



# **ASSESSMENT OF METHODOLOGIES: MRV FRAMEWORK FOR TRANSPORT SECTOR IN CAMBODIA**

## Initiative for Climate Action Transparency - ICAT

Deliverable 4: Final report on the assessment of methodologies for the development of MRV system, including assessment of GHG emission impacts of policies and actions in the transport sector.

### Deliverable 4

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## Acknowledgement

The Royal Government of Cambodia (RGC) ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1996 and the Paris Agreement in 2017. The country submitted her Intended Nationally Determined Contribution (INDC) in 2015 and the updated NDC in 2020 to the UNFCCC.

The transport sector plays a significant role in GHG emissions reduction. As such, several mitigation actions related to the transport sector were submitted to the UNFCCC through the updated NDC. Tracking progress made in implementing and achieving NDCs is a requirement of the Enhanced Transparency Framework (ETF). Therefore, having a Measurement, Reporting and Verification (MRV) system in place is essential for Cambodia to achieve these targets in a standard and transparent manner.

The UNEP-DTU Partnership is providing technical assistance to the RGC under this ICAT project, which aims to design an MRV system for selected mitigation actions in the transport sector of Cambodia. A Team of National Experts, and International Experts of Climate Smart Initiatives (Pvt) Ltd (ClimateSI), were selected to support the Cambodian Team for this project.

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## List of Acronyms

ASEAN	Association of Southeast Asian Nations
ASIF	Avoid, Shift, Improve and Shift Fuel
BAU	Business as Usual
BEF	Baseline Emission Factors
BRT	Bus Rapid Transit
CCAP	Center for Clean Air Policy
CDM	Clean Development Mechanism
COP	Conference of the Parties
DCC	Department of Climate Change
EERPAT	Energy and Emissions Reduction Policy Analysis Tool
ERIA	Economic Research Institute for ASEAN and East Asia
FOLU	Forestry and Other Land Use
GACMO	The Greenhouse Gas Abatement Cost Model
GEC	Global Environment Centre Foundation
GHG	Greenhouse Gas
GSSD	General Secretariat of the National Council for Sustainable Development
GVW	Gross Vehicle Weight
ICAT	Initiative for Climate Action Transparency
IPCC	Intergovernmental Panel on Climate Change
ITDP	Institute for Transportation and Development Policy
JCM	Joint Crediting Mechanism
JICA	Japan International Cooperation Agency
LRT	Light Rail Transit
MOVES	Motor Vehicle Emission Simulator
MPWT	Ministry of Public Works and Transport
MRTS	Mass Rapid Transit System
MRV	Measurement, Reporting and Verification
NAMA	Nationally Appropriate Mitigation Actions
NCV	Net Calorific Value
NDC	Nationally Determined Contribution
NIS	National Institute of Statistics
PKM	Person Kilometres
PPCA	Phnom Penh Capital Administration
REDD+	Reducing Emissions from Deforestation and Forest Degradation
RGC	Royal Government of Cambodia



SD	Sustainable Development
TEEMP	Transport Emissions Evaluation Models for Projects
TKM	Tonne Kilometers
TOD	Transit-Oriented Development
UNFCCC	United Nations Framework Convention on Climate Change
VKT	Vehicle Kilometre
WRI	World Resources Institute

## Glossary of Terms

<b>BRT</b>	A bus-based collective urban or suburban passenger transit service system that uses bus lanes for trunk routes and operates at high levels of performance, especially with regard to travel times and passenger-carrying capacity.
<b>Capacity building</b>	In the context of climate change, the process of developing the technical skills and institutional capability in developing countries and economies in transition enables them to address effectively the causes and results of climate change.
<b>CDM</b>	Clean Development Mechanism. A mechanism under the Kyoto Protocol through which developed countries may finance greenhouse-gas emission reduction or removal projects in developing countries and receive credits for doing so which they may apply towards meeting mandatory limits on their own emissions.
<b>COP</b>	Conference of the Parties. The supreme body of the Convention. It currently meets once a year to review the Convention's progress. The word "conference" is not used here in the sense of "meeting" but rather of "association". The "Conference" meets in-sessional periods, for example, the "fourth session of the Conference of the Parties."
<b>Deforestation</b>	Conversion of forest to non-forest.
<b>Greenhouse gases (GHGs)</b>	The atmospheric gases responsible for causing global warming and climate change. The major GHGs are carbon dioxide (CO <sub>2</sub> ), methane (CH <sub>4</sub> ), and nitrous oxide (N <sub>2</sub> O). Less prevalent --but very powerful -- greenhouse gases are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF <sub>6</sub> ).
<b>Intergovernmental Panel on Climate Change (IPCC)</b>	Established in 1988 by the World Meteorological Organization and the UN Environment Programme, the IPCC surveys worldwide scientific and technical literature and publishes assessment reports that are widely recognised as the most credible existing sources of information on climate change. The IPCC also works on methodologies and responds to specific requests from the Convention's subsidiary bodies.

<b>Leakage</b>	Leakage occurs when mitigation actions have an effect outside the system boundary in such a way that it undermines the intended positive impact of the mitigation actions. Leakages need to be included in the analysis depending on the possible magnitude.
<b>Mitigation</b>	In the context of climate change, a human intervention to reduce the sources or enhance the sinks of greenhouse gases. Examples include using fossil fuels more efficiently for industrial processes or electricity generation, switching to solar energy or wind power, improving the insulation of buildings, and expanding forests and other "sinks" to remove greater amounts of carbon dioxide from the atmosphere.
<b>MRTS</b>	Collective urban or suburban passenger services operating at high levels of performance, especially with regard to travel times and passenger-carrying capacity, and can be based on elevated, surface level, or underground roads, or rail systems. They can be rail-based systems such as subways/metros, Light Rail Transit (LRTs) systems, including trams, suburban heavy-duty rail systems, or road-based bus systems.
<b>MRV</b>	Measurable, reportable and verifiable. A process/concept that potentially supports greater transparency in the climate change regime.
<b>National communication</b>	A document submitted in accordance with the Convention (and the Protocol) by which a Party informs other Parties of activities undertaken to address climate change. Most developed countries have now submitted their fifth national communications; most developing countries have completed their first national communication and are in the process of preparing their second and third ones.
<b>Nationally appropriate mitigation actions (NAMAs)</b>	At COP 16 in Cancun, Mexico in 2010, Governments decided to set up a registry to record nationally appropriate mitigation actions seeking international support, to facilitate the matching of finance, technology and capacity-building support with these actions, and to recognise other NAMAs.
<b>NDC</b>	According to Article 4 paragraph 2 of the Paris Agreement, each Party shall prepare, communicate and maintain successive nationally determined contributions (NDCs) that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions.

**Non-Annex I Parties** Refers to countries that have ratified or acceded to the United Nations Framework Convention on Climate Change that are not included in Annex I of the Convention.

**Party** A State (or regional economic integration organisation such as the European Union) that agrees to be bound by a treaty and for which the treaty has entered into force.

**Retrofits** Retrofits involve the direct installation of technologies onto the vehicle/engine that improves the efficiency of engine operation by, for example, tapping into spare unused kinetic energy, solar energy or thermoelectric generation and/or generating hydrogen on board to be used as a catalyst, e.g. electro-catalytic efficiency technologies.

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## 1 Introduction

### 1.1 Background

The Royal Government of Cambodia (RGC) submitted her updated NDC to the UNFCCC in 2020, indicating a possible emission reduction of 41.7% against the BAU in 2030. Emission reductions were estimated considering FOLU, Energy, Agriculture, Industry, and Waste sectors. The energy sector including the transport sector expects a 40% emissions reduction against the BAU in 2030. NDC analysis has considered three mitigation actions from the transport sector representing passenger and freight transport.

1. Promote integrated public transport systems in main cities;
2. Enhance maintenance and inspection of vehicles; and
3. Shift long-distance freight movement from trucks to train.

GACMO analysis was conducted under the first deliverable of this assessment for different mitigation projects, which comes under the above mitigation actions. Sustainable development benefits associated with considered mitigation projects were also assessed qualitatively. Based on these assessments, two mitigation projects, namely i) Shift passengers from private cars to 23 public buses by 2021 in Phnom Penh; and ii) Introduce 14 vehicle inspection centers by 2030, were selected to develop the MRV system for the transport sector in Cambodia.

A Measurement, Reporting and Verification (MRV) framework includes three main key elements, namely i) International MRV, ii) Domestic MRV, and iii) MRV of REDD+. National MRV for transport sector of Cambodia will be considered under the Domestic MRV. Domestic MRV includes MRV of emissions, MRV of NAMA /mitigation actions, and MRV of support. Cambodia intends to develop an MRV system based on the mitigation actions in the updated NDC, this will be an MRV of mitigation action.

MRV of mitigation actions involves assessing (ex-ante or ex-post) the GHG emissions reduction effects of policies, projects, programs, and actions. It also involves assessing progress toward mitigation goals.

In accordance with the handbook on Measurement, Reporting and Verification (UNFCCC, 2014), two main steps need to be followed to establish a domestic MRV of mitigation actions: i) Determine arrangement for domestic MRV and ii) Report on domestic MRV.

The first step in setting up the domestic MRV framework is to determine the key processes, systems, and arrangements, including existing institutional structures, relevant information, methodologies, and experts to be engaged. As such, methodologies required to assess the GHG impacts of selected mitigation projects will be chosen in this deliverable. The existing domestic processes, arrangements, and systems in MRV frameworks, climate change management and transport sector were assessed under the Deliverable 3 of this assessment.

These domestic processes, arrangements, and systems will be utilized to establish the new MRV system for the transport sector in Cambodia.

The second step in setting up an MRV framework includes the development of an approach to measure mitigation actions, including data management systems, methodology, documentation, and an approach to verify the mitigation actions and institutional arrangement. These will be conducted under the Deliverable 5 of this assessment following the guidance given in the Handbook on Measurement, Reporting and Verification for developing country parties (UNFCCC, 2014) and the tool to develop MRV systems (GIZ, n.d.).

## 1.2 Objectives

### 1.2.1 Objectives of the project

- Develop an MRV Framework for the Transport Sector in Cambodia; and
- Develop capacity on the use of transparency related tools, ICAT SD assessment tool, and GACMO.

### 1.2.2 Objectives of the deliverable

- Select methodologies to assess the GHG impacts of selected mitigation projects; and
- Provide capacity building on the selected methodologies.

## 2 Methodology

A comprehensive desk review was conducted to identify the available methodologies to assess the GHG impacts of selected mitigation projects. Methodologies published by Asian Development Bank (ADB), ALMEC/ World Bank, Center for Clean Air Policy (CCAP), Clean Air Asia, Global Environment Centre Foundation (GEC)/ Joint Crediting Mechanism (JCM), Initiative for Climate Action Transparency (ICAT), Institute for Transportation and Development Policy (ITDP), Japan International Cooperation Agency (JICA), U.S. Federal Highway Administration, United Nations Framework Convention on Climate Change (UNFCCC), World Bank, World Resources Institute (WRI), etc., were considered for the selection. Methodologies were chosen considering their applicability and the scope of the mitigation projects.

## 3 Measurement

### 3.1 Background

A mitigation project refers to a specific activity or set of activities intended to reduce GHG emissions, increase carbon storage, or enhance GHG removals from the atmosphere. These actions can be categorised into Avoid, Shift, Improve and Reduce.

<b>Avoid</b>	Actions that reduce the total amount of person-km or tons-km (for freight). For example reducing person-km by affecting number of trips/person or distance ( km) /trip.
<b>Shift</b>	Actions that shift the mode of transport to low carbon systems; shift to public transport or cycle from car for example.
<b>Improve</b>	Mitigation actions that affect fuel/km (fuel efficiency); for example, through improved vehicle technology.
<b>Reduce</b>	Mitigation actions that have an effect on the carbon content of the energy carrier reduce the GHG emissions; fuel-switch from petrol to natural gas for example. .

Measurement may entail direct physical measurement of GHG emissions, estimating emissions or emissions reductions utilising activity data and emission factors (Singh et al., 2016). Specifics of measurement will depend on many factors, including data availability, existing policies and practices, donor agreements, etc. Various approaches to measure the mitigation actions are described below.

#### 3.1.1 Approaches to estimating transport emissions

There are two types of approaches to estimate actual or future emissions in the transport sector: i) Top-down approach, and ii) Bottom-up approach.

The top-down approach uses aggregated fuel consumption data to calculate GHG emissions. Such a top-down analysis can indicate whether GHG emissions are increasing or decreasing in the sector as a whole, but the changes cannot be attributed to any causes which are not represented in the driver variables (used to calculate aggregate consumption). In order to trace the cause and effect of many types of intervention, the GHG production process must be further broken down into disaggregated components with additional variables that cause variation in the amount of fuel used per person trip or tonne-km. Figure 3-1 illustrates the top-down model for GHG emissions from the transport sector.

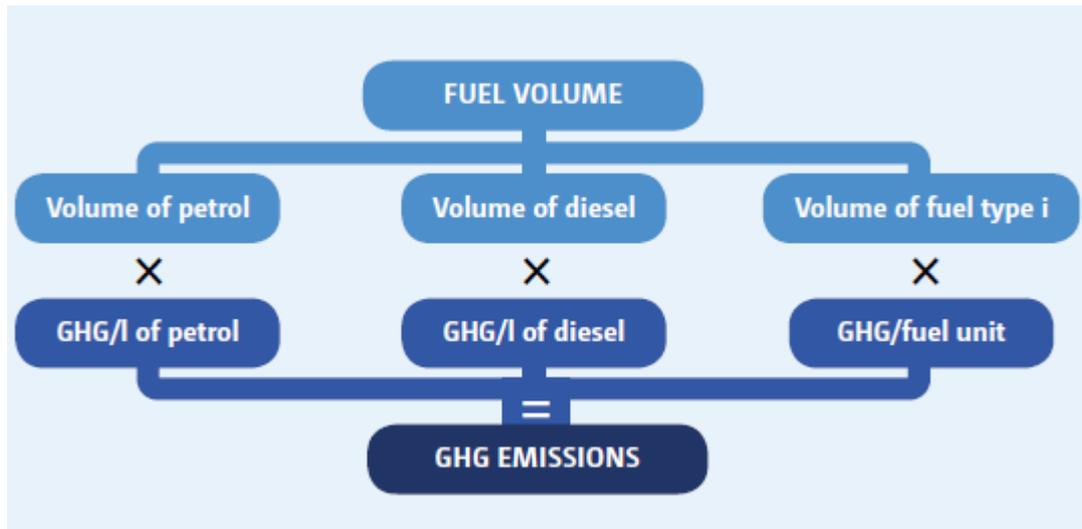


Figure 3-1: Top-down model of GHG generation from the transport sector

Source: UNFCCC 2018, *Compendium on greenhouse gas baseline and monitoring -Passenger and freight transport*

Basic components of the bottom-up approach are the number of trips, the length of the trip, the mode of the trip, the vehicle occupancy, and the fuel efficiency of the vehicle. A component variable can be disaggregated at any level. Thus, a complex tree of individual variables can be generated by disaggregating it at various levels.

In order to avoid complexities, some methodologies use intermediate variables such as person kilometres (PKM) or vehicle kilometres travelled (VKT) values for analysis. Figure 3-2 illustrates the bottom-up model for GHG emissions from the transport sector.

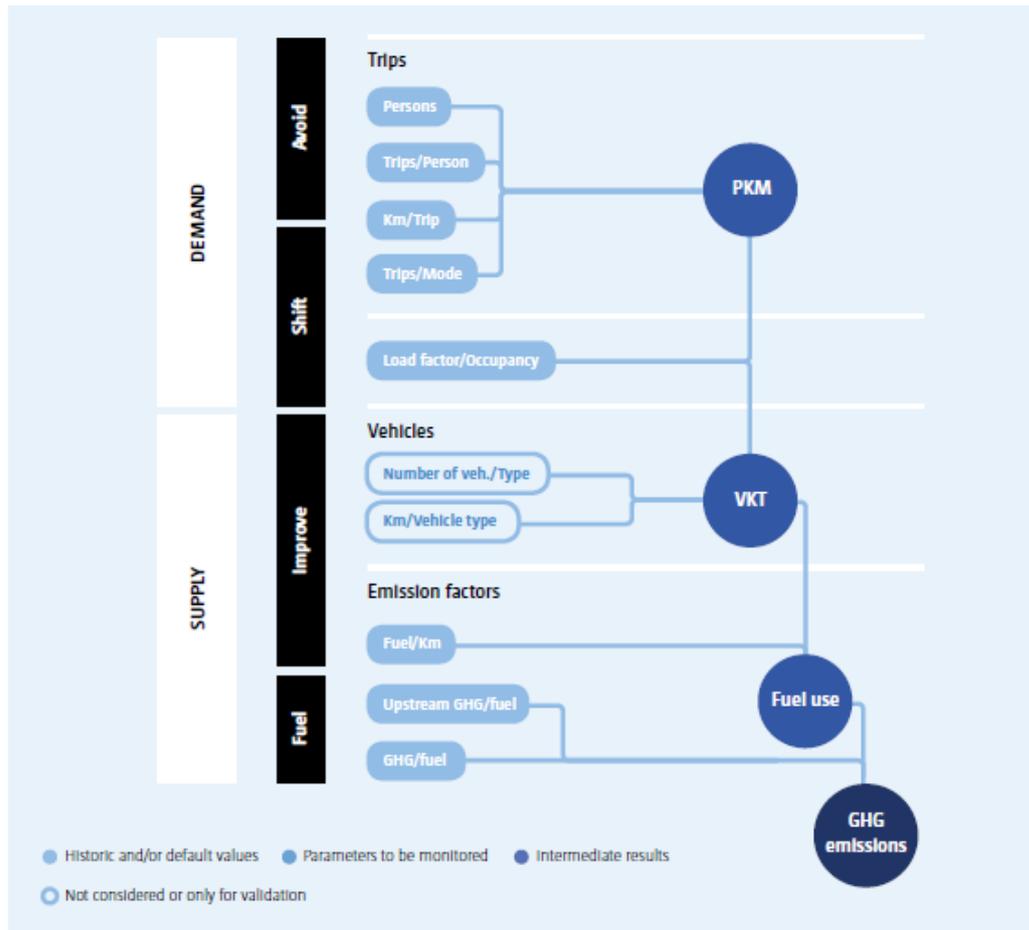


Figure 3-2: Bottom-up model for GHG generation from the transport sectors

Source: UNFCCC 2018, *Compendium on greenhouse gas baseline and monitoring -Passenger and freight transport*

### 3.1.2 Baseline setting

Baseline means a projection for future years assuming that the intervention is not implemented. A counterfactual baseline implies a projection of what would have happened but based on historical drivers in the absence of the mitigation action.

A dynamic baseline is a counterfactual projection based on drivers e.g., population, income, etc. Therefore, can change if one or more drivers change over time even in the absence of the mitigation action. Hence allow for revising the baseline at a later date if there are changes in emissions drivers since the ex-ante baseline was calculated.

Baselines can be done before the intervention take place (ex-ante) or after the intervention has taken place (ex-post) (UNFCCC, 2018).

### 3.1.3 Determine emission reduction

The reduction (mitigation) is the difference between the emissions of the with-mitigation scenario (Project scenario) and the emissions of the no-mitigation (BAU) scenario. In the ex-ante situation, both of these are future projections starting from the current emissions. In the ex-post situation, the project scenario becomes the current emissions, and the no-mitigation scenario is a BAU projection. A previous ex-ante, BAU projection could be used, or preferably, a new counterfactual projection that takes into account actual changes not due to the mitigation action can be considered.

### 3.1.4 Data collection

Data collection is challenging due to the lack of reliable data locally. A possibly greater challenge is getting reliable values of variables when data cannot be collected because they are in the future or based on an imaginary counterfactual scenario. Various techniques have been developed to obtain values for variables under these circumstances (UNFCCC, 2018). Table 3-1 indicates some data estimation methods.

Table 3-1 Available data prediction methods

Method	Description	Strength	Weakness
Travel demand modelling	Estimate important future activity variables such as trip length, mode choice, transit occupancy and road speeds using information about spatial interaction, that is, the relationship between origins, destination and transport infrastructure (road and transit systems).	<ul style="list-style-type: none"> <li>• The same model can be used for the project and the BAU scenarios.</li> <li>• Complex second-and third-level interactions such as rebound effects can be simulated.</li> <li>• High levels of disaggregation are possible</li> <li>• Powerful tools with respect to travel activity-related variables in baselines/scenarios</li> </ul>	<ul style="list-style-type: none"> <li>• Input data requirements are high</li> <li>• Cannot predict any vehicle technology related future developments.</li> </ul>
Historical trend	This can be as simple as drawing a line through data points or involving elaborate regression analysis on multiple parameters.	<ul style="list-style-type: none"> <li>• -Relatively simple approach</li> </ul>	<ul style="list-style-type: none"> <li>• Circumstances can change in the future, causing the trend to shift.</li> </ul>

Control group	<p>In this approach, to estimate variables for a counterfactual BAU scenario, another local area similar to that in which the intervention is planned / took place is selected as control. Similar boundary conditions are imposed, and then the key variables are measured in both the control area and the intervention area at the same time. The difference in value of the variable of interest (emissions) is then attributed to the intervention.</p>		<p>The challenge is to find a suitable control group. This method is primarily used by pharma / medical industry.</p>
Default or proxy data	<p>Using data from another non-local area or another time period as a substitute for locally measured data.</p>	<ul style="list-style-type: none"> <li>• Sometimes default data can be very accurate. For example, the default emission factors are based on the measurement of a sample of motor vehicles that is probably representative of the local fleet at the proper level of disaggregation.</li> </ul>	<ul style="list-style-type: none"> <li>• Use of default data from a non-local area to estimate the change in variables such as trip length or mode share may not be reliable due to spatial and demographic asymmetry with the local area.</li> </ul>



Survey question	Conduct surveys of the potential travellers. with relevant questions	-	<ul style="list-style-type: none"> <li>• Don't capture changes in circumstances that the respondent cannot predict or fails to consider</li> <li>• Answers may not reflect what people will actually do</li> </ul>
Expert opinion	Consulting and discussing with a range of experts and synthesizing their opinions.	<ul style="list-style-type: none"> <li>• Useful for questions involving future policy changes</li> </ul>	<ul style="list-style-type: none"> <li>• Less reliable when applied to projections of human behavior</li> </ul>

Source: UNFCCC 2018, *Compendium on greenhouse gas baseline and monitoring- Passenger and freight transport*

## 4 Assessing GHG Impacts of Mitigation Projects

### 4.1 Promote integrated public transport systems in main cities

- a. Shift passengers from private vehicles to 23 public buses in Phnom Penh<sup>1</sup>.

Phnom Penh has a population of about 2.3 million as of 2019 (NIS/MoP, 2020) and a land area of 678 km<sup>2</sup>. In recent years, traffic conditions and traffic accidents in Phnom Penh have worsened due to the rapid increase in vehicles and the lack of public transport facilities. As such, the 2035 Master Plan aims to increase the modal share of public transport by 30%.

As an initiation to improve the public transport system in the city, 80 buses provided by Japan were added to the fleet in 2018. With the new fleet, City Bus Authority of Phnom Penh expanded its service network from three lines in 2016 to 13 lines in 2018, covering the majority of Phnom Penh. With these improvements, 57 old buses operated in Phnom Penh Capital Administration (PPCA) were removed from the fleet (“Improving Public Bus Operations in Phnom Penh,” 2020; JICA, 2016)

Objectives of the project were to i) reduce traffic issues such as congestion, accidents, and air pollution; ii) increase average speed in the capital city and improve overall urban mobility; iii) reduce private-owned automobiles; iv) create employment for people; v) improve traffic flow in the capital as a pilot experiment for BRT; and vi) improve cityscape of the capital city.

However, private passenger cars, motorcycles, and para-transit modes such as Motodops are still main players in the city. It is expected that passengers will shift from these modes to public buses contributing to GHG emissions reduction

#### 4.1.1 Description and characteristics of the mitigation project

This mitigation project will shift passengers in Phnom Penh from private passenger cars, motorcycles, and para-transit modes such as Motodops to public buses. The passenger occupancy rate of a private car, a motorcycle and a Motodop is about 1.5<sup>2</sup>, 1.2<sup>2</sup>, and 1.4<sup>3</sup>, respectively, whereas it is about 50 in a public bus<sup>2</sup>. Due to the

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<sup>1</sup> <https://openjicareport.iica.go.jp/pdf/12267720.pdf>

In the absence of a large-scale project that can be assessed under this NDC, this project was used as a pilot project to develop the MRV. However, this MRV process can be used to any project which involves passenger shift from private vehicles to public buses.

<sup>2</sup> Default in GACMO

<sup>3</sup> The Characteristics of Paratransit Operation and Fare in Phnom Penh <http://dx.doi.org/10.11175/easts.11.1307>

higher occupancy rate of the buses compared to private vehicles, the number of vehicles required to accommodate a similar number of passengers will reduce under this mitigation project.

The project expanded public transportation capacity by introducing 23 new public buses in 2018, which will increase the modal share of public buses in the city, leading to traffic congestion reduction and increment of the overall efficiency of public transport.

With the replacement of old buses with new buses, it is expected that more passengers will use the public transport which will reduce the occupancy of other types of passenger vehicles. This will be supported by the increase in bus routes, providing better access to public transportation.

#### **4.1.2 Structure of mitigation effects**

##### *4.1.2.1 Cause-impact Chain*

Selected mitigation project can be categorized under the introduction of mass transits. As shown in Figure 4-1, the mitigation project falls into the Shift category of the mitigation actions. An increase in the share of public buses, a decrease in the share of private vehicles and an increase in the occupancy of public buses will be the significant effect of this action. Thus, changes in passenger kilometres (PKM) in different modes are the main indicator for the GHG emissions estimation.

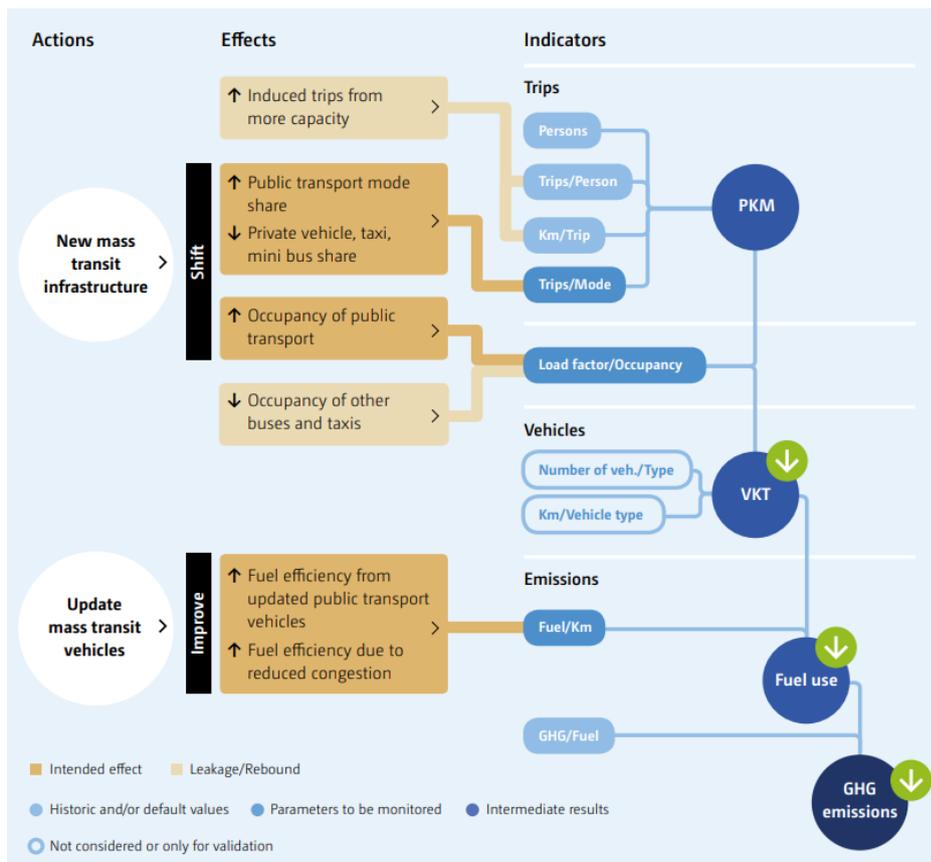


Figure 4-1 Causal Chain of Mass Transit Investments

Source: UNFCCC 2018, *Compendium on greenhouse gas baseline and monitoring -Passenger and freight transport*

As shown in Figure 4-1, this mitigation project comes under introducing a new mass transit infrastructure that will shift the passengers from private vehicles to public buses. An increase in the share of public buses, a decrease in the share of private vehicles and an increase in the occupancy of public buses will be the major effects of this action. Thus, the main indicator for the GHG emissions estimation will be the change in the passenger kilometres (PKM) travelled by public transport.

#### 4.1.2.2 Key variables to be monitored

As shown in Figure 4.1, the key indicators that need to be monitored to estimate the GHG effects are the number of passengers using public buses, number of passengers using private vehicles, number of vehicles, trips per person, km per trip, trips per public bus, trips per private car, trips per motorbike, trips per motodop and fuel economy of vehicles.

#### *4.1.2.3 Monitor for intended effects*

Change of the mode share is the intended main effect of this mitigation action. Due to the availability of new and improved public buses in the city, private vehicles users will be shifted to the public buses. As the number of private vehicles decreases due to modal shift of passengers, the traffic conditions will improve, facilitating the improvements in urban mobility, thus increasing vehicle speeds.

#### *4.1.2.4 Monitor for leakages<sup>4</sup> and rebound effect*

Increased number of buses and routes may lead to more commuting. These induced trips in new routes can create a negative rebound effect due to increased total transport capacity. The addition of new routes can lead to longer trip lengths as well. As per the Preparatory Survey Report on the Project for Improvement of Transportation Capacity of Public Bus in Phnom Penh (JICA, 2016), the bus travel distance will be increased to 8,830 VKT/day by 2021. Therefore, these leakage and rebound effects will be considered based on their significance to the total GHG emissions and data availability.

#### *4.1.2.5 Boundary*

The boundary of the project will depend on the size of the project and the data availability. The geographical boundary of this project is set as Phnom Penh city. This mitigation action will consider passenger shift from private cars and motorbikes to public buses as the data on motodops used in Phnom Penh is unavailable. The temporal boundary of the project will be 2021 - 2030. Emissions reduction will be limited to change of CO<sub>2</sub> emissions.

#### *4.1.2.6 Key methodological issues*

The main difficulty in estimating GHG emissions from the project activity is the variable on the number of passengers shifted from private cars and motorbikes to public buses, leading to a change in modal share in both types of vehicles. Due to the availability of public buses at an affordable fare, easy access and low fuel price per passenger, it will be more economical for passengers to shift to buses. Thus, a greater number of buses and trips will be required. Further, due to the reduction of traffic on roads, the speeds of the vehicles will improve. However the impact of this is on CO<sub>2</sub> emissions is not estimated.

#### *4.1.2.7 Double counting concerns*

In order to avoid potential double-counting of GHG emissions, mitigation actions related to fuel costs such as taxes and subsidy removal, vehicle fuel efficiency improvements, Transit-Oriented Development (TOD) policies that can change the mode share of public buses and private vehicles will be considered.

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<sup>4</sup> Leakage occurs when mitigation actions have an effect outside the system boundary in such a way that it undermines the intended positive impact of the mitigation actions.

### 4.1.3 Determining the baseline and calculating emissions reduction

#### 4.1.3.1 Analysis approach

The baseline emissions can be estimated by determining the PKM of private vehicles in the absence of new public buses in Phnom Penh. These PKM values of private vehicles can be converted to VKT values based on load factor/occupancy. Emissions can be estimated based on fuel economy and respective emission factors. Future baseline estimations can be projected using one of the following three methods:

- 1) Travel demand models which can be used to estimate future trips and PKM for private vehicles based on the local land use. This is used for ex-ante analysis;
- 2) Travel activity surveys which can be used to estimate the future number of passengers who use private vehicles for transportation in Phnom Penh via a stated preference survey for ex-ante analysis; and
- 3) Expert judgement based on historical trends which use time-series data for at least ten years.

Emissions reduction can be calculated taking the difference between BAU scenario; emissions in the absence of newly added 23 buses, and project scenario; operation of 23 public buses.

#### 4.1.3.2 Uncertainty and sensitivity analysis

The share of public buses and private vehicles and the number of new passengers shifted to new buses will bring uncertainty to the emissions estimation in this mitigation action. With the increase of public buses, there will be rebound effects, as explained in section 5.2.4. This may also cause uncertainty to the emission estimation.

### 4.1.4 Selection of analysis tools

Various organisations have published different analysis tools to assess GHG emissions impact in introducing/improving public transport systems. This section describes available methodologies, methodology selection process for the selected mitigation action and characteristics of the selected methodology. Only bottom-up methodologies were considered due to the use of disaggregated data.

#### **Disaggregated bottom-up methodology**

These types of methodologies require more disaggregated variables, and they provide precise guidance on how to collect those variables and calculate emissions using them. They are primarily used for ex-post assessments. Ex-ante guidance (at project level) is found only for CDM additionality testing. According to that, future trip length of public buses and mode share of buses and private vehicles should be estimated separately outside the methodology.

The following disaggregated bottom-up methodologies in Table 4-1 are applicable for mitigation actions that introduce/improve public transport systems.

Table 4-1 Disaggregated bottom-up tools for Mass Rapid Transit Systems

Name	Application	Scope	Developer
ACM0016: Mass Rapid Transit Systems (MRTS)	Project activities that establish and operate an MRTS without feeder lines	<ul style="list-style-type: none"> <li>Ex-post focus</li> <li>Leakage: bus and taxi occupancy change, congestion effect on fuel efficiency and induced trips, upstream emissions of gaseous fuels</li> </ul>	UNFCCC
AM0031: Bus Rapid Transit (BRT) projects	Construction and operation of a new BRT system or replacement or expansions of existing BRT systems (adding new routes and lines)	<ul style="list-style-type: none"> <li>Ex-post focus</li> <li>Leakage: bus and taxi occupancy change, congestion effect on fuel efficiency and induced trips, upstream emissions of gaseous fuels</li> </ul>	UNFCCC
CDM tool 18: Baseline emissions for modal shift measures in urban passenger transport	Activities in urban passenger transport that implement a measure or a group of measures aimed at a modal shift to urban public transit such as metro, BRT, light rail and trams	<ul style="list-style-type: none"> <li>Ex-post focus</li> <li>General PKM methodology</li> <li>Leakage: general guidance only</li> </ul>	UNFCCC
Traffic Congestion Mitigation/ Modal Shift (Passenger)	Activities of efficient inner-city passenger transport such as MRT (Mass Rapid Transit), railway, monorail, LRT (Light Rail Transit), BRT (Bus Rapid Transit) and trunk bus	<ul style="list-style-type: none"> <li>Ex-ante</li> <li>Baseline transport modes should be buses, private cars, taxis and existing railways, etc.</li> </ul>	JICA

Sources: UNFCCC 2018, *Compendium on greenhouse gas baseline and monitoring -Passenger and freight transport*

### Partially aggregated bottom-up

These are spreadsheets-based tools, and VKT level or trip level activity data can be used along with a variety of default values for missing and unavailable data to estimate emissions reduction. Future VKT, mode share or passenger numbers are estimated based on historical data combined with a score-card analysis. The partially aggregated bottom-up methodology shown in Table 4-2 applies to the new or expanded BRT system.

Table 4-2 Partially aggregated bottom-up tools for Mass Rapid Transit systems

Name	Application	Scope	Developer
BRT-TEEMP (full)	New or expanded BRT system	<ul style="list-style-type: none"> <li>Ex-ante focus</li> <li>Includes BRT mode shift estimation if local data available</li> <li>Includes co-benefits estimation</li> </ul>	Clean Air Asia/ITDP/ ADB

Source: UNFCCC 2018, *Compendium on greenhouse gas baseline and monitoring -Passenger and freight transport*

### Simple bottom-up

The local VKT, passenger numbers, or mode shift data should be input into a spreadsheet or other computer programme to estimate emissions. The following simple bottom-up tools shown in table 4-3 are applicable for project activities that establish and operate Mass Rapid Transit.

Table 4-3 Simple bottom-up tools for Mass Rapid Transit systems

Name	Application	Scope	Developer
BRT-TEEMP (Sketch)	New or expanded BRT system	<ul style="list-style-type: none"> <li>Ex-ante focus</li> <li>Includes BRT mode shift estimation based on defaults</li> <li>Includes co-benefits estimation</li> </ul>	Clean Air Asia/ITDP/ ADB
CCAP Emissions Guidebook	New or expanded BRT/ metro system	<ul style="list-style-type: none"> <li>Ex-ante tool</li> <li>Sketch planning estimates based on combining local data and defaults</li> <li>Includes fuel cost savings calculator</li> </ul>	CCAP

Source: UNFCCC 2018, *Compendium on greenhouse gas baseline and monitoring -Passenger and freight transport*

### Historical trend

This methodology uses disaggregated travel activity and fuel efficiency data input by the user extrapolated over time and along with default emission factors to estimate the emissions reduction. Tools that use historical trends to assess GHG impacts of MRT are given in Table 4-4.

Table 4-4 Historical trend tools for Mass Rapid Transit systems

Name	Application	Scope	Developer
Emission reduction volume calculator for BRT project	New or expanded BRT system	<ul style="list-style-type: none"> <li>Requires user to input all travel data except default emission factors</li> <li>Calculates total emissions and reduction</li> </ul>	ALMEC/ World Bank

Source: UNFCCC 2018, *Compendium on greenhouse gas baseline and monitoring -Passenger and freight transport*

#### 4.1.4.1 Selected methodology

Table 4-5 shows the comparison of applicability of bottom-up methodologies that can be used to establish and operate Mass Rapid Transit Systems.

Table 4-5 Comparison of applicability of methodologies to the proposed project activity

Methodology	Applicability of the methodology to the project activity
ACM0016: Mass Rapid Transit Systems (MRTS)	Since the proposed mitigation project does not involve separate lanes for buses, this methodology cannot be used. The operation of buses under mixed traffic conditions can result in different amounts of fuel consumption compared to that of the buses operating on separate lanes.
AM0031: Bus Rapid Transit (BRT) projects	
CDM tool 18: Baseline emissions for modal shift measures in urban passenger transport	
Traffic Congestion Mitigation/ Modal Shift (Passenger)	The proposed mitigation project involves passenger transport in Phnom Penh, and passengers shifting from private vehicles to buses can be considered as the project activity. Therefore, this methodology is more applicable for the selected mitigation action.
BRT-TEEMP (full)	All these methodologies are applicable for the new or expansion of the BRT system, which involves constructing dedicated bus lanes. But the proposed mitigation action does not involve separate bus lanes, which can result in different fuel consumptions due to different traffic conditions.
BRT-TEEMP (Sketch)	
CCAP Emissions Guidebook	
Emission reduction volume calculator for BRT project	

As in the table, Traffic Congestion Mitigation/ Modal Shift (Passenger), JICA Climate-FIT Version 3.0 methodology (JICA, 2019) was selected to estimate GHG emissions reduction from the proposed mitigation project.

#### 4.1.4.2 Baseline methodology

Baseline GHG emissions will be calculated based on the share of passengers using private cars and motorbikes in the baseline scenario. Equation 4.1 will be used for the emissions estimation.

Equation 4-1 Baseline emissions

$$BE_y = \sum_i \left( \frac{P_y \times MS_{b,i,y}}{OR_{b,i}} \times BTDP_y \times EF_{km,i} \right)$$

Where:

$BE_y$	Baseline emissions for year y (tCO <sub>2</sub> /y)
$P_y$	Number of passengers transported by public buses under the project in year y (passenger/y)
$MS_{b,i,y}$	Share of passengers by transport mode i (private cars, motorbikes) in the baseline scenario in year y (%)
$OR_{b,i}$	Average occupation rate of transport mode i (private cars, motorbikes) (passenger/vehicle)
$BTDP_{by}$	Average trip distance of the passenger of the public bus in year y (km)
$EF_{KM,i}$	CO <sub>2</sub> emission factor of transport mode i (private cars, motorbikes) (tCO <sub>2</sub> /km)

Equation 4.2 can calculate the CO<sub>2</sub> emission factor of private cars and motorbikes in tCO<sub>2</sub>/km units.

Equation 4-2 CO<sub>2</sub> emission factor of transport mode

$$EF_{KM,i} = SFC_i \times NCV_{x,y} \times EF_{fuel,x}$$

Where:

$SFC_i$	Fuel consumption rate of mode i (private cars, motorbikes) (litres/km)
$NCV_{x,y}$	Net calorific value of fuel type x in year y (TJ/litre)
$EF_{fuel,x}$	CO <sub>2</sub> emission factor of fuel type x (tCO <sub>2</sub> /TJ)

The number of passengers transported and the average trip distance of the public buses which are to be used under the project scenario and the share of passengers and specific fuel consumption by private cars and motorbikes should be measured.

In the absence of country-specific values, default values can be used for average occupancy rates and CO<sub>2</sub> emission factors by fuel types for private cars and motorbikes. Further, country specific Low Calorific Values will be used to generate the Net Calorific Value.

#### 4.1.4.3 Project methodology

The project emissions will be calculated based on fossil fuel consumed by 23 public buses, which were introduced under the project. Equation 4-3 will be used for the calculation of project emissions.

*Equation 4-3 Project Emissions*

$$PE_y = (FC_{PJ,y} \times NCV_{x,y} \times EF_{fuel,x})$$

Where:

$PE_y$	Project emissions for year y (tCO <sub>2</sub> )
$FC_{PJ,y}$	Fuel Consumption associated with the operation of the public buses in year y (t/y)
$NCV_{x,y}$	Net calorific value of fuel x in year y (TJ/t)
$EF_{fuel}$	CO <sub>2</sub> emission factor of fuel used in public buses (tCO <sub>2</sub> /TJ)

The amount of fuel consumed by 23 public buses under the project scenario should be measured. In the absence of country-specific values, default values in IPCC 2006 Guideline can be used for the CO<sub>2</sub> emission factor for fuel type used in public buses. Country specific Low Calorific Values will be used to generate the Net Calorific Values. If the total fuel consumption is not available, then it can be calculated by the product of total vehicle kilometers travelled by vehicle (km), specific fuel consumption by bus (in l/km).

## 4.2 Enhance maintenance and inspection of vehicles

### b. Introduce 20 vehicle inspection centres by 2030<sup>5</sup>

Cambodia has established vehicle inspection centres to improve the conditions of the vehicle fleet. Objectives of the project are to i) ensure road safety, ii) reduce traffic jams, and iii) reduce air pollution. Currently, 15 inspection centres are in operation throughout the country (Sen David, 2020). By the time of 2016, there were only 10 vehicle inspection centers<sup>6</sup>. In order to meet the NDC target with respect to the base year (2016) it is expected to introduce 20 more centres by 2030. Vehicle Inspection Centers undertake regular inspections, once a year for commercial vehicles and once every two years for private vehicles. Several measurements/tests are conducted during an inspection, including appearance inspection, speedometer testing, underbody inspection, headlight testing, sound level measurement, slide slip testing, weighing, and break testing and the exhaust gas test which measures the exhaust gases (Carbon monoxide (CO) and Hydrocarbons (HC)) as well as calculates the air/fuel ratio. These measurements together provide the combustion efficiency of an engine.

All vehicle owners have a liability to bring their vehicles to vehicle inspections. If a vehicle owner does not receive a proper inspection, they will be subjected to a fine. A certificate is issued when a vehicle passes all these tests. Vehicles that fail to meet the expected standards need to be repaired in order to obtain the certificate. Holding an expired certificate or failure to take the inspection within the required period are subject to fines (JICA, n.d.). However, the Ministry of Public Works and Transport has found that 28 per cent of vehicles have not passed or undertaken their most recent road safety assessment at a vehicle inspection centers in 2020. Currently, the ministry issues SMS alerts to vehicle owners when their vehicle needs to be inspected.

#### 4.2.1 Description and characteristics of the mitigation project

The project determines the requirement of improving the engine efficiency of the vehicle. This can be achieved by either tuning the engine or by installing retrofits that improve engine efficiency. Successful implementation of this mitigation action is expected to allow existing vehicles to achieve better fuel economy. According to the literature, fixing a car that is noticeably out of tune or has failed an emissions test can improve its gas mileage by an average of 4%, though results vary. Fixing a serious maintenance problem, such as a faulty oxygen sensor, can improve fuel economy by as much as 40%<sup>7</sup>.

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<sup>5</sup>

[https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Cambodia%20First/20201231\\_NDC\\_Update\\_Cambodia.pdf](https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Cambodia%20First/20201231_NDC_Update_Cambodia.pdf)

<sup>6</sup> [https://openjicareport.jica.go.jp/pdf/12340683\\_01.pdf](https://openjicareport.jica.go.jp/pdf/12340683_01.pdf)

<sup>7</sup> <https://www.exxon.com/en/car-maintenance-tips>

#### 4.2.2 Structure of mitigation effects

##### 4.2.2.1 Cause-impact chain

As shown in Figure 4-2, the fuel efficiency of the vehicle fleet can be improved through enhanced maintenance and inspection practices.

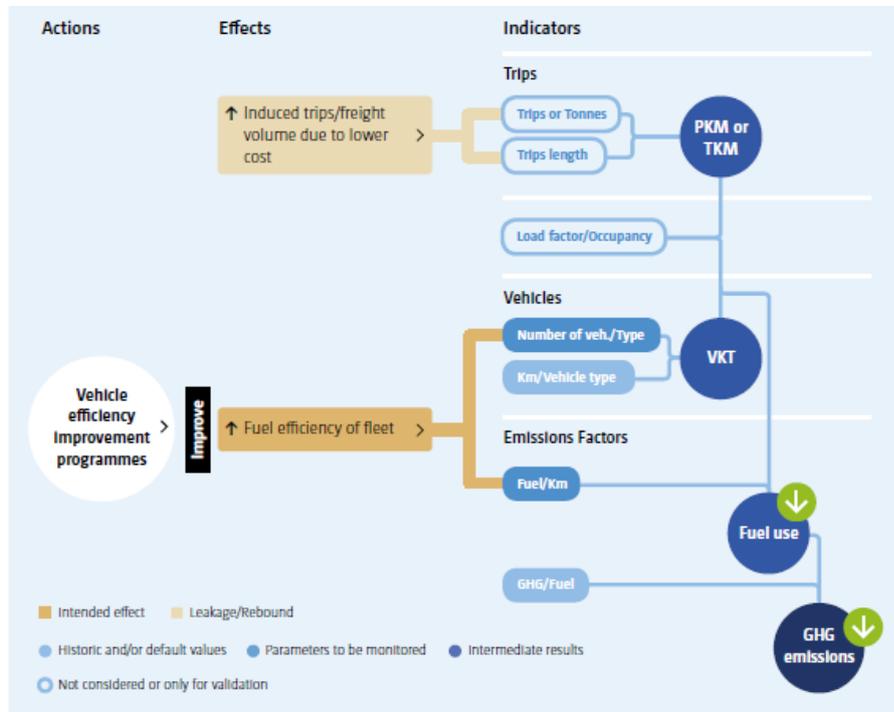


Figure 4-2 Causal chain for vehicle fuel efficiency improvement programs

Source: UNFCCC 2018, *Compendium on greenhouse gas baseline and monitoring -Passenger and freight transport*

Key indicators involve in GHG impact estimation in vehicle efficiency improvement programmes are the number of vehicles in different modes and distance travelled by each vehicle type. Thus, the reduction of fuel consumption due to the improved fuel economy can be considered as the major indicator that affects emissions reduction due to the considered mitigation action.

##### 4.2.2.2 Key variables to be monitored

The key variables that are expected to be increased due to regular maintenance and inspection of vehicles are fuel efficiency, number of trips and distance of a trip

##### 4.2.2.3 Monitor for intended effects

Improve the fuel efficiency (Fuel/km) of vehicles that are subject to inspection.

#### 4.2.2.4 *Monitor for leakages<sup>4</sup> or rebound effect*

Decreased fuel consumption may result in a reduced cost for fuel, resulting in induced trips and/or longer trips as a rebound effect. The inclusion of these rebound effects in the calculation will be decided based on the magnitude of the impact.

#### 4.2.2.5 *Boundary*

This national programme will create new inspection centres around the country. Hence, the national border is set as the geographical boundary for this mitigation action. The temporal boundary of this project is considered as 2021-2030. Commercial and private sector vehicles that are subject to inspection will be the scope. The emission of CO<sub>2</sub> gas is considered for this assessment.

#### 4.2.2.6 *Key methodological issues*

The GHG impact of this mitigation action depends upon the number of vehicles that adopt the new, fuel-efficient changes due to the increase of inspection and the amount of fuel each vehicle can save thereby. Disaggregated data for variables pertaining to total fuel consumption of the vehicle fleet after inspection may be needed if the direct measurement of fuel use is not available.

General issues to consider when selecting a methodology includes:

- How much improvement of vehicle FE will be achieved compared with the existing fleet and with 'business as usual' future projections;
- How the fleet turnover benefits of these improvements are realized over time; and
- What unintended consequences (i.e., rebound effects) might the policy have that could reduce the benefits.

#### 4.2.2.7 *Double counting concerns*

Mitigation actions that affect fuel costs or certain classes of vehicles can distort the vehicle market. This can lead to difficulty in attributing the reduction to a particular action or to counting the same values more than once for different actions. Mitigation actions such as national fuel economy standards, fuel subsidies or tariffs, and vehicle import fees or rebates may affect the variable fuel/km, while logistics measures may affect fuel/ tonne-km.

### 4.2.3 **Determining the baseline and calculating emission reduction**

#### 4.2.3.1 *Analysis approach*

The baseline scenario can be expressed as the overall fuel use by the targeted vehicles. The current fuel use or fuel efficiency data serve as the basis for this baseline calculation (depending on the data availability), which must be projected into the future for ex-ante analysis and counterfactually projected to create a BAU scenario

for ex-post analysis. The future projection of the mitigation action scenario must be done in ex-ante analysis to compare with the baseline scenario.

These counterfactual projections of current mitigation scenario emissions are also required for the ex-post analysis. The emissions reduction due to the implementation of the new inspection centres is the difference between emissions from vehicles in the absence of inspection centres and with the operation of inspection centres.

#### 4.2.3.2 Uncertainties and sensitivity analysis

The ex-ante estimate of the project scenario is the most uncertain variable in the emissions reduction analysis of this vehicle fuel efficiency improvement. Apart from that, there are uncertainties in the current make-up of the fleet, leading to the use of average values. Generally, VKT or tonne/kilometres is assumed to follow historical trends under baseline and mitigation scenarios, although some methodologies address rebound effects or directly track the VKT.

#### 4.2.4 Selection of analysis tools

Various organizations have published different analysis tools to assess GHG emissions impact in vehicle efficiency improvement programmes. This section describes available methodologies, methodology selection process for the selected mitigation action and characteristics of the selected methodology. Only bottom-up methodologies were considered due to the use of disaggregated data.

##### Disaggregate emissions models

The non-spatial policy analysis tool EERPAT can analyse scenarios with combinations of effects of various policies and transportation system changes. Since it provides rapid analysis by making several simplified assumptions, it limits the detail and precision of its outputs compared with a properly set up MOVES (Motor Vehicle Emission Simulator) or similar implementation. It can be modified to accept changes in vehicle type percentages in the fleet, average fleet fuel efficiency by vehicle type, as well as the travel range of plug-in hybrid vehicles and other variables. These values are applied to the VKT data specific to a region. Table 4-6 provides more detail on the methodology.

Table 4-6 Disaggregate emissions models

Name	Application	Scope	Developer
EERPAT	Non-spatial disaggregate model	Includes emissions module	U.S. Federal Highway Administration

Source: UNFCCC 2018, *Compendium on greenhouse gas baseline and monitoring -Passenger and freight transport*

### Disaggregated bottom-up ex-post guidance

The following (Table 4-7) disaggregated bottom-up methodologies can be considered for enhancing maintenance and inspection of vehicles by introducing 14 inspection centres by 2030.

*Table 4-7 Disaggregated bottom-up ex-post methodologies*

Name	Application	Scope	Developer
MRV Methodology titled "Improvement of Fuel Efficiency for taxis in Vietnam."	Improving fuel efficiency for taxis	<ul style="list-style-type: none"> <li>• Vehicle fuel efficiency measures</li> <li>• Transit efficiency measures (higher occupancy rate/ lower non-passenger mileage)</li> </ul>	GEC/JCM
AMS-III.AA.: Transportation energy efficiency activities using retrofit technologies	Engine retrofit (replacement) with a more efficient engine	Commercial passenger transport	UNFCCC
AMS III AT: Transportation energy efficiency activities installing digital tachograph systems to commercial freight transport fleet	Installing vehicles or engine tracking and record system	Centrally owned freight or passenger fleet	UNFCCC
AMS-III.BC.: Emission reductions through improved efficiency of vehicle fleets	For specific project activities that improve the efficiency of vehicle fleets (e.g. fleets of trucks, buses, cars, taxis or motorised tricycles), resulting in reduced fuel usage and greenhouse gas emissions. The activities include installing one or more of: (a) Idling stop device; (b) Eco-drive systems; (c) Tyre-rolling resistance improvements; (d) Air-conditioning system improvements; (e) Use of low viscosity oils (f)	Centrally owned freight or passenger fleets	UNFCCC

	Aerodynamic drag reduction measures (g) Transmission improvements (h) Retrofits that improve engine efficiency		
AMS -III.AP. Transport energy efficiency activities using post-fit Idling Stop device	For specific project activities which improves energy efficiency (Reduction of fossil fuel use and corresponding emissions through energy efficiency improvements)	Vehicles used for public transportation, Vehicles using gasoline or petrol diesel as fuel, Vehicles in which it is possible to install post fit idling stop device	UNFCCC

Source: UNFCCC 2018, *Compendium on greenhouse gas baseline and monitoring -Passenger and freight transport*

### Simple bottom-up tools with mostly default data

This spreadsheet programme accepts limited local data but offers default values for emissions based on rules of thumb derived from various studies. The user must enter VKT estimates or actual fuel use.

Table 4-8 Simple bottom-up methodologies

Name	Application	Scope	Developer
CCAP Emissions Guidebook	Fuel efficiency incentives, Anti-idling campaigns, Vehicle scrappage, feebates	<ul style="list-style-type: none"> <li>Ex-ante tool</li> <li>Sketch planning estimates based on combining local data and defaults</li> </ul>	CCAP

Source: UNFCCC 2018, *Compendium on greenhouse gas baseline and monitoring -Passenger and freight transport*

#### 4.2.4.1 Selected methodology

Table 4-9 shows the comparison of applicability of bottom-up methodologies to the scope of the project activity of enhancing maintenance and inspection of vehicles.

Table 4-9 Comparison of applicability of methodologies to the proposed project activity

Methodology	Applicability of the methodology to the project activity
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EERPAT	Applicable if the rebound effects from other policies are significant because this methodology can be used for analyzing combinations of effects of various policies. However, simplifying assumptions when combining effects may limit the detail and precision of its outputs.
MRV Methodology titled "Improvement of Fuel Efficiency for taxis in Vietnam."	Not applicable because the project activity includes all types of road transport vehicles while this methodology's scope is only concentrated on taxis.
AMS-III.AA.: Transportation energy efficiency activities using retrofit technologies	Not Applicable. Engine efficiency improvement can be achieved by more maintenance procedures other than engine retrofit. Hence this methodology does not cover the full scope of the project activity.
AMS III AT: Transportation energy efficiency activities installing digital tachograph systems to commercial freight transport fleet	Not Applicable. This methodology depends on tracking system to give feedback to driver.
AMS -III.AP. Transport energy efficiency activities using post- fit Idling Stop device	Not applicable because project activity does not include post-fit idling stop device introduction.
AMS-III.BC.: Emission reductions through improved efficiency of vehicle fleets	Applicable. Improving engine efficiency of the vehicle can be achieved by engine retrofit and other methods to improve engine performance.
CCAP Emissions Guidebook	Applicable because Engine efficiency improvement is a Fuel efficiency incentive. However, this methodology is applicable only for project scenarios as it is an ex-ante tool.

As detailed in Table 4-9, AMS-III.BC.: Emissions reduction through improved efficiency of vehicle fleets methodology was selected to estimate GHG removals from the proposed mitigation project.

### Applicability

This methodology is not applicable to project activities that include:

- (a) Measures that improve the system efficiency of the fleet, for example, a change of operational procedures to improve the occupancy rate of vehicles and modal shift in transportation.
- (b) Technologies employed to improve combustion efficiency without improvements in engine efficiency.
- (c) A switch from fossil fuels to biofuels in transportation applications. However, the usage of a fixed biofuel blend is admissible if project vehicles use the same blend of biofuel as used by baseline vehicles. In the case of using biofuel blends, the biofuel share is accounted for as zero-emitting.

The considered project activity is focused on increasing vehicle fuel efficiency by enhancing maintenance and inspection of vehicles. The exhaust gas test of the inspection process determines the requirement of improving combustion efficiency by improving engine efficiency of the vehicle, and it can be achieved by engine retrofit and other measures to improve engine performance. Therefore, this methodology is applicable<sup>8</sup>.

### Baseline methodology

Baseline emissions are calculated based on a baseline emission factors (BEF) derived from the monitored specific fuel consumption of a control group of vehicles and the monitored project activity level.

The metric used for the baseline emissions is:

- (a) Emissions per tonne-km (tkm) for heavy-duty vehicles
- (b) Emissions per km for all other vehicle categories

### Baseline emissions calculation for trucks and busses:

Baseline emissions for trucks and busses are calculated by Equation 4-4. It is based on the baseline emission factor, which is determined based on monitoring the control group vehicles. The Activity Level (the total travel distance for each vehicle type) should be measured.

*Equation 4-4: Baseline emission*

$$BE_y = \sum_{i,x} BEF_{tkm,i,x,y} \times AL_{tkm,i,x,y} \times 10^{-6}$$

Where:

- $BE_y$  Baseline emissions in the year y (tCO<sub>2</sub>)
- $BEF_{tkm,i,x,y}$  Baseline emission factor per tkm of vehicle category i using fuel type x in the year y (gCO<sub>2</sub>/tkm)
- $AL_{tkm,i,x,y}$  Activity level of the project in tkm of vehicle category i using fuel type x in the year y (tkm)

Baseline emissions are the emissions from vehicles before improving engine efficiency. The baseline emission factor can be calculated by Equation 4-5.

*Equation 4-5: Baseline Emission Factor*

$$BEF_{tkm,i,x,y} = \frac{SFC_{BL,i,x,y} \times NCV_{x,y} \times EF_{CO_2,x,y}}{AW_{BL,i,x,y}}$$

Where:

- $SFC_{BL,i,x,y}$  Specific baseline fuel consumption of control group vehicle category i using fuel type x in year y (g/km)
- $NCV_{x,y}$  Net calorific value of fuel type x in year y (MJ/g)
- $EF_{CO_2,x,y}$  CO<sub>2</sub> emission factor for fuel type x in year y (gCO<sub>2</sub>/MJ)
- $AW_{BL,i,x,y}$  Average Gross Vehicle Weight (GVW) per vehicle unit of control group vehicle category i using fuel type x in the year y (tonnes)

Specific baseline fuel consumption is the fuel consumption of vehicles before improving engine efficiency for each vehicle category using each fuel type. For electric or hybrid vehicles, the emission factor is determined in accordance with the latest version of "AMS-III.C: Emissions reduction by electric and hybrid vehicles". The GVW, as per vehicle registration or the maximum technical weight specified by the vehicle manufacturer, should be used for the calculations.

**Baseline emissions calculation for all other vehicles:**

Baseline emissions for all other vehicle categories except trucks and buses are calculated by Equation 4-6 based on the baseline emission factor.

*Equation 4-6: Baseline Emission*

$$BE_y = \sum_{i,x} BEF_{km,i,x,y} \times AL_{km,i,x,y} \times 10^{-6}$$

Where:

- BE<sub>y</sub> Baseline emissions in the year y (tCO<sub>2</sub>)
- BEF<sub>km,i,x,y</sub> Baseline emission factor per km of vehicle category i using fuel type x in the year y (gCO<sub>2</sub>/km)
- AL<sub>km,i,x,y</sub> Activity level of the project in km of vehicle category i using fuel type x in the year y (km)

Baseline emissions are the emissions from vehicles before improving engine efficiency. The baseline emission factor can be calculated by Equation 4-7.

*Equation 4-7: Baseline emission factor*

$$BEF_{km,i,x,y} = (SFC_{BL,i,x,y} \times NCV_{x,y} \times EF_{CO_2,x,y})$$

### Project methodology

Project emissions are the emissions from trucks and buses after improving engine efficiency. Equation 4-8 will be used for the analysis. The Activity Level (the total travel distance for each vehicle type) should be monitored.

*Equation 4-8: Project Emissions*

$$PE_y = \sum_{i,x} PEF_{tkm,i,x,y} \times AL_{tkm,i,x,y} \times 10^{-6}$$

Where:

- PE<sub>y</sub> Project emissions in the year y (tCO<sub>2</sub>)
- PEF<sub>tkm,i,x,y</sub> Project emission factor per tkm of vehicle category i using fuel type x in the year y (gCO<sub>2</sub>/tkm)

Project emission factor for trucks and buses can be calculated by Equation 4-9.

*Equation 4-9: Project emission factor*

$$PEF_{tkm,i,x,y} = \frac{SFC_{PJ,i,x,y} \times NCV_{x,y} \times EF_{CO_2,x,y}}{AW_{PJ,i,x,y}}$$

Where:

$SFC_{PJ,i,x,y}$  Specific project fuel consumption of project group vehicle category  $i$  using fuel type  $x$  in year  $y$  (g/km)

$AW_{PJ,i,x,y}$  Average GVW per vehicle unit of project group vehicle category  $i$  using fuel type  $x$  in the year  $y$  (tonnes)

The Specific project Fuel Consumption ( $SFC_{PJ,i,x,y}$ ) of busses and trucks after improving engine efficiency have to be monitored (km/l), and the annual  $SFC_{PJ,i,x,y}$  can be calculated in g/km using the fuel densities provided in Energy Statistics by Economic Research Institute for ASEAN and East Asia (ERIA).

Project emission for all other vehicles can be calculated by Equation 4-10.

*Equation 4-10: Project Emissions*

$$PE_y = \sum_{i,x} PEF_{km,i,x,y} \times AL_{km.i.x.y} \times 10^{-6}$$

Where:

$PEF_{km,i,x,y}$  Project emission factor per km of vehicle category  $i$  using fuel type  $x$  in the year  $y$  (gCO<sub>2</sub>/tkm)

Project emissions are the emissions from other vehicles after improving engine efficiency. Project Emission Factor for other vehicles can be calculated by Equation 4-11.

*Equation 4-11: Project Emission Factor*

$$PEF_{km,i,x,y} = (SFC_{PJ,i,x,y} \times NCV_{x,y} \times EF_{CO_2,x,y})$$

The Specific project Fuel Consumption ( $SFC_{PJ,i,x,y}$ ) of other vehicles except busses and trucks has to be monitored (km/l), and the annual  $SFC_{PJ,i,x,y}$  can be calculated in g/km using the fuel densities provided in Energy Statistics by Economic Research Institute for ASEAN and East Asia (ERIA).

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