, the vehicles are buses, including fixed and non-fixed route bus and small buses. Finally, vehicle type of truck will consider all truck, trailer, and semi-trailers. For the city travel, the private vehicle group will consider 2W&3W (2 wheeler and 3 wheeler), while 2W&3W will not be considered for the inter-city travel (see chapter 3 for further details).

For rail transport, the system is also classified into the passenger and freight movements. Rail system is divided into two main groups, urban-rail system and intercity rail system. The urban rail system is the electricity train serving the passengers traveling inside Bangkok. On the other hand, the intercity rail system is served both the passengers traveling inside Bangkok and the intercity-traveling passengers. Freight movements are also served by this intercity-rail system.

2.3. Monitoring and measuring NLTS

Following the IPCC Guidelines for Greenhouse Gas Inventories (IPCC, 2006), the fundamental methodologies for estimating greenhouse gas emissions can be based on two independent sets of data: fuel sold (top-down approach) and vehicle kilometres travel (bottom-up approach). The top-down approach is basically to give information concerning total transport emissions, and the trends over time, from the system (NLTS). Further, it should be also noted that, even though this approach delivers valuable information, it is not disaggregated enough to allow for an assessment of transport strategies and transport interventions. Results of GHG emission estimation from the top-down approach will be also used as the validation data for the GHG emission estimations from the bottom-up approach.

The bottom-up approach gives information concerning transport strategies and policies and reads? core trends, thus allowing to evaluate if a sustainable transport policy is on track. It can be separated in the areas of vehicles (monitored through emissions per VKT per mode and eventually vehicle category), freight with the indicators emission per t-km[3] and the mode share per t-km and passenger transport with the indicators emissions per p-km, emissions for transport per inhabitant and the mode share per p-km. The area of passengers is separated into urban and inter-urban passenger transport. Figure 2-4 and Table 2-1 present the top-down and bottom-up approach.

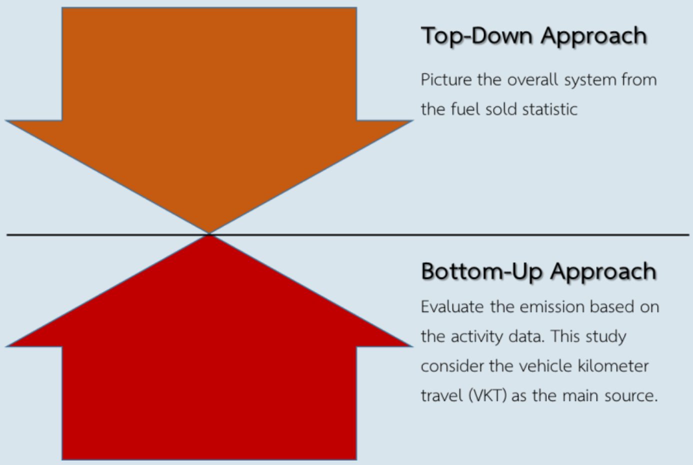


Figure 2-4 Top-down and bottom-up approach (Source: Authors)

Table 2-1 Summary of emission estimation approach and key indicators (Source: Authors)

Approach	Main Inputs	Main Outputs	GHG Outputs	Key Indicators
Top-Down	Fuel Sales Statistics (Road) Fuel Sales Statistics (Rail)	Fuel Consumption	tCO_2 tCH_4 tN_2O	tCO_2 of road and rail transport
Bottom-Up	Vehicle Registration Records Data from Road Side Interview Survey Data from Home Interview Survey Inter Urban Rail Transport Statistics Urban Rail Transport Statistics	VKT/PKT/TKT Fuel Consumption by type of vehicles VKT/PKT/TKT Fuel consumption of rail from operation data	tCO_2 tCH_4 tN_2O	tCO_2/VKT tCO2/TKT tCO2/PKT

[3] t-km / p-km can be considered equal to TKT / PKT; both are used in this report;

2.3.1. Top-down approach

To estimate emissions in the top-down approach, amount of fuel sale is used as the main source for GHG emission estimation. The emission can be estimated by multiplying the quantity of fuel sold by Net Calorific Value (NCV) and Emission Factor (EF) for each type of fuel. Equation 2.2-1 presents this calculation in the equation format.

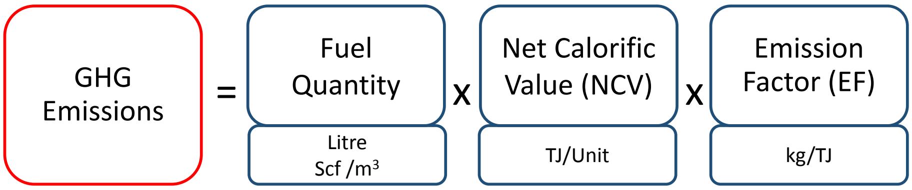


Figure 2-5 GHG emission estimation for top-down approach

$$CO2\ Emission = \sum_a Fuel_a * NCV_a * EF_a \qquad \text{[eq.2.2-1]}$$

where:

$Emission$ = Emissions of CO_2, CH_4, or N_2O (kg)
$Fuel_a$ = Fuel Sold (liter or scf)
NCV_a = Net Calorific Value (NCV) (TJ)
EF_a = emission factor (kg/TJ)
A = type of fuel (e.g. petrol, diesel, natural gas, LPG etc)

Additionally, for estimating CO_2 emissions from use of urea-based additives in catalytic converter (non-combustive emissions), the 2006 IPCC Guidelines recommend using equation 2.2-2.

$$CO2\ Emission = Activity * \frac{12}{60} * Purity * \frac{44}{12} \qquad \text{[eq.2.2-2]}$$

where:

$Emission$ = CO_2 emissions from urea-based additive in catalytic converter (Gg CO_2)
$Activity$ = amount of urea-based additive
$Purity$ = the mass fraction (= percentage divided by 100) of urea in the urea-based additive

The factor 12/60 captures the stoichiometric conversion from urea ($CO(NH_2)_2$) to carbon, while factor 44/12 converts carbon to CO_2. On the average, the activity level is 1 to 3 percent of diesel consumption by the vehicle. 2.5 percent can be taken as default purity in case country-specific values are not available.

Further, to estimate CH_4 and N_2O for road and rail transport, which can be significant particularly for CNG vehicles, see Section 3.1.

2.3.2. Bottom-up approach

In general, to estimate the GHG emissions in the bottom-up approach, the ASIF approach is applied (Schipper et al., 2000). ASIF stands for the variables of a generic equation to calculate the GHG emissions of transport, see Figure 2-6.

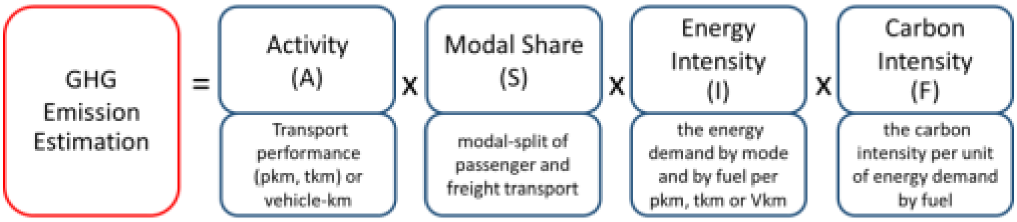


Figure 2-6 The ASIF approach to estimate the GHG emission

However, due to limited data availability in Thailand, the calculation of the (A), (S), and (I) are differently distinguished for each mode and types of vehicles. To clarify these differences, the estimation of transport demand are grouped into the followings 4 categories: (1) demand of private transport (Car), (2) demand of road public transport (Bus), (3) demand of road freight transport (Truck), and (4) demand of rail public and freight transport.

Private transport (Car) demand

The energy demand of private transport (Car; including motorcycles) is calculated from a product of four factors includes: total number of vehicle stock (VS), Average travel distance of vehicle (AvgTravel), share of energy types (Share), and Specific fuel consumption of vehicle (SFC). Using these factors, total energy consumption for private road transport can be calculated as shown below.

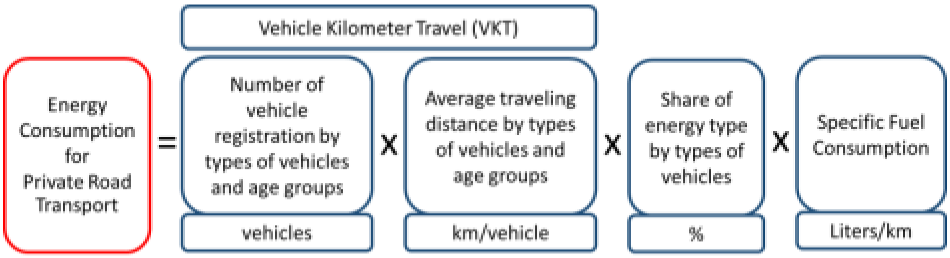


Figure 2-7 Energy consumption for private road transport

$$EC = \sum_j \left(\sum_i \sum_t \left(VS_{jit} \times AvgTravel_{jit} \times Share_{it} \times SFC_{it}\right)\right) \quad \text{[eq.2.2-3]}$$

where:

EC	= Energy consumption for private road transport (litre)
VS	= Number of vehicle registration (vehicles)
AvgTravel	= Average travel distance of vehicle (km/vehicles)
Share	= Share of energy type by types of vehicles (%)
SFC	= Specific fuel consumption of vehicle (litre/kilometre)
i	= vehicle type i
j	= energy consumption type j
t	= age of vehicle

To calculate PKT for private road transport, the total VKT data will be needed to classified into two: (1) total VKT for Bangkok and its vicinity area and (2) total VKT for provincial areas. Then, using results from home interview surveys, the VKT in both groups will be classified into three sub-groups of traveling characteristics including (1) urban travel in Bangkok and its vicinity areas, (2) intercity traveling, and (3) traveling for provincial cities. Finally, PKT in each sub-groups can be estimated by its average occupancy characteristics. The following figure summarises this calculation process.

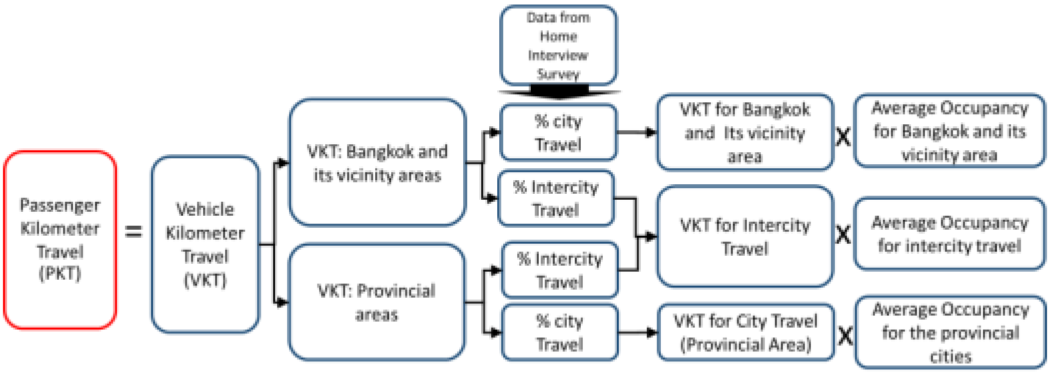


Figure 2-8 Alternative to estimate PKT for private road transport

Demand of road public transport (Bus)

The key difference in demand of road public transport (Bus) from the private transport is the classification of vehicles types. Currently, Department of Land Transport (DLT) registers vehicles by its criteria such as number of seats, engines, and services. Therefore, types of buses need to be carefully categorised before estimating total energy consumption for road public transport.

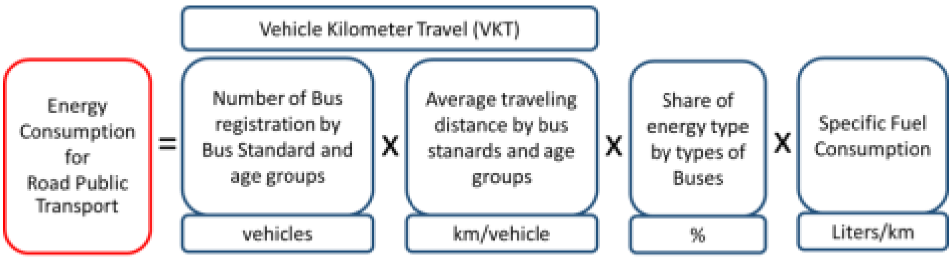


Figure 2-9 Energy consumption for road public transport

$$EC = \sum_j \left(\sum_i \sum_t \left(VS_{jit} \times AvgTravel_{jit} \times Share_{it} \times SFC_{it}\right)\right. \quad \text{[eq.2.2-4]}$$

where:

EC	= Energy consumption for road public transport
VS	= Number of bus registration (vehicles)
AvgTravel	= Average travel distance of bus (km/vehicles)
Share	= Share of energy type by type of bus (%)
SFC	= Specific fuel consumption of vehicle (litre/kilometre)
i	= Bus standard i
j	= energy consumption type j
t	= age of bus

To calculate passenger kilometre travel (PKT) for road public transport, the data of total services trips and total passengers for each bus routes from DLT will be used. DLT classifies type of bus services into 3 types including (1) Bangkok and Its vicinity areas, (2) Bus Services between provinces, and (3) Bus services inside the provinces. Hence, PKT for each bus service groups can be estimated.

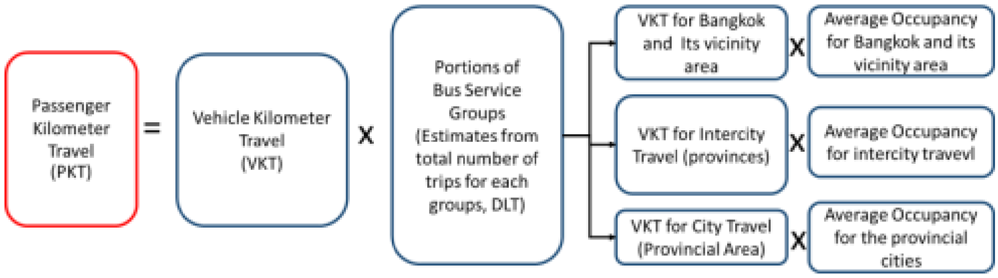


Figure 2-10 Estimation PKT for public road transport

Demand of road freight transport (Truck)

Similar to the private transport, the energy demand of road freight transport (Truck) are calculated from a product of four important factors includes: total number of vehicle stock, average travel distance of vehicle (AvgTravel), share of energy types (Share), and Specific fuel consumption of vehicle (SFC). Using these factors, total energy consumption for private road transport can be calculated as shown in Figure 2-11 and Equation 2.2-5.

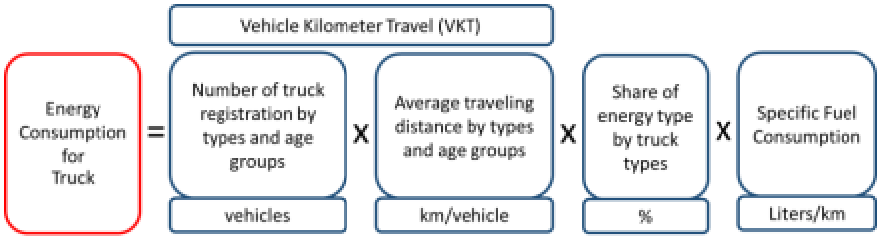


Figure 2-11 Energy consumption for truck

$$EC = \sum_j (\sum_i \ \sum_t (VS_{jit} \times AvgTravel_{jit} \times Share_{it} \times SFC_{it}) \qquad \text{[eq.2.2-5]}$$

where:

EC = Energy consumption for truck
VS = Number of truck registration (vehicles)
AvgTravel = Average travel distance of vehicle (km/vehicles)
Share = Share of energy type by types of trucks (%)
SFC = Specific fuel consumption of vehicle (liter/kilometer)
i = vehicle type i
j = energy consumption type j
t = age of vehicle

To evaluate Ton-Kilometer Travel (TKT) for trucks, the commodity survey from National Statistical Offices (NSO) will be used. Total VKT for trucks will then be multiplied by average tonnes/truck trips and regions in order to estimate number of tons kilometre travel, see Figure 2-12.

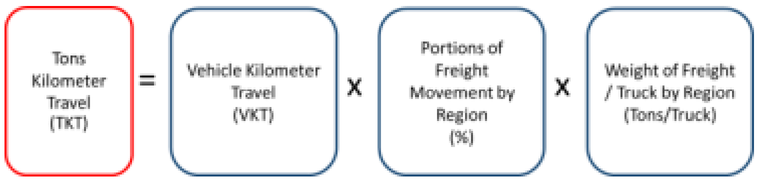


Figure 2-12 Estimation of TKT for public road transport

Demand of rail public and freight transport (Rail)

For city train, the systems of the city trains are currently operated by the electric and trains are for passenger movements. Currently, only few types of data are published and available (see Chapter 3). The data that are available and published from the city train system (MRT and BTS) are total number of passengers using the system. However, even though number of passengers by origin-destination could be gathered directly from the electronic ticket system, data are only available upon request. For total electricity consumption by the urban rail systems, the same may be true.

For intercity train, more details of data are available. The most important data which is amount of diesel used in locomotive are recorded. Therefore, amount of diesel uses in the intercity train can be directly measured. Allocation of fuel use to passenger and freight will be discussed in Chapter 3.

Additionally, for future estimation of the energy consumption for the intercity train, two indicators are required. The first indicator is “the energy consumption per passenger-km” and the second indicator is “the energy consumption per freight tonne-km”. These indicators can be easily calculated since Thai Railway Department annually records data of PKT and TKT. Equation 2.2-6 and 2.2-7 presents the calculations of these indicators.

$$ECperPKT = \frac{EC\ for\ Passengers}{Total\ PKT} \qquad \text{[eq.2.2-6]}$$

where:
ECperPKT = Energy consumption per passengers kilometre travel
EC for Passengers = Total energy consumptions for passenger locomotives (figure 2-13)
Total PKT = Total Passenger Kilometre Travel

$$ECperTKT = \frac{EC\ for\ Freight}{Total\ TKT} \qquad \text{[eq.2.2-7]}$$

where:
ECperTKT = Energy consumption per tons kilometre travel
EC for Freight = Total energy consumptions for freight locomotives (figure 2-13)
Total TKT = Total Tons Kilometre Travel

These indicators will be used as the parameters to estimate the energy consumptions of the intercity train system in the future year, Figure 2-13 and Figure 2-14.

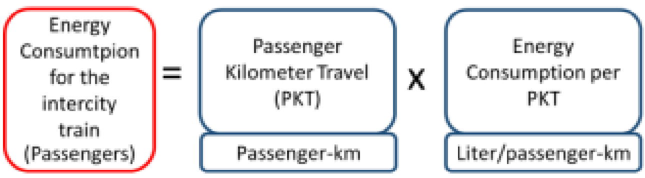


Figure 2-13 Estimation of energy consumption in the intercity train (Passengers) for future forecast

Figure 2-14 Estimation of energy consumption in the intercity train (Freights) for future forecast

3. Data inventory and gaps

This chapter discusses existing data that are necessary in using the methodology from Chapter 2.

3.1. Factors and parameters

Following IPCC Guidelines for National Greenhouse Gas Inventories, there are three Tiers presented for estimating emissions from fossil fuel combustion. Since, there are no country specific emission factors (EFs) available, for the Top-Down approach, this study will use the default parameters as recommended to use in the IPCC Tier 1 approach. Table 3-1 presents road transport default CO_2 emission factors and uncertainty ranges, Table 3-2 methane and nitrous oxide factors.

Table 3-1 Road transport default CO_2 emission factors (kg/TJ) and uncertainty ranges (IPCC, 2006)

Fuel Type	Default	Lower	Upper
Motor Gasoline	69,300	67,500	73,000
Gas/Diesel Oil	74,100	72,600	74,800
Liquefied Petroleum Gases	63,100	61,600	65,600
Kerosene	71,900	70,800	73,700
Lubricants	73,300	71,900	75,200
Compressed Natural Gas	56,100	54,300	58,300
Liquefied Natural Gas	56,100	54,300	58,300

Note: Values represent 100 percent oxidation of fuel carbon content

Table 3-2 Road transport N_2O and CH_4 default emission factors and uncertainty ranges

Fuel Type / Representative Vehicle Category	CH_4 (kg/TJ)			N_2O (kg/TJ)		
	Default	Lower	Upper	Default	Lower	Upper
Motor Gasoline-Uncontrolled	33	9.6	110	3.2	0.96	11
Motor Gasoline – Oxidation Catalyst	26	7.5	86	8.0	2.6	24
Motor Gasoline – Low Mileage Light Duty Vehicle Vintage 1995 or later	3.8	1.1	13	5.7	1.9	17
Gasoline/Diesel Oil	3.9	1.6	9.5	3.9	1.3	12
Natural Gas	92	50	1540	3	1	77
Liquefied petroleum gas	62	na	na	0.2	na	na
Ethanol, trucks, US	260	77	880	41	13	123
Ethanol, cars Brazil	18	13	84	na	na	na

Source: Table 3.2.2, Chapter 3 (Mobile Combustion), 2006 IPCC Guideline for National Greenhouse Gas Inventories

For rail transport, Table 3-3 presents default emission factors for the most common fuel used for rail transport (as per Tier 1 approach).

Table 3-3 Default emission factors for the most common fuel used for rail transport

Emission	Diesel (kg/TJ)			Sub-bituminous Coal (kg/TJ)		
	Default	Lower	Upper	Default	Lower	Upper
CO_2	74,100	72,600	74,800	96,100	92,800	100,000
CH_4	4.15	1.67	10.4	2	0.6	6
N_2O	28.6	14.3	85.8	1.5	0.5	5

Source: Table 3.4.1, Chapter 3 (Mobile Combustion), 2006 IPCC Guideline for National Greenhouse Gas Inventories

For the energy content of fuel (Net Calorific Value, NCV), this report follows the values recommended by Energy Policy and Planning Office (EPPO), Ministry of Energy, Thailand. Table 3-4 summarises those recommended values.

Table 3-4 Energy content of fuel (Net Calorific Value)

Type	Unit	kcal/Unit	toe/10^6 Unit	MJ/Unit	10^3 btu/Unit
Natural Gas (Wet)	scf	248	24.57	1.04	0.98
LPG	litre	6,360	630.14	26.62	25.24
Gasoline	litre	7,520	745.07	31.48	29.84
Diesel	litre	8,700	861.98	36.42	34.52

Source: EPPO (Energy Policy and Planning Office), Ministry of Energy, Thailand

Further, the other parameter that is also important is the specific fuel consumption (SFC). There are two public sources[4] of SFC available in Thailand that may be used for estimating the fuel consumption. The first data set is the SFC published by the Office of Transport and Traffic Policy and Planning (OTP) and the second data set is published by the Energy Policy and Planning Office (EPPO). The following discusses these two data sets.

In 2012, the OTP studied the emission factors (emissions per vehicle-km) and fuel consumption from five main categories of vehicles including gasoline (passenger car, taxi, van, and pickup), diesel vehicles (pickup, van, bus, and truck), motorcycle, and tuk tuk and 3-wheeler. A total of 208 vehicles were tested in the lab at six vehicle speeds (kilometers/hour) and recorded for their SFC. Truck SFC data were not published in the report.

Additionally, data from specific fuel consumption were directly published from the laboratory results and each record (each tested vehicle) represents the fuel consumption for a given testing speed. However, the SFC testing data show an increasing trend without an optimum, which would normally be expected at speeds around 70-90 km/hr; see Figure 3-1, which presents the typical internal combustion engine specific fuel consumption which the SFC modeling curve should generally represent. From the figure, at the optimum operation line, the engine SFC will be decreasing with the

[4] There are non-public sources as well.

increasing of engine speed until its minimum point. After its minimum SFC point, the engine SFC will be increasing with increasing engine speed. In another illustrative example, Figure 3-2 shows how specific CO_2 emission factor for one car type in China varies with different road categories and levels of service, with speeds varying from <10 to >55 km/hr.

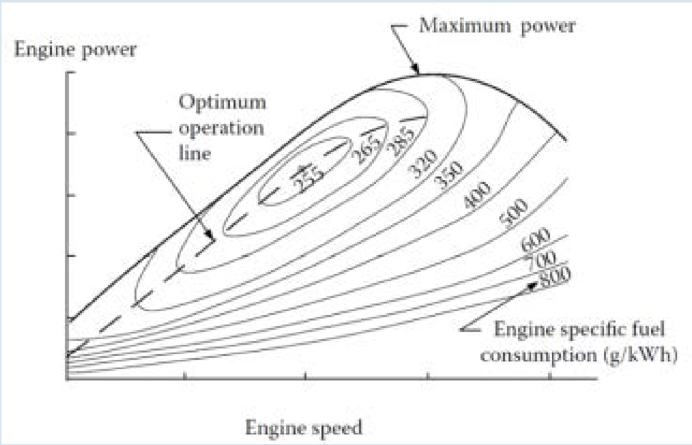


Figure 3-1 Typical internal combustion engine specific fuel consumption map (Source: Ben-Chaim et al., 2013)

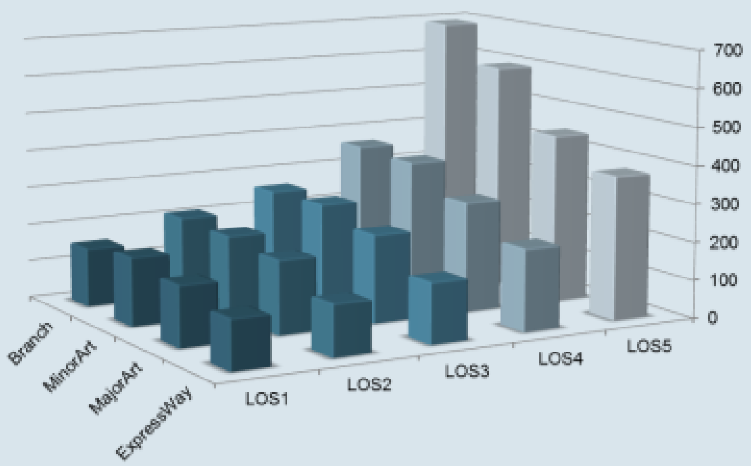


Figure 3-2 CO2 emission factors (g/km) for a typical Euro 4 1.6 litre passenger car in China under different road types and levels of service (Source: Bongardt et al., forthcoming)

Table 3-6 summarise the specific fuel consumption (SFC) from OTP's report based on type approval tests. The uses of this dataset, which shows relations of speeds to its fuel consumption, will be useful for testing of the policy impacts in the specific area where changes of the average traffic speed on networks or corridors can be determined. It should be further noted that, in Table 3-6, the reported SFC values of motorcycle (2W) between speed 33.2 kilometer/hour and 42.9 km/hr were decreasing after reaching its minimum SFC point at speed 23.4 km/hr. Following the typical internal combustion engine SFC in figure 3-1, the SFC values of speed 33.2 km/hr and 42.9 km/hr could potentially be switched. Rechecking details of this table before using as references is recommended.

Table 3-5 Specific fuel consumption (SFC, km/L) for bus, car, pickup, taxi, and van at different testing speeds

Vehicle Type	Fuel Type	MODEL	TISI Std.	MODEL YEAR	SPEED (kilometre/hour)					
					7.8	14.6	23.1	33.9	46.8	72.6
BUS	DIESEL	HINO	-	1992	3.17	4.36	5.26	6.05	6.73	10.11
Car	CNG	CHEVROLET OPTRA	-	2008	4.74	6.8	9.07	10.15	11.3	16.08
	CNG	TOYOTA ALTIS	-	2011	6.2	9.16	11.17	12.51	12.89	15.06
	CNG/NGV	MITSUBISHI LANCER	EURO III	2011	5.45	7.79	9.7	10.79	11.18	15.03
	GASOHOL 91	TOYOTA SULUNA VIOS	-	2004	8.78	11.6	13.6	15.6	16.3	20.1
	GASOHOL 91	TOYOTA VIOS	EURO III	2005	8.76	12.4	14.9	14.9	16.5	21.3
	GASOHOL 91	HONDA CITY	-	2009	7.95	11	13.4	14.8	15.3	21.3
	GASOHOL 91	HONDA CIVIC	EURO III	2009	7.55	10.3	12.6	14.49	14.29	20.72
	GASOHOL 91	NISSAN MARCH	-	2010	8.77	12.5	15.4	19	18.6	24.2
	GASOHOL 95	TOYOTA CORONA	EURO I	1992	5.15	7.91	9.96	11.47	11.67	15.84
	GASOHOL 95	MITSUBISHI LANCER	EURO I	1995	6.65	10.3	12.76	14.12	14.46	15.37
	GASOHOL 95	NISSAN SUNNY	-	2003	6.69	9.27	11.5	12.7	13.7	16.9
	GASOHOL 95	TOYOTA COROLLA ALTIS	EURO II	2004	6.99	9.62	11.51	12.51	13.57	17.76
	GASOHOL 95	HONDA CITY	EURO III	2005	9.25	12.94	16.34	18.25	17.9	20.13

Vehicle Type	Fuel Type	MODEL	TISI Std.	MODEL YEAR	SPEED (kilometre/hour)					
					7.8	**14.6**	**23.1**	**33.9**	**46.8**	**72.6**
Car	GASOHOL 95	TOYOTA VIOS	EURO III	2007	9.14	12.61	15.17	17.58	17.44	20.22
	GASOHOL 95	TOYOTA COROLLA ALTIS 1.6	EURO III	2011	7.11	9.78	11.5	12.8	13.2	14.8
	GASOHOL E20	NISSAN CEFIRO	EURO I	1999	4.58	6.76	8.06	9.2	8.93	12.1
	GASOHOL E20	TOYOTA CAMRY	-	2004	5.27	7.27	9.24	11.4	12	15.9
	GASOHOL E20	TOYOTA SOLUNA VIOS	EURO III	2007	8.48	12.6	14.7	17.6	17.3	20
	GASOHOL E20	HONDA JAZZ	EURO III	2008	8.05	11.6	13.88	16.14	15.91	17.86
	GASOHOL E20	HONDA CIVIC	-	2009	6.42	8.91	10.9	12.6	12.8	18.5
	GASOLINE 91	MITSUBISHI LANCER	-	1995	7.05	10.2	12.99	13.95	13.98	15.59
	GASOLINE 91	MITSUBISHI LANCER	-	1999	8.65	12.5	14.18	17.67	17.68	19.26
	GASOLINE 91	NISSAN MARCH	-	1999	4.87	7.96	10.48	12.56	13.04	16.05
	GASOLINE 91	FORD LASER	-	2002	6.39	10.31	11.76	13.22	13.25	16.66
	GASOLINE 91	TOYOTA ALTIS	-	2003	7.56	10.65	12.68	14.96	15.19	17.22
	LPG	TOYOTA COROLLA	EURO I	1996	4.1	5.83	6.96	7.7	8.61	13.14
	LPG	MAZDA ASTINA	EURO I	1998	3.52	5.64	7.35	8.55	8.92	12.62
	LPG	NISSAN SUNNY	-	2000	3.52	5.68	7.37	8.57	9.78	12.73
	LPG	MITSUBISHI LANCER	EURO II	2002	2.59	3.6	6.79	7.25	7.58	8.59

Vehicle Type	Fuel Type	MODEL	TISI Std.	MODEL YEAR	SPEED (kilometre/hour)					
					7.8	14.6	23.1	33.9	46.8	72.6
	LPG	NISSAN SUNNY NEO	EURO II	2003	3.97	6.28	7.89	8.89	9.73	13.04
PICKUP	CNG/NGV	MITSUBISHI TRITON	EURO III	2011	5.27	8.02	10.05	11.87	12.2	14
	CNG/NGV	TOYOTA HILUX	EURO III	2011	4.54	6.69	8.14	9.25	9.93	11.78
	DIESEL	TOYOTA HILUK D4D	Euro II	2003	7.49	9.38	12.4	14.68	14.95	17.49
	DIESEL	ISUZU DMAX	Euro III	2006	7.14	9.46	12.08	13.97	14.78	17.44
	DIESEL B3	NISSAN BIG M	-	1989	4.69	5.95	8.65	10.2	10.6	12.79
	DIESEL B3	TOYOTA MIGHTY X	-	1991	5.97	7.39	10	12.18	12.64	13.59
	DIESEL B3	MITSUBISHI STRADA L200	-	2002	5.94	8.48	10.08	11.41	12.8	13.55
	DIESEL B3	NISSAN FRONTIER	-	2006	6.45	8.26	10.64	12.92	13.34	15.49
	DIESEL B3	ISUZU MU7	-	2006	6.94	8.64	10.92	12.96	13.34	15.13
	DIESEL B3	NISSAN NAVARA	-	2007	6.27	8.51	10.73	11.57	13.06	15.43
	DIESEL B3	ISUZU D-MAX 2.5	-	2009	7.79	10.01	12.76	14.72	15.24	17.67
PICKUP	DIESEL B3	FORD RANGER	-	2010	7.6	9.57	12.45	14.39	14.86	17.14
	DIESEL B5	ISUZU TFR 2.5	-	1993	7.24	9.16	12.3	14.64	15.4	17.78
	DIESEL B5	FORD RANGER 2.5	-	2000	5.55	7.02	9.39	11.03	11.44	13.72
	DIESEL B5	ISUZU DRAGON POWER	-	2002	6.56	9.46	11.44	12.48	13.62	16.51

Vehicle Type	Fuel Type	MODEL	TISI Std.	MODEL YEAR	SPEED (kilometre/hour)					
					7.8	14.6	23.1	33.9	46.8	72.6
	DIESEL B5	TOYOTA HILUK D4D	Euro II	2003	7.82	9.89	12.96	15.35	15.64	18.9
	DIESEL B5	ISUZU D-MAX 3.0	-	2005	6.25	10.71	12.71	14.95	15.33	18.28
	DIESEL B5	TOYOTA HILUX VIGO	-	2005	7.61	9.35	12.22	14.13	14.29	16.96
	DIESEL B5	ISUZU DMAX	Euro III	2006	7.48	10.02	12.74	14.81	15.85	18.76
	DIESEL B5	MITSUBISHI TRITON	-	2011	7.27	9.51	12.96	14.72	15.12	17.66
TAXI	CNG/NGV	NISSAN TIIDA	EURO III	2009	5.85	8.88	11.38	13.22	13.65	16.6
	CNG/NGV	TOYOTA ALTIS	EURO III	2010	6.34	9.28	10.79	12.11	12.08	14.15
	LPG	TOYOTA ALTIS	EURO III	2008	5.96	8.48	9.64	10.65	11.38	11.65
VAN	CNG	TOYOTA HIACE	-	2011	4.03	5.9	7.57	8.31	8.58	10.31
	CNG/NGV	TOYOTA COMMUTER HIACE	EURO III	2011	4.49	6.61	8	9.09	9.18	11.09
	DIESEL B3	TOYOTA HIACE 2.5	-	1994	5.44	6.35	8.83	11.16	12.31	13.15

Source: The Study to Develop Master Plan for Sustainable Transport System and Mitigation of Climate Change Impacts (OTP, 2012)

Table 3-6 Specific fuel consumption (km/L) for motorcycle (2W) at different testing speeds

Vehicle Type	Fuel Type	MODEL	MODEL YEAR	SPEED (kilometre/hour)					
				7.4	14.6	23.4	33.2	42.9	56.1
2W	Gasoline 91	YAMAHA SPEED	2001	10.04	15.02	14.49	16.4	16.6	19.51
	Gasoline 91	HONDA NOVA DASH	2002	8.64	14.37	18.66	29.19	24.78	33.61
	Gasoline 91	HONDA DREAM	2003	36.17	52.9	51.52	54.74	51.85	60.48
	Gasoline 91	YAMAHA SPARK	2005	27.32	37.73	38.58	42.44	40.01	46.34
	Gasoline 91	HONDA WAVE 125	2005	36.3	51.63	51.72	53.81	50.08	64.63
	Gasoline 95	SUZUKI SMASH	2006	24.87	37.93	41.6	47.69	43.12	49.57
	Gasoline 91	YAMAHA FINO	2008	21.86	33.12	36.22	38.46	35.43	41.27
	Gasoline 91	HONDA CLICK I	2009	29.18	43.1	42.11	47.69	44.13	50.56
	Gasoline 91	SUZUKI JELATO	2009	24.4	36.8	37.4	43.1	41.7	50.8
	Gasoline 91	SUZUKI SHOGUN	2010	34.66	48.44	46.54	52.7	47.22	59.71
	Gasoline 91	YAMAHA MIO	2010	22.46	31.09	32.59	36.2	34.64	39.12
	Gasoline 91	HONDA WAVE I	2010	49	67.6	60.6	63.27	56.4	67.8
	Gasoline 91	HONDA SCOOPY I	2010	32.46	46.79	45.49	49.25	44.41	
	Gasoline 91	YAMAHA FIORE	2011	30.32	45.95	46.03	50.54	46.82	55.31
	Gasohol 91	HONDA WAVE 125 I	2011	41.7	59.2	58.8	64	57.7	63.1
	Gasohol 91	HONDA MIO 125 GTX	2011	23.7	34.3	37.8	42	41.8	50.6

Source: The Study to Develop Master Plan for Sustainable Transport System and Mitigation of Climate Change Impacts (OTP, 2012)

EPPO (2014) also published results of the SFC from their study. However, rather than estimating the SFC based on the engine tests in the laboratory, EPPO estimated SFC based on the questionnaire survey. A total of 10,766 questionnaires were distributed throughout the country, classified into seven regions including: (1) Bangkok and its vicinities, (2) Central region, (3) Eastern region, (4) Western region, (5) North Eastern region, (6) Northern region, and (7) Southern region. Five types of questions that are in the questionnaire are:

(1) Vehicle general information (i.e. model, engine, year of registration, and odometer read),
(2) Energy information and consumptions (i.e. type of energy and its consumptions by estimating from the daily usages),
(3) Usages of Vehicle (i.e. weekday usages, weekend usages, occupancy, number of trips/day in case of freight vehicles),
(4) Reasons for selecting types of fuel, and
(5) Interviewee characteristics (socio-economic).

Table 3-8 to Table 3-10 presents SFC published by EPPO. The SFC was recorded from questionnaires, which rely on users' inputs, not direct measurements from vehicles. When observing these data it should be noted that some of the SFC values seem higher than expected. For example, in Table 3-9, the LPG consumptions from Fixed Route Taxi is higher than those from Urban Taxi. Also, the value of gasoline consumption for Fixed Route Bus is equal to 12.74 kilometer/liter which is quite high for bus. The value is expected to be those from car or private vehicle. The possible reasons or explanation for these unexpected values are not known.

The default fuel consumption values used in Transport Emission Evaluation Model (TEEMP) published by Clean Air Asia are used to compare the average EPPO SFC data for eight vehicle types (see Table 3-7). TEEMP modules used for estimating CO_2 emissions in several Global Environment Facility projects on sustainable transportation. From the table, most SFC values are generally in a similar range. However, the SFC values from 3Ws and HCVs differ significantly. The reasons for these differences may range from driving behavior, types of engines, to roadway environment.

Table 3-7 Comparison of SFC published by EPPO and recommended SFC in TEEMP [L/100km]

Type of Vehicle	TEEMP	EPPO		
		Bangkok	Province	Average
2W	1.8	3.06	2.88	2.97
3W	3.5	-	7.70	7.70
PC (Gasoline)	8	8.74	7.52	7.66
PC (Diesel)	7	8.01	8.22	8.12
BUS	28	16.60	17.79	17.18
LCV[1] (Gasoline)	10	-	7.41	7.41
LCV[1] (Diesel)	8	7.46	7.76	7.61
HCV[3]	30	25.22	21.34	23.12

[1] LCV: Light Commercial Vehicle (i.e. pickup and van), [2]: HCV: Heavy Commercial Vehicle (i.e. trucks and trailers)

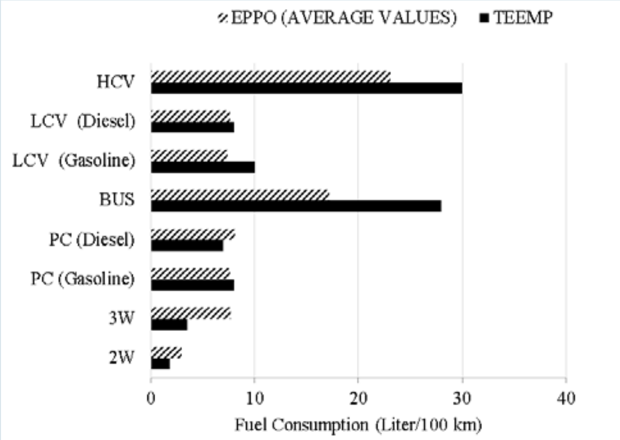


Figure 3-3: Comparisons of SFC published by EPPO and recommended SFC in TEEMP

Box 3.1 Note on checking data reliability

Checking reliability and accuracy of data is a crucial aspect of improving data and building an MRV system. This can be done through several options:

1. **Checking how and when the data were gathered:** the survey or collection method can be reviewed to see if the data were collected using accepted methods and approaches. For example, specific fuel consumption can be based on various driving cycles, each resulting in different outcomes, which may or may not be appropriate in the Thailand context. In case of data gathering using sampling, the sample sizes can also be reviewed. In addition, the date of data collection is important, as some parameters of the transport system tend to change quickly. For example, 5 year old modal split data for a city may be out of date. In any case, when using data, one needs to ensure that the details of data gathering are known. Quoting data without the necessary background may not be regarded as good practice and can lead to inappropriate policy advice.

2. **Checking of data outcomes with other data sources from the same geographical area as well as international sources that are (roughly) comparable**: other data sources (validation data) can be gathered and used compared with the collected of found data. In this case, the validation data set must be also published from the trusted source. Or, the validation data set could be gathered from the new survey. For example, new traffic data are gathered in the study area every time traffic studies were proposed in the area in order to validate the results of the traffic model or previous data set in the area.

3. **Monitor data trends through time series and indicators**: by monitoring the trend of a parameter over time (e.g. as done in this report with total fuel sales and vehicle registration), one can detect whether trends follow a pattern that can be explained. If a trend cannot be explained, there could be data issues. For example, a decreasing trend in total fuel consumption would require further investigation, and could be checked with trends in related parameters such as vehicle-km driven, annual mileage and fuel efficiency. In addition, monitoring indicators such as tCO_2/p-km, fuel consumption per capita, modal split, km driven per bus, etc, enable crosschecking of data as well as identifying key sustainable transport trends.

Table 3-8 Specific fuel consumption for Bangkok and its vicinity (Unit: km/litre)

Type of Vehicle	G	GH				D	LPG			NGV/CNG			
		91	95	E20	E85		type 1	type 2	type 3	type 1	type 2	type 3	type 4
Sedan (Not more than 7 passengers)	11.44	14.29	11.89	13.54		12.38		10.79	11.41		14	14.56	
Microbus & Passenger Van (more than 7 passengers)						11.66		11	13		12	12.04	10
Van & Pick Up		9	10.5			13.4			12.5				
Urban Taxi							12.24			11.72			
Fixed Route Taxi							14.73			15.47			
Motortricycle Taxi (Tuk Tuk)							14.61			15.86			
Hotel Taxi										10.69			
Tour Taxi	13	12.9				11.33				10.13			
Rental Car	13.22					9							
Motorcycle	32.65	34.42	35.47	37.57	38			32					
Tractor						2.28							
Motorcycle Taxi	36.57	34.23	36.91							11			
Fixed Route Bus	12.74					9.91				6.79			
Non-Fixed Route Bus						3.63							
Bus						4.53							
Non-Fixed Route Truck						3.89							
Private Truck						4.04							

Note: G: gasoline, GH: Gasohol, D: Diesel, LPG type 1: general LPG engine system, type 2: fumigation system, type 3: Injection system, NGV/CNG type1: general NGV/CNG engine system, type 2: fumigation system, type 3: injection system, type 4: diesel.

Source: Study Report from EPPO (The Study of Development of Forecasting Model and Survey of Energy in the Transport Sector, EPPO)

Table 3-9 Specific fuel consumption for provincial area (Unit: km/liter)

Type of Vehicle	G	GH				D	LPG			NGV/CNG			
		91	95	E20	E85		type 1	type 2	type 3	type 1	type 2	type 3	type 4
Sedan (Not more than 7 passengers)	12.87	13.27	12.81	15.18	12.76	12.55		12.23	11.16		12.75	18.42	11.38
Microbus & Passenger Van (more than 7 passengers)	13.5	8.5	8.33	9		11.05		11.09	10.94		8		
Van & Pick Up	13.5	13.23	11.93	17.63		12.88		11.25	12.16		12.5		11
Urban Taxi	10.38						12.9			11.88			
Fixed Route Taxi	11.93	12	11.33				10.28			25			
Motortricycle Taxi (Tuk Tuk)	12.98	16.83	27.25				17.01						
Hotel Taxi	25												
Tour Taxi	11.33	13.33	11			12	10.24			12.92			
Rental Car	10.25	11.55	11.25			10	11.14						
Motorcycle	34.68	32.23	33.84	20									
Tractor						4.44							
Motorcycle Taxi	27.47	38.9	38.64							23			
Fixed Route Bus						8.48	11.4			5.68			
Non-Fixed Route Bus						4.48				4.04			
Bus	4					3.9				3.7			
Non-Fixed Route Truck						4.23				3.94			
Private Truck						5.14				3.86			

Source: EPPO (2014) Note: G: gasoline, GH: Gasohol, D: Diesel, LPG type 1: general LPG engine system, type 2: fumigation system, type 3: Injection system, NGV/CNG type1: general NGV/CNG engine system, type 2: fumigation system, type 3: injection system, type 4: diesel.

Table 3-10 Specific fuel consumption for country (average value) (Unit: km/liter)

Type of Vehicle	G	GH				D	LPG			NGV/CNG			
		91	95	E20	E85		type 1	type 2	type 3	type 1	type 2	type 3	type 4
Sedan (Not more than 7 passengers)	12.16	13.78	12.35	14.36	12.76	12.47		11.51	11.29		13.38	16.49	11.38
Microbus & Passenger Van (more than 7 passengers)	13.50	8.50	8.33	9.00		11.36		11.05	11.97		10.00	12.04	10.00
Van & Pick Up	13.50	11.12	11.22	17.63		13.14		11.25	12.33		12.50		11.00
Urban Taxi	10.38						12.57			11.80			
Fixed Route Taxi	11.93	12.00	11.33				12.51			20.24			
Motortricycle Taxi (Tuk Tuk)	12.98	16.83	27.25				15.81			15.86			
Hotel Taxi	25.00									10.69			
Tour Taxi	12.17	13.12	11.00			11.67	10.24			11.53			
Rental Car	11.74	11.55	11.25			9.50	11.14						
Motorcycle	33.67	33.33	34.66	28.79	38.00			32.00					
Tractor						3.36							
Motorcycle Taxi	32.02	36.57	37.78							17.00			
Fixed Route Bus	12.74					9.20	11.40			6.24			
Non-Fixed Route Bus						4.06				4.04			
Bus	4.00					4.22				3.70			
Non-Fixed Route Truck						4.06				3.94			
Private Truck						4.59				3.86			

Note: G: gasoline, GH: Gasohol, D: Diesel, LPG type 1: general LPG engine system, type 2: fumigation system, type 3: Injection system, NGV/CNG type1: general NGV/CNG engine system, type 2: fumigation system, type 3: injection system, type 4: diesel.

Source: Study Report from EPPO (The Study of Development of Forecasting Model and Survey of Energy in the Transport Sector, EPPO, 2014)

3.2. Data inventory for MRV of NLTS

Following methodology discussed in Chapter 2, data that will be needed for estimating the GHG emissions in transport sector in Thailand are (1) Fuel Sold Statistic Data, (2) Vehicle Registration Data, (3) Vehicle Kilometer Travel (VKT) Data, (4) Average Vehicle Occupancy, (5) Home Interview Survey, (6) Truck Commodity Data, (7) Inter-Urban Rail Transport Data, and (8) Urban-Rail Transport Data. Currently, these data is either not reported in a regular manner or has significant reliability and accuracy problems. The data availability and discussions of its gaps are presented in the following. Further, readers can explore the full data collection in the excel file that accompanies this report (see Annex II for an index of data sheets).

3.2.1. Fuel sold statistics

The main data for estimating GHG in the top-down approach is the fuel sold data. In Thailand, the fuel sold statistics or related data are reported by several organisations, including: (1) Department of Energy Business (DOEB), (2) Energy Policy and Planning Office (EPPO), and (3) Department of Alternative Energy Development and Efficiency (DEDE).

The most original records of fuel sold statistics are collected by DOEB. DOEB provides the fuel sold statistic data which is the billing collections of fuel sold from the main distributors which are requested to report back their sale records to DOEB. The billing records are the fuel sold statistics from various government units, retailers, or large private sectors. DOEB classified these records into 8 groups including:

1. Fuel stations,
2. Fuel retailers/Shops,
3. Transport company,
4. Industries,
5. Electricity production,
6. Government,
7. Others (i.e. waste management), and
8. Consumers whose fall into the category of section 10 of the oil trade law (i.e. private company owning a large tank or fuel station)

The main problem of fuel sold statistics data from DOEB is how to allocate fuel use to transport activities ('mobile sources'). This is especially true for diesel since it is not only used for transport purposes but also in industries, with stationary equipment e.g. also for electricity production, construction, machinery, and in agriculture. Also, the diesel uses for inter-urban rail transport are not clearly classified but contained in the group 6 (government), as the government sector could use diesel in road transport as well. Three out of seven groups are identified as non-transport activities including group 4: Industries, group 5: Electric, and group 7: Others.

Hence, the estimation of fuel used in the transport sector will include DOEB's fuel sold statistics in the following groups: group 1: fuel stations, group 2: Fuel Retailers/Shops, group 3: transport, group 6: government, and group 8: consumers in section 10 of the oil trade law. It should be also noted that this compilation will be only for mode road and rail[5]. As fuel sold statistics from DOEB are still contains other uses of non-transport activities and cannot be classified, the cross check results between DOEB data and DEDE are expected that DOEB will have a little higher value when compare with the DEDE. Table 3-11 presents fuel sold statistic data published by DOEB in year 2012 and 2013. These data will be

[5] As per DEDE data, diesel consumption of water transport accounts for approximately 1.5% of total diesel consumption in transport

used to cross check with the DEDE data. The rest of data (year 2008 to year 2013) are presented in the companying excel file.

[note: the consumer group selection would need further investigation as to whether it could reflect the transport sector]

Figure 3-4 presents DOEB's fuel sold statistic data from 2006 – 2013 in total and Figure 3-5 presents DOEB's fuel sold statistic data from 2006-2013 for customer group number 1 (Fuel Station), 2 (Retailers), 3 (Transport), 6 (Government), and 8 (Section 10 of the oil trade law). The full data set can be found in the excel sheets accompanying this report.

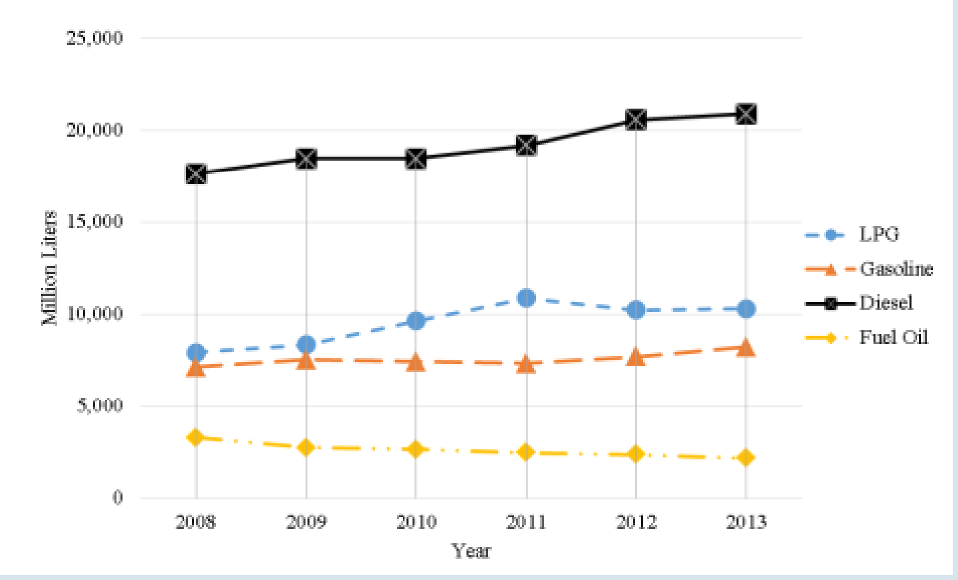


Figure 3-4: DOEB's fuel sold statistic data (Source: DOEB, 2014)

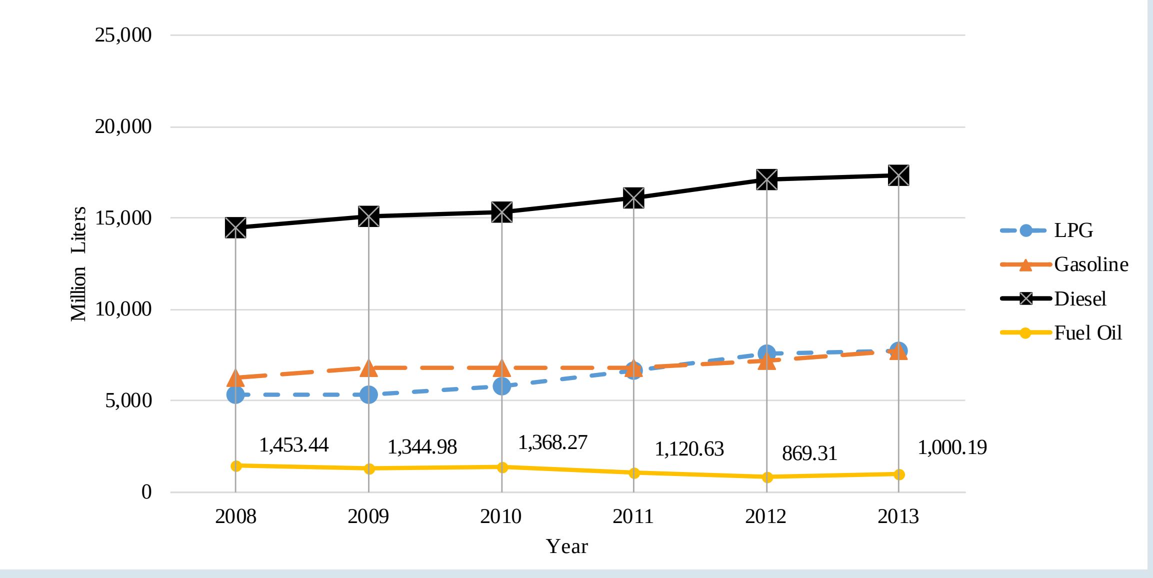


Figure 3-5: DOEB's fuel sold statistic data (customer group 1,2,3,6, and 8) (Source: DOEB, 2014)

Table 3-11 Fuel sold statistics published by DOEB (year 2013).

Cate gory	2013	LPG	ULG 91	ULG 95	Gasohol E10 (91)	Gasohol E10 (95)	GASOHOL E 20 (95)	GASOHOL E 85	Diesel	FUEL OIL
		million kg	Million litres							
1	Fuel Station	1,774.50	67.57	454.75	2,835.95	2,331.02	947.19	132.94	12,332	0.00
2	Retails/Shops	2,408.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Transport Company	0.00	1.24	2.75	9.31	18.00	0.04	0.00	0.78	844.64
4	Industry	592.11	1.84	2.09	26.03	15.28	3.07	0.66	1.11	725.74
5	Electricity Production	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	353.61
6	Governments	0.00	1.37	8.84	18.80	15.05	0.03	0.00	0.53	15.41
7	Others	785.49	10.65	40.27	171.40	244.92	1.08	5.65	2.28	75.35
8	Section 10 Oil trade law	0.00	64.26	107.52	275.54	405.31	11.33	1.32	3.73	140.14

Source: DOEB Energy consumption statistic (URL: http://www.doeb.go.th/v5/info_supply_import_export_fuel.php); Section 10 of the Oil trade law is relevant to private companies owning a large tank of fuel station.

Since 2012, DEDE has been publishing the energy balance and energy commodity account tables of Thailand (http://www4.dede.go.th/). DEDE's energy commodity account tables are constructed using the secondary data from various government sources. Especially, the fuel consumption data were gathered from the DOEB. The energy commodity account table also presents fuel consumptions in each transport modes (Road, Rail, Air, and Water), classified by fuel/energy types. Table 3-13 presents the data. The findings from these data are as follows:

- Records from DEDE are different from DOEB, in the transport sector, total amount of diesel consumptions has been continually decreased from 11,396 million liters in 2012 to 11,377 million liters in 2013, approximately 10.14 % decreasing. Records of biofuel (ethanol and biodiesel) are not separately reported in the DEDE energy commodity account table. Hence, total amount of diesel consumption report by DOEB and DEDE are in the same account which is considering amount of biodiesel consumption together with the regular diesel. Hence, the assumptions is that the amount of diesel records from DEDE is decreasing because DEDE did not take account of biofuel that cannot be used.
- On the other hand, as discussed above, the trends of diesel consumptions from DOEB data, both in total and from the selected customer groups, represent the consumption of transport sector has been continually increasing (e.g. 1.5% from 2012 to 2013). Figure 3-6 presents trend of fuel consumption (LPG, Gasoline, and Diesel) of the land transport sector (Road and Rail) from DEDE data. Also, Figure 3-7 compares the fuel consumptions data between DEDE and DOEB in year 2013. It should be noted that while trend of DEDE's data is declining in diesel consumptions in the transportation modes, the data from DOEB (fuel sold statistic) present the increasing trend of diesel consumptions. Data from DLT also present increasing in number of vehicle registrations of diesel engine (explanation in the next section) over the comparable periods. Therefore, further sources of explanations in declining of these number should be explained and report by DEDE, for example, how the energy balance and commodity account tables are developed and the processes of estimating fuel consumptions of different transport modes in the tables.

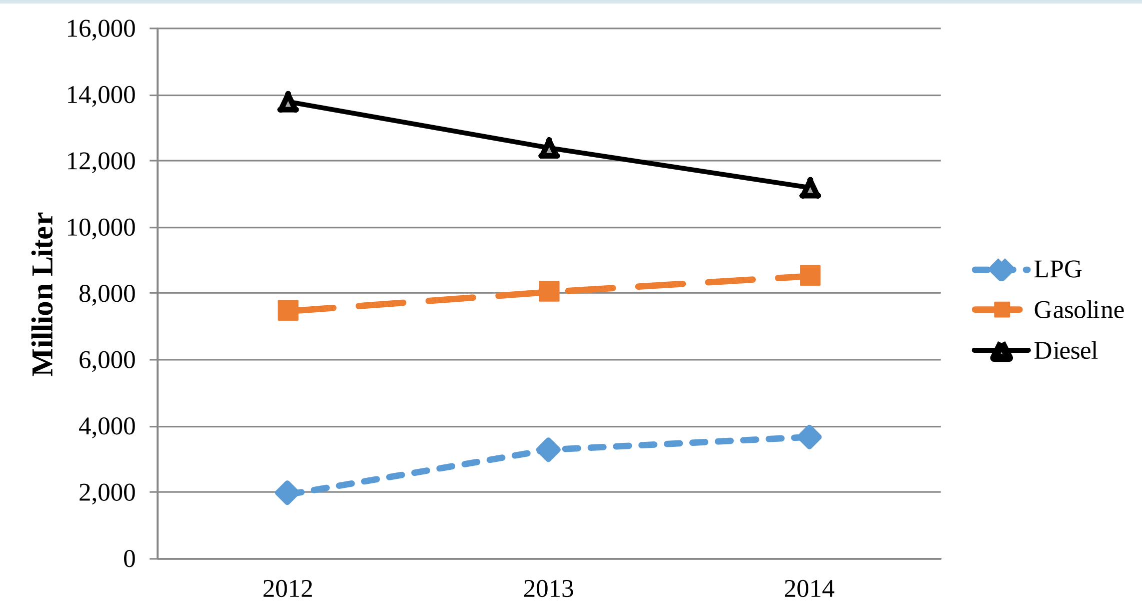


Figure 3-6 DEDE's Fuel consumption (Land transport sector, road and rail). (Source: Energy balance of Thailand report (2012, 2013, and 2014), DEDE, Ministry of Energy)

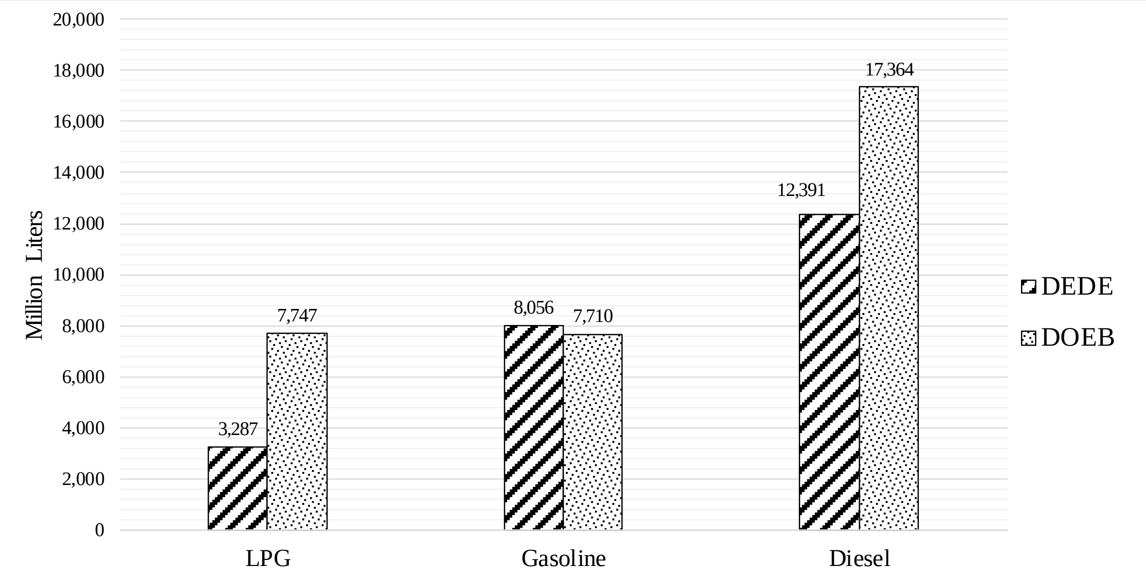


Figure 3-7 Comparison of fuel consumptions data between DEDE and DOEB (consumer groups 1,2,3,6,8) in 2013

- From DEDE's data, diesel used in the transport sector are 97.85 % for road transport, 1.43 % and 0.72% are for water and rail transport respectively.
  Note: if aviation (domestic and international) would be taken into account in transport, it would take approximately 17% of energy consumption.

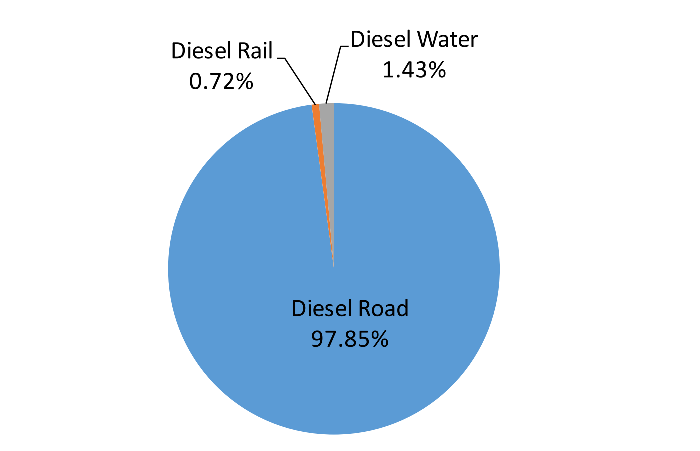


Figure 3-8 Portion of diesel consumptions in the transport sector (Source: Energy balance of Thailand report (2012, 2013, and 2014), DEDE, Ministry of Energy)

- DEDE's data also includes electricity consumption for rail transportation mode, which could from urban transport such as BTS and MRT system in Bangkok and its vicinity. However, number of electricity consumptions were declined from 164 GWh in 2013 to 105 GWh in 2014. Since, network of urban rail transport (BTS and MRT) are continuously growth from year to year, as well as number of ridership. Number of electricity used in rail transport should not be declined. Further investigation and clarification by DEDE of these data and reports would be desirable, for example how the energy balance and commodity account tables are developed and the processes of estimating fuel consumptions of different transport modes in the tables.

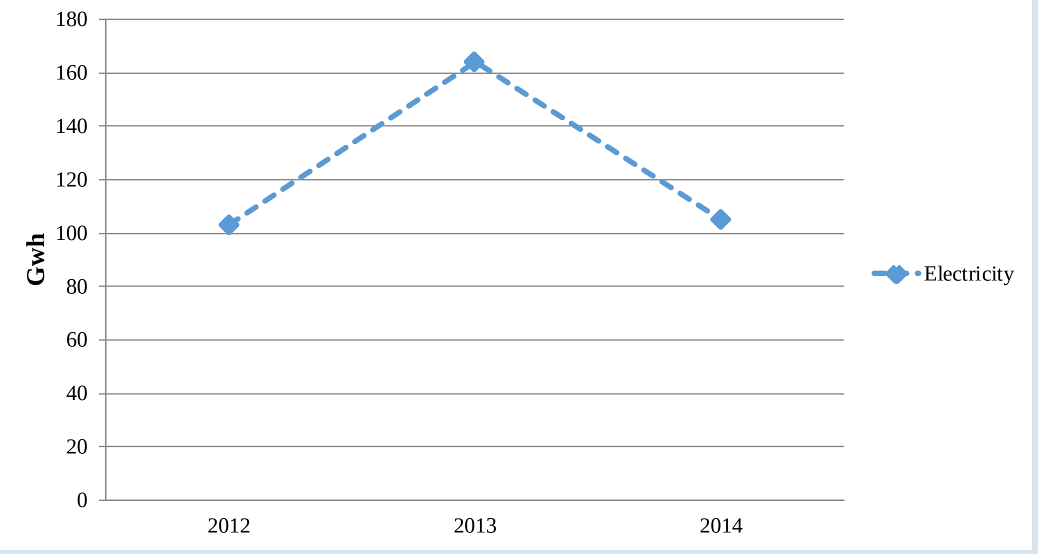
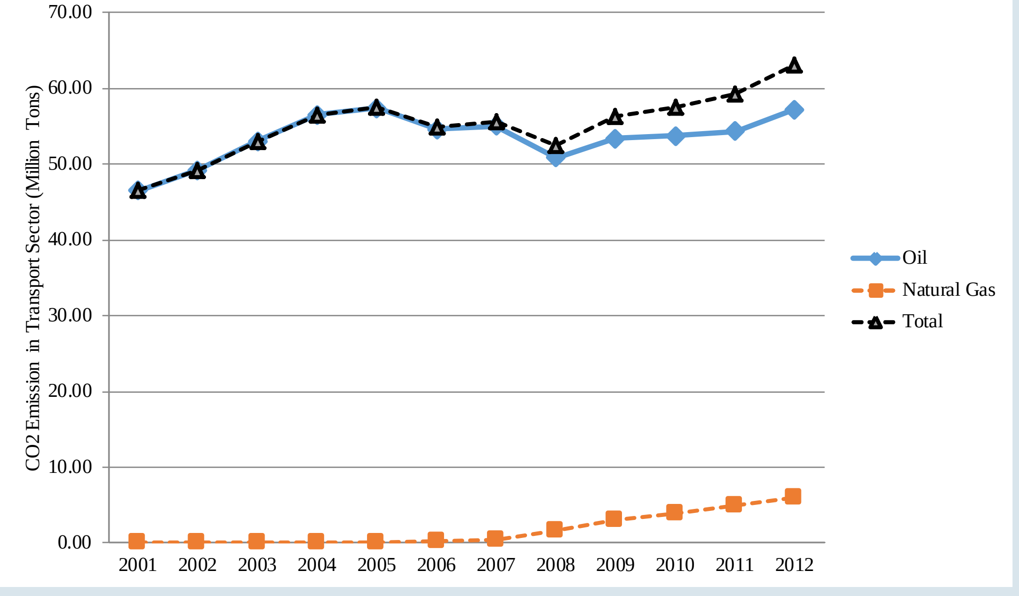


Figure 3-9 DEDE's Data of electricity for the rail transportation mode (Source: *Energy Balance of Thailand Report (2012, 2013, and 2014), DEDE, Ministry of Energy*)

Finally, EPPO published the results of CO_2 emissions in the transport sector. The CO_2 emissions were estimated based on the data from DOEB by classifying CO_2 only in category of oil (Gasoline, Diesel, Gasohol, and Bio-Diesel) and natural gas (CNG[6]). EPPO data considered energy consumption in the transport sector by assuming all gasoline used are for transportation. However, for diesel and natural gas, EPPO follows the portions published by DEDE. Figure 3-10 presents the trend of CO_2 emissions in the transport sector from 2001 – 2012 published by EPPO. These data could be useful when comparing with the results in the bottom up approach.



[6] The source and data collection methodology for the CNG data are not known.

Figure 3-10 CO2 Emissions in the transport sector from 2001 – 2012 (Source: Energy statistics of Thailand 2013 (EPPO) , (http://www.eppo.go.th/info/cd-2013/index.html)

Table 3-12 Illustrative comparison for CO_2 emissions from different sources (DOEB, DEDE, EPPO)

	DOEB (all groups)	DOEB (groups 1,2,3,6,8)	DEDE	EPPO
Energy data for transport sector	Reported in litres, from primary sources; NG not reported		From DOEB (unclear which customer groups), LPG + NG reported	Oil + natural gas, mostly from DEDE
Billion litres	40.9	32.8	23.2 (excl NG)	
MTOE, 2012	32 Own calculation	25.7 Own calculation	26 Narupiti et al. (2014) 21.2 Own calculation (data from Fig 3-6 + NG) 22.0 (DEDE, 2014; road, rail, water) 26.2 (DEDE, 2014; including aviation)	
CO_2 (Mt), 2012	95 Own calculation, not corrected for biofuels	76 Own calculation, not corrected for biofuels	62 Own calculation, based on Fig. 3-6, not corrected for biofuels	62 Reported (see also Fig. 3-10)

Note: 'Corrected for biofuels': CO_2 emissions of biofuel combustion is set to zero (following IPCC, 2006); own calculation: calculated by authors based on reported data and default emission factors and calorific value

Box 3.2 Summary of data issues in the top-down approach

From the discussion above, there are several issues regarding to the data that will be used to estimate emissions of the transport sector in the Top-Down Approach. The data from DOEB and DEDE present fuel consumption data while the data from EPPO present only CO_2 emission in the transport sector.

- DOEB records fuel consumptions based on 8 customer groups. However, the separation of fuels used for transport and for other purposes is critical and complex. This is especially true for diesel where a separation is difficult as diesel is not only used for transport purposes but also in industries, with stationary equipment e.g. also for electricity production, construction, machinery, and in agriculture. Also, the diesel uses for inter-urban rail transport are not clearly classified but contained in the group 6, government, which the government sector could be used diesel in road transport as well. Allocation of 'customer groups' to the transport sector or 'mobile sources' needs further discussion
- It needs to be checked to what extent jet fuels for aviation (domestic and/or international) are and should be included
- No records of electricity used are published from DOEB, especially from urban-rail transport data.

- No records of NGV/CNG consumptions are also published by DOEB.
- Reconciliation of fuel consumption data of DOEB and DEDE, with differences currently appearing particularly in diesel and LPG/CNG consumption
- DEDE records of diesel consumption data from 2012 to 2014 declining while records from DOEB's fuel sold statistics and number of vehicle registration are increasing during this period
- The source and methodology of energy data for the CO_2 emission data reported by EPPO would benefit from further clarification
- Records of electricity usages for rail transport decline from 2013 to 2014 while both urban rail transport network (BTS and MRT system) are continually growth and number of ridership are also increasing.

Other Issues[7]

- Electricity usage in transport is not recorded with top-down approaches as it is included in the energy sector. However, rail, metro and increasingly road vehicles (incl. hybrids) use electricity. Care needs to be taken to include only traction energy used[8]. Therefore, electricity usage for transport needs to be collected directly from usage sources or from detailed electricity statistics. This issue will not only be more relevant in the future with upcoming numbers of electric and plug-in hybrid vehicles but will also get more complex to monitor as electricity used for example for plug-in vehicle usage is not separated from other household electricity usage.
- CH_4 emission factors for vehicles are technology related and not fuel quantity related; this is relevant for vehicles using gaseous fuels where CH_4 emissions make a significant contribution towards total GHG emissions. At minimum top-down approaches need to make an assessment of gaseous vehicle technology in usage to apply a CH_4 default factor per gaseous energy unit.

[7] Source: Grütter, 2015

[8] For road transport energy used for communication, signalling etc. is also not included as road transport energy. In underground metros non-traction energy usage is very significant and can account for more than 40% of total energy usage.

Table 3-13 Energy commodity account for transport (DEDE, 2015)

Year	Transport Mode	NGV/ CNG	LPG	ULG 91	ULG 95	Gasohol E10 (91)	Gasohol E10 (95)	Gasohol E 20 (95)	Gasohol E 85	JET FUEL	Diesel	FUEL OIL	ELECTRICITY
		MMscf.					Million Litres						GWh
2014	ROAD	115,580	3,656	34	498	3,594	2,735	1,344	334	0	11,133	0	0
	RAIL	0	0	0	0	0	0	0	0	0	82	0	105
	AIR	0	0	0	0	0	0	0	0	5,513	0	0	0
	WATERWAY	0	0	0	0	0	0	0	0	0	162	1,083	0
	Total	115,580	3,656	34	498	3,594	2,735	1,344	334	5,513	11,377	1,083	105
2013	ROAD	112,050	3,287	32	616	3,332	2,994	942	140	0	12,301	0	0
	RAIL	0	0	0	0	0	0	0	0	0	90	0	164
	AIR	0	0	0	0	0	0	0	0	5,562	0	0	0
	WATERWAY	0	0	0	0	0	0	0	0	0	180	813	0
	Total	112,050	3,287	32	616	3,332	2,994	942	140	5,562	12,57	813	164
2012	ROAD	101,653	1,964	3,026	42	2,119	1,903	349	35	0	13,699	0	0
	RAIL	0	0	0	0	0	0	0	0	0	90	0	103
	AIR	0	0	0	0	0	0	0	0	5,091	0	0	0
	WATERWAY	0	0	0	0	0	0	0	0	0	176	806	0
	Total	101,653	1,964	3,026	42	2,119	1,903	349	35	5,091	13,965	806	103

Source: Energy Balance of Thailand Report (2012, 2013, and 2014) Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy

3.2.2. Vehicle registration data

Currently, Department of Land Transport (DLT) is providing a systematic vehicle registration data in yearly basis. Two types of data that are currently required for the MRV system is (1) the number of vehicle registration by ages, (3) the number of new vehicle registration, and (2) the number of vehicle registration by types of energy consumptions.

3.2.2.1. Number of vehicle registration

DLT publishes vehicle registration data by age and types of vehicles. Types of vehicles are classified into two group: total vehicle under motor vehicle act and total vehicle under land transport act. Up to 2004, also vehicles under the non-motorised vehicle act, i.e. bicycles and tri-bicycles, were recorded.

For the group of total vehicle under motor vehicle act, there are 17 types of vehicles (see Annex III for vehicle category definitions):

- Sedan (not more than 7 passengers),
- Microbus & Passenger van (more than 7 passengers),
- Van & Pick up,
- Motortricycle,
- Interprovincial taxi,
- Urban taxi,
- Fixed route taxi (Song Taew),
- Motortricycle taxi (Tuk Tuk),
- Hotel taxi,
- Tour taxi,
- Rental car,
- Motorcycle,
- Tractor,
- Road roller,
- Farm Vehicle,
- Automobile trailer, and
- Public motorcycle.

Additionally, for the group of total vehicle under Land Transport act, there are 6 types of vehicles:

- Fixed route bus,
- Private bus
- Non-fixed route bus,
- Non-fixed route truck,
- Private truck, and
- Small rural bus.

As detailed data for VKT, fuel economy etc – required to estimate emissions - are not available for every category, the groups of vehicle must be regrouped based on (1) data available for estimating the VKT, PKT, and TKT and (2) parameters for estimating the GHG emissions. To calculate VKT, PKT, and TKT, vehicle types are regrouped based on general vehicle classification for transport and traffic studies in Thailand. Further, based on the limitation of specific fuel consumption (SFC) data (see Section 3.1), the estimated VKT will be regrouped again into Car, Taxi, Van, Pickup, 2W&3W,

Bus, and Truck based on the availability of SFC before estimating the GHG emissions. Table 3-14 presents DLT's vehicle types and recommended regroup types.

Table 3-14 DLT's vehicle types and recommended regrouping

DLT's Vehicle Types	Regroup Types for GHG Emission Estimation
Sedan (Not more than 7 passengers),	Car
Interprovincial Taxi,	Taxi
Urban Taxi,	
Hotel Taxi,	
Tour Taxi,	
Rental Car,	
Microbus & Passenger Van (more than 7 passengers),	Van
Pick Up,	Pickup
Motortricycle,	3W
Motortricycle Taxi (Tuk Tuk),	
Motorcycle,	2W
Public Motorcycle.	
Small Rural Bus.	Bus
Fixed Route Bus,	
Non-Fixed Route Bus,	
Fixed Route Taxi (Song Taew),	
Non-Fixed Route Truck,	Truck
Private Truck	
Tractor,	Agricultural Vehicles
Road Roller,	
Farm Vehicle,	

Note: see Annex III for more definition of each vehicle type

Additionally, for vehicle types of bus and truck, rather than classified these vehicles base on its service characteristics (Table 3-14), DLT also classifies them by its physical characteristics or standards, Table 3-15 for Bus and Table 3-16 for Truck. However, vehicle registration data which classify buses and trucks by its standards are separately reported and only available from 2012 – 2015. Hence, to ensure consistency between different sources and available data, regrouping of buses and trucks will be done based on standards and physical characteristics.

Table 3-15 Classification of bus by its sizes and standards

Bus Types	DLT's Groups	Number of Seat
Mini Bus (MB)	Standard 3F, 7	< 12
Large Bus (LB)	Standard 2C, 2D, 2E,3C,3D,3E	13-30
Heavy Bus (HB)	Standard 1A,1B,2A,2B,3A,3B, 4A-F, 5A,5B,6A-6B	>30

Note: see appendix A for more definition of each standard types

Table 3-16 Classification of truck by its sizes and standards

Truck Types	DLT's Groups	Note
Mini Truck (MT)	Characteristics 1, 3	-
Large Truck (LT)	Characteristics 2, 4, 5	-
Heavy Truck (HT)	Characteristics 9	Characteristics 6-8 are (Trailer and Semi-Trailer which are using with characteristics 9, there are no-engine vehicles)

Note: see appendix A for more definition of each standard types

In 2014, there are total 35.8 million registered vehicles in the system. Figure 3-11 present a breakdown of vehicle types in 2014.

Further, when considering number of vehicle registration in the past decade (2004-2014), car has the highest annual growth rate (10.7 % per year) followed by pickup (5.8 % per year), Taxi (4.8 % per year), and 2W (4.4 % per year) respectively. Figure 3-12 and Figure 3-13 present total number of vehicle registration from 2004-2014.

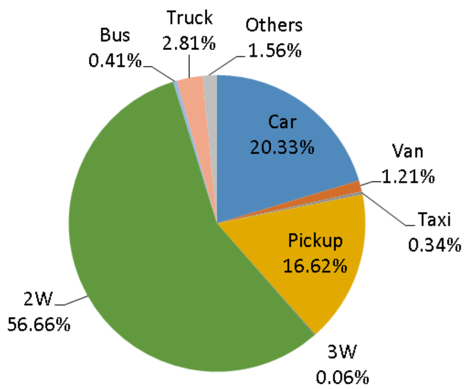


Figure 3-11 Vehicle Type Breakdown in 2014 (Source: Vehicle Registration Statistics, DLT)

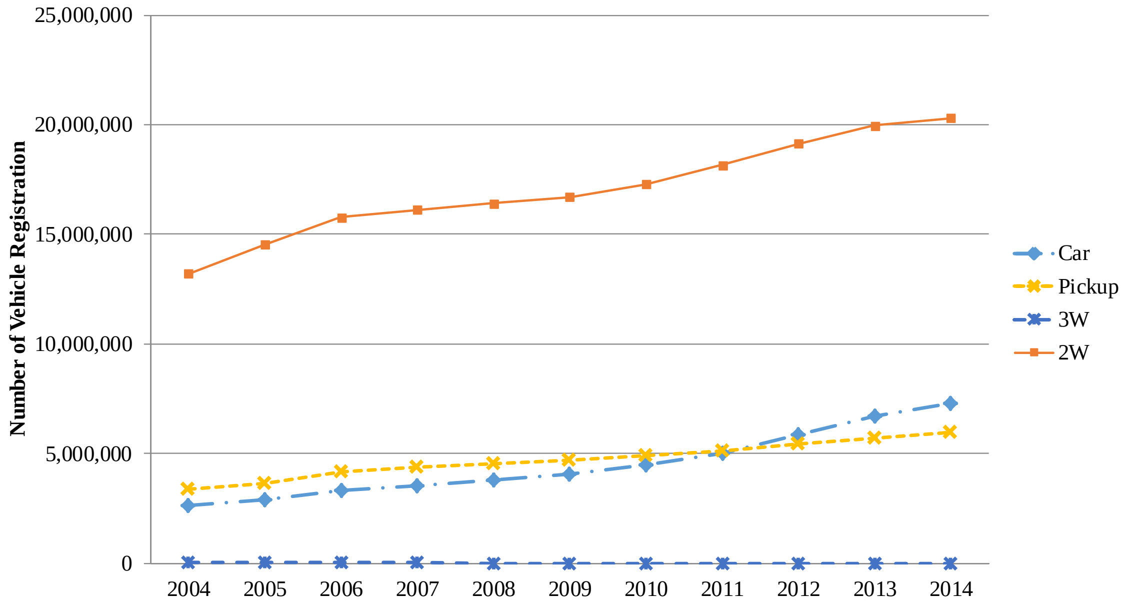


Figure 3-12 Total number of vehicles registered (Source: Authors, based on vehicle registration statistic, DLT)

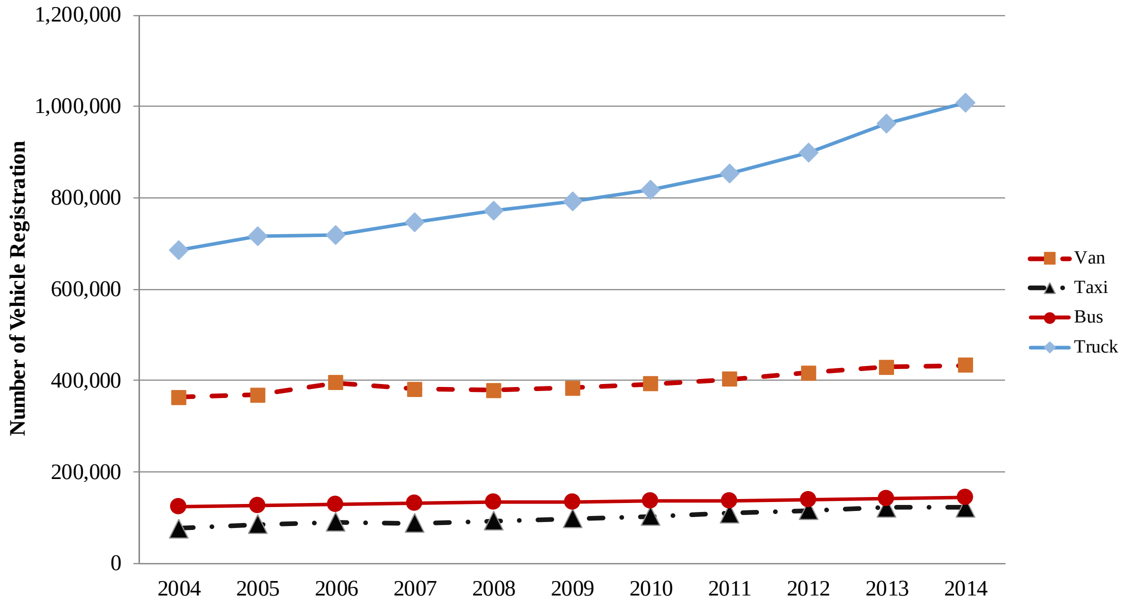


Figure 3-13 Total number of vehicles registered 2004-2014 (Source: Authors, based on DLT vehicle registration statistics)

In 2014, there are 2.9 million new vehicles registered in the system. From total new vehicle registration in this year, 2W has the highest number of vehicle registrations (1.8 million vehicles), followed by car (0.60 million) and pickup (0.28 million). Figure 3-14 presents a breakdown of new vehicle registration by types of vehicles. Further, total number of new vehicle registrations is decreasing since 2012, from 3.72 million vehicles in 2012 to 2.89 million vehicles in 2014. Car registrations were down approximately 0.3 million from 2013 to 2014, with the rest of the decrease predominantly from fewer motorcycle sales.

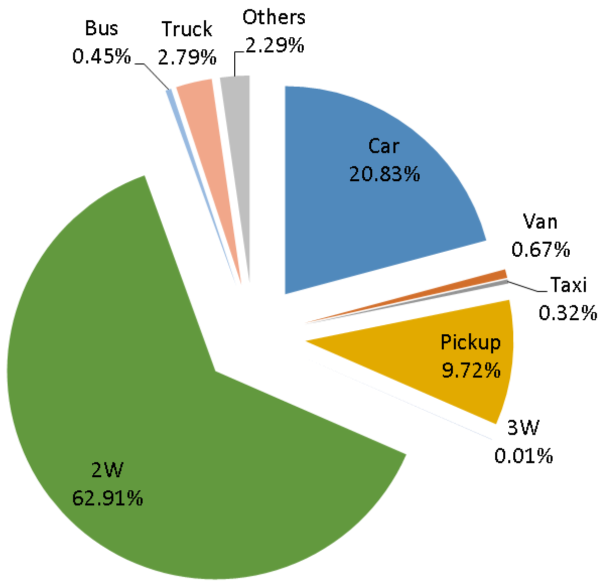


Figure 3-14 New vehicle registration by types of vehicles in 2014. (Source: DLT vehicle registration statistics)

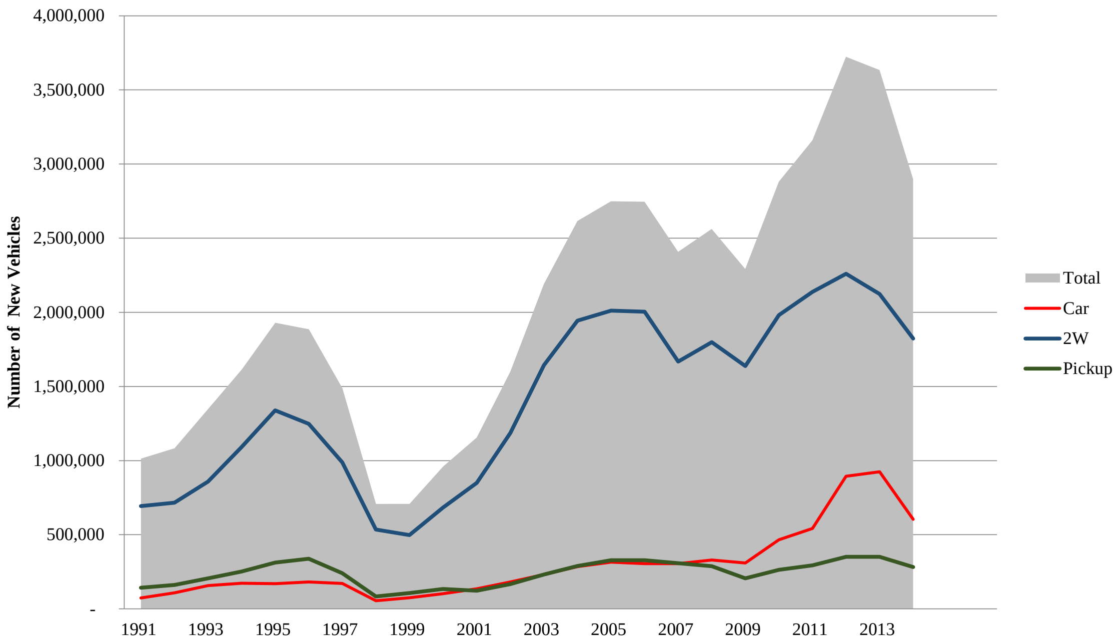


Figure 3-15 New vehicle registration from 1991 – 2014. (Source: DLT Vehicle registration statistics)

Table 3-17 presents vehicle registration by age from 2007 to 2014. In the course of this period, we can observe an increase in the vehicle age categories 6-10 years, 16-20 years and more than 20 years. About 50% of pick-ups, buses and trucks are older than 10 years, and approximately 20% older than 20 years.

Since the data were collected based on the annual vehicle registration processes, there are several vehicles failed to be on the registration processes. The reasons could be ranged from the scrap vehicles to late submissions of registered documents. Hence, to clarify this problem in the data, the DLT may publish further attributes into the data including the number of vehicles that failed to register and the number of scrapped vehicles.

Table 3-17 Vehicle registration by age (2007-2014) Unit: Million vehicles

Vehicle Age	2007	2008	2009	2010	2011	2012	2013	2014
< 1	2.29	2.41	2.09	2.62	2.91	3.47	3.41	2.66
1	2.63	2.28	2.40	2.08	2.60	2.89	3.46	3.39
2	2.72	2.62	2.27	2.39	2.07	2.60	2.89	3.44
3	2.63	2.72	2.62	2.27	2.39	2.07	2.59	2.88
4	2.11	2.46	2.53	2.45	2.14	2.24	1.95	2.43
5	1.51	2.01	2.36	2.43	2.36	2.07	2.17	1.88
6	1.05	1.42	1.90	2.21	2.31	2.25	1.98	2.06
7	0.84	0.98	1.33	1.78	2.08	2.18	2.12	1.86
8	0.58	0.77	0.91	1.24	1.66	1.95	2.04	1.97
9	0.52	0.53	0.72	0.85	1.17	1.57	1.83	1.91
10	1.06	0.46	0.49	0.67	0.80	1.11	1.47	1.71
11-15	4.73	4.64	4.04	3.47	3.07	2.81	3.02	3.91
16-20	1.69	1.89	2.20	2.52	2.86	3.23	3.36	3.00
> 20	1.26	1.21	1.32	1.50	1.77	2.05	2.35	2.74
Total	25.62	26.42	27.18	28.48	30.19	32.48	34.62	35.84

Source: Vehicle registration statistic (Department of Land Transport, DLT)

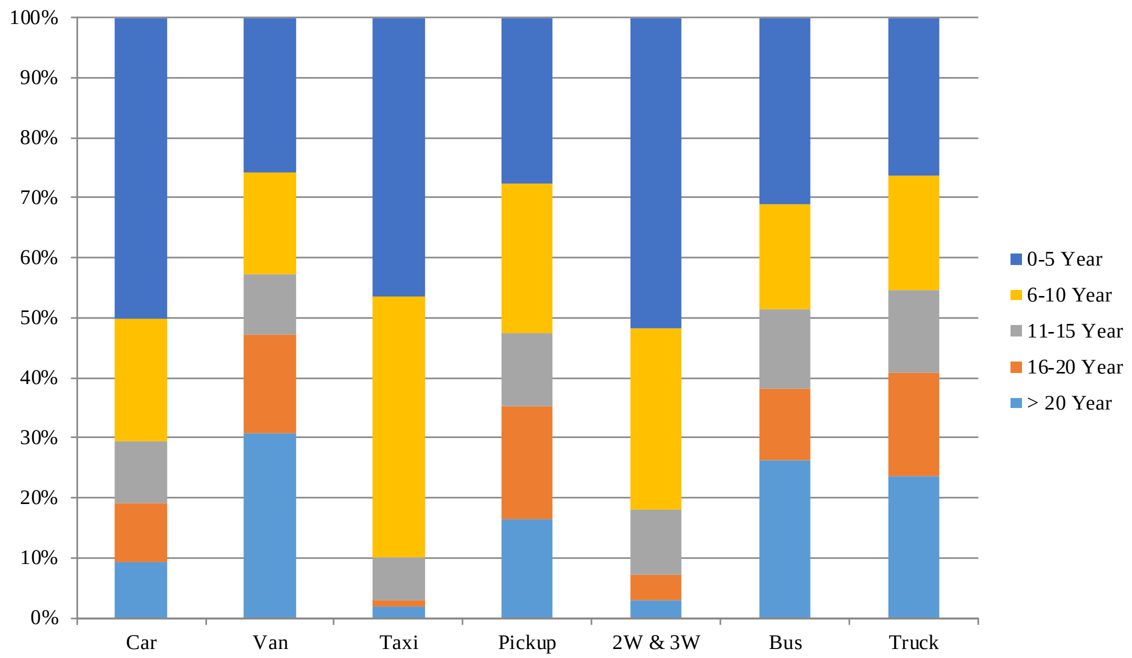


Figure 3-16 Age Distribution of Vehicles in 2014. (Source: DLT Vehicle Registration Statistics)

3.2.2.2. Vehicle Registration by Fuel Type

Portions of vehicle registration by type of energy consumption are also required for bottom up analysis. DLT publishes such data and uses twelve categories: (1) Petrol, (2) Diesel, (3) LPG, (4) LPG&Petrol, (5) LPG&Diesel, (6) CNG, (7) CNG&Petrol, (8) CNG&Diesel, (9) Electricity, (10) Non-Fuel, (11) Hybrid (gasoline-electricity), and (12) Others.

Type number 10 (Non-Fuel) includes trailer parts for either buses or trucks. Also, the classification vehicles in the group of (Others) in type number 12 are number of vehicles that were registered in the past which were not yet recorded for types of energy consumptions. The number of vehicles in this category is 0.1% of total registrations, i.e. not significant.

In order to align these categories with the available fuel economy data (Section 3.1), the 12 categories will be reclassified into 6 categories: (1) Petrol (2) Diesel, (3) LPG, (4) CNG, (5) Electricity, and (6) Hybrid, see Table 3-18. The regrouping is based on the fact that the hybrid systems (Hybrid, LPG&Petrol, LPG&Diesel, CNG&Petrol, and CNG&Diesel) are considering to be only Petrol, LPG, or CNG because (1) most of the times users are using Petrol, LPG, and CNG (Petrol and Diesel will be switched to use only on the emergency cases) and (2) No SFC data (as discussed in section 3.1) for these hybrid engine available. Also, for hybrid LPG and CNG, engines are same as regular LPG or CNG.

Table 3-18 Group of vehicles by types of energy consumptions

DLT's Groups	Recommended Regroup
Petrol	Petrol
Hybrid	Hybrid
Diesel	Diesel
LPG	LPG
LPG&Petrol	
LPG&Diesel	
CNG	CNG
CNG&Petrol	
CNG&Diesel	
Electricity	Electricity
Non-Fuel	-
Others	-

The data in 2014 shows that vehicle type of gasoline has the highest portion of 69.63%, followed by diesel (25.57%), LPG (3.47%), NGV (1.16%), Hybrid (0.18%), and Electric (0.01%). Figure 3-17 presents the portion of engine types from total vehicle registration in 2014. Additionally, Figure 3-18 and Figure 3-19 present trend of number of vehicle registration by types of engine. One issue that should be noted is the trend of diesel vehicles are continuously growth since 2006 to 2014, 6.07% annually. These numbers would be expected to indicate that amount of fuel sold statistics or fuel consumptions for diesel should be increasing, instead of declining. Trends such as improvements in fuel economy and decreasing annual mileage occur however are not likely to compensate for the growth in number of vehicles. Hence, this issue supports the discussions of DEDE's energy consumption data in section 3.2.1.

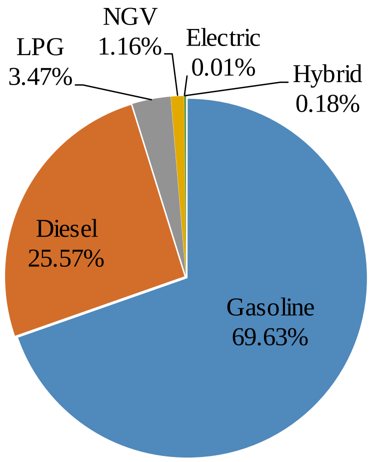


Figure 3-17 Vehicle Registration by Engine Type in 2014. (Source: Vehicle Registration Statistics (DLT))

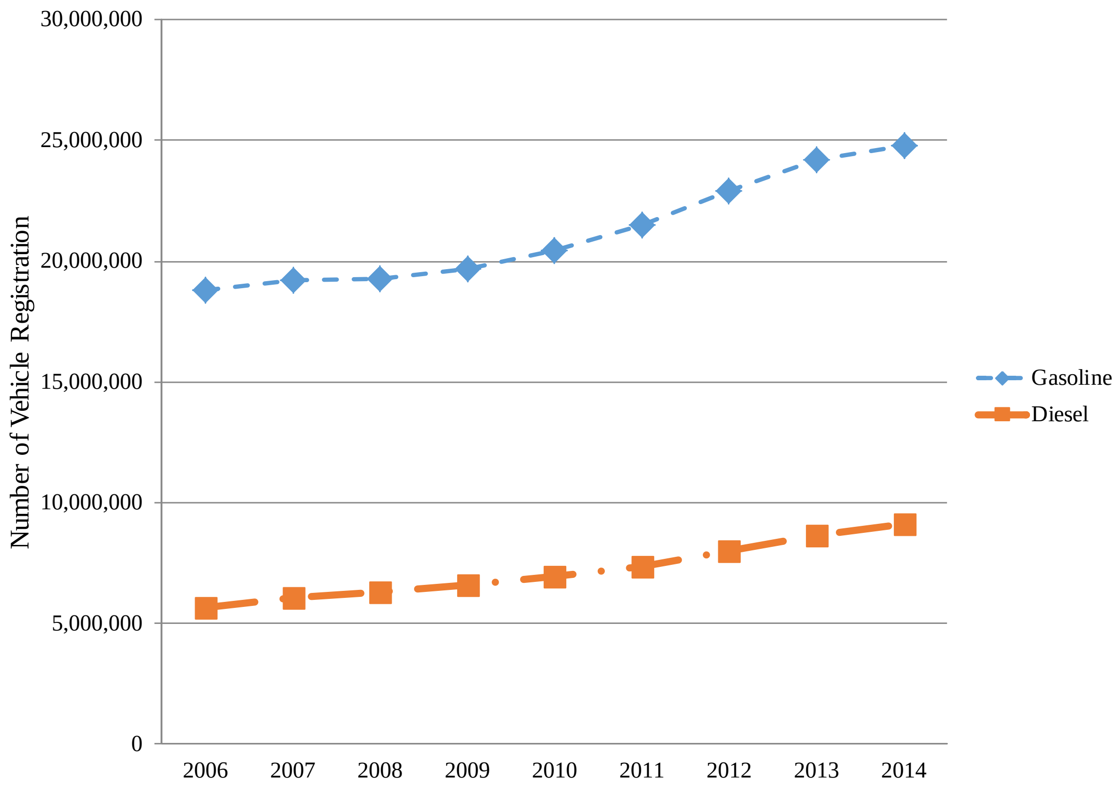


Figure 3-18 Number of vehicle registration from 2006-2014 (Gasoline and Diesel). (Source: Vehicle Registration Statistic (DLT))

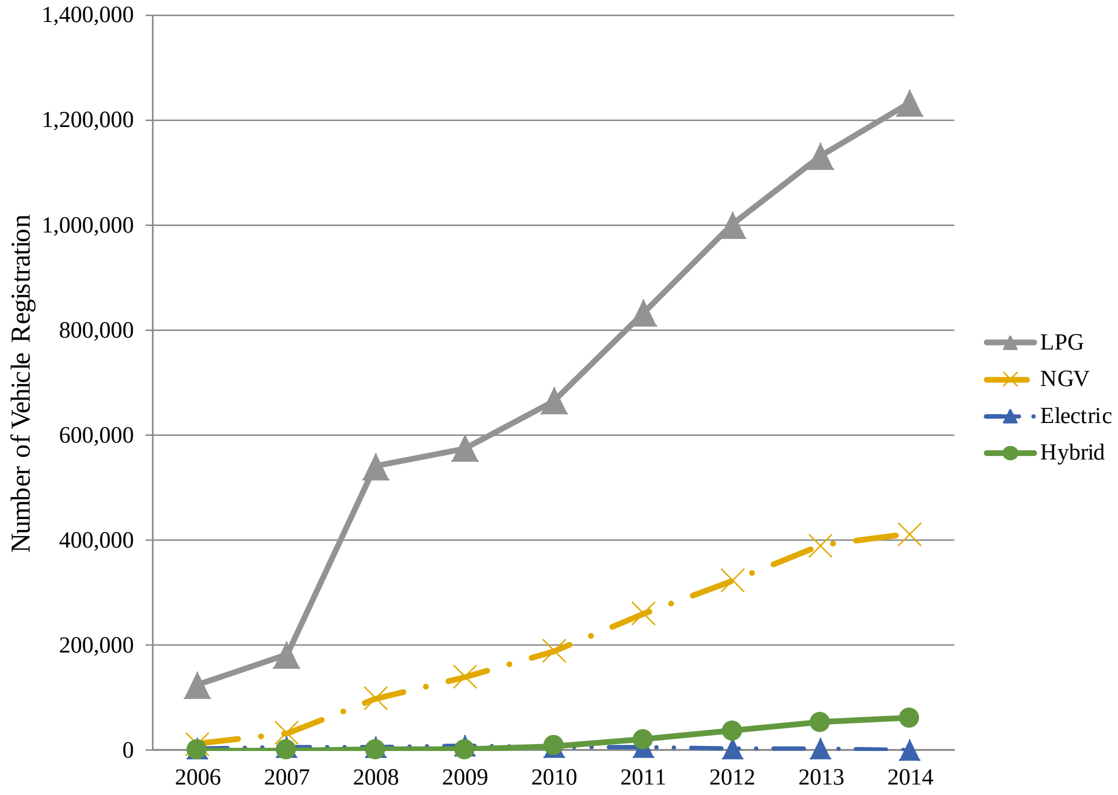


Figure 3-19 Number of vehicle registration from 2006-2014 by fuel type. (*Source: DLT Vehicle registration statistics)*

3.2.3. Vehicle kilometres travelled (VKT)

Vehicle kilometers travelled is one of the most important indicators of transport demand, and is required for estimating emissions. Several approaches could be used to estimate the VKT depending on available of data, budgets, study objectives, and size of the study area. Leduc (2008) distinguishes four methods:

- Odometer readings
- Traffic counts
- Driver survey
- Fuel consumption-based

The traffic counts approach is used in many EU countries as the main method to estimate VKT, however other methods are also used, including as secondary approach to support the primary method.

Estimation of VKT based on developed transport model, normally the conventional four-step method. The transport model could be used to estimate VKT in the specific area (i.e. city or local traffic area). However, the VKT in the national level will be relatively too complex for the model. Since, most nation level models are concentrated on the intercity traveling characteristics, not included city traveling characteristics/demands.

For the MRV purposes which data must be periodically or annually recorded or collected, the 2nd approach on estimating the VKT data from vehicle odometers would be the best alternative. However, currently, Department of Land Transport (DLT) in Thailand who's taken care of vehicle registration records do not annually collected the odometer data except for the vehicle aged more than 7 year. Briefly, the processes of vehicle registration in Thailand could be generally classified into 2 processes. First, the new vehicle registration process is taken as the first time registration for new vehicles, vehicles which are changed owners (in case of second hand vehicles), or vehicles which are failed to do annual registration more than 3 years. In this process, the records of odometer read are not required. Second, the annual vehicle registration process is required for all vehicles' owners to renew their vehicle registration every year. In this step, currently, DLT requires to record the odometer read only from vehicle aged more than 7 years through vehicle inspection process. It is implied that, there are no odometer records data from new vehicle aged less than 7 years which is counted as 52 percent based on the total vehicle registration in year 2014.

For Thailand, the Department of Highways (DOH) annually collects VKT data[9], however this only covers highway travel.

VKT data are only found in few research studies. Udomsri and Punravee (2003) developed vehicle distance traveled model to calculate annual VKT which mainly included daily distance at Chiang Mai urban area in 2003. The VKT Models were developed based on odometer readings and travel characteristics of household travelers. The results indicated that average daily distance travel by household traveler and frequency of using vehicle in a week significantly affect annual VKT of household vehicles. Also, Limamond et al. (2009) estimated VKT at Bangkok and Nakhon Ratchasima based on records of odometer under the ATRANS (Asian transportation Research Society) research project in 2009. Total 5,213 and 2,660 records were taken in Bangkok and Nakhon Ratchasima, respectively. The study surveyed 9 types of vehicle by classification of the DLT. Table 3-19 briefly presents results of average annual VKT of vehicles which were sampling in this study. However, these researches are results from small sampling data which are not reliable to apply its results for GHG emissions at the national level.

Table 3-19 Annual VKT by Vehicle Type (Limamond et al. 2009)

Vehicle Type	Average Annual VKT (km)	
	Nakhon Ratchasima	Bangkok
Motorcycle	5,662	4,015
Motorcycle Taxi	8,844	4,219
Tuk Tuk	40,382	40,351
Pickup	18,140	32,475
Taxi	132,476	109,351
Car	15,640	31,368
Bus	28,579	48,627
Truck	59,115	40,989
Songtaew	40,591	54,702

9 Annual VKT data is available to download at bhs.doh.go.th

Another source of annual mileage data is the report 'Motor Pollution control in Bangkok Strategy for Progress' by PCD in 1994, shown in Figure 3-20. However the methodology and assumptions for these data are not known.

It is clear that, more specific data based on VKT by vehicle, and preferably also by vehicle age, are required, e.g. from DLT.

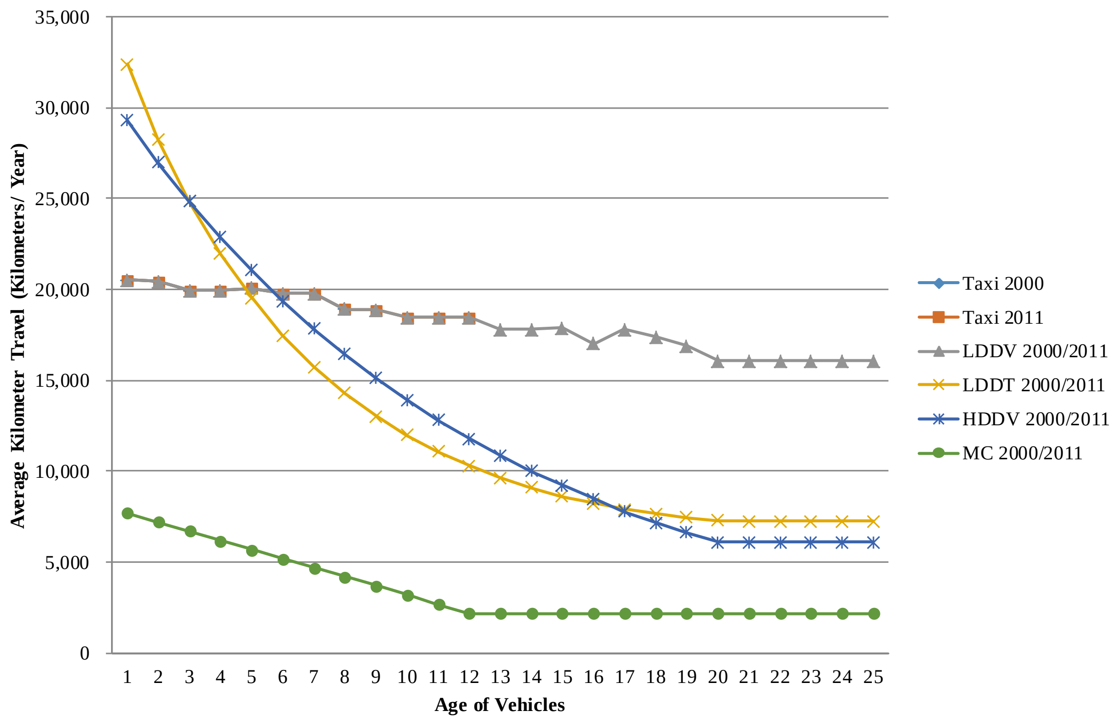


Figure 3-20 Annual VKT by vehicle age. (Source: Motor Pollution control in Bangkok Strategy for Progress, 1994, PCD.)
Note: LDDV: Low Duty Diesel Vehicles, LDDT: Low Duty Diesel Truck, HDDV: Heavy Duty Diesel Vehicle, MC: Motorcycle

The Department of Public Works and Town & Country Planning (DPT) conducts origin-destination (O-D) surveys and automatic traffic counts for city planning project or road construction projects. Secondary data from DLT, DOH and DRR are also used. City plans will be evaluated every 5 years and during the evaluation process O-D survey and traffic count will be conducted again to check the suitability of existing city plan.

Another method to collect VKT data is collection of sampling of drivers' occupations by roadside interview surveys. The sampling of drivers' occupations on the roadway could be separate sampling between (1) highway and motorway for intercity travel and (2) urban street, rural road, and local road for city travel. The portions of drivers' occupations on these traveling categories (Intercity and City trips) can then be used to connect with the home interview survey in order to estimate number of trips or VKT in case of traveling demand or vehicle kilometer travel are estimated based on household data (approach 2 in topic 3.2.3).

3.2.4. Average vehicle occupancy

An occupancy survey counts the number of passengers who are traveling in the same vehicle. The average vehicle occupancy can generally be gathered from roadside interview surveys. The result from this survey is the average number of occupancy by type of vehicles. Three area types that must be verified for the average vehicle occupancy are (1) Bangkok and metropolitan area, (2) provincial area, and (3) the intercity travel along the highway. Further, percent of inter-city traveling from households in the Bangkok metropolitan area and households in the provincial areas must be delivered from the home interview survey. These shares can be used to distinguish VKT, i.e. (1) VKT for urban traveling from Bangkok, (2) VKT for inter-city traveling from Bangkok, (3) VKT for urban traveling from provincial area, and (4) VKT for inter-city traveling from provincial area.

Table 3-20 show occupancy rate data from two studies. First, for the Bangkok and metropolitan area, the average vehicle occupancy were collected though the study of BMA road network, bridges, and traffic integrated development master plan in 2011. The data were collected from 7.00 am -19.00 pm from 22 locations on the bridges along the Chao Phraya River in Bangkok. Second, for intercity travel, the average numbers of vehicle occupancy were collected through the O-D survey from the Feasibility Study of Economic Engineering and Environmental Impact for National Highway Master Plan (Department of Highway 2008).

Table 3-20 Average vehicle occupancy in Bangkok Metropolitan Area

Vehicle Type	Average Occupancy Rate		
	Bangkok Metropolitan Region (OTP, 2011)		Intercity DOH, 2008)
	Weekday	Weekend	
1. Motorcycle and motor tricycle	1.10	1.10	n/a
2. Passenger car	1.15*	1.20*	2.1
3. Pickup	1.20**	1.25**	1.82
4. Van (public)	5.20	4.70	n/a
5. Small bus	9.60	10.10	14.01
6. Medium bus	13.80	13.80	32.9
7. Heavy bus	25.10	20.90	n/a
8. Medium truck	1.70	1.90	1.56
9. Heavy truck	1.70	1.70	1.39

* includes taxi; ** includes van. Note: definitions of vehicles are not necessarily comparable between the two sources

For the provincial area, the average numbers of vehicle occupancy could be collected from several traffic master plan projects for the provincial cities which have been published by the OTP. However, the data is outdated and needs to be checked on its reliability. For examples, the new data sources should be collected in the sampling city and then used the results of sampling data to re-check its reliable and tendency of these data. Alternative data sources would be the survey results from ad-hoc projects which are studied by several departments. Each year the Department of Highway (DOH), Department of Rural Road (DRR), and Department of Public Works and Town & Country Planning (DPT) have spent budgets for roadside interview surveys to support their ad-hoc projects. Gathering these data over the years from these departments could be very useful both for the records of average vehicle occupancy for the provincial area and also to crosscheck and to update the values of average vehicle occupancy for the other areas.

Further, suggestion to improve this type of data would be adding question on driver's occupations and incomes range (if possible). These types of questions will be very useful in connecting the data with the home interview survey.

3.2.5. Home interview survey

Two types of home interview survey from National Statistical Office (NSO) can be used for MRV of NLTS. These surveys are the population and housing census, and the annual household socio-economic survey[10].

The census data are surveyed every 10 years, with updates every 5 years. The last data set were its 11th population census in September 2010. The target of census data is to count everyone who resides in Thailand and classify their characteristics and distribution. Hence, Thai residents (both citizens and non-citizens) will be included. The census coverage includes:

- Every Thai citizen who live in Thailand on the census date, September 1st, 2010
- All Thai government officials and their family members who are on diplomatic posts overseas
- Foreigners or non-Thais who have lived in Thailand for at least 3 months by the census date except those with diplomatic posts in Thailand
- Thais/Non-Thais/Foreigners who have their usual place of residence in Thailand but on the census date are temporarily overseas.

The census data are collected by (1) face to face interview, (2) data entry via internet, (3) self-administered questionnaire, and (4) telephone interview. The census questions asked about everyone living in the household regardless of their legal status, ability to communicate in Thai language and whether they are registered in the household where they currently live in or not.

Questions about the following details are asked: age, sex, nationality, religion, education, speaking language, occupation, place of birth, marital status, number of children ever born, number of living & dead children, handicap status, migration, type and characteristics of household, registered in the living household or not, sanitation and water supplies, ownership of basic living appliances. Regarding transport, household vehicle ownership is the only relevant question[11]. This question is included: 'As of 1 July 2010, which of the following items does your household have?' Two options can be ticked: 'car/pick-up, truck/van' and 'motorcycle'[12].

There are already some micro-census data that could be used for MRV of NLTS, as the NSO have surveyed the population time use data every 5 years. The last published data set were on 2009. The data were sampled from different parts of Thailand, including Bangkok metropolitan area, central region, northern region, north eastern region, and southern region. The sampling procedure is to randomly select number of buildings from each census block group based on size of population and number of buildings in the block group. The data also includes both population socio-demographic

[10] The name of survey has been changed from household survey which was conducted every 5 years
[11] Pastharee Panmee (NSO), personal communication
[12] Population and Housing Census 2010, English version.

attributes and daily activity attributes. Table 3-21 presents a summary of population socio-demographic attributes. For daily activity attributes, the time use data were originally coded based on the International Classification of Activities and Time-Use Statistics (ICATUS) standard[13]; more than 190 activity types were classified.

[13] Time Use Survey data are record based on the ICATUS guidelines. The survey monitors all activities (include travelling) of the sampling population in one day based on a 15-minute interval period. The data can be used for travel demand estimates, however there is no information on travel modes. For more info: http://www.unece.org/fileadmin/DAM/stats/documents/ece/ces/ge.30/2014/mtg_1/Item_8_UNSD_ICATUS_revision_HSS_SENT_01.pdf

Table 3-21 Summary of population socio-demographic attributes (Population Time Use Data)

Variables	Description
PID	Personal ID (References for Survey Database)
MEM	Number of household members (age 10 years and over)
REL	Relation to household: 1. Householder, 2. Wife/Husband, 3. Single Son/Daughter, 4. Married Son/Daughter, 5. Son-in-law/Daughter-in-law, 6 Son/Daughter's children, 7.Father/Mother/Grandfather/Grandmother, 8 Relatives 9 Lodger or Servant
SEX	Gender: 1. Male, 2. Female
AGE	Age: 10-98 years old
MAR	Marital status: 1. Single 2. Married
ATT	School Attendance: 1. Attending School 2. Not Attending School
EDU	Education: 1. Illiterate, 2. Less than Lower Elementary, 3. Elementary Level, 4. Lower Secondary Level, 5. Upper Secondary Level (General Program), 6. Upper Secondary Level (Vocational Program), 7. Upper Secondary Level (Teacher Training Program), 8. Diploma Level (Academic Program), 9. Diploma Level (Technical Vocational Program), 10. Diploma Level (Vocational Program), 11. University (Academic Program), 12 University (Technical Vocational Program), 13 University (Teacher Training Program), 14. Others, 15. Unknown
WK	Working status: 1. Employed, 2. Unemployed, 3. Wait for Working Season (Mainly Agriculture), 4.Housekeeper, 5. Study, 6. Children/Elderly, 7. Illness or Disabled, 8. Vacation/Retirement, 9. Others, 10. Age less than 15 years old.
RG	Religion: 1. Buddhism, 2. Christianity, 3. Islam, 4. Others
OCC	Occupation: 1. Employer, 2. Business Owner with no Employees, 3. Working for Family Business (No Salary), 4. Government Employee, 5. State Enterprise Employee, 6. Private Firm Employee, 7. Group/Organisation, 8. Others

For city travel, number of trips from population time use survey data can be used to estimate the demand of household daily trips in the city which can then be later estimate for the annual traveling demand. However, in the population time use survey data, there are no questions regarding to class of household or individual incomes. Only one question that may help to classify household incomes is the question of the preferred rate of wage of house working in the opinion of sampling households/persons. The relation between wage of house working to household or personal incomes would need further clarification.

The annual household socio-economic survey (sample size 52,000) collects some relevant transport data, including monthly expenditures on transport and communication (vehicles purchase, maintenance, local transportation, and special occasion travelling and tour[14]. However, while household income data is collected, individual income is not.

In addition, the population time use survey data can only describe the city travel demand, i.e. estimating intercity travel would need additional questions.

In sum, further data from home interview surveys are required in order to better estimate VKT in urban and intercity traveling. For developing the MRV system is important to add questions about household traveling and transport data into census and/or microcensus, including e.g., number of trips traveling in daily basis, and number of trips urban and intercity travelling during the year, and modes of travels. Discussions with the National Statistical Office (NSO) to have extra micro-census, specific for transportation purposes, are recommended.

Such discussions can be informed by looking at international practice. From a brief literature search across six English speaking countries, we found all countries include one or multiple questions related to travel behaviour in their censuses. In addition to vehicle ownership, common questions in censuses are 'How do you usually travel to work or school?' or 'which is your main mode of travel to work or school on census day'?[15] Countries' approaches differ slightly in this question: 1) whether the question is asked for one particular day (day of census, or the day before) or 'usually', and 2) whether only one mode can be ticked or multiple modes. In Ireland (similar to Canada), the following questions are asked[16]:

- How do you usually travel to work, school or college?
- What time do you usually leave home to go to work, school or college?
- How long does your journey to work, school or college usually take?

Together with location of residence and work or school, detailed trip data and travel behaviour data can be generated. Given the large sample size of the census, as compared to e.g. a national travel survey, these questions yield key information for transport planners. It is often used to update travel models, estimate modal share[17], travel behaviour reports, estimate efficiency of the transport system and the various modes, and across different hours of the day if that question is included. In the context of MRV, modal share and travel behaviour patterns are essential in estimating (urban) transport emissions and potential impacts of measures aiming to change behaviour such as improving public transport.

3.2.6. Truck commodity data

National Statistical Office (NSO) has been conducting commodity flow survey since 2007. The survey is repeated every five years. The survey sample covers companies which have more than 11 employees. Four groups of industries were classified, based on International Standard Industrial Classification of All Economic Activities: ISIC Rev. 3.0), including: mining, production, retail and

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[14] Table 6 of survey: average monthly expenditure per household by type of expenditure and area
[15] see e.g. http://www.stats.govt.nz/Census/2013-census/info-about-2013-census-data/information-by-variable/main-means-of-travel-to-work.aspx
[16] http://census.ie/the-census-and-you/the-census-form/
[17] noting that commuting to work and school does not cover all trips; other purposes include e.g. shopping, visits and business trips

wholesale, and warehouse. The survey is split into four quarters during the year: January to March, April to June, July to September and October to December. The data from the 2012 survey cover a sample size of 17,482 companies, from total of 31,158 companies in Thailand. Data that will be surveyed and collected for each company are:

- Number of trips in which commodities were transported in the last 7 day period,
- Value and weight of the commodity,
- Types of the commodity which is categorised based on types of industry (see Table 3-22),
- Origin and destination of the commodity,
- Transportation mode (private truck, contractor truck, private pickup, contractor pickup, and others i.e. rail, post offices, and boat),
- Import / Export commodity to/from companies: the commodity trips will be recorded as trips of import (in) or export (out) of the company locations to/from the destination locations.

The survey should be cross-checked with rail/shipping data and road bottom-up calculations. Finally, the results from this commodity survey should later be cross checked with the goods movement from inter-urban rail data. From the commodity flow data, the estimation of total commodity flow by rail can be done based on the result samplings by expansions these results with companies in each category size. In addition, inter-urban rail transport data now contain the collection of commodity movement in tons weight. Hence, the estimations of total tons weight from the commodity flow data could be rechecked with the total tons weight data published by the State Railway of Thailand (SRT).

Table 3-22 Category of industry classify in truck commodity survey (NSO)

No.	Category of Industry
1	Mining of metal ores
2	Other mining and quarrying
3	Manufacture of food products
4	Manufacture of beverages
5	Manufacture of textiles
6	Manufacture of wearing apparels
7	Manufacture of wood and of products of wood and cork (except furniture);
8 + 9	manufacture of articles of straw and plaiting materials
10	Manufacture of paper and paper products
11	Printing and reproduction of recorded media
12	Manufacture of coke and refined petroleum products
13	Manufacture of chemicals and chemical products
14	Manufacture of rubber and plastic products
15	Manufacture of other non-metallic mineral products
16	Manufacture of basic metals
17 + 18	Manufacture of fabricated metal products (except machinery and equipment)
19	Manufacture of computers, electronic and optical products
20	Manufacture of chemicals and chemical products
21	Manufacture of electrical equipment
22	Manufacture of machinery and equipment, n.e.c
23	Manufacture of motor vehicles, trailers and semi-trailers
24	Manufacture of other transport equipment
25	Manufacture of furniture
26	Other manufacturing
27 + 28	Wholesale and retail trade; repair of motor vehicles and motorcycles
29	Wholesale trade (except of motor vehicles and motorcycles)
30	Warehousing and support activities for transportation

Source: The 2012 Commodity Flow Survey, National Statistical Office, Ministry of Information and Communication Technology

3.2.7. Urban rail transport data

For urban rail transport (city train), the data that are available on an annual basis is the total number of passengers using the urban rail system. Data are published by operators of the system, BTS (Bangkok Transit System) and MRT (Mass Rapid Transit). In 2014, 321.74 million passengers used the urban rail system. From 2008 to 2014, ridership is increasing at approximately 7% per year (Figure 3-21). With this increasing trend, it would be expected that energy consumption would follow a more or less similar trend. Checking the electricity consumption data with Figure 3-9, which shows a different trend, is therefore recommended.

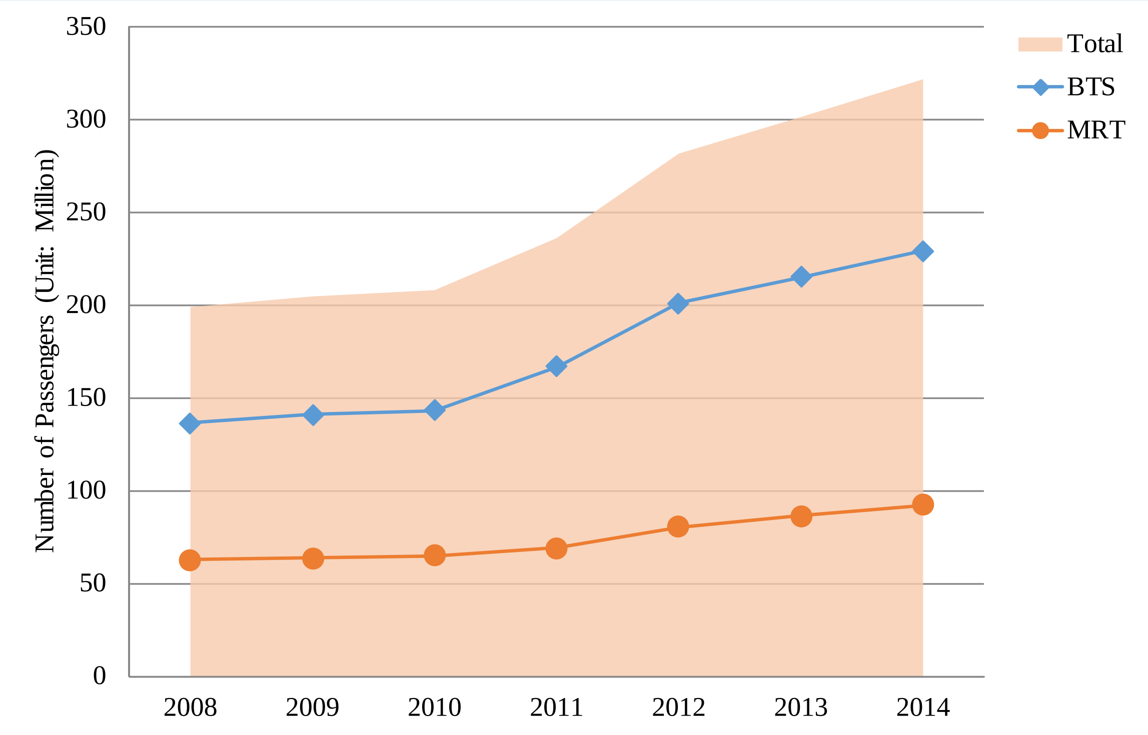

Figure 3-21 Number of passengers traveling by urban rail system (Source: Bangkok traffic statistic book 2014)

As presented in Section 2.2.2, to estimate PKT for the urban rail system, the average number of passengers traveling from origin station to destination station could be used. Currently, both BTS and MRT do not publish their total number of passengers in the O-D table format. However, MRT provides the average number of passenger in the daily basis for the O-D table format. Hence, to estimate PKT, alternatively, data from MRT can be used to estimate the parameters of "the average kilometer travel" per passenger. Then, this parameter can be multiplied by the total number of passenger traveling by urban railway system, in order to get value of PKT.

The accompanying excel file includes O-D tables for the average number of passengers published by MRT for the month of May 2011. These data may be helpful in estimating trip lengths and "average kilometer travelled" for passengers on weekday and weekend & holidays.

3.2.8. Inter-urban rail transport

As discussed in chapter 2 (section 2.2.2), inter-urban rail transport (inter-city train) has more data available compared to those data from the city train. Data that are required (and available) for GHG emission estimations, are:

- Total energy consumption for inter-city train,
- Portion of energy consumption for using in the traction activities,

- Total passenger kilometer travelled, and
- Total tons kilometer travel.

For total energy consumption, State Railway of Thailand (SRT) has been collected amount of diesel used on their operation activities. SRT also reports amount of diesel which is classified by activities including:

- Passenger trains,
- Freight trains,
- Sledding,
- Air condition,
- Civil,
- Mechanic,
- Telecommunication, and
- Operation.

Hence, energy consumptions using in inter-urban rail transport (inter-city train) system can be directly derived from this data. Table 3-23 presents total energy consumption of inter-city train from 2007-2014. Additionally, considering only total diesel consumption for passengers train and freight trains, there are, approximately, 90 million liters of diesel consumptions in 2012 and 81 million liters in 2014. These numbers of passenger and freight trains diesel consumptions are closely to those number of diesel consumption in rail transport which is reported by DEDE.

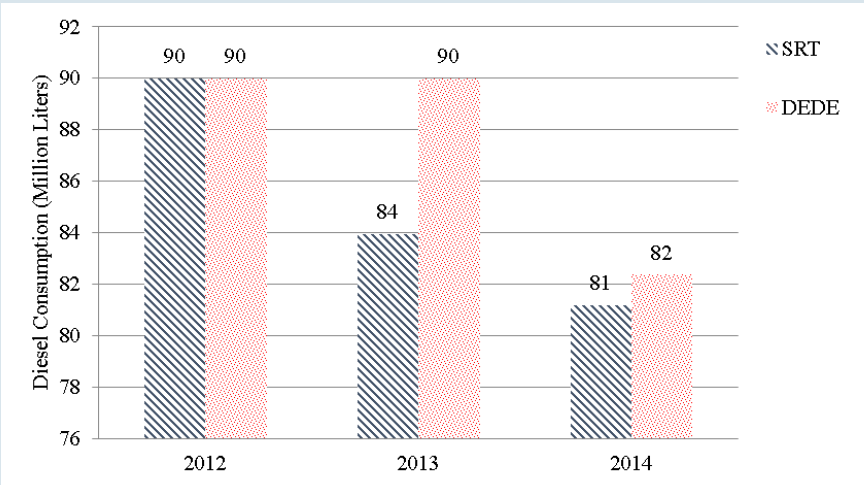

Figure 3-22 Diesel consumtpion for inter-city train (Source: SRT, DEDE)

(See also section 3.2.1 for more details).

State Railway of Thailand (SRT) also collects data of PKT and TKT. PKT were collected based on the ticket sale statistics, while the TKT were collected based on billing information of freight movements. The weight of goods transported in bulk and container were estimated based on the number of containers. Also, currently there are no direct standards or factors for weight by type of commodity published by SRT. Hence, there is a need to verify how State Railway of Thailand collected the commodity data which are transported in bulk or containers such as coal and petroleum. The final product of this verification could be the conversion factors for weight of each commodity types. Table 3-24 summarises tonne-km and passenger-km travelled for inter-city rail transport system.

Table 3-23 Energy consumption (Diesel, litre) for inter-city rail transport (Intercity-train)

Activities	2007	2008	2009	2010	2011	2012	2013	2014
Passenger Trains	68,325,598	67,480,938	65,021,964	64,110,231	61,346,987	63,409,459	58,736,170	59,056,654
Freight Trains	33,837,551	31,744,187	27,490,606	27,037,343	25,426,831	26,322,542	25,226,147	22,122,084
Sledding	102,163,149	99,225,125	92,512,571	91,147,574	86,773,819	89,732,001	83,962,317	81,178,738
Air Condition	4,784,376	4,695,945	4,975,062	4,829,302	4,727,097	5,300,144	4,757,942	4,674,129
Civil	580,216	626,955	625,178	652,405	648,134	606,495	601,235	602,229
Mechanic	376,774	344,906	383,942	384,132	318,615	361,365	428,289	483,815
Telecommunication	5,900	10,504	7,733	10,368	10,800	15,101	13,160	13,692
Operation	2,015	2,800	5,330	6,240	7,570	6,980	7,840	8,840

Source: State of Railway Thailand

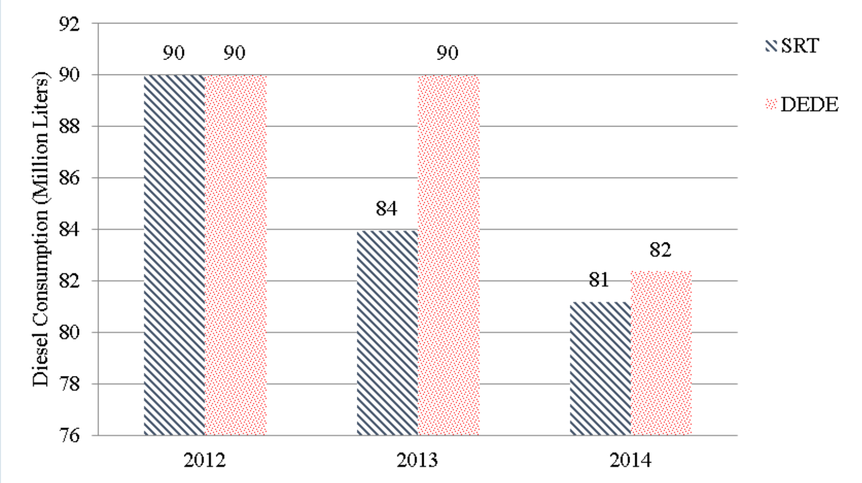

Figure 3-22 Diesel consumtpion for inter-city train (Source: SRT, DEDE)

Table 3-24 Rail (inter-city) tonne-km and passenger-km

Year	TKT (tons-kilometer)	PKT (passengers-kilometers
2010	2,651,508,245	8,082,727,000
2011	2,523,438,456	7,503,965,000
2012	2,402,935,928	7,566,412,000
2013	2,590,022,890	6,784,026,000

Source: State of Railway Thailand

3.3. Summary of data inventory for MRV of NLTS

To summarise this chapter, Table 3-25 presents the data inventory overview. The overview includes data sources, data availability, and problems and comments for the data improvements.

Table 3-25 Summary of data inventory for MRV of NLTS

Data/ Parameter	Sources	Availa bility	Collection Method	Notes	Data Issues	Recommendations	Secti on
Fuel Sold Statistic and Electricity Consumption	DOEB	2008-2013	Data were collected from the bill of fuel sold from DOEB to the customers. DOEB recorded the fuel sold statistics by grouping the customers into 8 categories (described in 3.2.1)	More details on methodology may be required	• The separation of fuels, in particular diesel, used for transport and for other purposes is critical and complex. • DOEB and DEDE data may not be matching for diesel and LPG/CNG • DOEB does not report CNG data separately • Fuel stock changes might not be tracked over time thus potentially under- or overestimating for specific years emissions. However this is a minor issue which happened in the border when high fuel price differentials between neighbouring countries fuel smuggling or cross-border fuel sales i.e. fuels are sold in country “Laos” but used in country “Thailand” can be a relevant issue. • Electricity usage in transport is not recorded. However rail, metro and increasingly road vehicles (incl. hybrids) use electricity. Car needs to be taken to include only traction energy (for metro) used.	• The DOEB data could be used as the main source for emission estimation in the top-down approach. Relevant customer groups include: group 1: fuel stations, group 2: Fuel Retailers/Shops, group 3: transport, group 6: government, and group 8: consumers in section 10 of the oil trade law. However, other groups may also be relevant for a comprehensive estimation of emissions from ‘mobile sources’ as per IPCC 2006 guidelines, and further discussion is required among key stakeholders, particularly DOEB, DEDE, EPPO and TGO • Electricity use for transport needs to be collected directly from usage sources or from detailed electricity statistics.	3.2.1

	DEDE	2012-2014	No further explanation of how these data were collected or estimated	Data were taken from DEDE's the energy balance and energy commodity account tables of Thailand	• Diesel consumption data from 2012-2014 show a decreasing trend. Electricity Uses in rail mode are also declined from 2013-2014. Also, the data do not specify which share is used for traction energy.	• Given the trend of diesel data and electricity use by rail are different from other sources, further discussions on the sources and methodology are needed.	3.2.1
	EPPO	1988-2012	Estimate CO_2 based on DOEB data	EPPO only published total CO_2 emissions in the transport sectors. The CO_2 were estimated based on the data from DOEB. No detailed data sources and methodology of fuel consumptions data in the transport sector are found in the EPPO report.	• Only CO_2 emissions were published. However, CH_4 emission factors for vehicles are technology related and not fuel quantity related; this is relevant in Thailand, with a significant and growing share of NG vehicles. At minimum top-down approaches need to make an assessment of gaseous vehicle technology in usage to apply a CH_4 default factor per gaseous energy unit.	• These data could be used to recheck with the CO_2 emissions estimated from DOEB data and also the bottom up approaches. • Further discussions with EPPO on method of estimating the CO_2 emissions from their report are needed. • Assessment of CH_4 emissions is required	3.2.1
Specific Fuel Consumption	EPPO	2014	Survey among 10,000 vehicle users, real fuel consumption; all vehicle types and different fuels		• Some values are outside the expected range	• Real-life SFC data in real life need updating	3.1
	PCD		Vehicle testing in lab based on 6 different speeds	PCD data are published in OTP (2012)	• SFC values do not follow the expected trend with rising speed • There are three agencies carrying out fuel efficiency and emissions tests (PCD, TAI and PTT); it is expected that all three will use the Worldwide Harmonized Light vehicles Testing	• SFC type approval data need updating and should be based on common and reliable methodology	3.1

					Procedure within a few years, whereas currently driving cycles may differ		
Vehicle Registration	DLT	2006-2014	All data were recorded from the vehicle registration process which is done annually for every vehicle.	Vehicle categories include trailers and vehicles that could not be classified (however the number is not very significant with 0.1% of vehicles)	• DLT uses 17 vehicles types. To match these to those classified by other department (OTP, DOH, DRR, etc.), the data are recommended to regroup types of vehicle into 7 groups	• DLT may publish further attributes into the data including the number of vehicles that are failed to register and the number of scrap vehicles.	3.2.2
Vehicle Kilometre Travel	ATRANS and PCD	2008 / 1994	ATRANS: odometer readings and travel characteristics of household travellers. Total 5,213 and 2,660 records were taken in Bangkok and Nakhon Ratchasima, respectively. PCD: no further discussions on collecting methods are provided in the report. DOH collects VKT data for highways		• These researches (ATRANS) are results from small sampling data which are not reliable to apply its results for GHG emissions at the national level. • Data from PCD is quite out of date (1994).	• More specific data collection based on VKT by vehicle ages (odometer records) are required from DLT. • Distance driven can also be based on company records (buses, trucks, taxis), and household surveys (buses, cars, motorcycles). • Surveys, traffic counts and fuel-consumption based approaches can also be used. • Using at least two approaches is recommended in order to allow for cross-checking	3.2.3
Average Vehicle Occupancy	OTP DOH	OTP-2011 DOH-2008	Roadside interview survey: vehicles on the road will be randomly asked to stop by the officers conducting the survey; questions include origin-destination and traveling	Data of driver occupations may be needed in order connect data with results from the household survey.	• These data are only available as ad-hoc projects which are not periodically updated and are not necessarily reliable or representative	• Improved occupancy rate data are required based on peer-reviewed methodology, which should be agreed among	Sec. 3.2.4

			purposes. Other data, such as type of vehicle and occupancy, are also collected. Sample size is based on the traffic volume the field site.			key stakeholders. • Gathering more existing data from roadside interview survey from DOH, DRR and DPT would help to improve data and cross-check several sources.	
Home Interview Survey	NSO	General population census (every 10 yrs) Household socio-economic Survey (annually)	(1) face to face interview, (2) Data entry via internet, (3) self-administered questionnaire, and (4) telephone interview The data were sampled from five regions covering entire Thailand; based on random selection number of building from each census block group based on size of population and building density in the block group.	Currently no specific set of transport data are in census (except household vehicle ownership) Annual survey includes questions on vehicle ownership, travel mode and cost of travel (exact questions not know to authors)	• No direct question regarding to household or personal incomes provided in the time use data, question regarding to wage of house working are asked, which require clarification as to the relation to personal income.	• The improvement of transport questions in census are required, including number of trips traveling in daily basis, time spent travelling, modes of travels used, cost of travel. • Transport questions in annual survey to be checked, and questions could be added: number of trips daily and time spent on each trip	Sec. 3.2.5
Commodity Data	NSO	Every 5 years since 2007	The survey samples cover the establishment which have more than 11 employees. The survey is split into 4 quarters during the year. The survey is collected based on the company's transport bill and receipt.	Four groups of industries were classified, based on International Standard Industrial Classification of All Economic Activities: ISIC Rev.3.0), includes: mining, production, retail and wholesale, and warehouse	• Random sample based on 17,482 companies based on database of registered companies clustering according to size and sector with a confidence level of 95%. The confidence level seems a bit doubtful considering that questions can be interrelated (distance and mode e.g.) where the sample size might not be sufficient. The survey is based on the	• Check appropriateness of sample size and procedure and increasing if required. • Raw data or summarised data which representing weight of commodity (by types) flow from original to destinations are needed to be published. In order to be	3.2.6

					US procedure for the Commodity Flow Survey (CFS). However the US 2007 CFS used a sample of 40,000 units.	able to estimate TKT.	
Urban Rail Transport	BMTS BEM SRT	2005-2014	Data were collected based on the tickets sold (electronic tickets).	Further details of type of passengers (student or not), times, and origin-destination would be possible.	• Current published data are available only in total number of passengers by stations. • The original destination (OD) of passengers by stations are existed but there are not able publish online. The data will be available as per requested.	• Publication of O-D data	3.2.7
Intercity Rail (Passenger and Freight)	SRT	2010-2014	For passengers, data were collected base on the ticket sold statistics. For freight, the data collected base on the record of good shipments. All goods were estimate into gross weight.		• For freight movement, the data are available in kilogram.	• Verification on how SRT collected the commodity data which are transport in bulk or container such as coal and petroleum.	3.2.8
Modal Split	OTP, BMA		Freight data available, passenger modal split is not	Covered in Narupiti et al., (2014); not in this report		• Passenger modal split data, at country level and at urban level the Bangkok Metropolitan Region and other cities are key in bottom-up estimates	-

4. Stakeholder analysis

Results of data inventory and data gaps in Chapter 3 have presented that there are needed on involvement from several organisations which mainly are the government agencies. Also, there are several immediate issues to be work on in order to process the progress of developing the MRV of emission for National Land Transport System and, also, the MRV of emissions for NAMAs. It needs collaboration among the involved organisations or stakeholders, as illustrated in this chapter. It needs to be noted that this chapter is a summary of issues, for more details on particular data types we refer to the analysis in Chapter 3, particularly Table 3-25.

According to the data for MRV discussed in Chapter 3, at least 17 organisations from five ministries are involved.

Ministry of Natural Resource and Environment (MNRE):

The MNRE has responsibility of the national MRV system particularly on NAMAs and GHG inventory for all sectors. The departments involved under the MNRE are the Office of Natural Resource and Environment Policy and Planning (ONEP) and the Pollution Control Department (PCD).

Office of Natural Resource and Environment Policy and Planning (ONEP)

As ONEP is mandated to be a national focal point in conducting and publishing the national GHG inventory, ONEP should play the most important role on publishing national MRV report and guidance about the emission estimation and its parameters (which is not limited to transport sector but cover all related sectors)

Immediate Action: Cooperate with stakeholders such as Ministry of Energy to improve top-down emission estimates.

Thailand Greenhouse Gas Management Organisation (Public Organisation), TGO

TGO is responsible to provide technical assistance in greenhouse gas emission collection to MNRE. Together with OTP, they are developing MRV methodologies for transport, including for modal shift in urban transport. Therefore, they can suggest the appropriate methodology for GHG emission measurement to ONEP and Ministry of Transport as well as comments on the quality of data.

Immediate Action: Cooperate with MNRE and Ministry of Transport to improve the data collection system as well as suggest the appropriate methodology.

Ministry of Transport (MOT):

The MOT plays key role in MRV as the main data source for transport system, transport activities, modal split, impacts of policies and projects, and the energy consumption. The departments under the MOT which are involved on data provider for the MRV are:

Office of Transport and Traffic Policy and Planning (OTP);

OTP may take part as the centre of data inventory, to collect related data from other departments, and cross-check data from the transport forecasting model. It also includes the development of VKT model, bottom-up estimates and analysis of emission estimation model for MRV.

Immediate Action: Current transport data are quiet mixed between the forecast or model value and the real statistic data. The data and its sources and collection methodology must be clearly published and collected. The OTP will need to annually published the transport data and well indicated which are from the forecast and which are the real survey or statistical data collected from the other departments. Secondly, OTP could develop, guided by and in coordination with the Joint Working Group (see below), common reporting formats for data collection and reporting.

Department of Land Transport (DLT)

Provide information of the vehicle registration and develop for odometer data collection.
Immediate Action: Odometer read data are currently not collected by the DLT. More working steps in negotiation with DLT to collect and provide these data are required.

Department of Highway (DOH), Department of Rural Roads (DRR), and Expressway Authority of Thailand (EXAT)

Responsible for providing the roadside interview and traffic count data.
Immediate Action: Results from roadside interview data especially average vehicle occupancy by type of vehicle on the highway road are requested. Systematic of data collections are required (i.e. whole country data collection every 5-10 years and project based data collection on yearly basis).

State Railway of Thailand (SRT)

Role: take part on data collection from Airport Rail Link (urban rail) and inter-urban rail system on their operations and demand statistic data especially on Origin-Destination of passenger data for PKT calculation.
Immediate Action: For airport rail link system, passenger data are needed to publish in the format of origin-destination in order to use for calculating the PKT. Operations data are required from the SRT. The data includes fuel uses (for inter-urban rail system) and electric uses (for airport rail link system), locomotive engine lists and its operations schedules.

Marine Department (MD)

Provides information of total number of users on waterway transport.

Ministry of Information and Communication Technology (MICT):

The National Statistical Office (NSO) which is the key organisation under the MICT, is responsible for the Population Census Data, Population Time Uses Data, Household socio-economic survey, and the Commodity Flow Data surveying. There may also be scope to for integration of certain data collection the process of Thai government database that is being prepared and hosted by MICT.

Immediate Actions: Transportation-relevant questions, such vehicle ownership and commuting behaviour of population in the household can be added to census[18]. The transport questions in the annual socio-economic survey can be expanded with questions such as number of daily trips (either 'usually' or on a particular survey day), trip purpose of each trip, modes taken and time spent travelling for each trip.

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[18] two to four questions can be included, see section 3.2.5

Ministry of Interior

Department of Public Works and Town & Country Planning (DPT),

Role: to undertake roadside interview, in the similar format with DOH, DRR, and EXAT, as well as traffic counts and O-D surveys.

Immediate Action: DPT will be needed to annually collect and publish the transport and traffic data that are normally requested to collect during DPT's projects every year. The data are, mainly, results from roadside interview data especially average vehicle occupancy by type of vehicle as well as speed, traffic counts and O-D surveys. Systematic of data collections are required (i.e. whole country data collection every 5-10 years and project based data collection on yearly basis)

Bangkok Metropolitan Administration (BMA)

Role: responsible to cooperate with BMA's public service providers, which are; Bangkok Expressway and Metro Public Company Limited (BEM), Bangkok Mass Transit Authority (BMTA) and Bangkok Mass Transit System Public Company Limited (BTS). Their passenger data, energy consumption, and operation schedules are required to be in the same origin-destination format in order to calculate PKT for public transport modes.

Immediate Action: Passenger data should be published in the format of origin-destination in order to use for calculating the PKT. Operations data are required from the BMTA for the BTS, including ridership, electricity uses, locomotive engine lists and its operations schedules; and bus transport (including BMTA and private operators): ridership, bus operational km per day, fuel consumption and speeds. Total number of users of waterway transport are also required.

Ministry of Energy (MOE)

- Department of Energy Business (DOEB),
- Energy Policy and Planning Office (EPPO), and
- Department of Alternative Energy Development and Efficiency (DEDE).

Immediate Action: collaborate on providing fuel sold statistics and energy consumption by vehicle types in order to improve top-down emission estimates for the transport sector ('mobile sources'). This set of data is required to be systematically collected in the same format for top-down and bottom-up calculation method (see further Table 3-25).

Apart from the stakeholders which are mentioned above, some organisations should be involved on providing relevance information, for example, Ministry of Finance (MOF) and the Office of the National Economic and Social Development Board (NESDB) should be consulted by request in order to provide the country's economic forecasting, and nation's policies information.

The key stakeholder from 5 ministries, which are; Ministry of National Resource and Environment, Ministry of Transport, Ministry of Energy, Ministry of Interior, and Ministry of Information and Communication Technology, would assign their representatives to work together in the joint working group (JWG), namely MRV for transport sector working group. One of the representatives from Ministry of Transport must be a key staff from Office of Traffic and Transport Policy and Planning (OTP), who is recommended to take a leader role in this working group. Moreover, OTP would be the centre for data collections which manages and distributes data to relevant stakeholders. The other members of the working group should be able to coordinate with related organisations in their ministries to collect required data and send it to OTP. On the other hand, Office on Natural Environmental Resources Policy and Planning (ONEP), which is responsible for National climate change policy and greenhouse gas emission reductions target, would be the national auditor to verify data from the MRV for transport sector working group.

Stakeholders have commented that rules and regulations regarding disclosure of data cause difficulty in accessing data, as well as delay in sharing and publication of data. Therefore, the JWG should also promote timely sharing and online publication of data to the extent possible as well as initiate a revision of regulations related to data sharing and data disclosure to facilitate data collection for MRV.

The potential roles and collaboration among stakeholders are represented in Figure 4-1. Finally, Table 4-1 summarises stakeholders' roles and their data inventory that must be worked on.

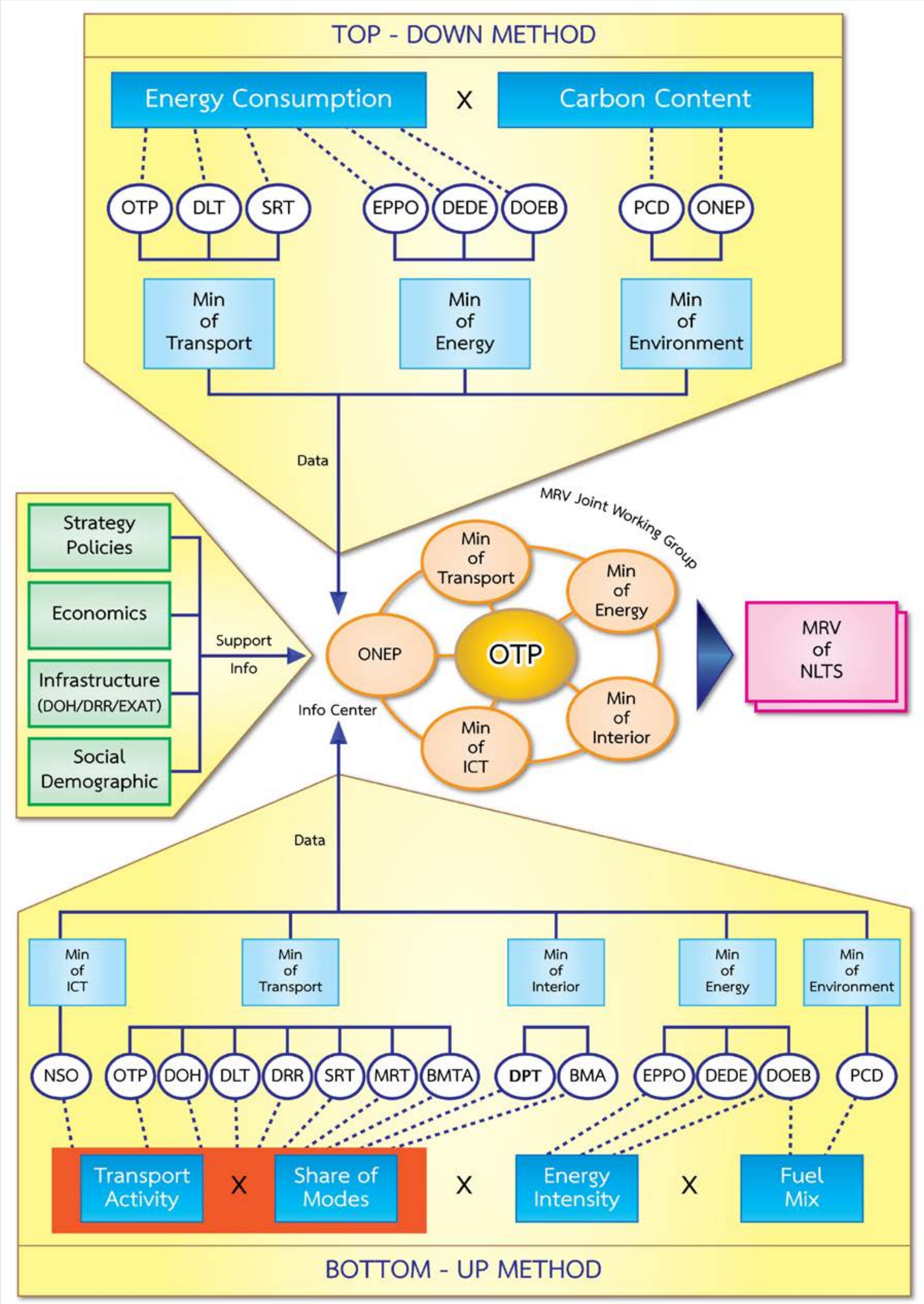

Figure 4-1 Proposed stakeholder's roles in NLTS data inventory and collaboration in a MRV Joint Working Group (Source: Authors)

Table 4-1 Summary of recommended stakeholder roles in data inventory for NLTS

Organisation	Stakeholder	Data	Role	Remark
Ministry of Natural Resources and Environment	Office of Natural Resource and Environment Policy and Planning (ONEP)	MRV Report Emission estimation	Collect data[2] Cross-checking[3] Analysis[4] Report / Publish[5]	Working group[1]
	Pollution Control Department (PCD)	Parameters/ factor for emission estimation	Review[6] Analysis	
Ministry of Transport	Office of Transportation and Traffic Policy and Planning (OTP)	Transport forecasting Mode share (incl. NMT) Trip lengths VKT/annual mileage	Develop data formats Review[6] Cross-checking Analysis Report / Publish	Working group[1] Centre of data inventory
	Department of Land Transport (DLT)	Vehicle registration, Odometer data, annual mileage Share of energy types on mode	Collect data	Working group[1]
	Department of Highway (DOH), Department of Rural Road (DRR), Expressway Authority of Thailand (EXAT)	Road side interview Traffic counts	Collect data	

	Marine Department (MD)	Waterway transport user and operation data	Collect data	
	State Railway of Thailand (SRT)	Rail transport operation data: No. of passenger/freight, gas usage, operational schedules	Collect data	
Bangkok Metropolitan (Ministry of Interior)	Bangkok Metro Public Company Limited (BMCL)	MRT operation data : No. of passenger, electric usage, operational schedules	Collect data	Working group (BMA)[1]
	Bangkok Mass Transit System Public Company Limited (BTS)	BTS operation data : No. of passenger, electric usage, operational schedules	Collect data	
	Bangkok Mass Transit Authority (BMTA)	BMTA and private bus operation data: No. of passenger on buses and vans, fuel consumption, operational schedules	Collect data	
Ministry of Information & Communication Technology	National Statistics Organisation (NSO)	Household travel survey data and vehicle ownership Commodity flow survey data Vehicle ownership* Inter-city travel frequency*	Collect data	Working group[1]
Ministry of Interior	Department of Public Work and Town and City Planning (DPT)	Road side interview data: vehicle occupancy by type of vehicle on road*	Collect data	

		Traffic counts O-D surveys		
Ministry. of Energy	Energy Policy and Planning Office (EPPO)	Fuel sale statistics; by type, by province, by time	Collect data	Working group[1]
	Department of Energy Business (DOEB)	Fuel sale statistics; by type, by province by time	Collect data	
	Department of Alternative Energy Development and Efficiency (DEDE)	Other energy sale on transport sector; by type, by province, by time	Collect data	

Notes:
[1]: Working group; the organization, should have a representative as a part of MRV Joint Working Group
[2]: Collect data: the collection of data in the usable format for MRV, which are certified for validity and reliability, and updated.
[3]: Cross-checking: the process of recheck the received data with other sources of data.
[4]: Analysis: the process of the data analysing using the statistic or mathematic models.
[5]: Report/publish; the organisation is responsible in reporting and publication MRV's result to public.
[6]: Review; the work on investigation, gathering relevant information which may effect to NLTs and emission from transport sector.

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Annex I Summary of MRV stakeholder workshop

MRV Stakeholder Workshop was held on 25 April 2016 at OTP meeting room. There were total 63 participants from MOT, MNRE, MOE and others organisations such as DPT, NSO, BEM and Transportation and Traffic of BMA. From the activities, participants raised their opinion regarding MRV transport sector as follow;

1) Transport data collection of each organisations

- Transport data collection
  - All organisations participated in this workshop are responsible for data collection including socio-economic, energy consumption and GHG emission especially transport data which are being collected by 13 organisations.
  - Energy and fuel consumption data are not only the responsible of ministry of energy but also relevance to other ministries.
  - GHG emission data are increasingly significant. This data relevance to three ministries; MOT, MNRE and MOE.
  - Socio-economic data is also important for transport activities estimation.
  - In the future, Ministry of Energy plans to establish the energy data center in order to collect all relevant energy data from all organisations.
- Problems in data collection
  - Most of participants indicated that the most important problems in data collection are lacking of technical knowledge in transport data collection and insufficient of human resource as well as budget in data collection respectively.
- Problem in data transfering/exchanging
  - Most of participants indicated that the major problems in data transfering/exchanging are no host party of the central data system. Other problems are Law & Regulation limitation and communication

2) Transport data exchanging between organisations.

- Obstacles in data exchanging
  - Participants indicated the high priorities problems are
    1. Lack of main organization for data integration cause the problem in data replication.
    2. Limitation in regulation of each organization/ministry cause the delay and unable to transfer data between organization. In addition, some data are unable to share due to the rules to allow data disclosure under Official Information Act.
    3. Variation in method and format of data collection cause the data of each organization difference.
- The need for supporting
  - Participants selected the most important obstacle and identified supporting needed to rectify the obstacle. The supporting needed is establishing host organization to integrate transport data.

- Other supporting required from participants are technical support, budget and human resource, data collection form/format and absolute policy and authorization from government or high level official.

- Opinion regarding host organization for transport data collection
  - Most of participant proposed OTP to be the host for transport data collection
  - Other opinion proposed permanent office Office of Permanent Secretary (OPS) to be a host or establish the task force committee to responsible for transport data collection.

3) Opinion regarding the draft report on MRV transport sector.

- Participants shared the information and their opinion to improve draft MRV report as well as express their opinion on stakeholder diagram which illustrate coorperation between organization in transport data collection.

Annex II Table of Contents accompanying data file

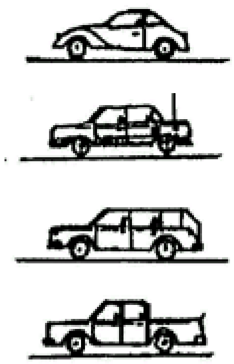
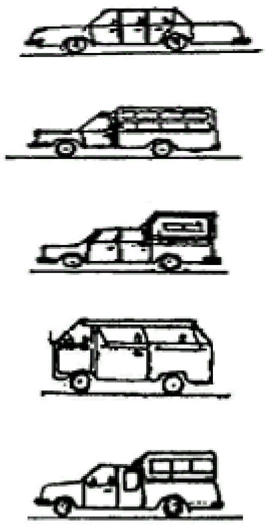
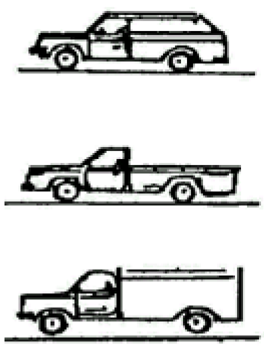
1	Ref No.	Title	Available
2	1	Factors & Parameters	-
3	1.1	Road Transport Default CO2 Emission Factors and Uncertainty Ranges	-
4	1.2	RoadTtransport N2O and CH4 Default Emission Factors and Uncertainty Ranges	-
5	1.3	pollutant weighting factors as functions of engine design parameter for uncontrolled engines (dimensionles	-
6	1.4	Energy Content of Fuel (Net Calorific Value)	-
7	2	Specific Fuel Consumption (SFC)	-
8	3	DEDE Energy Consumption in Transport Sector	2012 - 2014
9	4	DOEB Fuel Sold Statistics	2008 - 2013
10	5	EPPO CO2 Emission in Transport Sector	1988 - 2012
11	6	Total Number of Vehicle Registration	1989 - 2014
12	7	Total Vehicle Registration by Types of Engines	2006 - 2014
13	8	Total Vehicle Registration by Age	2007 - 2014
14	9	Total Number of New Vehicle Registration	1991 - 2014
15	9.1	Total Number of Vehicle Registration by Bus Standards and Truck Characteristics	2013-2014
16	10	Kilometer Travel Distribution by Vehicle Type	1994
17	11	Vehicle Kilometer Travel (VKT) by Type of Vehicle	2007-2013
18	12	Outbound shipment characteristics wth 16 persons engaged and over by size of establishement: 2012	2012
19	13	Outbound Shipment Characteristics with 16 persons engaged and over by category of industry: 2012	2012
20	14	Average Vehicle Occupancy	-
21	14.1	Average Vehicle Occupancy in Bangkok Metropolitan Area (BMA)	-
22	14.2	Average Vehicle Occupancy for Intercity Travel	-
23	15	Intercity Rail Transport	-
24	16	Urban Rail Transport	-
25	17	Socio-Economic Data	2000 - 2013
26			

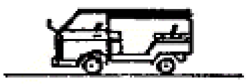
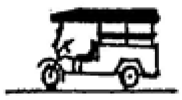
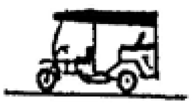
TOC | Ref 1 | Ref 2 | Ref 3 | Ref 4 | Ref 5 | Ref 6 | Ref 7 | Ref 8 | Ref 9 | Ref 9.1

Ready

Annex III DLT Vehicle definitions

Table A.1 Car definitions (passenger light duty vehicle include agriculture and roller)

Type	Name	Notes	Figure
1	Sedan (Not more than 7 Passengers)	Width < 2.50 meters and Length < 12 meters Note: cars in this category (Sedan) are: passenger car with seat < 7 passengers and pickup with double cab, and passenger light truck.	
2	Microbus and Passenger Van (Passengers > 7)	Width < 2.50 meters and Length < 12 meters Note: cars in this category (micro bus and passenger van) are: limousine, passenger car with seat > 7, and pickup with high roof or light commercial truck.	
3	Van & Pick Up	Transport vehicles with Width < 2.50 meters and Length < 12 meters Note: cars in this category (micro bus and passenger van) are: limousine, passenger car with seat > 7, and pickup with high roof or light commercial truck.	
4	Motortricycle	Vehicle width < 1.50 meters and Length < 4 meters with engine less than or equal to 500 cm^3	

Type	Name	Notes	Figure
			  
5	Interprovincial Taxi	Vehicle weight > 1,000 kg, width < 2.50 meters, and Length < 6 meters with engine less than or equal to 1,500 cm^3 Note: Uses of this vehicle category is for provincial passenger services or taxies.	
6	Urban Taxi	Passenger Car with at least 4 doors, Vehicle width < 1.50 meters and Length < 4 meters with engine less than or equal to 1,000 cm^3 Note: Uses of this vehicle category is for urban passenger services or taxies.	
7	Fixed Route Taxi	Vehicle width < 1.50 meters and Length < 4 meter with engine less than or equal to 800 cm^3 Note: Small van which can carry up to 8-9 passengers with have at least 2 doors. Normally, vehicles are used for bus services in the city.	
8	Motortricycle Taxi (Tuk Tuk)	Vehicles have two rows of seats with width < 1.50 meters, length < 4 meters and engine less than or equal to 550 cm^3	 
9	Hotel Taxi	Rental Cars with capacity of lesser than 7 passengers. Vehicle weight > 1,000 kg, width < 2.50 meters, and Length < 6 meters with engine less than or equal to 1,500 cm^3	

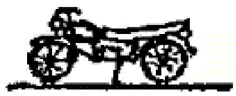
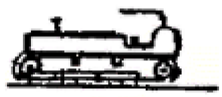
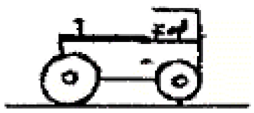
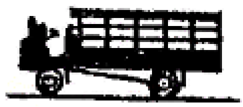
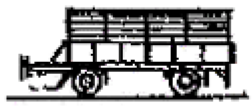
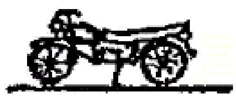
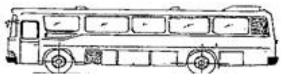
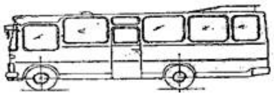
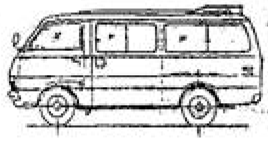
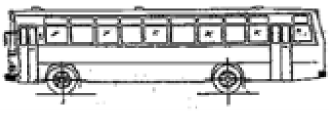
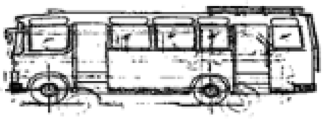
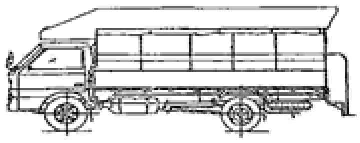
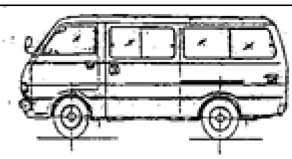
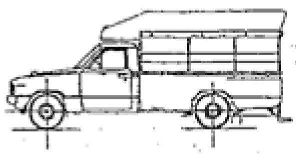
Type	Name	Notes	Figure
10	Tour Taxi	Passenger Car capacity of lesser than 7 passengers. Vehicle weight > 1,000 kg, width < 2.50 meters, and Length < 6 meters with engine less than or equal to 1,500 cm^3	
11	Rental Car	Passenger Car capacity of lesser than 7 passengers. Vehicle weight > 1,000 kg, width < 2.50 meters, and Length < 6 meters with engine less than or equal to 1,500 cm^3	
12	Motorcycle	Vehicle width < 1.10 meters with length < 2.50 meters. Trailers should have size of width < 1.10 and length < 1.75 meters	
13	Tractor	Agriculture vehicle with wheel or roller belt and not using for the transportation purposes, vehicle must have width < 4.40 meters with length < 16.20 meters	
14	Road Roller	roller road for material compactions or for dragging other vehicles, width < 3.50 meters and length < 8 meters	
15	Farm Vehicle	Agriculture Vehicles weight < 1,600 kg, width < 2.00 meters, and Length < 6 meters with engine less than or equal to 1,200 cm^3	
16	Automobile Trailer	Trailers or Semi-Trailers with width < 2.50 meters and length < 12 meters	 
17	Public Motorcycle	Public motorcycle width < 1.10 meters with length < 2.50 meters. Trailers should have size of width < 1.10 and length < 1.75 meters	

Table A.2 Bus definitions

- Fixed Route Bus : Public buses for transporting passengers with fixed service routes
- Non Fixed Route Bus: Public buses for transporting passengers without service routes
- Private Bus: Private buses with have passenger capacity > 12 passengers and vehicle weight > 2,200 kg.
- MiniBus: Vehicles for transporting passengers or freight with weight < 4,400 kg.

Stad.	Name	Notes	Figure
1A 1B	special air condition bus	buses must have toilets and bars 1A buses fixed passenger seat < 3 seats/row	
2A 2B	air condition bus passenger seats > 30 seats	2A buses are not allow passengers to stand, 2B buses allow passengers to stand	
2C 2D	air condition bus passenger seats 21-30 seats	2C buses are not allow passengers to stand, 2D buses allow passengers to stand	
2E	air condition bus passenger seats < 20 seats		
3A 3B	non-air condition bus passenger seats > 30 seats	3A buses are not allow passengers to stand, 3B buses allow passengers to stand	
3C 3D	non-air condition bus passenger seats 21-30 seats	3C buses are not allow passengers to stand, 3D buses allow passengers to stand	
3E	non-air condition bus passenger seats 13-24 seats		
3F 3G	non-air condition bus passenger seats < 12 seats (song teaw)		 

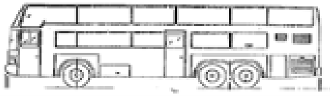
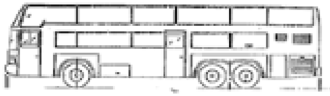
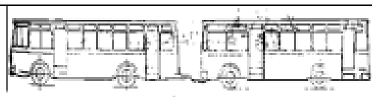
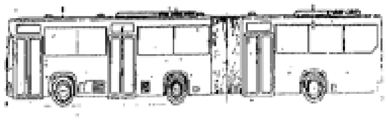
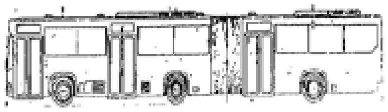
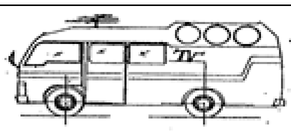
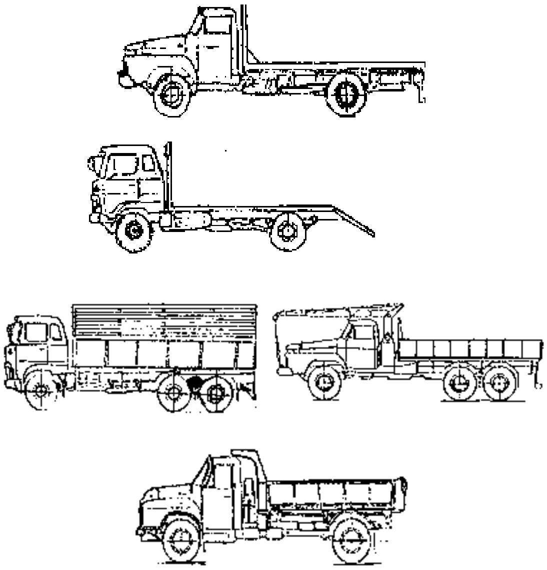
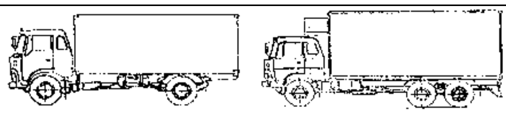
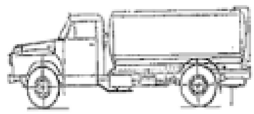
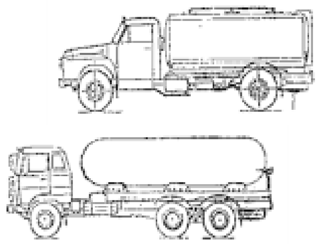
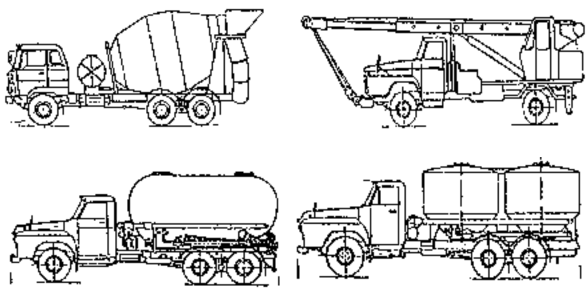
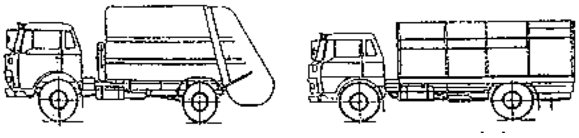
Stad.	Name	Notes	Figure
4A 4B 4C 4D	air condition bus with 2 levels	4A busses have space for passengers to stand at level 1 4C buses don't have toilet 4D buses don't have both toilet and bars	
4E 4F	non-air condition bus with 2 levels	4E busses have space for passengers to stand at level 1 4F buses have space for storing baggages	
5A 5B	air condition bus with trailer		
6A	air condition connecting bus		
6B	non-air condition connecting bus		
7	Specific bus	emergency, bank, post office, television vans or buses	

Table A.3 Truck definitions

- Non-Fixed Route Truck: public trucks that are rental or hire for transporting animal or freights
- Private Truck: private truck for the private businesses or companies with weight greater than 2,000 kg.

Character	Name	Figure
1	Pickup Truck	
2	Container Truck	
3	Carrying liquids	
4	Carrying Hazardous Materials	
5	Others	

Character	Name	Figure
		

Annex IV MRV framework and recommendations by Grütter Consulting

This annex includes paragraphs of the MRV report written for GIZ by Grütter (2015).

General points

The rationale to monitor GHG emissions of transport is basically to assess the impact of policies, strategies, actions and investments in an overall framework. The MRV proposal realized is to establish a framework of having an overview of transport GHG data on a national and urban level. It can thus be considered like a "macro-MRV" for transport (see Figure 2-1).

Individual actions might not be measured very precisely with a macro-level approach and the information generated will in many cases not be sufficient for specific NAMAS – however the overall impact of sustainable transport policies is measured. With this sectoral approach the country can compare progress over time, can benchmark with best practice and other countries, can assess the impact of policies and can measure the achievement of targets. It can then improve the planning process, invest resources into policies which provide for a higher impact, evaluate, assess and improve policies and strategies in the transport sector and improve the access to climate finance.

The Mega-level approach is basically to give information concerning total transport emissions. This can be realized well with a top-down approach and for projections energy-economics modelling can be used. This type of data is already collected and reported in NCs. Whilst the approach does deliver valuable information it is not disaggregated enough to allow for an assessment of transport strategies and transport interventions.

The Macro-level approach gives information concerning transport strategies and policies and reads core trends thus allowing to evaluate if a sustainable transport policy is on track. It can be separated in the areas of vehicles (monitored through emissions per VKT per mode and eventually vehicle category), freight with the indicators emission per tkm and the mode share per tkm and passenger transport with the indicators emissions per pkm, emissions for transport per inhabitant and the mode share per pkm. The area of passenger transport is separated into urban and inter-urban passenger transport. This is the focus of the report and is therefore detailed further in the following sections. Currently data in this part is either not reported in a regular manner or has significant reliability and accuracy problems.

The Micro-level approach is activity or intervention oriented. Data is often collected on an ad-hoc base financed through project budgets i.e. not using a standard and comparable approach over a longer time period. Indicators are project oriented e.g. a metro line is built and a metro project specific O-D survey is realized. NAMAs will to a certain extent also be on this level depending on their scope and approach. Data in this area is collected widely and also reported. However approaches chosen data reliability and precision levels are intervention/activity specific. Data usage and conclusions which can be drawn from such an approach are also basically activity/intervention level based.

The guiding principles used for parameters and indicators are that they need to be objective / transparent / replicable, consistent, relevant, reliable/ accurate / measurable, available / accessible and cost-effective. The indicators proposed above can be used for the BURs. They should be complemented with activity our input based indicators for explanatory purposes.

Mega-level: Top-down approach

The top-down approach is basically useful for GHG inventories such as reported in the NC and transport GHG projections. Top-down data is also very useful to assess plausibility of bottom-up approaches and to check bottom-up data. The top down data has however an insufficient disaggregation level to assess transport policies and strategies.

The top down approach relies on fuel statistics per type of fuel. Transport fuels used are gasoline, diesel, gaseous fuels (CNG, LPG, LNG), biofuels and electricity[19]. The separation of transport and non-transport fuel usage is thereby a critical element.

Methods to collect fuel usage data are basically from fuel producers (refineries), fuel aggregators, fuel importers and at the end of the supply chain from records of fuel stations, and industrial/commerce/logistics bulk fuel buyers. To determine GHG emissions, the emission factor per unit of fuel based on the NCV and the CO_2-EF per fuel are applied. For gaseous fuels a CH_4 factor would need to be applied also. Latter is however vehicle technology dependent i.e. measured in emissions per km and not fuel usage dependent i.e. not related to emissions per unit of fuel. For electricity GHG emissions can be based on the average emission factor of the grid. However NC and IPCC do not include electricity based transport emissions within the transport sector but within the energy sector.

Problems associated with the top-down approach and its reliability concerning total transport emissions include:

- The separation of fuels used for transport and for other purposes is essential and complex. This is especially true for diesel where a separation is difficult as diesel is not only used for transport purposes but also in industries, with stationary equipment e.g. also for electricity production, construction, machinery, and in agriculture. Often expert judgements are used to assign a share of diesel to transport fuels. In some cases differential taxes apply to transport and non-transport usage which again lead to incentives to use the lower taxed fuel for all purposes. Therefore care needs to be taken in detailing in a transparent manner the approach used to determine the transport share in fuels.
- Electricity usage in transport is not recorded with top-down approaches as it is included in the energy sector. However rail, metro and increasingly road vehicles (incl. hybrids) use electricity. Care needs to be taken to include only traction energy used[20]. Therefore electricity usage for transport needs to be collected directly from usage sources or from detailed electricity statistics. This issue will not only be more relevant in the future with upcoming numbers of electric and plug-in hybrid vehicles but will also get more complex to monitor as electricity used for example for plug-in vehicle usage is not separated from other household electricity usage.
- CH_4 emission factors for vehicles are technology related and not fuel quantity related; this is relevant for vehicles using gaseous fuels where CH_4 emissions make a significant contribution towards total GHG emissions. At minimum top-down approaches need to make an assessment of gaseous vehicle technology in usage to apply a CH_4 default factor per gaseous energy unit.
- Stock changes might not be tracked over time thus potentially under- or overestimating for specific years emissions. However this is in general a minor issue. In some smaller countries due to high fuel price differentials between neighbouring countries fuel smuggling or cross-

[19] In the future also potentially hydrogen
[20] For road transport energy used for communication, signalling etc. is also not included as road transport energy. In underground metros non-traction energy usage is very significant and can account for more than 40% of total energy usage.

border fuel sales i.e. fuels are sold in country "x" but used in country "y" can be a relevant issue.

Macro transport GHG indicators

For the macro level of the MRV framework a separation is made in vehicles, freight and passenger transport which again is separated in urban and inter-urban passenger transport[21]:

1. Total transport emissions based on vehicle-km travelled and the emission factor per mode.
2. Freight transport emissions in absolute terms (tCO_2 for freight) and in relative terms using gCO_2/tkm. The mode share per tkm is also registered.
3. Inter-urban passenger emissions in absolute and in relative terms as gCO_2/pkm. The inter-urban mode share in terms of pkm is also recorded.
4. Urban passenger emissions in absolute and in relative terms as gCO_2/pkm as well as in gCO_2 used for transport per inhabitant. The urban mode share in terms of pkm is also recorded.

The areas are separated in order to reflect:

- Different actors and stakeholders;
- Different actions, strategies, policies;
- Different indicators and measurement approaches.

Vehicles and indicator emissions per VKT

For total vehicle emissions the core indicator is total transport emissions based on vehicle-kilometres travelled (VKT) travelled. This indicator is especially useful for assessing vehicle performance standards initiatives and policies or strategies which intend to improve the vehicle efficiency (e.g. eco-drive, hybridization). Core elements are:

- The activity is vehicle-km. The data required for this indicator is:
  - Number of vehicles per category[22] and fuel type;
  - Annual distance driven per vehicle per category in km;
  - Specific fuel/energy consumption per vehicle category and fuel type in fuel unit/km;
  - Emission factor per unit of energy/fuel in gCO_2/fuel unit;
- The amount of vehicles per category is basically derived from vehicle registration statistics; registration statistics might not coincide with vehicle tax statistics, can potentially include vehicles not in service anymore or might not include all vehicles; However in most countries annual vehicle tax collection systems are getting more comprehensive and reliable due to having electronic control systems and increasing usage of electronic tags[23];
- Distance driven can be based on company records (buses, trucks, taxis), household surveys (buses, cars, motorcycles), surveys combined with odometer readings, registration or vehicle inspection programs;

[21] A clear cut separation urban and inter-urban cannot be made. In practice however countries and transport companies distinguish that e.g. rail companies in general separate urban and inter-urban customers (mostly different companies manage the traffic). In some countries e.g. India a 3rd category used in rail is sub-urban transport which can however be included in urban transport. A general definition of urban transport is such which takes place within the larger urban zone (LUZ) using the national definition for LUZ or metropolitan area.

[22] based on the categories used in the national vehicle registry system

[23] As example in Bolivia annual car registration has been linked recently to an electronic tag which gas stations require to sell you fuel.

- The specific fuel consumption (SFC) needs to be differentiated per category (idem to distance) and fuel type. Data can be based on type approval testing, sample measurements, company records (trucks, taxis, buses), or international default rates as 1st approximation.
- The emission factor per unit of fuel is based on the Net Calorific Value (NCV) per fuel type and the CO_2 emission factor per fuel type plus the CH_4 EF per km for gaseous vehicles. NCV, EF_{CO2} and EF_{CH4} can be based on National Communications (NC) or IPCC. For electricity the average emission factor of grid electricity generation is taken.
- Rail, air and shipping also need to be included. Pipelines can be included with their total emissions (no km distance).
- The bottom-up calculation can be compared with the top-down estimates.
- Following parameters are reported: total vehicle emissions (VE) in tCO_2[24], total VKT, and gCO_2 per VKT (EF_{KM}) for different vehicle categories (trucks, buses, cars, motorcycles; potentially including also sub-categories in accordance with vehicle registration categories).

$$EF_{KM,i} = \frac{\sum_x \left(SFC_{i,x} \times NCV_x \times EF_{CO2,x} \times N_{x,i}\right)}{N_i} \quad \text{and} \quad VE = \sum_i (EF_{KM,i} \times DD_i)$$

Where:

$EF_{KM,i}$	=	Emission factor per kilometre of vehicle category *i* (gCO_2/km)
$SFC_{i,x}$	=	Specific fuel consumption of vehicle category *i* using fuel type *x* (mass or volume units of fuel/km)
NCV_x	=	Net calorific value of fuel *x* (J/mass or volume units of fuel)
$EF_{CO2,x}$	=	Carbon emission factor for fuel type *x* (gCO_2/J)
N_i	=	Number of vehicles of category *i* (units)
VE	=	Vehicle emissions for period of time e.g. 1 year (tCO_2)
DD_i	=	Distance driven of all vehicles of category *i* for period of time e.g. 1 year (million km)

Total freight plus inter-urban and urban passenger emissions[25] should total the VKT based GHG emissions.

Freight and indicator emissions per TKM

For freight GHG emissions the core indicator is total freight emissions based on ton-kilometres (TKM) travelled combined with the mode share per tkm for relevant freight modes (basically road, rail, shipping and pipeline). This indicator is especially useful for assessing freight programs including mode shift as well as efficiency improvements within each mode. It cannot capture directly avoidance of freight (albeit indirectly by comparing the relation total freight emissions relative to GDP). Core elements are:

- The activity is ton-km[26]. The data required for this indicator is:
  - Tons of freight moved incl. the origin-destination per mode of transport (road, rail, ship, pipeline);
  - Specific fuel/energy consumption per mode and fuel type;
  - Emission factor per unit of energy/fuel.
- The tkm for rail, shipping, and pipeline is in general recorded by operators based on average lead time (based on invoices[27]) and tons of freight based on weighting or assumed average

[24] Based on SFC per category per fuel multiplied by the distance driven per category per fuel multiplied by NCV per fuel and EF_{CO2e} per fuel

[25] See for determination of these parameters the following sections

[26] 1tkm is equal to moving 1ton of freight for 1km

[27] Waybills of rail and shipping companies indicate origin and destination of freight (therefore distance)

weight. Care needs to be taken that net tkm is reported based on transported cargo and not gross-tkm which includes the vehicle/carriage/vessel weight. The tkm for road (as well as for other modes) can be based on commodity flow surveys. As alternative for road it can be based on sample interviews and measurements on roads to determine the average load factor of trucks and the average trip distance. This needs to be complemented with the vehicle registration statistics of the number of trucks.

- The SFC per mode and the emission factor per mode are the same as required by the VKT indicator.
- It is recommended to report the indicator as total GHG emissions for freight in tCO_2 (this can again be related to GDP to determine the freight –GDP elasticity), overall gCO_2/tkm and mode specific gCO_2/tkm for rail, road, shipping, and pipeline. The total gCO_2/tkm gives information on the overall impact of greening freight including mode-shift as well efficiency improvements while the comparison of the gCO_2/tkm per mode gives an indication of per mode efficiency improvements e.g. due to increased load factor or due to vehicle performance improvement.
- The mode split per tkm for different freight modes should also be reported. The mode split is the share of rail, truck, shipping, pipeline and air in terms of tkm. The procedure is that for each mode the tkm are determined (see steps above). The total is the sum of tkm per mode.

Inter-urban passenger movement and indicator emissions per PKM_{IU}

For inter-urban passenger movement the core indicator is emissions per pkm (PKM_{IU}) which is complemented with the mode share in pkm per relevant inter-urban mode (basically road separated in bus and car, rail, air and if relevant ship). This indicator is especially useful for assessing inter-urban passenger programs including mode shift as well as efficiency improvements within each mode. It cannot capture directly avoidance of passenger transport (indirectly the emissions or inter-urban passenger transport can be related to GDP per capita to assess changes of the elasticity factor over time). A separation is made with urban passenger transport due to having different actors, stakeholders, policies and approaches. Following are the core elements:

- The activity is inter-urban passenger-km[28]. The data required for this indicator is:
    - Passengers moved incl. the origin-destination per mode of transport (road, rail, air, ship);
    - Specific fuel/energy consumption per mode and fuel type;
    - Emission factor per unit of energy/fuel.
- The pkm for rail, shipping, and air is in general recorded by transport operators based on the average trip length (based on tickets sold) and numbers of passengers (based on ticketing). The pkm for road includes basically bus and cars. For inter-urban buses data sources are company surveys, company records or sample surveys realized e.g. at major inter-urban bus stations or on highways determining origin-destination and average occupation rate. Total bus numbers are derived from registration statistics. Average annual distance driven of inter-urban buses can be based on sampling or company surveys. For cars the average inter-urban occupation rate can be based on highway sampling. The average distance driven inter-urban can be based on household surveys or sample surveys. This needs to be complemented with the vehicle registration statistics of the number of cars.
- The SFC per mode and the emission factor per mode are the same as required by the VKT indicator.

[28] 1pkm is equal to moving 1 passenger for 1km

- It is recommended to express the indicator as total inter-urban passenger movement emissions in tCO_2, overall gCO_2/pkm for inter-urban passenger transport, and gCO_2/pkm for the individual modes being rail, road (separate car and bus), shipping, and air transport. The total gCO_2/pkm gives information on the overall impact of improving inter-urban passenger transport including mode-shift as well efficiency improvements while the comparison of the gCO_2/pkm per mode gives an indication of per mode efficiency improvements e.g. due to increased occupation rates or due to vehicle performance improvement.
- The mode split per pkm for relevant inter-urban transport modes should also be reported. Important is that the mode-share is reported in pkm and not as mode share based on the number of trips as former is relevant for GHG emissions and not the number of trips. Latter can of course be reported additionally as supplemental information and for interpretation purposes.

Urban passenger movement and indicator PKM_U and emissions per inhabitant

For urban passenger movement the core indicators are urban passenger transport emissions per unit of travel (PKM_U) and urban transport emissions relative to the number of inhabitants in the same urban zone as defined nationally e.g. based on the concept of LUZ or metropolitan area. Additionally the urban mode split per pkm between relevant urban transport modes (cars, taxis, NMT, public transport eventually split in different types, motorcycles, 3-wheelers, etc.) is reported. The indicator pkm is especially useful for assessing urban passenger programs including mode shift as well as efficiency improvements within each mode. The indicator emissions for transport of passengers relative to number of inhabitants (gCO_2/inhabitant) is relevant to capture also the impact of avoidance strategies and polices which reduce trip lengths and trip numbers next to mode shift and efficiency improvement. This indicator requires for total emissions the same information as GHG per pkm. However for explanatory purposes it should also measure the NMT (Non-Motorized Trips) (not necessarily required for GHG per PKM) and therefore basically depends on household surveys which register all trips with all modes and the corresponding distances. Following are the core elements:

- The activity for the indicator GHG per PKM is urban pkm. The data required for this indicator is:
    - Passengers moved incl. the origin-destination per mode of transport; NMT for emissions per PKM not necessarily needs to be monitored but should be included for the modal split determination;
    - Specific fuel/energy consumption per mode and fuel type;
    - Emission factor per unit of energy/fuel.
- The pkm for all modes can be derived from household surveys asking for O-D of trips incl. intermediate stops. The household survey must include modes used and an identification of mode change points (additionally time used can be asked which is an important sustainable development indicator for time spent in transit). An alternative measurement procedure basically for public urban transport modes is based on records held by operators based on average trip length (based on ticketing) and numbers of passengers. These are especially reliable if electronic ticketing is used. Alternatively surveys of passengers on average trip length can be realized. The pkm for other modes is based on average occupation rates and average distance driven in urban areas per mode which again is basically from sample visual

observation studies and surveys. Also the number of cars, taxis and motorcycles registered in the city needs to be known.

- The SFC per mode and the emission factor per mode are the same as required for the indicator VKT.
- It is recommended to express results as total urban passenger emissions in tCO_2, as average total emissions in gCO_2/pkm, and as mode specific emissions in gCO_2/pkm. The total gCO_2/pkm gives information on the overall impact of improving urban passenger transport including mode-shift as well efficiency improvements while the comparison of gCO_2/pkm per mode gives an indication of per mode efficiency improvements e.g. due to increased occupation rates or due to vehicle performance improvement.
- The mode split per pkm for relevant urban transport modes should also be reported. Important is that the mode-share is reported in pkm and not as mode share based on the number of trips as former is relevant for GHG emissions and not the number of trips. Latter can of course be reported additionally as supplemental information and for interpretation purposes.

Important micro indicators

Additional to the macro GHG indicators some core activity indicators need to be monitored to assess the impacts, make plausible results measured and to provide for explanations of changes monitored. The activity indicators include financial inputs and physical inputs and should be based on real (ex-post) and not planned values.

Important activity related indicators include:

- Investment in transport, road, rail, shipping, public urban transport, MRTS, NMT absolute and relative to GDP;
- Km built in MRTS (separate metro, LRT/tram and BRT), inter urban rail separating HSR, and grade-separated bike lanes (these indicators are also listed in ISO 37120:2014 for sustainable development of communities)

Important sustainable development indicators include:

- Economic ones incl. basically time savings;
- Social indicators incl. basically health impact, accident rate per mode, accessibility and affordability;
- Environmental indicators including air quality and noise levels;
- Indicators which measure well-being and happiness as core objective of any policy[29].

Summary of indicators

The following table summarizes the indicators proposed with a focus on GHG.

Table 1: Proposed core GHG transport indicators

ID	Area	Indicator
1	Overall	Vehicle registration data
2		Total fuel consumption per fuel type
3		Biofuel content per fuel type (bio-gas, bio-diesel, bio-gasoline)
4		Specific fuel consumption per category
5		Vehicle distance driven per category

[29] E.g. the UK Office of National Statistics is developing currently new measures to capture well-being; see http://www.ons.gov.uk/ons/guide-method/user-guidance/well-being/index.html; measurements are also made with Eurostat or the OECD

6		CO_2 emission factor per fuel/energy source and CH_4 emission factor for gaseous fuels per km
7		GDP, population data, inhabitants of city
8	Vehicles	gCO_2/VKT separated per vehicle category
9	Freight	- gCO_2/tkm total and per freight mode - tkm per mode → is sum of various other indicators incl. average lead, tons of freight, average load factor, distance driven of trucks; - mode split per tkm
10	Passenger inter-urban	- gCO_2/pkm total and per inter-urban mode - pkm per mode inter-urban → is sum of various other indicators incl. average trip length, number of passengers, average occupation rate, distance driven of cars and buses - mode split per pkm inter-urban
11	Passenger urban	- gCO_2/pkm total and per urban mode - pkm per mode urban → is sum of various other indicators incl. average trip length, number of passengers, average occupation rate, distance driven of various modes - mode split pkm urban
12		Emissions per inhabitant → is sum of various other indicators incl. average trip length per mode and emission per mode per km

The frequency recommended for indicators is on average every 2-3 years.
A core aspect is that the data should be collected in a regular and standardized form i.e. not ad-hoc project based data collection but standardized "official" data collection. It is recommended to establish clear definitions, methods of data collection, procedures, QA assurance and statistical analysis including a document on statistical approach and methodology used and data reliability, robustness and accuracy. This points to a clear need of institutionalization of the data collection procedure.

Proposed steps forward for Thailand

The overall gap for freight is – under the premise that the goods movement survey is reliable – the smallest and therefore this area could first be covered. The next step would then be inter-urban passenger transport where also data availability is better than in urban transport. VKT could be calculated today already with defaults for distance driven per vehicle category and SFC defaults.
Following overall steps are recommended to be taken to move towards a macro dataset for transport emissions:

1. Further collect and check data;
2. Realize with default values the initial calculations for VKT emissions, for freight and inter-urban passenger transport emissions;
3. Realize an agreement with the Statistics Department to include in the household survey passenger transport relevant questions to determine the pkm and mode of urban and inter-urban passenger movement.
4. Realize for each indicator a complete monitoring and statistical guideline approved by the respective Ministry and an Expert Panel.
5. Replace with the time default values and estimates with monitored values thus refining the approach and exactitude.

In detail following steps are suggested:

1. Further assess data availability and reliability with a focus on institutionally collected data and not ad-hoc measurements by consultants. This includes a clear documentation of data collection procedures and approaches.
2. Fuel sales data:

a. Collect and review the refinery and import statistics on fuel production /imports with the fuel sales statistics.
b. Track and document in a transparent manner the industrial and agricultural diesel fuel usage to establish a percentage of diesel used by transport. This could be based on data of Ministry of Industry / Agriculture including industrial energy statistics and reports.
c. Include electricity consumption from rail (urban and inter-urban) plus pipeline.
d. Check top-down estimates with bottom-up calculations.

3. Vehicle registration data:
   a. Check original data to clarify problems with age of vehicles;
   b. Check assignment of vehicles to fuel types;
   c. Cross-check data on fuel type, age, Euro standard and distance driven with the bus survey currently realized on y regular base by the Statistical Department.
4. Review the reports on "bus survey" and "goods movement survey" of the Statistical Department. Concerning the bus survey the core data to check is the distance driven of buses and the average occupation rate. This can be checked with a sample survey from major bus companies. Also the vehicle registration data can be used to cross-check. Check the goods movement survey for data on tkm based on average lead distance and tons of freight with rails and shipping data (reported by the rails operator and the shipping operators) plus bottom-up truck calculations (e.g. based on a sample survey of major trucking companies asking for average load factor 7 tons of goods transported and average annual distance driven of trucks).
5. Start negotiations with the Statistical Department upon inclusion of passenger transport data in the regular 5-year household survey.
6. Specific fuel consumption:
   a. Check data availability from company records for SFC of taxis, buses, and trucks (e.g. bus, taxi, trucking companies). Data can be compared over various companies as well as with international default values for quality control.
   b. Check data availability of type approval testing used primarily for cars and taxis including method of determination of SFC (preferred option but in general not available for trucks and buses);
7. Data on annual distance driven per vehicle:
   a. Check if included in the vehicle registration data in a reliable manner[30];
   b. Check if included in annual inspection data records (latter need not be complete as only the average is required i.e. an unbiased sample would be sufficient[31]);
   c. Check possibility of making sample measurements on distance driven per vehicle category. This is realized e.g. for taxis, motorcycles and cars through sample surveys at petrol stations asking for odometer reading and age of vehicle; for buses, trucks and taxis the same approach can be used at company level; The Federation of Thai Industries (FTI) collects for example this data for their member companies managing trucks;
8. Include pipeline data on energy usage and tkm for liquid / gaseous fuels;
9. Check highway data on vehicle count and pkm for method how pkm is determined and if bus/car is determined separately. This data could be used to extrapolate the total car-pkm

[30] This can be controlle by comparing with international default values as well as by comparing total fuel consumed (SFC multiplied by distance multiplied with total number of vehicles) with top-down fuel consumption estimates. Latter tend to be quite precise for gasoline relevant basically for cars and motorcycles.

[31] For assessment of biased versus unbiased sampling standard statistical e.g. under https://onlinecourses.science.psu.edu/stat100/node/18

inter-urban (the bus-pkm inter-urban should be known from the bus survey of the Statistical Department).

Annex V Marginal abatement cost analysis: a primer

Marginal abatement cost analysis can be helpful tool for decisionmakers to gain insights in costs, benefits and potentials of GHG reduction options. For the transport sector in Thailand, no comprehensive analysis exists as yet, though for some specific options such as biofuels data have been published. This chapter provides an initial overview and one example of MAC for the transport sector. Further work, in order to assist in the development of NAMAs and implementation of the Intended Nationally Determined Contribution, or the climate action plan submitted by Thailand in October 2015.

Marginal Abatement Cost (MAC)

Marginal abatement cost (MAC) is an economic decision support tool for the policy-makers. It illustrates the economics associated with climate change mitigation. It summarises the estimate of the realistic volume and costs of opportunities to reduce GHG emissions.

In the course of time the MAC concept has been studied and expanded, from a linear relationship between marginal cost and the emission reduction (McKitick, 1999) to an inverse curvy relation between social cost and the emission reduction (Klepper and Peterson, 2006). Figure 5-1 show how marginal costs of emission reduction increases with decreasing total emissions.

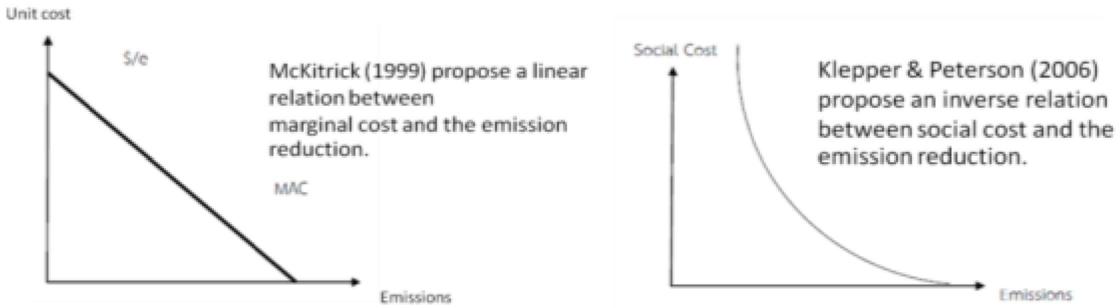


Figure 0-1 Relation between emissions and social costs.

In this paper, a linear relation of MAC is selected to analyse the measures for pilot study. The MAC of the selected measures would be calculated from the marginal cost of the selected measures (or policies / projects) divided by the change in GHG emissions resulting from the project, equation (5.1-1).

$$MACofProject = \frac{\Delta\, Cost}{\Delta\, GHG.T} \qquad \text{[eq. 5.1-1]}$$

Where Δ Cost = Marginal cost of project in order to reduce GHG emission (Baht)

Δ GHG = Reduction of GHG emission from the project (Ton CO_2/yr)

T = Project life-cycle time (years)

To simplify above conceptual model, the World Bank's Energy Sector Management Assistance Program (ESMAP, 2010) has published an expert based MAC curves based on a simplified methodology of calculating marginal abatement costs. For each mitigation action under consideration, Equation (5.1-2) is used.

$$C_t = \frac{C_{mi} - C_{bi}}{CO2e_{bi} - CO2e_{mi}} \quad \text{[eq. 5.1-2]}$$

Where Ct = the abatement costs in ton CO_2e,
Cmi = the cost incurred by the implementing agent when intervention/mitigation (i) is implemented,
Cbi = the cost incurred by the implementing agent in the baseline, assuming that mitigation action (i) was not implemented,
CO_2ebi , CO_2emi = the CO_2 equivalent emissions with and without the abatement measure (i) implemented.

The abatement cost can either be for one year plan, or the cumulative cost over a long term plan. If it is for a particular year, then capital costs are annualised, using the discount rate and the life time of technologies and are added to the annual operating costs (maintenance and fuel). The abatement cost is the total annualized costs incurred by the agent divided by CO_2e abated per annum.

Once the economic cost and abatement potential of each project or measure are calculated, charting the cost curve will be pretty simple. It is an arranging technique of the data in order to support the standard column chart type, so called – "MAC curve". Hence, the marginal abatement cost for each ton of carbon based on each project abatement potential and with the projects ordered from least-cost to most-cost are required.

In general, MAC curve of projects usually presents on a biaxial graph, to analyse how much abatement can be done in an economy at what cost, and where policy should be directed to maximise the GHG emission reduction efficiency.

MAC curves represent abatement potential (X-axis) against the marginal abatement cost (Y-axis). The width of each bar represents the emissions reduction potential which the project or measure can deliver compared to business-as-usual. The height of each box represents the average economic cost of abating one ton of CO_2e (carbon dioxide equivalent) from the project or measure, as illustrated in Figure 5-2.

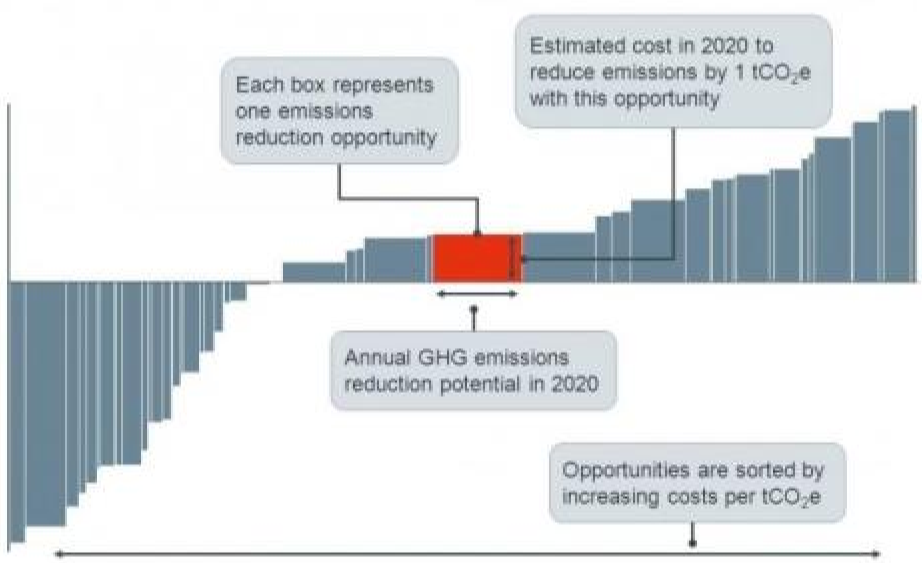


Figure 0-2 Illustrative example of MAC curve and interpretation

The bars on chart are ranked from the lowest cost to the highest MAC. Those bars that are under the horizontal axis indicate net benefits to the national economy rather than costs. The bars that appear above the horizontal axis come with cost to pay.

Illustrated example of MAC analysis: NMT Project

Results of GHG estimations from NMT master plan's projects

The illustrated example in this section takes the results from the Study of Urban Public Transport Connectivity Plan or the NMT project from Office of Transport and Traffic Policy and Planning (OTP). The followings are summary of this study

The project study aims to push for urgent measures to promote non-motorised transport in the short term, hoping to directly reduce volume of unnecessary commuting or motorized transport distance, thereby leading to a shift to energy-efficient and eco-friendly modes of transportation. The objectives of this NMT study are as follows:

1. To integrate ideas and participation of concerned agencies and the general public in NMT promotion and public transport connectivity improvement.
2. To establish a framework for NMT promotion and public transport connectivity improvement that meets traveling requirements and demand from people in the target areas in order to ultimately achieve sustainable transportation.
3. To hold campaigns and public relations so as to ensure public's awareness and participation in the use of NMT and mass transport.

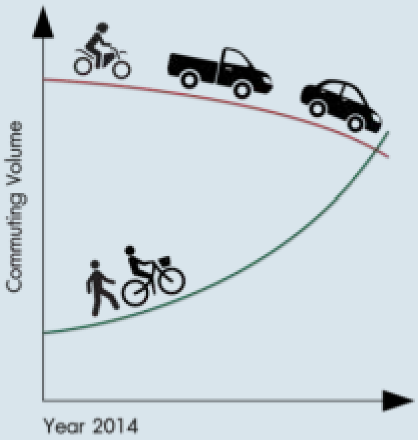
Further, output and outcome from this project can be summarised as follows

Output

- Suggestions on projects/measures to promote NMT and details of public transport connectivity improvement in Bangkok and its vicinities
- Details of project/demonstration that are suitable and viable in Bangkok and its vicinities or any appropriate areas, involving three projects with differing use of land
- Recommendations on establishment of a Bicycle City in one pilot province
- Results of legal study, review and advice and measures relating to walking and cycling to promote walking and bicycling as part of people's everyday life
- Guidelines and results of an analysis on efficiency in reduction of greenhouse gas emission and energy consumption as a consequence of sidewalk and bikeway development

Outcome

- Promoting a reduction in private vehicle use, leading to a decline in demand for petrol and other kinds of energy
- Promoting an eradication of congestion problems, helping to cut down on energy consumption rate from commuting
- Encouraging and generating a change in traveling modes via public buses, resulting in an optimized and efficient use of energy
- Promoting a decrease in emission of greenhouse gas and air pollutants (HC, Nox, particulates, etc.) from vehicle use
- Promoting social equality by making efficient transport services available for and accessible to people of all classes



There are four procedures or working sections in this project including review, analysis, planning, and public relations. Two target areas are also focused including: (1) Bangkok and its vicinities and (2) Bicycle City. This report discusses and uses results of this study related to Bangkok and its vicinities area.

For the target area of Bangkok and its vicinity, the NMT study project selected the areas ideal for preparation of suggestions on pilot projects/measures to promote NMT and details of public transport connectivity improvement in Bangkok and its vicinities, and divided them into three groups (comprising a total of 140 locations) as follows:

1. Road transport transit area (36 locations);
2. Rail transport transit area (53 locations); and
3. River boat transport transit area (51 locations).

Based on the study of all these connectivity points, the project mapped out a development master plan for NMT promotion and public transport connectivity improvement in Bangkok and its vicinities, with the project life of 10 years and an estimated budget of THB 450 million (approximately US$ 12.5 million). The plan is divided into three phases of 3-4 years each, details of which are as follows:

- Short-term plan/project, 2015-2017 (0-3 years): This phase features a plan that is achievable in an immediate term. It involves the areas ready for development with respect to their physical, economic and social conditions, including the three selected pilot areas, namely Mo Chit Bus Stop and BTS Station, Phayathai BTS Station, and Pak Kret Pier, 12 other recommended areas and another 29 areas, making up a total of 44 locations.

- Medium-term plan/project, 2018-2020 (4th-6th years): This phase focuses on projects that will be carried out after completion of the short-term plan or projects that are of a lesser degree of importance than the short-term plan. It entails development of 17 rail transport connectivity locations, 12 road transport connectivity locations, and 15 water transport connectivity locations, making 44 locations in total.

- Long-term plan/project, 2021-2024 (7th-10th years): This phase concerns projects to be implemented in the long term in developing additional connectivity areas to cover Bangkok and its vicinities to a broader extent, consisting of 19 rail transport connectivity locations, 12 road transport connectivity locations, and 21 water transport connectivity locations, making 52 locations in total.

Initially, the authorities responsible for the development budget are as follows:

Bangkok Metropolitan Administration: responsible for development of sidewalk and bikeway in Bangkok Metropolitan areas.

Nonthaburi Municipality: responsible for development of sidewalk and bikeway in Nonthaburi Municipality areas.

Pak Kret Municipality: responsible for development of sidewalk and bikeway in Pak Kret Municipality areas.

Bang Bua Thong Municipality: responsible for development of sidewalk and bikeway in Bang Bua Thong Municipality areas.

Rangsit Municipality: responsible for development of sidewalk and bikeway in Rangsit Municipality areas

AOT Airports of Thailand Plc.: responsible for development of sidewalk and bikeway in bus stop areas at Suvarnabhumi International Airport.

State Railway of Thailand: responsible for development of sidewalk and bikeway in the areas under supervision of SRT.

The illustrated example of MAC Analysis in this section will use the results of CO_2 emission reductions, estimated from the study projects.

It is important to note that, later, the results of the MRV of NMT master plan projects may be different from the forecasting results published by the OTP. The main reason is that the results of CO_2 emission estimation from the OTP are mainly relied on the forecasting data from the transport planning model. The estimations are mainly for forecasting and planning purposes. However, the MRV of NAMAs as presented in this report is concentrated on the real collected data. Hence, the final results from the proposed MRV system may be differenced from those forecasting model but similar and comparable.

The following is a summary of results of CO_2 emission reductions taken from the Study of Urban Public Transport Connectivity Plan from Office of Transport and Traffic Policy and Planning (OTP), 2014.

Travel demand of public transport in Bangkok and its vicinities

The project conducted an eBUM[32] analysis to project the future commuting patterns in Bangkok and its vicinities (for the years 2017, 2022, 2027 and 2032), by focusing on the analysis and forecast of number of commuters through different modes of public transport. The outcome of future traveling demand analysis and prediction in Bangkok and its vicinities, using the eBUM model, is as follows:

Box II.1 Summary travel demand analysis by public transport in Bangkok and its vicinities:

- Ratio of commuting by public transport in 2017-2037 will reach 59% on average.
- In 2037, electric train ridership will grow from 2017 (from 2,798,000 person-trips/day to 10,898,000 person-trips/day), while number of public bus commuters will still rank top.
- In 2037, number of public transport commuters will reach 25,173,000 person-transit trips/day, using transportation modes such as electric train, train, van, public bus and boat, which are almost two-folds higher than the ridership in 2017 thanks to the more complete transport network.

Main Commuting Including Public Transport Connections, **(***000's person-trips/day) in the BMR*

Year	Total	Private Vehicles	Private Vehicles (%)	Public Transport	Public Transport (%)
2560	25,900	11,300	43.63%	14,600	56.37%
2565	30,100	12,300	40.86%	17,800	59.14%
2570	33,900	13,600	40.12%	20,300	59.88%
2575	39,200	14,900	38.01%	24,300	61.99%
2580	43,800	18,600	42.47%	25,200	57.53%

Source**:** eBum model analysis in Bangkok and its vicinities conducted by the Consultants
Note: Including transit trips

*Forecast of Main Public Transport Ridership (000's person-trips/day)***)**

Mode	2017	2022	2027	2032	2037
Electric train	2,798	5,611	7,065	10,309	10,898
Public bus	10,902	11,167	11,975	12,520	12,857
Passenger boat	300	318	383	487	526
Others	598	750	876	991	892

[32] eBUM (extended Bangkok Urban Area Model) is the transport forecasting model which was developed by OTP under the concept of the traditional 4 steps transport travel demand modeling methodology. The model covers the area of Bangkok and its vicinity areas.
NAM (National Area Model) is the national transport forecasting model which developed under the concept of the traditional 4 steps transport travel demand modeling methodology. The model has the main objective to forecasting the intercity travel demand both people and freight in Thailand.

Total	14,598	17,846	20,299	24,307	25,173

Source **:** eBum model analysis in Bangkok and its vicinities conducted by PSK Consultants

Mode share at the main public transport connectivity locations

To analyse travel choices, the study conducted a survey on data for restructuring of choice model. The Stated Preference method was employed, whereby respondents of the questionnaires selected their preferred non-motorised travel mode versus other commuting modes. The study conducted a field survey and had a total of 1,500 questionnaires filled out at various public transport interchanges and service stations. The questionnaire comprised three parts:

1. general information including age, occupation, income levels, education levels
2. trip information including, trip origin and destination, trip purposes, travel mode, reasons of choosing to travel in the current mode, and cost
3. stated preference questions which comprise of 6 situations for travelers to decide their travel mode, with each situations different on utilities (costs, accessibility, and time)

Results of modal shift analysis in the report are as follows.

From a forecast in the case where the NMT project plan is not implemented, it is found that most commuters prefer high-performance public modes (HPM), i.e. BTS, MRT or BRT, accounting for 29.85%, followed by motorcycle, 23.56%, and private car, 23.20%. The reason why HPM captures the highest commuting ratio is because most of the sample commuters chose to travel by public transport. A forecast in the case where the NMT project plan is implemented points to growth in travel mode by public transport, with, for example, HPM increasing by 1.56% and LPM (conventional bus) by 4.67%.The outcome of the analysis on a shift of travel mode is as tabulated below.

Table II-1 Preferred modes with and without NMT project plan (OTP, 2014)

Travel Choices in Case NMT Project Plan Is not Implemented **)**from sample groups**(**					
Private Car	Motorcycle	HPM	LPM	Rail	Para Transit
23.20**%**	23.56%	29.85%	13.97%	4.02%	5.39%
Travel Choices in Case NMT Project Plan Is Implemented **)**from sample groups**(**					
19.83%	20.14%	31.41%	18.65%	5.36%	4.61%

Summary of emission reductions from the project

In analysing a reduction of greenhouse gas emissions due to the development of NMT in Bangkok and its vicinities under this project, the NMT project focused on three types of development:

1) Development of bikeways in Bangkok;

2) Development of a bicycle sharing program; and

3) Development of commuting connectivity.

For the projects in (1) and (3), the analysis primarily based on the plan derived from this project study under the assumption that the public bicycle, or bicycle sharing, program is fully developed by 2027.

In the analysis of efficiency in reduction of greenhouse gas emission and energy consumption due to the development of sidewalk and bikeway in Bangkok and its vicinities, the CO_2 emissions were estimated under the following scenarios:

- BAU without BTS/MRT expansion: modelling and analysis in the project study to devise a master plan on sustainable transport development and climate change solution.
- BAU with BTS/MRT: the study uses secondary data derived from the eBUM model for additional analysis with TEEMP (Transport Emission Evaluation Models for Projects).
- Implementation of short-term NMT plan: based on change of travel demand or modes in case there is improvement of transport connectivity under the NMT development plan at 44 locations.
- Implementation of medium-term NMT plan: change of travel demand in case there is improvement of transport connectivity under the NMT development plan at 44 additional locations, making up a total of 88 locations.
- Implementation of long-term NMT plan: change of travel demand in case there is improvement of transport connectivity under the NMT development plan at 52 additional locations, making up a total of 140 locations.

It is found from the analysis that, for the year 2014, the development of rail transport systems under BTS and MRT projects is estimated to help reduce greenhouse gas (CO_2) emissions by 2.83 Mt CO_2e or 1,380 ktoe. After full completion of rail transport system development by 2030 as planned, the estimated volume of greenhouse gas (CO_2) reduction will reach 5 Mt CO_2e or 2,440 ktoe.

By comparing all of the three phases of the NMT development plan in the short, medium and long terms under which a total of 140 transport connectivity locations will be developed and are expected to impact a shift of traveling modes more towards public transport and NMT, it is discovered that in 2026, when all of the three NMT development phases will be accomplished, the greenhouse gas (CO_2) emission will be reduced by 8 Mt CO_2e or 3,900 ktoe (see Table II-2)

Table II-2 CO_2 emissions in Bangkok and vicinities in BAU and NMT scenarios (unit: Mt CO_2e) (OTP, 2014)

Year	BAU without BTS/MRT	BAU with BTS/MRT	NMT Short Term Plan	NMT Mid Term Plan	NMT Long Term Plan	Notes
2014	28.68	25.84 (2.84)	-	-	-	Base Year
2017	29.76	27.58 (2.18)	-	-	-	-
2019	31.74	29.56 (2.18)	29.03 (2.71)	-	-	Finish NMT

					Short Term Plan
2022	35.53	32.53 (3.00)	31.52 (4.01)	-	Finish NMT Mid Term Plan
2026	41.17	36.48 (4.69)	34.55 (6.62)		Finish NMT Long Term Plan
2030	45.43	40.44 (4.99)	37.43 (8.00)		All urban rail public transport project are completed

Note: numbers in the parentheses are emission reduction compared to BAU without BTS/MRT

Marginal abatement cost analysis for NMT master plan projects

The project is the 10 year plan from 2016 to 2026. However, the CO_2 evaluation for MAC analysis will take place on 2030 which is the year that all urban public transport in Bangkok will be completed as plan. Hence, the period target year is approximately 15 years. The total project cost for improving urban public transport connectivity is approximately 448,288,000 Baht. Also, at the end of year 2030, the project is expected to help in reducing CO_2 emissions at approximately 8.00 Mil.Ton CO_2e. Thereby, the Marginal Abatement Cost of the urban public transport connectivity solely make 86 baht /TonCO_2e or approximately US$2.5 /t$CO_2e$.

For comparison, several measures in the industrial sector were estimated at 172 – 4931 baht/tCO_2e (TDRI, 2005). However, GHG abatement costs calculations are very sensitive to parameter variations with respect to the baseline assumption for example, estimated investment costs, energy/fuel savings, energy prices, and discount rates. These sensitive parameters are found to be most pronounced in transportation sector especially on the investment cost and energy cost saving are the most factored. Sensitivity to those parameters variation is also found for options in other sectors as well, with a lesser effect.

The implication of the MAC curves should be only one tool as part of several possible decision-making aids used in assessing measures. A number of limitations with MAC curves are noted, for example, omit ancillary benefits of greenhouse gas emission abatement, and uncertainty is considered only in a limited manner. MAC curves based on the individual assessment of abatement measures suffer from additional shortcomings such as the non-consideration of interactions and non-financial costs, a possibly inconsistent baseline, double counting and limited treatment of behavioral aspects. Policy makers should therefore be cautious when interpreting MAC curves, pay attention to the underlying assumptions, consider non-financial costs and be aware of the important uncertainties and underlying path dependencies.

Regarding to uncertainties in cost estimation and sensitive of parameter variations, abatement cost figures should not be expected high accuracy more than a single digit. Therefore, only the order of magnitude can be considered meaningful.

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