COMPENDIUM ON GREENHOUSE GAS BASELINES AND MONITORING

PASSENGER AND FREIGHT TRANSPORT

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GLOSSARY

Activity data	A quantitative measure of a level of economic activity that results in greenhouse gas (GHG) emissions. Activity data are multiplied by an emission factor to estimate the GHG emissions associated with a process or an operation
Additionality	A criterion of the clean development mechanism that asks if the projects or programme might occur without the financial input from emission credits
Base year	A specific year of historical data against which emissions are compared over time
Baseline scenario	Baseline scenarios are projections of GHG emissions and their key drivers as they might evolve in a future in which no explicit actions are taken to reduce GHG emissions
Baseline scenario assumption	A quantitative value that defines how an emissions driver in a baseline scenario is most likely to change over a defined future time period
'Business as usual' (BAU) scenario	A reference case that represents future events or conditions most likely to occur as a result of implemented and adopted policies and actions. Sometimes used as an alternative term to "baseline scenario" (see volume 1)
CO_2 equivalent (CO_2 eq)	The universal unit of measurement to indicate the global warming potential (GWP) of each GHG, expressed in terms of the GWP of 1 unit of CO_2. It is used to evaluate releasing (or avoiding releasing) different GHGs against a common basis
Cross-price elasticity of demand	A policy of the responsiveness of the quantity demanded for a good to a change in the price of another good, ceteris paribus. The cross-price elasticity is used to estimate the indirect impact, or the gross effect of a fuel price increase on transport demand in alternative modes. It is the percentage change of a good's demand
Cumulative emissions	Sum of annual emissions over a defined time period
Double counting	Occurs when the same transferable emissions unit is counted toward the mitigation goal of more than one jurisdiction or action. Double counting includes double claiming, double selling and double issuance of units
Dynamic baseline scenario	Baseline scenario that is recalculated based on changes in emissions drivers

Emissions driver	Socioeconomic or other conditions or other policies/actions that influence the level of emissions or removals. For example, economic growth is a driver of increased energy consumption. Drivers that affect emission activities are divided into two types: policies or actions and non-policy drivers
Emission factor	A carbon intensity factor that converts activity data into GHG emissions data, usually given in grams of carbon dioxide equivalent per kilometre (g CO_2 eq/km)
Emission reduction	Reduction in GHG emissions relative to a base year or baseline scenario
Ex-ante	Analysis that is done before an intervention is made
Ex-post	Analysis that is done after an intervention is made
Greenhouse gas (GHG)	Gases that trap heat in the atmosphere, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluorinated gases
Inventory	An analysis of the quantity of emissions that occurred over a given period of time in the past, broken down by sources
Leakage	Increase in emissions outside of the boundary of a mitigation action that results as a consequence of mitigation actions, such as policies, actions and projects, implemented to meet the goal
Mitigation action	A policy, programme, project or measure that is expected to reduce GHG emissions if it is implemented. A mitigation action is an intervention
Mitigation scenario	A mitigation scenario presents future emissions with the assumption of the introduction of certain policies and measures targeting GHG emission reductions
Mode	The method of travel, usually the type of transport system that is used
Model	A framework used to represent the operation and/or the characteristics and/or the reactions of a more complex (natural, engineering or socioeconomic) process
Non-motorized transport (NMT)	Own-price elasticity is used to estimate the direct impact or the net effect of a fuel price increase on fuel demand. It is the percentage change of a good's demand divided by the percentage change of that good's price
Own-price elasticity of demand	Transport modes that require no energy source other than human effort. Usually walking or human-powered vehicles
Parameter	A variable that is part of an equation (here) used to estimate emissions. For example, "emissions per litre of petrol" and "litres of petrol" are both parameters in the equation "2.34 kg CO_2eq/l of petrol × 100 litres = 234 kg CO_2eq"
Person kilometres (or passenger kilometres) (PKM)	Distance travelled by a person or passenger multiplied by the number of persons or passengers
Policy	A set of formally described, adopted or planned legal actions, rules, guidelines to be followed and/or enforced by a government or authority. A policy typically includes its area and date of validity, its implementing organizations, and its objectives
Projection	An estimation of the evolution of certain parameters, indicators, variables (e.g. fuel cost, population, etc.) based on a set of assumptions and optionally a model (depending on the approach chosen)

Reference year	A year against which commitments are made and measured, typically in the form of emission abatement. Most frequently it is a year in the past, for example 1990 for the Annex I Parties' commitments under the Kyoto Protocol, but in some cases it is a future year. Occasionally it can be set as an average of a period of years (as is the case of the base year for some countries with economies in transition under the Kyoto Protocol)
Scenario	The description of several key variables in a possible state of the future. Scenarios are used when the total number of possible combinations of variable states is too great to analyse efficiently. A scenario has to be plausible in the sense that under certain assumptions it can occur and should contain consistent and coherent outcomes. A scenario is not a probabilistic forecast but a deterministic description of a situation whose actual probability is not completely known
Sensitivity analysis	A method to understand differences resulting from changes in methodological choices and assumptions and to explore model sensitivities to inputs. The method involves varying the parameters to understand the sensitivity of the overall results to changes in those parameters
Static baseline	Static baselines use a given year or the average of several years as a reference value. A static baseline can also be defined as a reference level using an estimation which is not based on a reference year or the average of years, but which remains fixed throughout all monitoring years and is not recalculated
Transit oriented development (TOD)	Mixed use residential and commercial urban development centred around access to public transport
Uncertainty	A general term that refers to the lack of certainty in data and methodology choices, such as the application of non-representative factors or methods, incomplete data on sources and sinks, or lack of transparency. It can also be a measurement that characterizes the dispersion of values that could reasonably be attributed to a parameter
Vehicle kilometres travelled (VKT)	Distance travelled by a vehicle multiplied by number of vehicles
Tonne kilometres (TKM)	Distance travelled by a tonne of freight multiplied by number of tonnes

ABBREVIATIONS

ASIF	activity, share, intensity, fuel
BAU	‘business as usual’
BRT	bus rapid transit
CDM	clean development mechanism
FE	fuel economy
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GHG	greenhouse gas
MRV	measurement, reporting and verification
MYC	MobiliseYourCity
NAMA	nationally appropriate mitigation action
NMT	non-motorized transport
OECD	Organisation for Economic Co-operation and Development
PKM	person kilometres (or passenger kilometres)
SLoCaT	Partnership on Sustainable Low Carbon Transport
SUMP	Sustainable Urban Mobility Plan
TKM	tonne kilometres
TOD	transit-oriented development
UNFCCC	United Nations Framework Convention on Climate Change
VKT	vehicle kilometres travelled

INTRODUCTION

Transport-related emissions are growing worldwide. Transport currently accounts for about 28 per cent of total end-use energy. Greenhouse gas (GHG) emissions from the transport sector have more than doubled since 1970, and have increased at a faster rate than any other energy end-use sector to reach 7.0 gigatonnes of carbon dioxide equivalent (Gt CO_2 eq) in 2010. The Intergovernmental Panel on Climate Change has found that without mitigation actions, transport emissions could increase at a faster rate than emissions from the other energy end-use sectors and reach around 12 Gt CO_2 eq/year by 2050 (Sims et al., 2014).

Much of this growth will come from transport demand per capita in developing and emerging economies, which is expected to increase at a much faster rate in the next decades due to rising incomes and development of infrastructure. Two thirds of the growth in light-duty vehicle ownership, which is expected to double in the next few decades, will be in countries that are not members of the Organisation for Economic Co-operation and Development (OECD). In OECD countries vehicle kilometres travelled (VKT) per capita has tended to stabilize, but freight and air passenger transport has continued to increase. Also for freight transport, economic globalization has increased the volume and distance of movement of goods and materials worldwide. If no additional measures are taken, CO_2 emissions from global freight alone could increase by 160 per cent, as international freight volumes grow threefold by 2050, largely owing to increased use of road transport, especially for short distances and in regions that lack rail links, such as South-East Asia (OECD/ITF, 2017).

However, decoupling of transport GHG emissions from economic growth may be possible. GHG emissions from passenger and freight transport can be reduced by a range of both technological and behavioural mitigation actions. Since rebound effects can reduce the CO_2 benefits of purely technological efficiency improvements, a balanced package of actions has the best chance of achieving maximum mitigation effects. Broadly, mitigation actions fall into four categories:

- **Avoiding** journeys where possible – achieved by actions such as changing urban form, improving freight logistics systems, substituting information and communication technologies (ICT) for travel, etc.;
- Modal **shift** to lower-carbon systems – achieved mainly by increasing investment in public transport, walking and cycling infrastructure;
- **Improving** the energy intensity of travel per passenger kilometre or ton kilometre – by improving vehicle and engine performance, or overall transport system performance;
- **Reducing** carbon intensity of **fuels** by replacing oil-based fossil fuels with natural gas, biomethane or biofuels, or electricity or hydrogen produced from renewable energy sources.

The development of effective transport climate strategies to implement appropriate and cost-effective mitigation actions rests upon the availability of comprehensive data and the application of sound assessment methods for emission reduction potentials. Unfortunately, many countries lack comprehensive transport emission inventories and mitigation scenario analysis to inform sound climate action planning. One effort to build capacity in this area is the development of the Compendium on GHG Baselines and Monitoring (hereinafter referred to as the compendium).

This passenger and freight transport volume of the compendium was coordinated by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) in cooperation with the UNFCCC secretariat, with funding from the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety and written with the assistance of the Center for Clean Air Policy (CCAP).

Table 1

Characteristics of mitigation actions

Scale	ASIF lever	Mode
Project level City-regional level National	Travel activity Mode shift Energy intensity Fuel type	Non-motorized Transit/ bus/ trolley/etc. Private vehicle Freight

The methodologies presented in this volume were chosen with a view to covering a broad range of different mitigation action types in terms of scale, type of intervention and affected modes. In addition, focus was put on interventions with significant mitigation potential. The selection was based on the Partnership on Sustainable Low Carbon Transport review of transport methodologies and tools[1] and categorized by type of mitigation action.

The mitigation actions are loosely grouped based on their geographic scale, mechanism within an 'activity, share, intensity, fuel' (ASIF) model and the affected modes as outlined above.

The remainder of this volume starts with an overview of approaches on GHG quantification in the transport sector, followed by a reader guide to the mitigation action sections. The main content is divided into eight mitigation action chapters:

- **Chapter 1: Mass transit investments**: This chapter covers regional or local projects and programmes of investment aimed at shifting travel to public transit modes.
- **Chapter 2: Comprehensive urban transport programmes and plans**: This chapter covers regional or local programmes of planning/investment/policy to reduce motorized VKT (activity or mode change).
- **Chapter 3: Vehicle efficiency improvement programmes**: This chapter covers national/regional level economic/regulatory tools to affect intensity/fuel type of passenger transport and freight modes.
- **Chapter 4: Alternative fuels incentives, regulation and production**: This chapter covers national or regional economic or regulatory policies to affect fuel type for road transport modes.
- **Chapter 5: Inter-urban rail infrastructure:** This chapter covers national or regional investments aimed at mode shifting passenger and/or freight trips to rail.
- **Chapter 6: Shift mode of freight transport from road to rail or water:** This chapter covers national or regional investment projects or programmes to shift freight movement from truck to rail or water.
- **Chapter 7: National fuel economy standard:** This chapter covers national regulations to reduce carbon intensity of passenger and/or freight vehicles.
- **Chapter 8: Fuel pricing policies:** This chapter covers economic and fiscal policies, at the national or regional level, affecting cost of transport fuels with the aim of shifting road transport towards lower carbon intensity transport modes.

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[1] <http://slocat.net/sites/default/files/u10/transport_ghg_methodologies_and_tools_-_2017-05-05.xlsx>

OVERVIEW OF THE SECTOR

APPROACHES TO ESTIMATING TRANSPORT EMISSIONS

Each human decision that causes a person or piece of freight to travel from an origin to a destination creates a trip. While many trips are made by walking or other non-motorized means, millions of trips are made every day using vehicles powered by combusting hydrocarbons. Each of these trips produces an amount of GHG emissions, depending upon the type of vehicle and other characteristics of the trip and energy source or fuel type used.

It is not practical to collect data on the specific characteristics of every trip made every day in order to calculate the GHG emissions produced. Instead, two simplified methods are used to estimate actual or future emissions:

- Top-down approach
- Bottom-up approach

The following sections will provide the general approach for both methods, irrespective of the individual mitigation action.

Box 1

Example of variation in trips

A person in Delhi who rides a motorcycle with a 50 cc engine for 5 km travelling an average of 30 km/hour might produce 280 g CO_2 eq for that trip. Another person, in Dallas, who drives 20 miles in a pickup truck with a 6.4 litre engine going 120 km/hour might produce 7,800 g CO_2 eq during that trip. The next day the person in Delhi could make the same trip, but he races another motorcycle for two minutes then stops to contemplate an advertisement for new cars while revving the engine. That same day the Dallas truck driver makes the same trip but she patronizes a drive-through coffee shop, and then gets stuck in traffic congestion. In both cases the greenhouse gas emissions for that person's second trip will be different. Finally, imagine that the Dallas pickup truck driver takes three passengers on the same route. The emissions for the vehicle trip could be still be 7,800 g but the emissions for each person trip will be 1,950 g. This suggests that actions for reducing the emissions of an individual's trip can be targeted at different levels.

Top-down approach

One way to estimate transport GHG emissions is to do what is called a top-down estimate. For example, it is often possible to obtain aggregate data on the amount of motor fuel or energy that is produced for and purchased by users in a region. This quantity can be used to represent the sum, or aggregate, of all the individual trips made, but it may also include non-transport uses (generators, off-road equipment, construction machinery, etc.) and/or miss alternative fuels such as electricity. This fuel volume is the **first variable** of the emissions equation.

A second variable is then needed – the GHG emission factor (emissions per unit of the **first variable**). With these data a simplified equation for GHG emissions would then be:

Total fuel volume * GHG/unit volume = Total GHG

An aggregated variable represents the sum of many different subvariables. In this simplified example a single GHG/unit volume emission factor represents a weighted average of values for different fuels. Real fuel sales data would be disaggregated into fuel types, resulting in the following equation:

$$\sum_{i=1}^{n} F_i * E_i = Total\ GHG$$

Where:

- ***n*** is the total number of fuel types sold
- ***i*** is the type of fuel
- ***F*** is the volume of fuel type *i* sold
- ***E*** is the emission factor (GHG/unit volume) of fuel type *i*

Emission factors could also be disaggregated by gases, that is, carbon dioxide, methane, nitrous oxide, etc., leading to even more accurate and complex equations. While using aggregate values may obscure important differences in specific mitigation actions, the potential for increased accuracy through disaggregation must be balanced against the data collection and calculation complexity and cost.

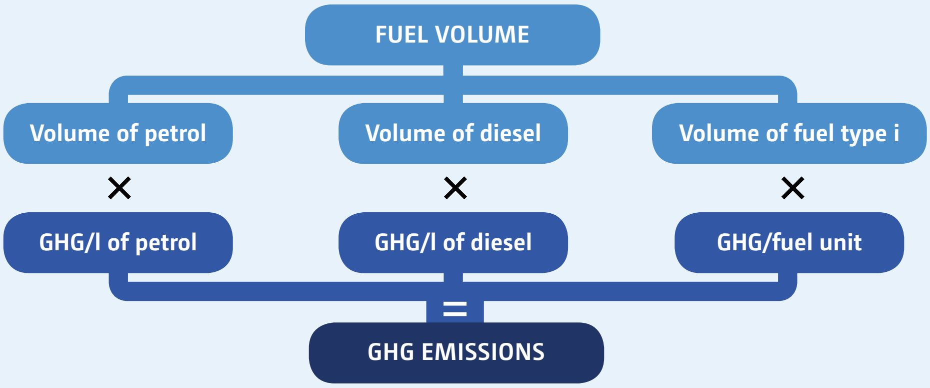
Such a top-down analysis can show whether GHG emissions are increasing or decreasing in the sector as a whole, but the changes cannot be attributed to any cause not represented in the driver variables. In order to trace the cause and effect of many types of intervention, the GHG production process must 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.

Bottom-up approach

As mentioned above, individual person trips (or freight trips per unit weight) using motor vehicles are the basic unit of travel that ultimately leads to fuel volume and

Figure 1

Top-down model of GHG generation from transport



GHGs emission values. The number of trips, the length of the trip, the mode of the trip the vehicle occupancy, and the fuel efficiency of the vehicle are the basic components of a bottom-up model, applied in multiple steps. A component variable can be disaggregated at any level. However, in the causal chain of a bottom-up model, once a variable is disaggregated, it is used in the next step and the resulting intermediate variable can be disaggregated again, leading to a complex tree of individual variables. For example, if trips are disaggregated into private car, bus and tram modes, and each mode is disaggregated into electric, petrol and diesel fuels, then data for nine new variables must be tracked. Some methodologies will avoid this issue by working with disaggregated intermediate variables, for example person kilometres (PKM) or VKT values. This can simplify calculations, but it is important to know how the intermediate variables were obtained.

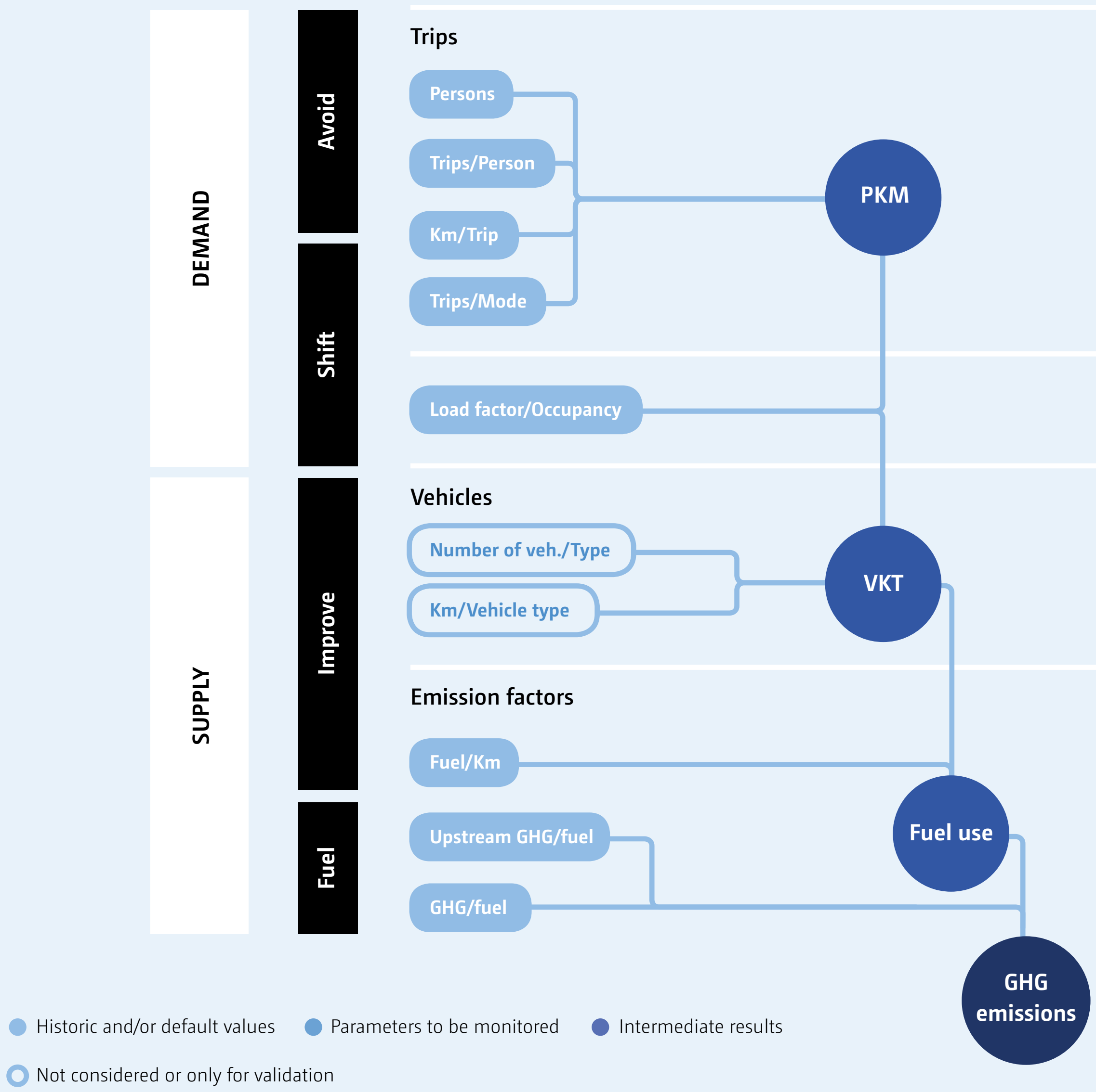


Figure 2

Bottom-up model of greenhouse gas generation from transport

Because every trip is a human decision, the intermediate steps through which a trip results in GHG emissions may vary. This primarily occurs in the choice of destination and choice of mode[2]. Sophisticated travel demand models, discussed below, attempt to sort out these possibilities in the trip making process. For purposes of this document, a typical model of trip making, shown in figure 2, will be considered. The figure shows a schematic representation of a bottom-up model in which persons generate trips, trips generate PKM leading to VKT and finally to fuel consumed. The model for freight is slightly different, and discussed in figure 19.

The ASIF model

This bottom-up model, which, as its final step again includes converting the quantity of fuel consumed into the amount of GHG emissions, can be designated using the short acronym "ASIF" (OECD/IEA, 2000). This is based upon the following scheme:

- Variables that lead to PKM/tonne kilometres (TKM) are grouped and called Activity;
- The variables that lead to VKT by mode are called mode Share (sometimes structure);
- Fuel efficiency variables that lead to fuel use values are called Intensity;
- Emission factor variables leading to GHG emission values are called Fuel mix.

This leads to the following equation:

$$A * S_i * I_i * F_{i,j} = Total\ GHG$$

Where:

- ***A*** is total transport activity (in PKM)
- ***S*** is share of PKM by mode *i*
- ***I*** is fuel efficiency by mode *i*
- ***F*** is emissions per unit of fuel by mode and type of fuel *i,j*
- ***i*** is mode
- ***j*** is type of fuel

The potential for disaggregation of variables, and the resulting complexity, is greater in the bottom-up model than in the top-down model. Multiple modes with different fuel intensities and fuel types can lead to a profusion of disaggregated variables that are difficult to track and for which data may be unreliable; however, this is balanced by the potential for a much more accurate basis for effective decision-making. Travel demand models actually disaggregate first at the activity level (A above), by geography of origin and destination and trip purpose, leading to multiple values for trip length and a level of complexity that requires specialized computer software to track the variables through the equation.

Interventions (mitigation actions) aimed at reducing GHG emissions from transport can also take a wide variety of forms, ranging from improving the technology of vehicles and fuels to economic policies that make it more costly to drive a car. An easy way to organize this universe of mitigation actions is to put them into the categories of "Avoid, Shift, Improve and Fuel(switch)." These categories roughly map to the ASIF variables as follows. Interventions that are expected to reduce the amount of person or TKM, by affecting the trips/person rate or the km/trip rate are classified as actions that Avoid trip kilometres. Interventions that are expected to affect the trips/mode (mode share) or the persons or tonnes/vehicle (occupancy) are said to Shift trips to more efficient modes or loading. Interventions that affect fuel/km (fuel efficiency) are said to Improve vehicle technology. Interventions that have an effect on the carbon content of the energy carrier are said to switch the Fuel.

Life cycle emissions

Even the bottom-up model outlined above does not fully represent the complexity of emissions in the transport sector. There is a large industrial enterprise devoted to the manufacture and operation of transport fuels, vehicles and infrastructure systems and upstream emissions have been estimated at between 18 and 43 per cent of direct GHG emissions (ICF Consulting, 2006). Figure 3 shows the relationship of the upstream and downstream emissions of these aspects. Generally transport mitigation efforts focus on the column labelled activity/operation, since

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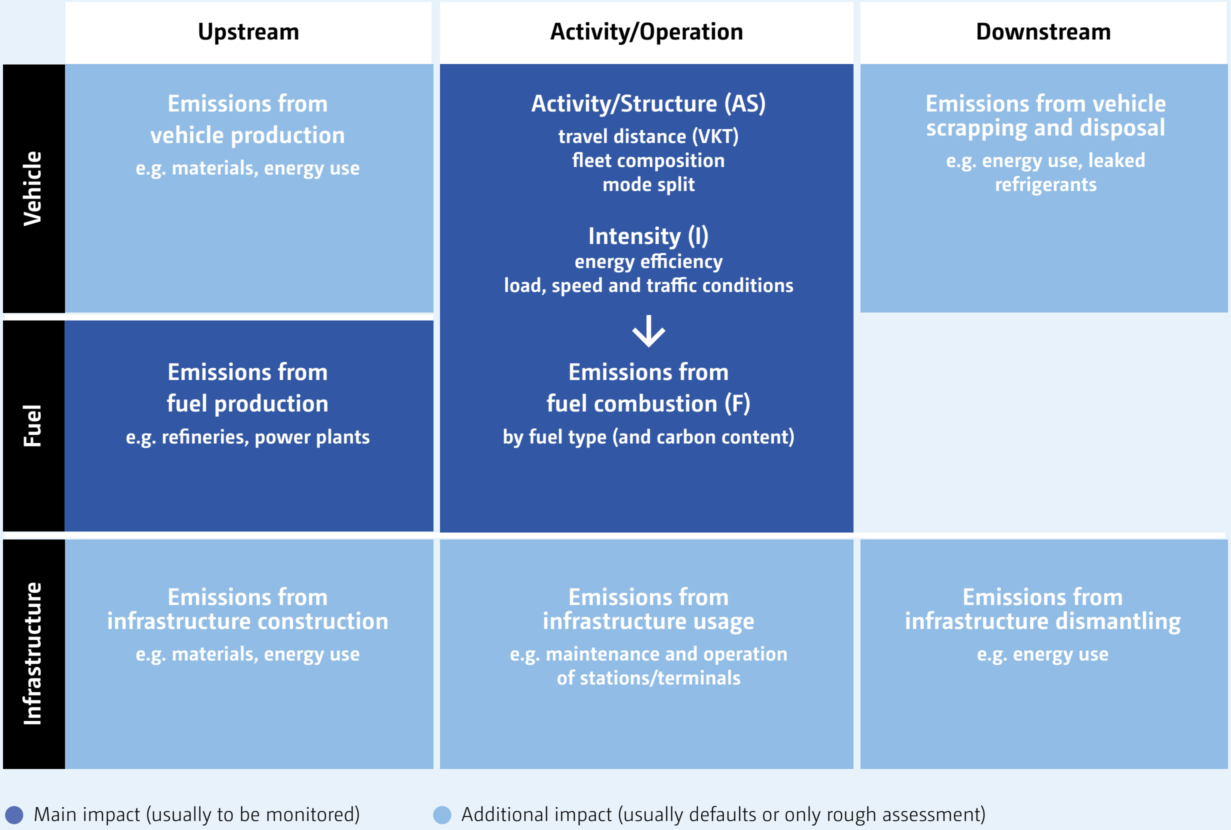
[2] For example, a person may decide to ride a bicycle to get a cup of coffee before deciding which coffee shop to patronize. Someone with a choice of car, non-motorized transport and public transport may choose a coffee shop based on preference for its coffee, and then decide which mode to use. Choices will depend on individual preferences as well as the cost or utility of available choices.

Figure 3

Mapping life cycle GHG emissions in the transport sector



	Upstream	Activity/Operation	Downstream
Vehicle	Emissions from vehicle production e.g. materials, energy use	Activity/Structure (AS) travel distance (VKT) fleet composition mode split Intensity (I) energy efficiency load, speed and traffic conditions ↓ Emissions from fuel combustion (F) by fuel type (and carbon content)	Emissions from vehicle scrapping and disposal e.g. energy use, leaked refrigerants
Fuel	Emissions from fuel production e.g. refineries, power plants		
Infrastructure	Emissions from infrastructure construction e.g. materials, energy use	Emissions from infrastructure usage e.g. maintenance and operation of stations/terminals	Emissions from infrastructure dismantling e.g. energy use

● Main impact (usually to be monitored)

● Additional impact (usually defaults or only rough assessment)

these generate the bulk of total emissions. Various aspects of upstream emissions must be incorporated into both the baseline and the mitigation scenario when circumstances require it. The upstream emissions of fuel production often need to be considered, especially when the substitution of electricity or biofuels for fossil fuels is being considered as part of mitigation measures. Upstream and downstream vehicle emissions from production and scrapping may play a role if mitigation measures reduce the lifetime of vehicles. As the graphic also shows, maintenance and operations of infrastructure can also have an impact on emissions. Roads and highways require large vehicle fleets to police, clear and maintain them, transit stations require heating and cooling and maintenance facilities to keep buses and trains working. Depending on the mitigation action being analysed and the level and purpose of analysis, these emissions may need to be estimated and included as well.

Leakage

Leakage occurs when mitigation actions have an effect outside the system boundary in such a way that it undermines the intended positive effect of the mitigation action, for example if ‘fuel tourism’ increases across borders when one country increases fuel prices, or if old, inefficient cars are sold to another country after import is restricted. Another example of leakage could be a shift to an unregulated mode in order to evade the effects of a mitigation action. The possible magnitude of leakage should be considered when determining whether to include it in an analysis.

Rebound effects

Rebound effects are mechanisms that result in increases in emissions caused by a mitigation action. An example for transportation is growth in total trips induced by the in-

Box 2

Reference document on Measurement, Reporting and Verification in the Transport Sector

The reference document provides guidance on how to develop comprehensive and consistent national systems for monitoring transport-related emissions, including monitoring or measurement, reporting and verification (MRV) of transport nationally appropriate mitigation actions (NAMAs). The document builds on existing knowledge and lessons learned in ongoing NAMA activities and experiences in greenhouse gas (GHG) emissions quantification in the transport sector in developed and developing countries. By summarizing the existing state of the art in one publication, the reference document presents decision makers in charge of building up national monitoring systems with a concise source of information.

Available at:
<http://transport-namas.org/wp-content/uploads/2014/10/Reference-Document_Transport-MRV_final.pdf>

Bottom-Up GHG Inventory and MRV of Measures: Synergies and Limitations in the Transport Sector

This report discusses the ways that data and variables from a bottom-up national GHG inventory can help to simplify MRV of mitigation measures. Depending upon the type of mitigation measure and the scale and level of disaggregation of data, it may be possible to reduce MRV costs and harmonize results. In other cases, desired levels of accuracy and local differences in statistics make it risky to try to use national inventory data. The document provides useful advice and examples regarding when and how to take advantage of synergies.

Available at
<http://transport-namas.org/wp-content/uploads/2017/05/Transport-GHG-Inventory-and-MRV-of->

creased capacity, reduced costs, for example due to higher vehicle efficiency leading to lower fuel consumption, or other supply-side changes such as a new transit line.

DETERMINING THE BASELINE AND CALCULATING EMISSIONS

Purpose of analysis

Estimating the GHG emissions of the transport sector is done at varying stages of planning or policy analysis and for a variety of purposes, and each imposes different requirements and constraints. Before implementing any actions, transport planners and climate change policymakers need to prioritize available policies and strategies, understand the potential effectiveness of options and decide on appropriate measures. They face a multitude of challenges to deliver the right kind of transport at the right place and time, at affordable prices and with minimum damage to the population's health and safety and the environment. As they proceed with selected options, the mitigation planning stage requires them to realistically balance environmental and development goals and objectives with funding and implementation capacity. Reliable methodologies for projecting future results will give them confidence that they can provide high-quality sustainable transport and meet national and international low-carbon development objectives.

After implementing mitigation actions, transport planners and climate change policymakers want to know how well they have accomplished their goals. They need to understand the results of actions taken and reliably report this to other interested parties. While simply demonstrating reductions may be sufficient for some reporting purposes, methodologies should give confidence that the reductions are a result of the actions taken. This is most important in emissions trading or crediting schemes, such as the clean development mechanism (CDM). Under trading or crediting, money is exchanged for each tonne of GHG emissions reduced; usually the buyer and seller are in different countries. A methodology for CDM-type schemes needs to not only rigorously measure the amount of emission reductions after an action, but clearly document a causal link between the reduction and the action.

Thus we can list four general purposes for which GHG reduction analyses are done:

1. Prioritizing policies
2. Mitigation planning
3. Reporting results
4. Emissions trading

These are used as the framework throughout this volume for navigating the range of available methodologies and selecting appropriate tools for analysis.

Baseline setting

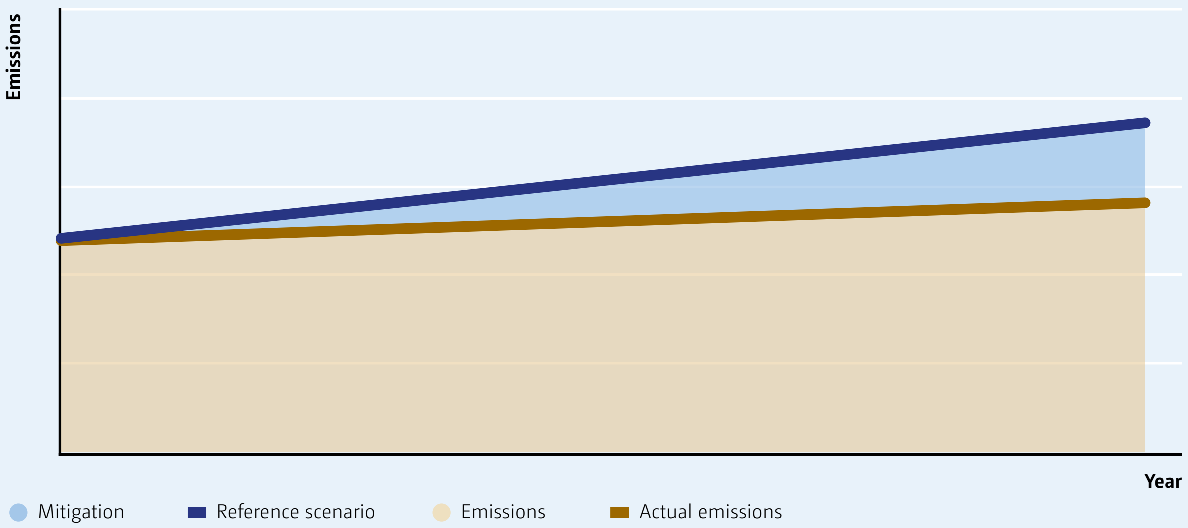
Analysis can be done to determine current or past emissions based on real measured data. Analysis can also be used to project future emissions under circumstances that may happen with the intervention, or without intervention, which is often called baseline or 'business as usual' (BAU)[3]. Analysis can also project past emissions under circumstances that would have happened without the intervention (called counterfactual baseline). When an analysis is done to support a particular action it can be done before the intervention takes place (ex-ante). It should also be done after the intervention has taken place or during an extended intervention (ex-post).

The Latin terms ex-post (short for ex-postfacto, or after the fact) and ex-ante (before the fact) are often used in economics or law to describe whether a result is showing actual past data or is a prediction of the future. In the case of GHG policy analysis we often bend that definition slightly to say ex-ante means before the intervention being implemented and ex-post means after the intervention (this can also include analysis done during the implementation phase). Baseline or BAU means a projection of a future year assuming no intervention is implemented and counterfactual baseline means a projection of what would have happened in the past without the intervention, but based on historical drivers other than the mitigation action.

A dynamic baseline is a counterfactual projection of one or more variables that looks for any changes that might have occurred over time in the absence of the mitigation action and accounts for changes in emissions drivers that have occurred since the ex-ante baseline was calculated, for example, different gross domestic product (GDP) growth rates than were assumed ex-ante. It can be difficult to untangle these changes from those that occurred after the mitigation action but the result is a more accurate form of baseline.

Figure 4

Mitigation outcome of an action



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[3] The terms baseline and 'business as usual' (BAU) scenario can be used as synonyms.

Approaches to determining the emission reduction

Determining the reduction expected or caused by a mitigation action usually requires comparing the mitigation action scenario with an estimation of either future BAU emissions or present emissions under a counterfactual BAU scenario. The reduction (mitigation) is the difference between the emissions of the with-mitigation scenario and the emissions of the no-mitigation (BAU) scenario (see figure 4). In the ex-ante situation both of these are future projections starting from the current emissions. In the ex-post situation the with-mitigation scenario becomes the new 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, for example, real values of economic and population growth.

Calculating actual emissions is a challenge of data collection and estimation, that is, having reliable locally collected data to feel confident in making an estimate and/or using appropriate defaults based on comparable situations. There are many established protocols for collecting and estimating data included in guidance documents, such as CDM methodologies. A possibly greater challenge is to get reliable values of variables when data cannot be collected, because they are in the future or because they are based on an imaginary counterfactual scenario. Various techniques have been developed to obtain values for variables under these circumstances.

Travel demand modelling

Travel demand models 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). They differ from non-spatial models or techniques in that they are based on geographic mapping of land uses, population, employment and transport infrastructure. Models are calibrated by entering local data from detailed travel surveys and comparing the model output to known results in the past. Then future scenario input data is added – usually future demographic and transport network information at the level of geographic zones.

The strength of this approach is that the same model is used for the with-mitigation and the BAU scenarios. Complex second- and third-level interactions such as rebound effects can be simulated that are difficult to take into account using other methodologies. High levels of disaggregation are possible because the sophisticated travel demand model software automatically passes disaggregated variables through to the next step of analysis so all cascading effects are accounted for. Although well-calibrated models are capable of good accuracy, the input data requirements are high and the basic uncertainty of projecting the future is pushed into the realm of the demographic and transport network information.

It is important to note that travel demand models, while they are powerful tools with respect to travel activity related variables in baselines/scenarios, cannot predict any vehicle technology related future developments.

Historical trends

Analysing the historical record of the trends in local variables is a common way to project future or counterfactual values. This can be as simple as drawing a line through data points, or it can involve elaborate regression analysis on multiple parameters. The main weakness of this method is that circumstances can change in the future, causing the trend to shift.

Control group methods

Another way of estimating variables for a counterfactual BAU scenario is to use a control group. In this method another local area similar to that in which the intervention 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. If the contextual characteristics of the control area are close to those of the intervention area, except for the intervention itself, this method can yield good results. The challenge is to find a suitable control group. The larger the geographic boundary (and therefore the more complex and unique), the harder it will be to use a control group approach.

Default or proxy data

Using data from another non-local area or another time period as a substitute for locally measured data is often possible. Sometimes default data can be very accurate, for example the default emission factors are based on measurement of a sample of motor vehicles that at the proper level of disaggregation is probably representative of the local fleet. Using default data to estimate the change in other variables such as trip length or mode share may not be as reliable. The place where they were measured may not have the same spatial and demographic characteristics as the local area, so the effect of the intervention is not necessarily comparable.

Survey questions

Another method for determining the travel behaviour of people is to ask them. Survey questions such as "How would you go to work if there were no train?" or "If there were a train would you use it to go to work?" can provide values for future or counterfactual variables. CDM guidance may recommend survey methods as a way to determine BAU. While surveys can be useful, there can be problems similar to those arising from using historical trends, because survey methods don't capture changes in circumstances that the respondent cannot predict or fails to consider, and because answers may not reflect what people will actually do.

Expert opinion

The judgment of knowledgeable experts can be considered a blend of historical trends and survey methods. This technique usually involves consulting and discussing with a range of experts and synthesizing their opinions. Expert opinion can be quite useful for questions involving future policy changes, such as fuel efficiency rules or freight investment strategies, but may be less reliable when applied to projections of human behaviour such as transit passenger numbers or non-motorized mode choices.

As discussed above, each type of method has strengths and weaknesses that make it suitable to be used for certain classes of interventions. In general, travel demand models were designed to predict the effects of investments in new infrastructure and are the best choice for that type of intervention. Some models are also able to simulate the effect of changes in travel price and can be used for taxes, subsidies and other such mitigation actions. Survey instruments are the second best option for these types of actions.

Mitigation actions that promote or require technological changes, such as new fuels or vehicle types, present a challenge in ex-ante estimating the penetration or uptake of the new technology. For these interventions default data from other areas, surveys or expert opinion are often useful.

It is most difficult to estimate the influence of education, incentives and regulatory actions. Historical trends from other areas may be used as a benchmark, but there is no guarantee that the subject area will behave the same way.

READER GUIDE TO THE MITIGATION ACTION SECTIONS OF THE TRANSPORT VOLUME

Each mitigation action type in this volume follows the same structure, labelled with the name of the action type. Mitigation actions are grouped into types that have similar profiles in terms of mechanisms, scope and indicator variables.

Description and characteristics of action type

First, the mitigation action type is briefly described along with key characteristics such as implementation scale, focus within the ASIF framework, and travel modes affected. The expected outcomes of successful implementation are described. The description lays out the general mechanisms through which the mitigation actions reduce GHG emissions and briefly mentions some of the non-GHG effects that could occur from those mechanisms.

Structure of mitigation effects

Cause-impact chain graphic

This section shows the possible specific activities within the mitigation action that are intended to cause GHG emissions to decrease. Each activity points to the changes it is intended to cause to one or more indicator variables. Unintended rebound effects may be shown as well. These changes flow through the transportation emissions causal chain, which leads to changes in the intermediate variables and the final result of lower GHG emissions. In this way the graphic summarizes the basic approach of each mitigation action type and the monitoring requirements that go with it. Figure 5 shows an example of the graphic.

Key variables to be monitored

The key variables that could change as a result of the mitigation action are shown in list form, followed by a brief explanation of the expected mechanism that causes them to change. This list includes variables that need to be monitored for either intended or unintended effects (e.g. rebound). It is, of course, possible that a specific mitigation action may not affect every variable. The variables are highly dependent on the specific characteristics of the mitigation action and the related mechanism of change.

Interaction factors

This section describes both specific design characteristics and external contextual factors that might affect the magnitude of GHG emission reductions from the mitigation action. For example, the land-use density in a transit corridor affects passenger numbers, and land-use density is in turn affected by land-use planning documents. Thus, the transit line passenger number forecasts are affected by interaction with land-use planning documents.

Boundary setting

This section describes the options within the various parameters that are typically used when setting the boundaries of the analysis for the mitigation action being discussed.

Key methodological issues

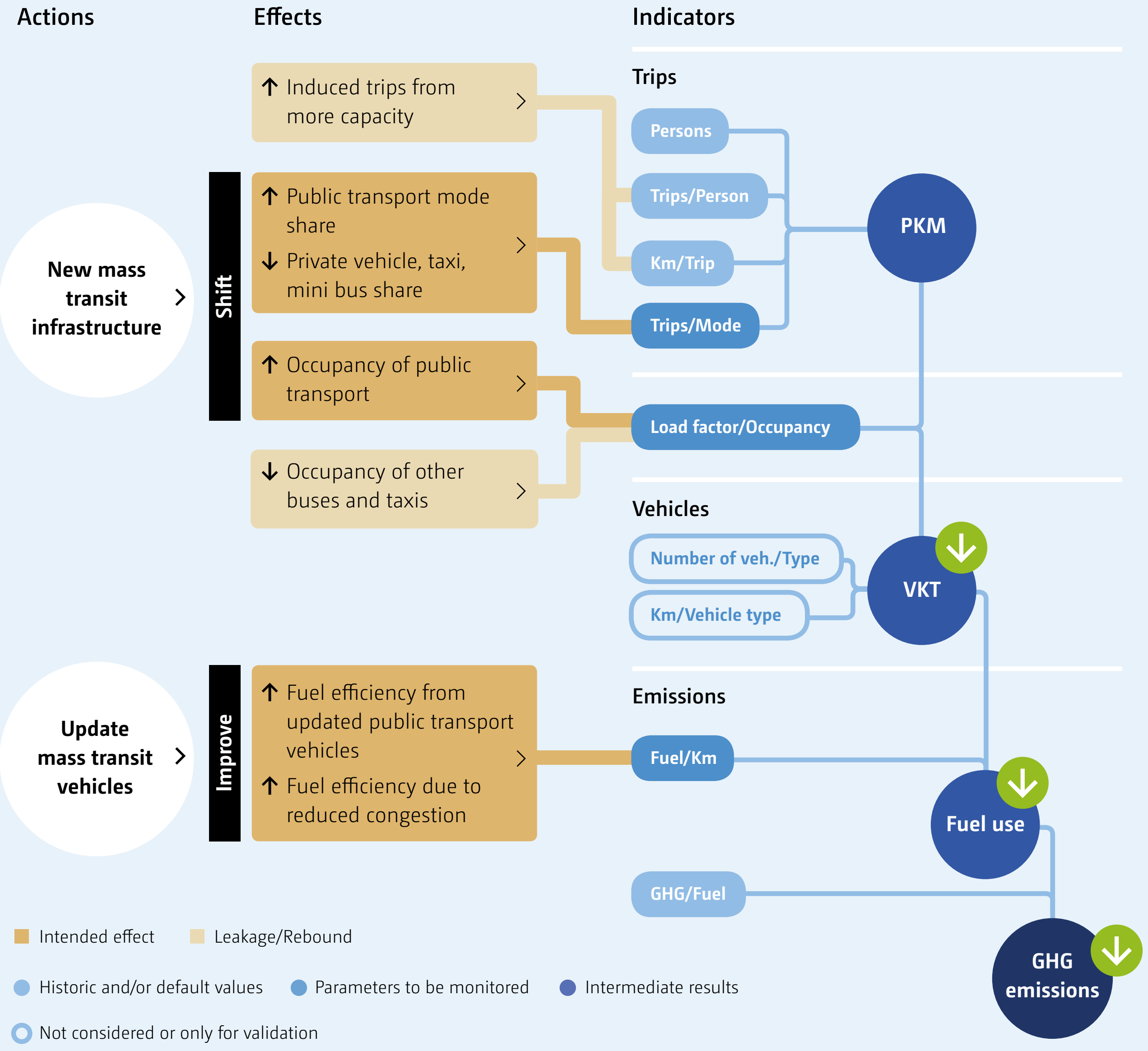
Each mitigation action type has different methodological issues based on the causal mechanism and data availability of key variables. These issues are described in this section.

Double counting concerns

Other mitigation policies and actions outside the analysis boundaries may have synergistic or interaction effects that lead to difficulty in attributing the reduction to any particular action or to counting the same values more than once for different actions. In some cases the interaction factors described above may be affected by other mitigation actions, which should be evaluated to assess the potential for the action to contribute to a broader programme of GHG emission mitigation in the transport sector. Examples include consis¬tency with a low-carbon transport plan, national policies supporting appropriate pricing of carbon, efficiency standards, etc. This section lists the most important issues.

Figure 5

Mass transit Investments causal chain



Certain indicators are coloured to show that they are to be monitored for the magnitude of change caused by the actions. Other variables are in a different colour to show that the actions are not expected to significantly affect them, and therefore it is permissible to use default or historical values in calculating the impacts.

Determining the baseline and calculating emission reductions

Analysis approach
There are often multiple options for determining the baseline and mitigation scenarios which are needed for analysing the effects of a selected mitigation action type. Some mitigation action types will require a specific analysis approach while others may be more flexible. Ex-ante and ex-post analysis usually have different needs for projections and forecasts versus collection of existing data. This section discusses the typical approaches.

Uncertainties and sensitivity analysis
This section gives an overview of which variables are least certain and discusses the level of sensitivity the final results may show owing to that uncertainty.

Guidance on the selection of analysis tools for the mitigation action type

Depending upon the mitigation action type, certain key variables may need to be highly disaggregated to achieve good accuracy in estimation while others may not. The section contains a table listing the variables specific to the mitigation action type by level of accuracy, such as the following:

- Lower accuracy: lists aggregated variables;
- Medium accuracy: lists partially disaggregated variables;
- Higher accuracy: lists highly disaggregated variables.

The navigation map is a graphic representation of the range of tools that are currently available for analysing the mitigation action type. The names of specific software tools, CDM methodology documents and other works that address GHG emission reduction analysis for the mitigation action type is superimposed upon the map of analysis purposes and accuracy levels. The navigation map should be used as a basic guide for selecting available analysis methodologies and tools based on the availability of accurate data and the objective of the analysis. The underlying categories are shown in figure 6.

The last part of the navigation section presents a fuller description of the various tools shown in the map, including a qualitative estimation of the level of effort and technical capacity required to use various types of tools, and a table summarizing further details of specific tools in each type, grouped into general categories based on the methodological approach and the navigation map.

Monitoring

Monitoring involves the collection of indicator data pertaining to the mitigation action. It is the first step in the monitoring, reporting and verification (MRV) process. Specifics of monitoring will depend on many factors, including data availability, policy commitments, donor agreements, etc. A basic three-level method of monitoring is suggested as a starting point for developing individual monitoring schemes, using implementation, performance and impact level variables. A table will present a minimum list of key variables and recommended intervals for measurement if no other requirements are present, (e.g. more frequent interval may be required for CDM).

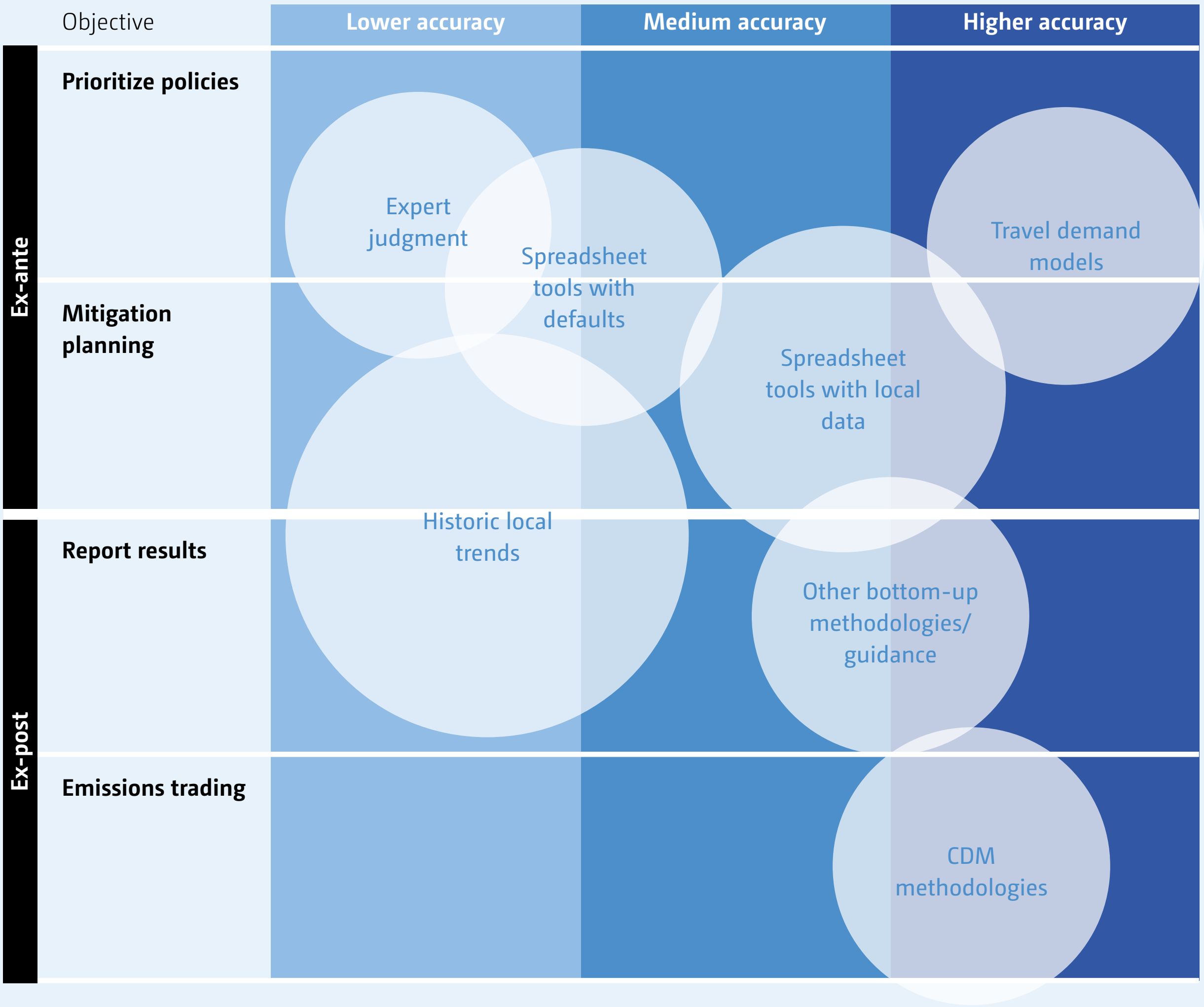
Although monitoring is only the first step of MRV, this volume does not focus on reporting or verification. Reporting structures are often agreed to with a donor or finance provider, such as a bank or nationally appropriate mitigation action (NAMA) funder. National programmes may contain monitoring arrangements included in the legislation or directive. Other circumstances may require reporting to be aligned with national reporting structures for international commitments. For verification, cross checking with fuel sales data and other national or international values and historical results can be done to provide confidence. CDM and NAMA verification may require independent third-party review. Rigorous verification can also include spot checks of data sources. In all cases, good documentation is key to verification, including transparency about assumptions used in the BAU or baseline scenario, references to sources of default data and documentation confirming that proper statistical procedures were followed (e.g. survey guidelines).

EXAMPLE

A brief synopsis and a link to further materials for a case study of an analysis of a mitigation action within the mitigation action type that is ongoing or has been completed.

Figure 6

Navigating classes of available methods and associated tools actions



Chapter 1

MASS TRANSIT INVESTMENTS

1.1 DESCRIPTION AND CHARACTERISTICS OF MASS TRANSIT INVESTMENTS

This mitigation action covers project-level investments that create or extend specific mass transit passenger transport infrastructure in a region. This includes bus rapid transit (BRT), tram, metro, cable cars, etc. These actions expand the capacity, frequency, speed and/or coverage of public transport with the goal of increasing its mode share while decreasing the mode share of less efficient modes, especially private vehicles. Secondary goals are to increase per vehicle occupancy of public transport, update the vehicles and improve traffic flow.

The outcomes of successful implementation of this mitigation action are expected to increase the mode share of public transport to reduce the VKT of private vehicles, and increase the overall efficiency of public transport, leading to reduced GHG emissions through lower overall VKT and transport energy use in the region. Mass transit investments are known to generate a number of sustainable development co-benefits, which may include access to affordable mobility, shorter travel times and fewer accidents. It can also encourage more compact urban development with increased non-motorized transport (NMT), reduced vehicle ownership and improved health outcomes owing to more opportunities to exercise and lower pollution levels.

1.2 STRUCTURE OF MITIGATION EFFECTS

1.2.1 Cause-impact chain

Mass transit investment actions should result in measurable effects that are reflected in certain indicators in bottom-up models (ASIF approach). The expected changes in those variables will effect the desired outcomes (see figure 7).

1.2.2 Key variables to be monitored

The key variables that are expected to change by mass transit investment are listed below, followed by the expected mechanism that causes them to change. A given project may not affect every variable if the appropriate mechanism of change is not present. For example, if updating to more modern transit vehicles is not part of the project, then the portion of change in vehicle occupancy and fuel consumption due to modern vehicle technology is not present. If no change from any other factor is expected (e.g. speed), then historical/default values can be used.

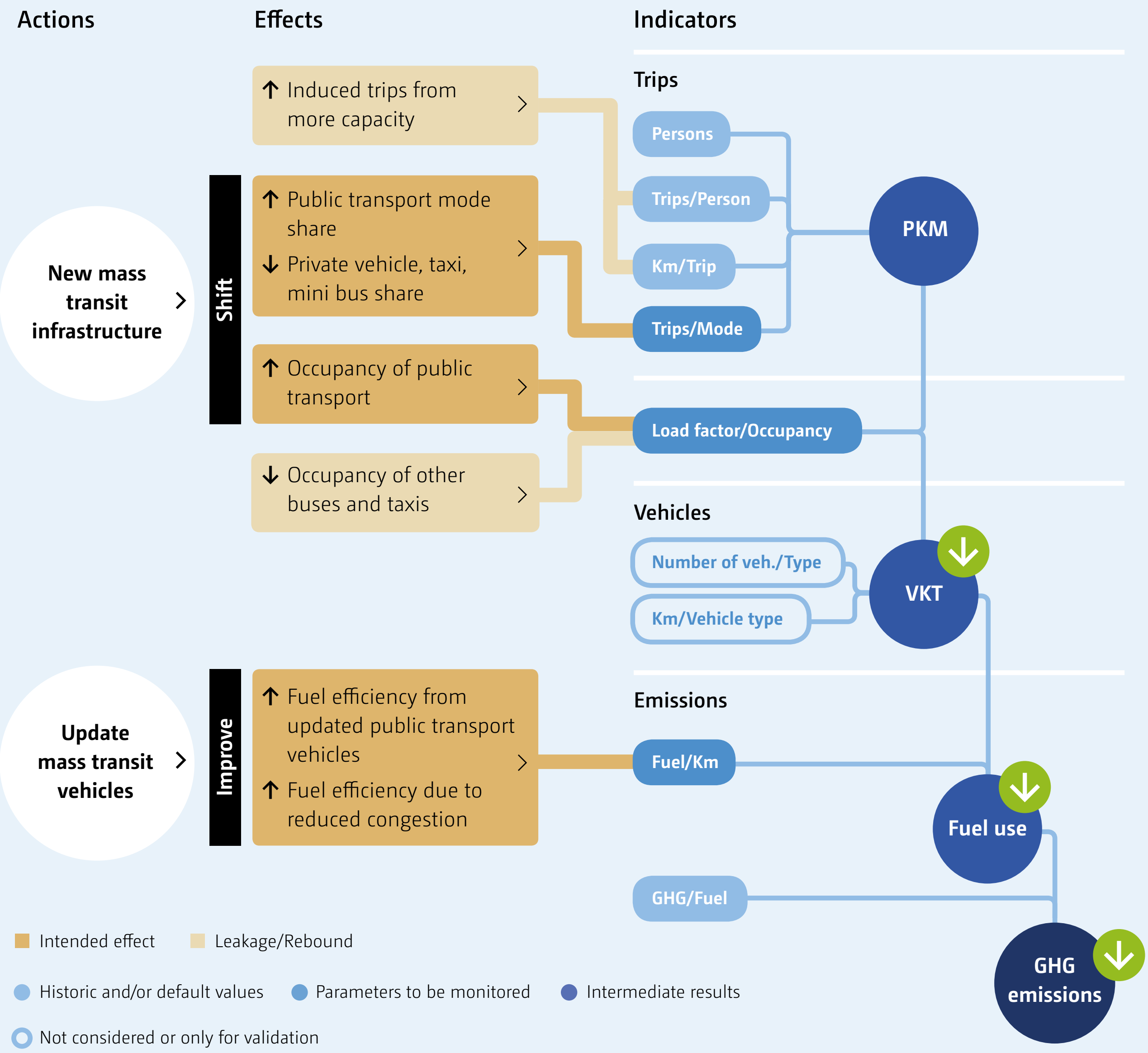
1.2.3 Monitor for intended effects

- Mode shares – new, improved transit system will attract travellers from other modes;
- Vehicle occupancy of modes – new transit vehicles will have more capacity than old vehicles and will be more utilized;
- Fuel efficiency of new vehicles – new transit vehicles will employ more efficient technology and have different fuel consumption and/or different drive technologies, including self-driving vehicles;
- Traffic speeds – congestion will decrease leading to higher average travel speeds which can affect fuel consumption of all modes.

1.2.4 May be monitored for leakage or rebound effects

- Trips – induced trips can be created by the increased total transport capacity (negative rebound effect), this could include NMT trips shifting to create new vehicle transport trips;
- Trip length – increased capacity can sometimes lead to longer trip lengths because the induced trips have more distant origins or destinations;
- Reduced occupancy of other modes – competing modes such as taxis may see reduced numbers of passengers resulting in lower occupancy.

Figure 7
Mass transit investments causal chain



1.2.5 Interaction factors

The magnitude of change in the key variables will be affected by the specific characteristics of the mass transit investment and also by other contextual factors. To achieve the best effects, the mitigation action must be tailored to the specific context in each city. Some methodologies such as travel demand models may be able to quantitatively account for certain contextual factors. For other methods a qualitative assessment using expert judgment may be needed. When performing ex-ante estimation of the mitigation potential of a mass transit action, the following factors can have a substantial impact on magnitude and should be taken into account:

- Quality (travel time, comfort, convenience, etc.) and fare structure of the new public transport lines;
- Potential for improved overall travel conditions in corridor (e.g. level of congestion);
- Land use density and diversity in corridor;
- Parking availability in corridor;
- Pedestrian and bicycle infrastructure;
- Transit-supportive land use plans (transit oriented development (TOD), parking, pedestrian access).

1.2.6 Boundary setting

New transit lines can draw passengers from within walking distance of the corridor, but also via other modes such as bicycle or park and ride from within a larger ride shed. In the longer term, new transit lines can affect the urban form of an entire city, so the boundary could be as large as the urban area. The boundary will depend upon the size of the project and on data availability; larger geographical boundaries for analysis can capture more interaction and temporal effects but will require greater data collection costs. Methodologies for urban programmatic actions may become useful if the scope of the project is quite large or includes multiple transit lines (see action type 2).

Upstream emissions from electricity generation should be included if the transit system is powered electrically. However, if the mitigation action of the project aims solely at the switch to electric energy, that is, if the mass transit line is part of the baseline and the only difference is energy source, then the analysis should consider methodologies under fuel switching (action type 4).

Large projects such as new subways may have substantial construction emissions, which should be considered as part of the life cycle emissions and factored into calculations. In this case it may be necessary to also calculate baseline construction emissions if the BAU scenario includes a large roadway or other construction projects.

Large projects such as new subways may have substantial construction emissions, which should be considered as part of the lifecycle emissions and factored into calculations. In this case it may be necessary to also calculate baseline construction emissions if the BAU scenario includes large roadway or other construction projects.

1.2.7 Key methodological issues

The GHG impact depends on the specific characteristics of the transit line and surrounding land uses, so collection of local variables becomes important. Variables pertaining to the operational characteristics of the old and the new line such as length, current passenger numbers and fuel use of transit vehicles, are usually known or can be obtained

Table 2

Dimensions of boundary setting for mass transit investment mitigation actions

Dimension	Options for boundary setting
Geographical	Corridor, ride shed, urban area
Temporal	10 – 50 years
Upstream/downstream	Energy sector (electricity, biofuels), may also consider infrastructure construction
Transport subsector	Passenger transport, public transit
Emissions gases	CO_2 eq (may include CH_4, N_2O)

without too much difficulty. Future land uses can be forecast based on trends and planning documents. The main difficulty is in developing a calibrated model of the effect of these variables on passenger numbers to estimate how much the project will attract new passengers, change the mode share and reduce private vehicle VKT. Many existing tools contain models that range in complexity and their use of default values versus user supplied values. Specific issues to consider when selecting a methodology include:

- Establishing a clear causal chain between new transit line and measurable effects: determine whether the effects could have occurred without the new investment;
- Estimating mode shares and potential new passengers, especially ex-ante: account for the influence of new land uses, costs of travel and other factors;
- Determining whether new transit passenger numbers (PKM) will increase transit VKT or increased occupancy will reduce transit VKT;
- Data availability on trip length by mode: are recent local data available?
- Estimating rebound effects – induced trips for public transport and private modes if project increases total capacity: is this effect expected to influence results?
- Availability of disaggregated emissions factors for old and new vehicle types and at BAU and mitigation scenario speeds.

1.2.8 Double counting concerns

Other policies and actions taken to mitigate GHG emissions may have synergistic or interaction effects on a mass transit mitigation action. 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. Care should be taken in this regard if any of the policies or actions listed in table 2 are being implemented concurrently with mass transit lines. In some cases a dynamic baseline could account for the effect; in other cases it may be better to analyse the combined effect of the actions rather than trying to disaggregate the reductions (see action type 2 urban programmatic actions).

1.3 DETERMINING THE BASELINE AND CALCULATING EMISSION REDUCTIONS

1.3.1 Analysis approach

The baseline scenario for mass transit investments can be described thus: “Passengers are transported using a diverse transport system involving buses, trains, cars,

Table 3

Actions with potential for double counting for mass transit investment mitigation actions

Mitigation action	May affect this variable
Fuel switching (e.g. subsidies for specific fuel types)	GHG emission factor per unit fuel
Fuel cost (taxes or subsidy removal)	Mode share
Vehicle fuel efficiency improvements (e.g. emission standards)	Fuel efficiency, mode share
Parking pricing	Mode share
TOD policies (promote additional mode shift)	Induced trips, mode share

non-motorized transport modes, etc. operating under mixed traffic conditions and possibly using older, less-efficient vehicles”. Baseline emissions are estimated by determining the PKM of each mode, converting them into VKT by the vehicle type each mode uses and applying an appropriate emission factor.

Current travel data serve as the basis for this baseline calculation, which must then be projected into the future for ex-ante analysis and counterfactually projected for ex-post analysis. Any mass transit investment project should be considered to create a new mode within the study area that alters the distribution and amount of VKT among modes. Ex-ante analysis requires a future projection of this scenario to compare with the baseline scenario.

Travel demand models, the most rigorous method for ex-ante analysis, make future estimates of trips, PKM and VKT for all modes based on spatial interactions between origin and destination locations from local land use. Travel models provide this travel activity input to separate emission factor models to calculate the final GHG emission impacts. Other methodologies estimate some or all travel activity variables using one of the three methods described below, and apply default values for remaining variables. Some older methodologies focus on the projection of passenger trip shares and use defaults for the calculation of PKM and conversion to VKT.[4]

There are three general approaches for projecting or counterfactually projecting travel activity for baselines or mass transit investment scenarios:

- Travel demand models – generally used for ex-ante analysis of BAU or mitigation scenarios;
- Travel activity survey – ex-post analysis is usually done with MRT project passengers, comparing alternative modes to the real situation of using the MRT. Ex-ante analysis can estimate future passenger numbers via a stated preference survey;
- Expert judgment based on historical trends, using time series data gathered ideally for at least 10 years – can be used for ex-ante projection or ex-post counterfactually projecting situations.

Ex-post analysis also requires estimates of current emissions, which are calculated based on the current transit passenger numbers and traffic counts and respective emission factors within the defined boundaries. Most methodologies focus on the new passengers of the mass transit project. Emission reductions, as always, are the difference between the project emissions (real or estimated ex-ante) and the baseline. Methodologies may vary as to whether upstream emissions from fuel production are considered. These emissions can be a factor if the new transit project uses different fuels or substantially more fuel than the baseline.

1.3.2 Uncertainties and sensitivity analysis

The most uncertain variable in the emission reduction analysis of a mass transit system is usually the ex-ante estimate of mode split and new passenger numbers. Because it depends on the relative attractiveness of the mass transit system versus the previously available modes for each individual passenger, it can be hard to estimate. Travel demand models offer the most sophisticated option, but even then there can be a range of error due to input uncertainty.

Ex-post methodologies all have characteristic uncertainties. Survey methods can introduce the subject’s personal biases as they ask users to state future preference or imagine a counterfactual scenario. Historical methods start with past data but must assume that no critical changes will be introduced. As mentioned, travel models require projections of future growth as inputs to the model, which is a source of uncertainty for that methodology.

The potential for rebound effects such as induced trips or changes in trip lengths in some modes can be significant. The associated uncertainty can be high if there are no previous experiences in the city/country from which to draw analysis, as this effect is culturally and locally specific.

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[4] See <http://www.apta.com/resources/hottopics/sustainability/Documents/Quantifying-Greenhouse-Gas-Emissions-APTA-Recommended-Practices.pdf>

1.4 GUIDANCE ON THE SELECTION OF ANALYSIS TOOLS FOR MASS TRANSIT INVESTMENTS

Higher degrees of accuracy can be obtained with more disaggregated data, if some or all data are locally derived. While combining local data with defaults can yield benefits, using disaggregated default data alone is seldom more accurate than aggregated default data. For example, highly disaggregated emission factors for various types of vehicles at different speeds are available. Using these factors without accurate values for trip length, mode share and

Table 4

Level of disaggregation of key variables for mass transit investment mitigation actions

	Degree of local data disaggregation		
	Lower accuracy	**Medium accuracy**	**Higher accuracy**
Travel activity data	· Total vehicle trips · Forecast change in transit passenger numbers · Average occupancy of privately owned vehicles and transit vehicles* · Average trip length*	· Vehicle trips in boundary area by vehicle type · Vehicle trip length by vehicle type · Proposed change in transit VKT from operations (by vehicle type) · Traffic speeds in corridor by vehicle type (and time of day) · Forecast travel speeds by vehicle type after strategy implementation · Forecast change in transit passenger numbers · Trip lengths of new transit trips* · Prior mode shares of new transit passengers*	· Person trips in boundary area by vehicle type · Person trip length by vehicle type · Occupancy by vehicle type · Proposed change in transit VKT from operations (by vehicle type) · Traffic speeds in corridor by vehicle type (and time of day) · Forecast travel speeds by vehicle type after strategy implementation · Forecast change in transit ridership · Trip lengths of new transit trips · Prior mode shares of new transit riders · Adjustment for induced traffic due to lower congestion* · Forecast change in private vehicle VKT by vehicle type (modelled)** · All data items by time of day**
Emission factors	· Average emission rates *	· Emission factors by vehicle type · Emission rates by speed* · Emission rates for new transit vehicles (by speed)*	· Emission factors for new transit vehicles (by speed) · Current and future (or improvement factor) emission rates by vehicle type and speed · Factors by emission gas or particle type* · Construction emission of new transit vehicles and infrastructure**

*=default OK, **= optional item

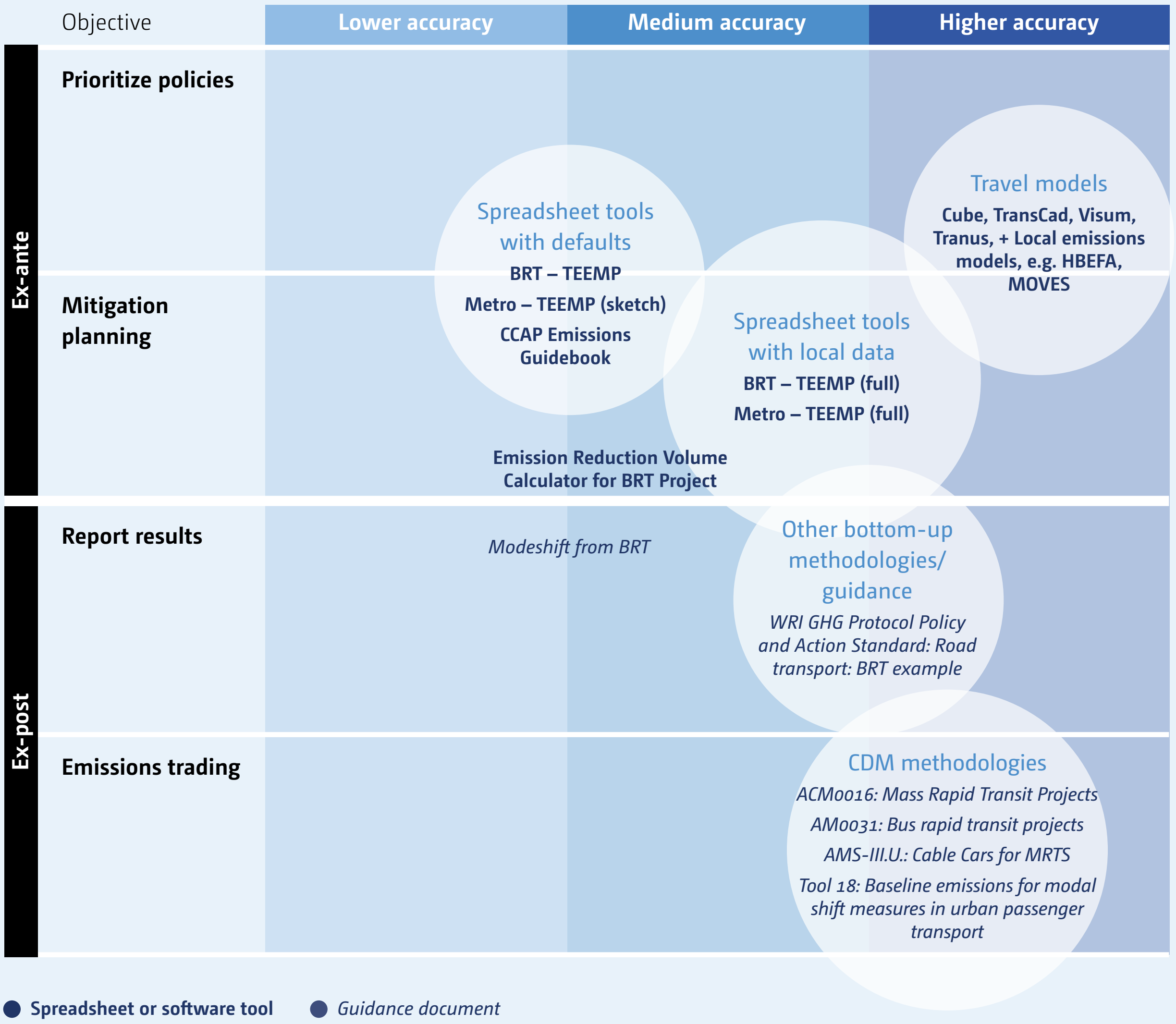
fleet composition yields little improvement in accuracy over using average, aggregated factors. Table 4 shows the level of data disaggregation that is desirable for each general level of accuracy.

Mass transit actions have a long history of in-depth analysis, such as ex-ante investment grade demand forecast studies using travel demand models and the detailed methodologies developed for ex-post emissions crediting (e.g. CDM). More recently a number of sketch planning tools have also been developed for rapid assessment of the potential GHG emission reductions that might be obtained from new transit projects and other similar programmes that expand public transport capacity.

Figure 8 maps existing methodologies and tools for mass transit investments according to their purpose (y axis) and level of accuracy (x axis).

Figure 8

Navigating classes of available methods and associated tools for mass transit investment mitigation actions



1.4.1 Description of tool types

The following sections describe a number of tools that are available for estimating GHG emission reduction from transit projects. They are classified according to similarities in methodology.

1.4.2 Travel demand models

These are spatial interaction models that are used to calculate VKT variables disaggregated by mode, vehicle type, time of day and speed. Trip lengths are disaggregated based on location of origins and destinations. Mode choice can be modelled based on interaction of origins, destinations and transport systems. Induced trips can be modelled using a capacity restraint formula (activity models may have more sophisticated methods). With appropriate submodules some models can include freight, transit and NMT. Some models can include land use simulations as well. Important disaggregated variables cascade through analysis. Some defaults may be included and models include the ability to change any variable. Models are calibrated by entering local data from detailed travel surveys and comparing the model output to known results. This option is the most accurate choice for forecasting future travel activity parameters.

Typically, highly disaggregated activity data, usually VKT, from travel demand models are input to a separate emissions model calibrated to national or supranational fleets. Some software packages incorporate emission factors from various sources for a surcharge. External standard emissions models that accept highly disaggregated inputs include MOVES (Motor Vehicle Emission Simulator), HBEFA (Handbook Emission Factors for Road Transport) and IVE (International Vehicle Emissions). (Highly disaggregated, e.g. speed-sensitive, emission models are discussed under mitigation action type 8.) Emissions models also have to be adapted to local or at least country-specific circumstances regarding, for example, the underlying fleet composition and emission factors to deliver meaningful results. Travel model outputs can, however, also be aggregated and emissions calculated with simpler emission factors.

Table 5

Travel demand models for mass transit investment mitigation actions

Ease of use/data collection: Highly resource and data intensive

Name	Application / summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
Cube	Travel activity	Land use module available	Citilabs, Inc.	Excellent	Paid training offered	Internal parameters*	High
TransCad	Travel activity	Emissions module available	Caliper Corporation	Excellent	Paid training offered	Internal parameters*	High
VISUM	Travel activity	Emissions module available	PTV Group	Excellent	Paid training offered	Internal parameters*	High
EMME	Travel activity	No other modules	INRO Software	Excellent	Paid training offered	Internal parameters*	High
Tranus	Travel activity and land use	No other modules	Modelistica	Very good	Fair	Internal parameters*	Free

*For example, friction factors, mode choice curves and other coefficients for internal submodels.

Table 6

Disaggregated bottom-up ex-post guidance for mass transit investment mitigation actions

Ease of use/data collection: Moderately resource and data intensive

Name	Application / summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
ACM0016: Mass rapid transit projects	Project activities that establish and operate an MRTS without feeder lines	Ex-post focus; Leakage: bus and taxi occupancy change, congestion effect on fuel efficiency and induced trips, upstream emissions of gaseous fuels	UNFCCC	Excellent	Excellent Includes survey template and guidance	Technology improvement factor Capacity restraint factor IPCC upstream fuel emission factors	Free
AM0031: Bus rapid transit projects	Construction and operation of a new BRT system or replacement or expansions of existing BRT systems (adding new routes and lines)	Ex-post focus; Leakage: bus and taxi occupancy change, congestion effect on fuel efficiency and induced trips, upstream emissions of gaseous fuels	UNFCCC	Excellent	Excellent Includes survey template and guidance	Technology improvement factor Capacity restraint factor IPCC upstream fuel emission factors	Free
AMS-III.U: Cable Cars for Mass Rapid Transit System	New cable car passenger transport	Ex-post focus; Leakage: general guidance to consider, occupancy guidance for upstream emissions of electricity	UNFCCC	Excellent	Excellent Includes survey template and guidance	Technology improvement factor IPCC upstream fuel emission factors	Free
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	Ex-post focus; General PKM methodology Leakage: general guidance only	UNFCCC	Excellent	Fair, general guidance on parameters to collect	Technology improvement factor Global defaults for vehicle occupancy, fuel efficiency, electricity consumption	Free
WRI GHG Protocol Policy and Action Standard: Transport sector guidance 2	Uses BRT as example of how to apply protocol	Ex-ante or ex-post; Guidance on setting boundaries and selecting level of detail, identifying first, second and third order effects	WRI	Very good	Good; guidance on developing monitoring plans	Examples of baseline vehicle emission factors	Free
Modeshift from BRT	New BRT projects	General PKM methodology; refers to the first three CDM methodologies in this table	JICA	Good	Poor	None	Free

Table 7

Partially aggregated bottom-up spreadsheet tools with defaults for mass transit investment mitigation actions

Ease of use/data collection: Moderate

Name	Application / summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
BRT-TEEMP (full)	New or expanded BRT system	Ex-ante focus; includes BRT mode shift estimation if local data available; includes co-benefits estimation	Clean Air Asia/ITDP/ ADB	Good	Fair	Fuel efficiency by speed Occupancy Trip length Fuel emission factors Construction factors	Free
Metro-TEEMP (local data)	New or expanded metro system (fixed rail)	Ex-ante city-wide; requires local data on mode shift for best accuracy; includes land-use effect factor; includes construc-tion life cycle emissions estimator	Clean Air Asia/ITDP/ Veolia	Good	Fair	Fuel efficiency by speed Occupancy Trip length Fuel emission factors Construction factors	Free

1.4.3 Disaggregated bottom-up ex-post guidance

This consists of CDM methodology documents or general guidance documents that detail the disaggregated variables that should be collected. The documents often give precise methodological guidance on how to collect these variables and how to calculate emissions using them, emphasizing the most conservative assumptions. Because CDM is focused on documenting precise amounts of real values, CDM tools are primarily used ex-post. Ex-ante guidance is found only for CDM additionality testing, which states that future trip length and mode share must be estimated outside of a methodology. Sometimes induced trips may be estimated using this methodology. The selected disaggregated variables cascade. Defaults and spreadsheets are not included, although default sources may be referenced.

These ex-post methodologies have two ways of estimating the counterfactual baseline.

Some of the simpler methods (designated in the table as "general PKM methodology") begin by calculating the emissions per PKM of the baseline system. Then they measure the fuel actually used and the number of passengers moved by the new (mitigation) system. They assume the total number of passengers of the baseline system would have been the same as the passengers of the new system. The reduction is the difference in emissions.

Other more rigorous methods estimate the emissions by various baseline modes. They then typically perform a survey of passengers on the new system and determine the current trip length and the counterfactual mode. Actual emissions per PKM are measured through fuel use and both the actual and the counterfactual emissions rates are multiplied by actual kilometres travelled.

1.4.4 Partially aggregated bottom-up spreadsheet tools with defaults

These spreadsheet-based tools are focused on ex-ante assessments that allow disaggregated local VKT-level or trip-level travel activity data to be entered, and include a variety of defaults for missing or unavailable data. The BRT methodology includes many more variables and includes a method for estimating future VKT, mode share or passenger numbers based on historical data combined with a 'score-card' analysis of the quality of the proposed BRT system.

1.4.5 Simple bottom-up tools with mostly default data

These tools are ex-ante spreadsheet or other computer programmes that accept aggregated local data and combine them with default values for emissions. The local VKT, passenger number or mode shift data required must be determined outside the model and entered by the user.

Table 8

Simple bottom-up tools with mostly default data for mass transit investment mitigation actions

Ease of use/data collection: Moderate to low

Name	Application / summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
BRT-TEEMP (sketch)	New or expanded BRT system	Ex-ante focus; includes BRT mode shift estimation based on defaults; includes co-benefits estimation	Clean Air Asia/ITDP/ ADB	Good	Fair	Fuel efficiency by speed Occupancy Trip length Fuel emission factors Construction factors	Free
Metro-TEEMP (default data)	New or expanded metro system (fixed rail)	Ex-ante city-wide focus; offers default mode shift choices; includes land-use effect factor; includes construction life cycle emissions estimator	Clean Air Asia/ITDP/ Veolia	Good	Fair	Fuel efficiency by speed Occupancy Trip length Fuel emission factors Construction factors	Free
CCAP Emissions Guidebook	New or expanded BRT/ metro system	Ex-ante tool; sketch planning estimates based on combining local data and defaults; includes fuel cost savings calculator	CCAP	Good	Fair	Rules of thumb based on case studies	Free

Table 9

Historical trends or expert judgment tools for mass transit investment mitigation actions

Ease of use/data collection: Low

Name	Application / summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
Emission Reduction Volume Calculator for BRT Project	New or expanded BRT system	Requires user to input all travel data except default emission factors; calculates total emissions and reductions	ALMEC/ World Bank	Fair	Poor	Bus emission factors by vehicle type; construction emission factors	Free

1.4.6 Historical trends or expert judgment methods

This methodology uses simple time series extrapolation of user-input disaggregated travel activity and vehicle fuel efficiency data. VKT and fuel use by mode are calculated and combined with default emission factors to calculate either ex-ante or ex-post GHG emissions.

1.5 MONITORING

Performance of the mitigation action can be monitored by tracking key variables over time. The monitoring frequency will vary, depending on the monitoring regimen and the budget available for data collection. CDM methodologies generally require annual monitoring. National-level biennial update reports are submitted every two years to the UNFCCC secretariat but may not need the most precise project-level data. Key mode share and trip length data can require transport surveys that may not be possible on an annual or biannual basis. Although new methods such as mobile phone tracking can substitute for surveys in some instances, many organizations cannot be assumed to have reliable data for all variables annually. However, different variables can be updated at different intervals. Transit ridership data is usually collected regularly so that annual monitoring is possible, even if factors such as trip length are updated only every few years.

It is also suggested that information on implementation and performance be included in the monitoring plan to show progress before the full effects of the action may be apparent. table 9 presents a minimum list of key variables and recommended maximum intervals for measurement if no other requirements are present (e.g. more rigorous requirements are often in place for CDM).

1.6 EXAMPLE – COLOMBIA TRANSMILENIO

The Colombia TransMilenio CDM project was registered in 2006 for a seven-year crediting period. During this time the procedures of methodology AM0031, "Baseline methodology for bus rapid transit projects", were used to monitor the effects. A total of seven monitoring reports were issued. The methodology was refined slightly during the seven years but generally consisted of collecting fuel consumption data, VKT data and passengers carried data from the TransMilenio system operators to calculate the mitigation scenario. The counterfactual baseline scenario was calculated each year by a series of surveys of passengers which queried them about the mode, number and length of trips they would have taken "in the absence of TransMilenio".

Leakage and life cycle parameters were also measured. This included construction emissions for periods of expansion, emissions from bus manufacturing as well as the possible effects of reduced congestion on induced travel. For years 3 and 7 emissions due to reduced load factors of other buses and taxis were also included. Generally the load factor leakage was found to be negligible.

Table 10
Minimum indicator set for mass transit mitigation action

Category	Indicator	Normal monitoring frequency
Implementation indicator	Construction and operation of new transit line	One time or by construction phase
Performance indicators	Passenger numbers on new line	Annual
	Traffic in corridor	Annual
Impact indicators	Calculated passenger transport VKT by mode	5 years
	Latest emission rates by mode	5 years
	Calculated emissions in study area	5 years

At the last reporting period the actual GHG emission reductions for that year were found to be 80,128 t CO_2 eq as compared with the ex-ante estimate of 307,300 t CO_2 eq. According to the original CDM project design document all phase III trunk routes as well as two routes of phase IV should have been operational by 2012. However, these suffered delays for various reasons, including re-planning of routes based on experience with phase II, as well as ongoing discussions about BRT versus a rail-based mass rapid transit system. Due to the low demand for carbon credits and the less than expected amount of reductions, the project was voluntarily withdrawn from the CDM in 2014.

Further details are available at:
https://cdm.unfccc.int/Projects/DB/DNV-CUK1159192623.07/view?cp=1

Chapter 2

COMPREHENSIVE URBAN TRANSPORT PROGRAMMES AND PLANS

2.1 DESCRIPTION AND CHARACTERISTICS OF URBAN TRANSPORT PROGRAMMES AND PLANS

This mitigation action covers programmes and plans that coordinate planning, investment and policy to reduce motorized VKT through activity reduction and/or mode change in urban transport. Some programmes also include measures to improve vehicle efficiency or promote alternative fuels; if they are a major part of the programme, their individual effects are better addressed through the methodologies discussed in chapter 6 or 7. Comprehensive urban transport mitigation actions can range from national-level programmes to support sustainable urban transport across the country to regional or local plans that implement a range of strategies. National-level programmes can be more centralized or more decentralized depending upon the degree of autonomy given to the regional or local authorities as they choose strategies and projects (Diaz and Bongardt, 2013).

The key characteristic that differentiates these programmes and plans from other mitigation actions is that they support a range of potential measures that are integrated and coordinated in order to achieve a synergistic effect, so that, in the long term, travel is pushed away from private vehicles and pulled towards sustainable modes such as public transport and/or NMT. Some programmes also address urban freight and city logistics. The specific actions within a given urban transport programme or plan will vary between nations or regions depending upon the particular emphasis. Although programmes and plans can conceivably include any type of strategy, in general, these mitigation actions improve the accessibility of cities through land planning and regulation, promoting increased density and mixed uses; expand investment for non-motorized and public transport; and may create disincentives for private and commercial vehicle use by restricting parking and road capacity or regulating access rights for freight and delivery transport. Secondary goals may include modernizing transit vehicles and improving traffic flow.

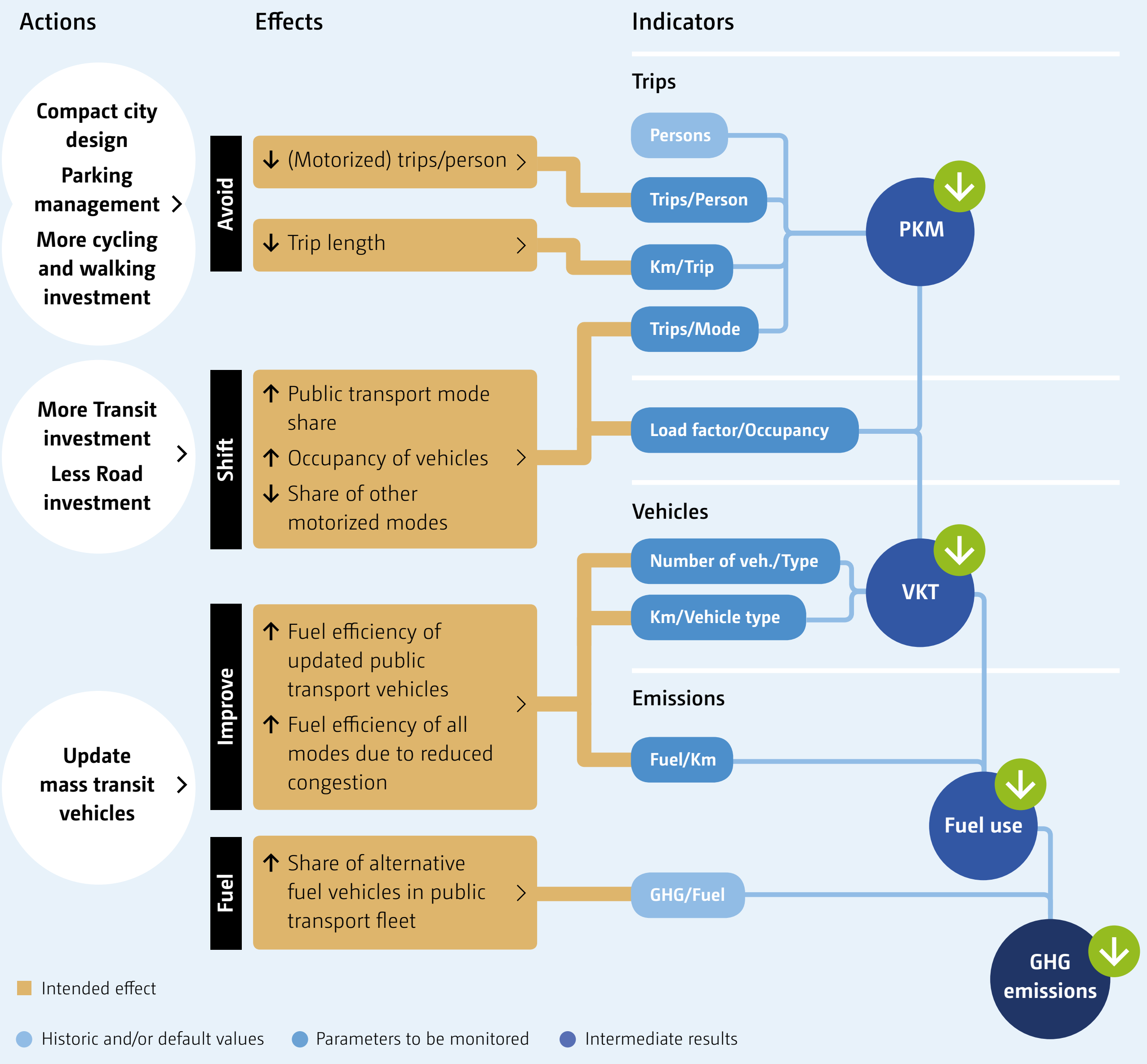
The successful implementation of these programmes and plans is expected to reduce the number of motorized trips (passenger and freight), reduce the length of trips and increase the mode share of non-motorized and public transport to reduce the VKT of private vehicles, and increase the overall efficiency of public transport, leading to reduced GHG emissions through lower overall VKT and transport energy use in the area of implementation. Comprehensive urban transport programmes and plans are known to generate a number of sustainable development co-benefits, which may include access to affordable mobility, shorter travel times and fewer accidents. They can also improve the quality of life and sense of place, increase economic returns on investments in mass transit, reduce car ownership and improve health outcomes as a result of more opportunities for physical activity and lower pollution levels.

2.2 STRUCTURE OF MITIGATION EFFECTS

2.2.1 Cause-impact chain of urban transport programmes and plans

The causal chain of comprehensive urban transport programme and plan actions can encompass many intervention points in a bottom-up model. The combined effects of a package of 'avoid, shift and improve' measures will result in measurable changes in the indicators in bottom-up models (ASIF approach) manifested at the level of the urban area. The expected changes in those variables will cause the desired outcomes in intermediate variables. Rather than focus on the individual effects of single measures, methodologies for these types of action look at changes in indicators or intermediate variables holistically. The advantage of this method is that interactions and synergies are included in the results; the disadvantage is that the effect of the individual measures is not known, so it is difficult to learn which measures within the package are the most effective. See figure 9 (illustrated for urban transport).

Figure 9
Comprehensive urban transport programmes and plans causal chain (passenger transport)



2.2.2 Key variables to be monitored

Comprehensive urban transport programmes and plans have the potential to change most of the key variables in a bottom-up model. The variables are listed below, followed by the expected mechanism that causes them to change. Some methodologies focus on intermediate variables, especially VKT, in order to capture the overall effects of a programme. A given project may not affect every variable if the appropriate mechanism of change is not present. Although a comprehensive programme or plan should affect all the variables listed below, if no change from any other factor is expected (e.g. speed), then historical/default values can be used. For example if NMT or compact city measures are not included, the number of motorized trips per person might not be expected to change.

2.2.3 Monitor for intended effects

- Trips/person – land use changes and NMT investment may shift some trips to non-vehicle trips which can be considered to reduce the (motorized) trips/person that produce GHG emissions
- Km/trip – compact cities with increased density and mixed use bring origins and destinations closer together, reducing the length of necessary trips;
- Mode shares – new, improved transit system may attract travellers from other modes;
- Vehicle occupancy of modes – new transit vehicles will have more capacity than old vehicles and improved routes will be more fully utilized, and ride sharing may increase;
- Fuel efficiency of new vehicles – new transit vehicles will employ more efficient technology and have different fuel consumption and/or different drive technologies;
- Traffic speeds – congestion may decrease leading to higher average travel speeds which can affect fuel consumption of all modes;
- Use of alternative fuels – some programmes may lead to an increase in the fleet of vehicles using fuels with lower carbon intensities;
- PKM – some methodologies may use data at the PKM level, which would change based on interventions affecting the variables above;
- Vehicle kilometres travelled – some methodologies use data at the VKT level, which would change due to interventions affecting the variables above.

2.2.4 May be monitored for leakage or rebound effects [not shown in figure 9]

- Km/trip – there is some evidence that improving overall accessibility can lead to more long distance trips as a rebound effect
- Construction emissions may need to be included for major projects such as metro systems or new separated bus lanes.

2.2.5 Interaction factors

Comprehensive mobility plans are by their nature integrated strategies. Nevertheless, the magnitude of changes in the key variables will be affected by the specific projects and characteristics of the urban transport programme or plan used as mitigation action. To achieve the best effects, the specific actions should be locally designed to best align with the political, economic, geographic and cultural context of the urban area. National-level programmes are implemented through local or regional plans to a greater or lesser extent depending upon the degree of decentralization. Some methodologies may be able to quantitatively account for certain contextual factors, while others may use default assumptions that are applied to all cities under a programme. A qualitative assessment using expert judgment may be needed to adjust default factors. Especially when performing ex-ante estimation of the mitigation potential of a comprehensive urban mobility programme or plan, the following questions should be considered:

- What are the expected GHG impacts of individual strategies included in the plan?
- What are the synergistic or antagonistic effects of the combination of strategies included in the plan?
- Are legal authority, institutional arrangements, funding, etc., in place to implement the plan?
- Are there unique cultural, climatic, economic, geographic or other factors that may affect performance and uptake of the strategies?

2.2.6 Boundary setting

Because these methodologies can be used for national programmes or for regional or local plans, boundaries will depend on the size of the project, that is, the geographic scope of the programme or plan. The expected changes will be manifested at the level of the city or urban area, so national-scale programmes will use the methodologies on a city by city basis and sum the expected results. When analysing larger programmes it may be easier to use average data applied across all relevant cities, while for smaller regional- or local-scale plans one should be sure that local circumstances are properly reflected in the data, although this may entail higher collection costs.

Table 11

Dimensions of boundary setting for comprehensive urban transport programmes and plans

Dimension	Options for boundary setting
Geographical	National (sum of cities), regional, local
Temporal	10 – 20 years, beyond 20 years
Upstream/downstream	Energy sector (electricity, biofuels), infrastructure construction
Transport subsector	Entire sector or applicable subsectors
Emissions gases	CO_2eq (may include CH_4, N_2O)

Upstream emissions from electric power generation might need to be considered if the grid factor (emissions per kilowatt) is substantial or if fuel switching measures are included in the mitigation action.

Extensive programmes may have substantial construction emissions, which should be considered as part of the lifecycle emissions and incorporated into ex-ante calculations. In this case the mitigation scenario should be compared with the baseline construction emissions of an equivalent BAU mobility implementation.

2.2.7 Key methodological issues

The GHG impact depends not only on the scope of the programme but also on how the design maximizes synergies among components. For this reason the key issue is the level of detail of the analysis. Individual strategies can be evaluated using specialized methodologies but a simple summation of results from these methods cannot be assumed because measures will interact in many different ways to suppress, amplify or duplicate effects. Broader sketch planning methods can provide order of magnitude estimates that can be refined with individual methodologies. Other specific issues to consider when selecting a methodology include:

- What set of strategies will be considered in the BAU scenario? How will the new programme's interactions and synergies with the current implementation pipeline be considered?
- Is it clear how the programme or plan will be implemented in the form of specific measures and regulations?
- Data availability – what size statistically valid sample is required to capture the entire effect of the mitigation action?
- What level of accuracy is needed for ex-ante estimation and for ex-post? Some simple inexpensive strategy mixes can be assumed to produce directionally correct results, while other, expensive packages of actions may need to be evaluated more carefully for rebound effects or other factors;
- How will land-use changes affect travel activity?

2.2.8 Double counting concerns

Other policies and actions being implemented to mitigate GHG emissions may have synergistic or interaction effects with the strategies within the urban mobility programme. Although a comprehensive programme should include all the actions within the boundary, national-level actions or local actions which are not in the programme need to be considered. In addition, actions may have been taken before the adoption of the programme that might change their expected results now that a programme is in place. All these issues need to be carefully considered in the establishment of the BAU scenario. For example, a new subway line may be planned for construction before the mitigation action is begun but it is also included as

Table 12

Actions with potential for double counting for comprehensive urban transport programmes and plans

Mitigation action	May affect this variable
National-level fuel economy standards or fuel taxes	Number of vehicles/type, fuel/km
Previously planned transit infrastructure and service improvements	Mode split, vehicle occupancy
Previously planned non-motorized improvement	(motorized) Trips per person
Pricing policies and strategies	Mode split, vehicle occupancy, (motorized) trips per person
TDM policies and strategies	Mode split, vehicle occupancy, (motorized) trips per person
Land use coordination with transport	Mode split, vehicle occupancy, (motorized) trips per person

part of the comprehensive urban mobility programme.

This can lead to difficulty in attributing the reduction in emissions to the comprehensive urban mobility programme, or to counting the same values more than once or, conversely, not attributing important reductions to the mitigation action. Caution should be taken in this regard if any of the following policies or actions are being implemented concurrently. Usually the expected effects of these policies can be incorporated into a dynamic baseline.

2.3 DETERMINING THE BASELINE AND CALCULATING EMISSION REDUCTIONS

1.3.1 Analysis approach

Setting the baseline for evaluating a comprehensive urban mobility programme mitigation action is more challenging than for other types of actions. Because an existing mobility plan may already be in place, and parts of it could be carried over to the new plan, it is necessary to decide what aspects of the new plan are not in the BAU scenario and how they will interact with the rest of the plan. This can be especially difficult if land-use changes are contemplated. Travel demand models are the tools specifically designed for evaluating comprehensive urban mobility plans and remain the method of choice. However, the cost, capacity and data requirements can be overwhelming, especially in less developed countries. For this reason sketch models have been developed that allow easier estimation of the ex-ante or ex-post effects. Also, since comprehensive urban mobility programmes have not been submitted under the CDM there are no UNFCCC approved methodologies to consider.

The baseline scenario for a given city-level comprehensive urban mobility plan can be described as the most plausible continuation of current transportation investment and regulation plans and policies. As mentioned above, there may be an existing plan that can be used, or the current infrastructure can be ‘frozen’ and a no-build scenario considered.

Because there are so many potential interactions between strategies, baseline emissions are usually estimated by determining the total overall VKT by vehicle type within each mode and applying appropriate emission factors. Current travel data from counts and surveys serves as the basis for this baseline calculation, which must then be projected into the future for ex-ante analysis and counterfactually projected for ex-post analysis. Ex-ante analysis requires a future projection of the mobility plan scenario to compare with the baseline scenario.

There are two general approaches that can be used for projecting or counterfactually projecting travel activity for baselines or comprehensive urban mobility plan scenarios:

- Travel demand models – used for ex-ante analysis of BAU or mitigation scenarios;
- Expert judgment based on historical trends, using time series data gathered ideally for at least 10 years – can be used for ex-ante projection or ex-post counterfactual projection situations.

Travel activity surveys are less useful in forecasting future or counterfactual use of a comprehensive network of transport infrastructure. While stated preference surveys can be useful for a single proposed project, most respondents cannot accurately describe how they would choose among a variety of competing modes and routes that do not yet exist.

Emission reductions, as always, are the difference between the project emissions (real or estimated ex-ante) and the baseline. Consideration of upstream emissions from fuel production or electricity may vary between methodologies. These emissions can be a factor if any of the included strategies uses different fuels or substantially more fuel than the baseline.

1.3.2 Uncertainties and sensitivity analysis

The most uncertain variable in the emission reduction analysis of a comprehensive urban mobility programme mitigation action is usually the ex-ante estimate of mode split and trip lengths. Sensitivity depends on the magnitude and relationship between the two variables; for example, if private vehicles have a smaller mode share but a long trip length resulting in substantial VKT it may offset a transit mode that is widely used but produces low VKT.

Ex-post methodologies also face uncertainty in estimating the counterfactual scenario, but historical data can often be sufficient for this purpose, albeit with lower accuracy. It is easier to compare the existing results of the programme with known trends of historic BAU than to accurately forecast the future results of a fundamentally different programme.

2.4 GUIDANCE ON THE SELECTION OF ANALYSIS TOOLS FOR COMPREHENSIVE URBAN MOBILITY PROGRAMMES OR PLANS

Higher degrees of accuracy can be obtained with more disaggregated data, if some or all of the data are locally derived. While combining local data with defaults can yield benefits, using disaggregated default data alone is seldom more accurate than aggregated default data. For example, highly disaggregated emission factors for various types of vehicles at different speeds are available. Using these factors without accurate values for trip length, mode share and fleet composition yields little improvement in accuracy over using average, aggregated factors. Table 12 shows the level of data disaggregation that is desirable for each general level of accuracy.

In developed countries transportation planners have been using a variety of tools to evaluate their plans and programmes for decades. Travel models to estimate VKT, mode choice and trip assignment have reached a very high level of sophistication and reliability. They are the best way to evaluate the interaction between several strategies implemented at the same time. However, these models require a substantial investment in capacity development, data collection and software purchase. For this reason they are not always practical when the goal is to evaluate a range of scenarios or when resources are limited.

So called sketch planning tools and methodologies have been used to fill the gap in analysis needs. Two broad categories exist. Comprehensive sketch tools try to assess the overall effect of a package of measures, often in terms of mode split and total VKT. Trip-based methods estimate VKT from changes in mode share and average trip length, while other methods suggest additional ways to measure VKT using traffic counts, models or surveys, such as that recommended by MobiliseYourCity (2017). A

VKT-based approach – rather than calculating VKT based on trips – may use traffic counts collected on a road and then multiplied by the length of the road to estimate VKT. This method can be scaled up using samples of different types of roadways to generate overall urban VKT estimates (Bongardt et al., 2016)[5]. In addition to comprehensive methods, a range of specialized spreadsheet tools and methods have been developed for specific strategies, and they can also be useful for estimating the portion of the overall result that might be due to a certain strategy.

Table 13

Level of disaggregation of key variables for comprehensive urban transport programmes and plans

	Degree of local data disaggregation		
	Lower accuracy	**Medium accuracy**	**Higher accuracy**
Travel activity data	· VKT estimate for private vehicles · tVKT estimate for public transport	VKT estimate by vehicle type · 2–3 wheeler · Light-duty private vehicle · Light truck · Heavy truck · Small bus · Large bus · Rail transit	Number of trips, occupancy and trip length · 2–3 wheeler · Light-duty private vehicle · Light truck · Heavy truck · Small bus · Large bus · Rail transit
Emission factors	· Emission factor for private vehicles · Emission factor for public transport	· Emission factors for all above by type of fuel	· Emission factors for all above by type of fuel

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[5] Bongardt et al. (2016) provide guidance on data collection methods at different levels of disaggregation for monitoring urban transport emissions. Although targeted at Chinese cities, the data collection approaches are universal.

Figure 10

Navigating classes of available methods and associated tools for comprehensive urban transport programmes and plans

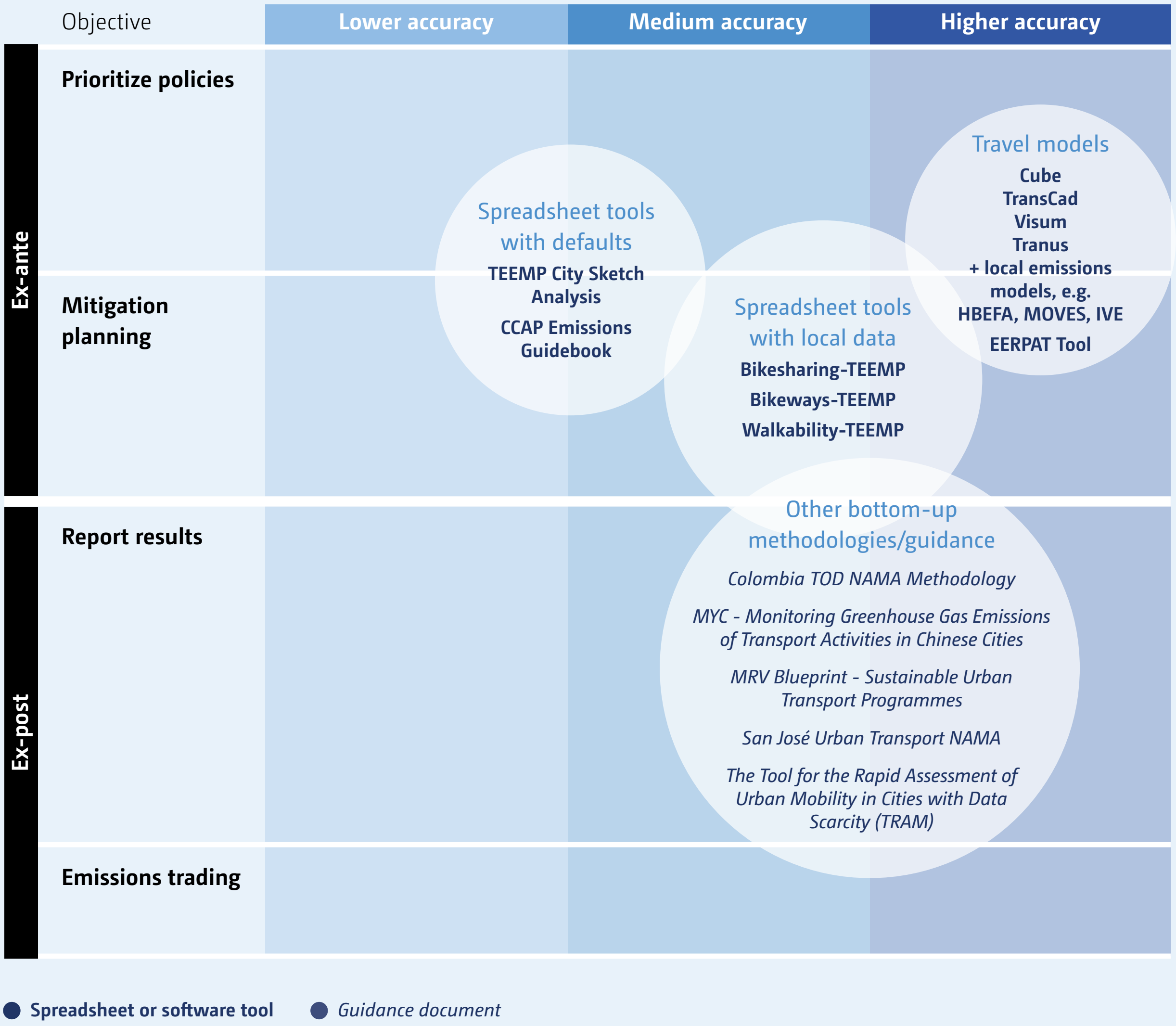

figure 10 maps some existing methodologies and tools for evaluating comprehensive urban mobility programmes and plans according to their purpose (y axis) and level of accuracy (x axis).

2.4.1 Description of tool types

The following sections describe a number of tools that are available for estimating GHG reduction from urban transport programmes or plans. They are classified according to similarities in methodology.

2.4.2 Travel demand models

These are spatial interaction models that calculate VKT disaggregated by mode, time of day and speed. Trip lengths are based on location of origins and destinations. Mode choice can be modelled based on interaction of origins, destinations and transport systems. Induced trips can be modelled using capacity restraint formula (activity models may have more sophisticated methods). With appropriate submodules some models can include freight, transit or NMT. Some models can include land use simulations as well. Important disaggregated variables cascade through analysis. Some defaults may be included and models include the ability to change any variable. Models are calibrated by entering local data from detailed travel surveys and comparing the model output to known results. This option is the most accurate choice for ex-ante forecasting of future travel activity parameters. It is more difficult to use for ex-post monitoring since a calibrated model is usually not prepared more often than every five years.

Typically, highly disaggregated activity data from travel demand models is input to a separate emissions model calibrated to national or supranational fleets. Some modelling software packages offer add-ons that include emission factors. External standard emissions models that accept highly disaggregated inputs such as speeds or cold starts include MOVES, HBEFA, IVE. Emissions models also have to be adapted to local or at least country-specific circumstances regarding, for example, the underlying fleet composition and emission factors to deliver meaningful results. Travel model outputs can, however, also be aggregated and emissions calculated with simpler emission factors.

EERPAT (Energy and Emissions Reduction Policy Analysis Tool) is a non-spatial policy analysis tool, designed to provide rapid analysis of many scenarios that combine the effects of various policy and transportation system changes. In order to provide quick response comparing many scenarios, it makes a number of simplifying assumptions (consistent with emissions and advanced regional travel demand modelling practice) that somewhat limit the detail and precision of its outputs compared to a spatial travel demand model.

Table 14

Travel demand models for comprehensive urban transport programmes and plans

Ease of use/data collection: Highly resource and data intensive

Name	Application / summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
Cube	Travel activity	Land use module available	Citilabs, Inc.	Excellent	Paid training offered	Internal parameters*	High
TransCad	Travel activity	Emissions module available	Caliper Corporation	Excellent	Paid training offered	Internal parameters*	High
VISUM	Travel activity	Emissions module available	PTV Group	Excellent	Paid training offered	Internal parameters*	High
EMME	Travel activity	No other modules	INRO Software	Excellent	Paid training offered	Internal parameters*	High
Tranus	Travel activity and land use	No other modules	Modelistica	Very good	Fair	Internal parameters*	Free
EERPAT	Non-spatial disaggregate model	Includes emissions module	U.S. Federal Highway Administration	Very good	Good	Defaults for United States – allows user input for other areas	Free

*For example friction factors, mode choice curves and other coefficients for internal submodels.

Table 15

Disaggregated bottom-up ex-post guidance for comprehensive urban transport programmes and plans

Ease of use/data collection: Moderately resource and data intensive

Name	Application / summary	Scope	Computer based	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
TRAM	Survey focused data collection guidance	Trip-based City scale travel activity data	Clean Air Asia and the Institute for Transportation and Development Policy for UN-Habitat	Excellent	Excellent	None	Free
Mobilise our City Monitoring and Reporting Approach	Sustainable Urban Mobility Plans	VKT-based territorial approach to urban transport emission inventory	GIZ for Mobilise YourCity	Excellent	Excellent	None	Free
MRV Blueprint: Sustainable Urban Transport Programmes[6]	Comprehensive urban transport plans/ programmes	VKT-based territorial approach to urban transport emission inventory	GIZ	Excellent	Excellent	None	Free
San José Urban Transport NAMA	Sustainable urban transport programme/plan for San José	Trip-based inventory approach for the whole city using surveys /GPS/mobile data	Grütter Consulting for IDB	Excellent (Spanish language only)	Excellent	Yes – lists travel activity and emission factors used for San José, Costa Rica	Free
Colombia TOD NAMA method	Specific to TOD programme	Trip-based Uses neighbour- hood control groups	Center for Clean Air Policy for NAMA Facility	Good	Fair, under development	None	Free
Step-by-step guide to data collection	Data collection for urban transport GHG monitoring	VKT-based territorial approach to urban transport emission inventory	GIZ	Excellent	Excellent	None	Free

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[6] MRV Blueprint essentially describes the same methodology as the MobiliseYourCity monitoring and reporting approach approach – an urban transport GHG inventory using a territorial approach. MRV Blueprint is more illustrative, using China as an example for a national urban transport programme, whereas the MobiliseYourCity guidance is a more concise document, describing only the methodological approach.

2.4.3 Disaggregated bottom-up ex-post guidance

This consists of general guidance documents that detail the disaggregated variables that should be collected. The documents may offer methodological guidance on how to collect these variables and how to calculate emissions using them. These tools are primarily used ex-post and offer less rigorous guidance on how to estimate counterfactual baseline emissions. The selected disaggregated variables cascade. Defaults and spreadsheets are not included, although default sources may be referenced.

The tools evaluated here fall into trip-based and VKT-based approaches. Trip-based approaches attempt to determine the trip length and mode of trips through surveys and/or Global Positioning System/phone tracking means and calculate the VKT from that; for example, the methodology applied for the San José urban transport NAMA project (by Grütter Consulting). VKT approaches, for example in the MobiliseYourCity MRV guidance, focus on the vehicle-level data obtained from traffic counts, travel models or other sources. These ex-post methods for urban transport GHG inventories monitor emissions over time to determine the overall effect of the programme or plan. Another methodology uses control groups to determine the BAU compared with areas that have not been subject to an intervention to estimate reductions versus a baseline, such as in the Colombia TOD NAMA.

The methodology being developed for the Colombia TOD NAMA plans to track implementation, performance and impacts at multiple levels: neighbourhood, city/regional and national. Local measurement includes comparing changes in land use characteristics and travel patterns in intervention and control neighbourhoods to calculate GHG reductions. Long-term, city-wide GHG reductions would be calculated based on aggregate travel data and national GHG mitigation by monitoring fuel use.

2.4.4 Single strategy partially aggregated bottom-up spreadsheet tools with defaults

These are spreadsheet-based tools that allow local data to be used but also include a variety of defaults, especially for emission factors. Some have limited methods for estimating future VKT, mode share or passenger numbers. These methods can supplement the comprehensive analysis methodologies by estimating the magnitude of the overall reduction that may be due to NMT.

2.4.5 Simple bottom-up ex-ante tools with mostly default data

These may be spreadsheets or other computer programs that accept limited local data but offer default values for emissions. Usually VKT, passenger numbers or mode shift are determined outside the model and entered by the user. They are most useful for ex-ante comparison of various packages of strategies when developing a comprehensive programme or plan.

Table 16

Partially aggregated bottom-up spreadsheet tools with defaults for mass transit investment mitigation actions

Ease of use/data collection: Moderate

Name	Application / summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
Bikesharing-TEEMP	Bikesharing projects	Estimates avoided VKT (user inputs shift to bikeshare)	Clean Air Asia/ITDP/ADB	Good	Fair	Vehicle emission factors Trip lengths	Free
Bikeways-TEEMP	Bicycle facilities	Estimates avoided VKT Estimates mode shift based on biking environment	Clean Air Asia/ITDP/ADB	Good	Fair	Vehicle emission factors – also allows user input Trip lengths	Free
Walkability-TEEMP	Pedestrian projects	Estimates mode share change from project	Clean Air Asia/ITDP/ADB	Good	Fair	Vehicle emission factors	Free

Table 17

Partially aggregated bottom-up spreadsheet tools with defaults for mass transit investment mitigation actions

Ease of use/data collection: Moderate to low

Name	Application / summary	Scope	Computer based	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
TEEMP City sketch analysis	Investment in various modes	Roads, bikeways, metro, brt, train	Clean Air Asia/ITDP/ Veolia	Good	Fair	Default GHG savings per lane km/year of various strategies	Free
CCAP Emissions Guidebook	A range of specific strategies can be aggregated	Ex-ante tool; sketch planning estimates based on combining local data and defaults; includes fuel cost savings calculator based on VKT reduction and fuel efficiency	CCAP	Good	Fair	Rules of thumb based on case studies, can be adapted to local circumstances	Free

As an example for a national urban transport programme, whereas the MYC guidance is a more concise document, describing only the methodological approach.

2.5 MONITORING

Performance of the mitigation action can be monitored by tracking key variables over time. The monitoring frequency will vary, depending on the monitoring regimen and the budget available for data collection. National-level biennial update reports are submitted every two years to the UNFCCC secretariat but may not need the most precise project-level data. Key VKT data by mode can require transport surveys that may not be possible on an annual or biannual basis. Here, traffic counts can be used as a less expensive approach to collect VKT data for private vehicles. Although new methods such as mobile phone tracking can substitute for surveys in some instances, many organizations cannot be assumed to have reliable data for all variables annually. However, different variables can be updated at different intervals. Road traffic and transit passenger number data is usually collected regularly so that annual monitoring is possible, even if trip length, etc., are updated only every few years. VKT of formal public transport vehicles is usually available from operators.

It is also suggested that information on implementation and performance be included in the monitoring plan to show progress before the full effects of the action may be apparent (see the Colombia TOD NAMA or MobiliseYourCityMRV approach). Table 17 presents a minimum list of key variables and recommended maximum intervals for measurement if no other requirements are present.

2.6 EXAMPLE – JAKARTA TRAVEL DEMAND MANAGEMENT

Jakarta, Indonesia, was considering a NAMA based on a comprehensive package of travel demand management (TDM) strategies. Through collaboration with the Transport Research Laboratory, the Asian Development Bank and the Inter-American Development Bank, an MRV methodology was developed to determine the GHG emission reduction that might be obtained. Reflecting existing local priorities, three specific elements of TDM were examined, namely electronic road pricing, parking restraint and BRT.

According to the published study:

Table 18

Minimum indicator set for comprehensive urban transport programme or plan mitigation actions (passenger transport)

Category	Indicator	Normal monitoring frequency
Implementation indicator	Completion of projects or phases of projects from within the programme	Annually or by construction phasing schedule
Performance indicators	Mode shares for NMT	Annual
	Transit passenger numbers	Annual
Impact indicators	Calculated passenger transport VKT by mode	5 years
	Latest emission rates by mode	5 years
	Calculated emissions in study area	5 years

"The project used a travel demand model developed by the University of Bandung. The model provided 'business as usual' projections, against which the impacts of the implementation of a range of different mitigation measures, both individually, and combined into suites of measures (i.e., scenarios), could be calculated. In modelling the impacts of the three TDM measures, the model was run firstly assuming no changes to policy (business as usual), and then using scenarios which included different levels of applications of the TDM measures, represented in the model as changes to;

- The origin/destination metrics,
- The road/rail network, or
- Vehicle fleet parameters.

Changes to the origin/destination metrics are associated with scenarios which affect the demand for travel (either in a spatial sense, or absolute levels). In the case of the three TDM elements, this applies to ERP and parking restraint, whereby their implementation would essentially increase the price of travel." (Dalkmann, 2010)

The TDM model demonstrated that a typical combination of the three TDM policies leads to a sustained reduction in total transport demand (in vehicle kilometres, below the baseline by approximately 4–5 per cent in the entire urban area, all other policies being equal. This study did not calculate actual emission reductions; however, estimations of fuel consumption – a direct proxy for carbon emissions – were made. Because the travel model was able to isolate different areas of the city it showed that in the downtown central business district a reduction of between 20 and 30 per cent compared with BAU was projected. Although this NAMA did not advance beyond the feasibility study phase, the effort developed valuable information for future transport planning efforts in the city.

Further details are available at:
http://www.slocat.net/wp-content/uploads/2009/11/TRL-Jakarta-final-report.pdf

Chapter 3

VEHICLE EFFICIENCY IMPROVEMENT PROGRAMES

3.1 DESCRIPTION AND CHARACTERISTICS OF VEHICLE EFFICIENCY IMPROVEMENT PROGRAMMES

This mitigation action covers national, regional or local programmes to improve the fuel efficiency of some or all road vehicles in the passenger and/or freight fleets. This covers a broad range of strategies promoting technological or behavioural changes that result in less fuel being used to achieve the same amount of travel activity. This mitigation action type does not include national fuel economy (FE) standards (addressed as mitigation action type 7), or general fiscal policies (addressed as mitigation action type 8). This section looks at subsidies and incentives targeting specific technologies that improve fuel efficiency (e.g. low rolling resistance tyres, anti-idle devices, etc.), scrapping programmes to replace older vehicles and education programmes promoting negative cost technologies or simply more efficient driving techniques.

The outcomes of successful implementation of this mitigation action type are expected to allow existing vehicles to achieve better FE and/or replace less efficient vehicles in a fleet with more efficient vehicles.

Vehicle fuel efficiency improvement programmes are known to generate a number of sustainable development co-benefits mainly structured around lessening of overall transportation costs and reducing pollution. In addition there could be new jobs generated by installing technologies or offering education or training.

3.2 STRUCTURE OF MITIGATION EFFECTS

3.2.1 Cause-impact chain

Mitigation actions through vehicle fuel efficiency improvement programmes should result in measurable effects that are reflected in certain indicators in bottom-up models (ASIF approach). The expected changes in those variables will cause the desired outcomes. See figure 11.

3.2.2 Key variables to be monitored

The key variables that are expected to be changed by vehicle fuel efficiency improvement programmes are listed below, followed by the expected mechanism that causes them to change.

3.2.3 Monitor for intended effects

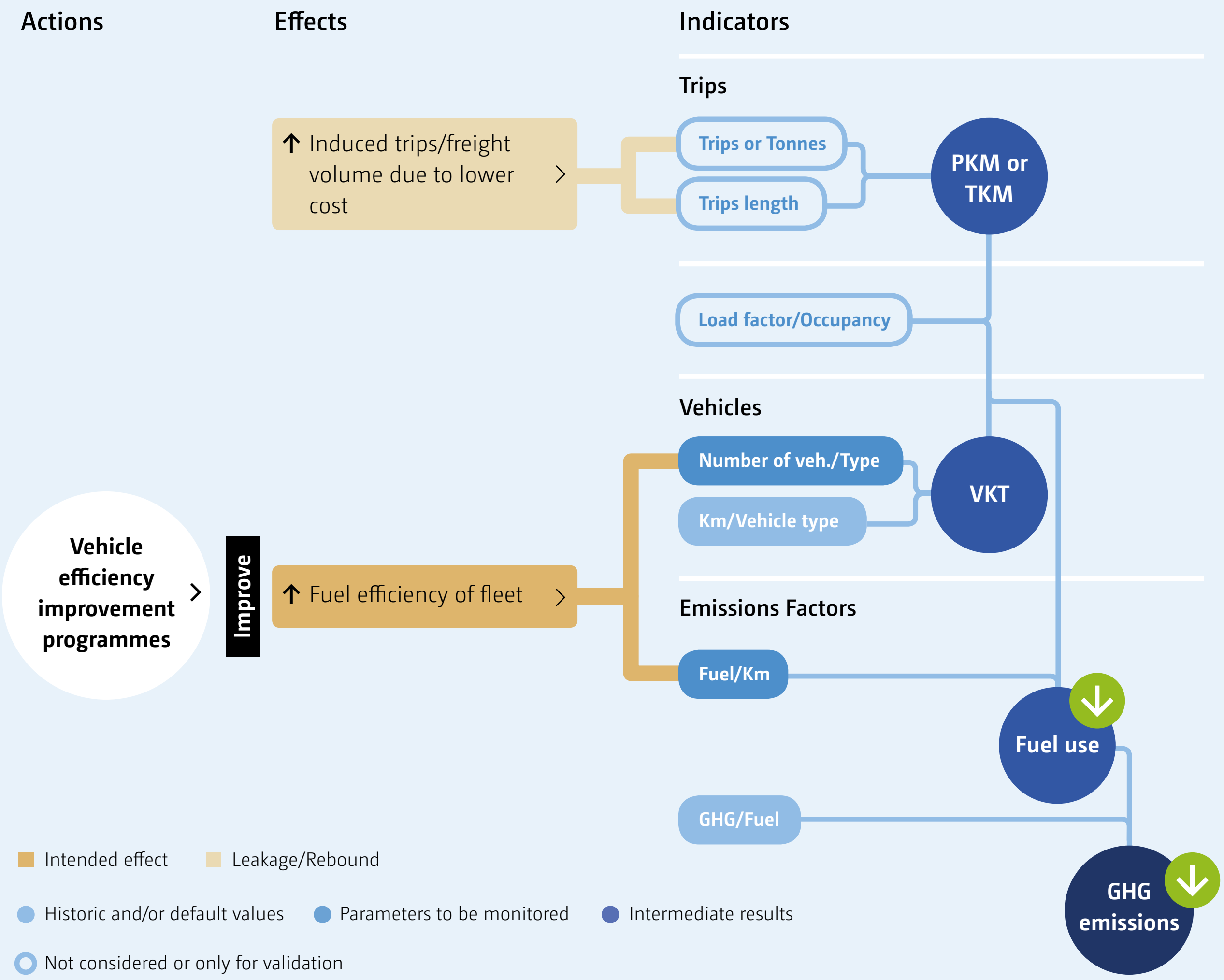
- Fuel/km – technologies or behaviours promoted by the mitigation action will improve the fuel efficiency of certain classes of vehicles.

3.2.4 May be monitored for leakage or rebound effects

- Trips/person (or tonnes/economic unit) – decreased fuel costs may result in induced trips;
- Km/trip – decreased fuel costs may result in longer trips;
- VKT – can be measured in lieu of the above variables.

Figure 11

Vehicle fuel efficiency improvement programmes causal chain



3.2.5 Interaction factors

The magnitude of change in the fuel use variable will be affected by the specific target of the vehicle efficiency improvement programme. A programme that targets taxis or heavy freight vehicles may have very different results from a programme that subsidizes new light passenger vehicles (e.g. the Cash for Clunkers programme in the United States of America). While cost-benefit considerations are usually the primary driver of uptake, penetration or participation within a programme can also be affected by other economic and political contextual factors, especially if programmes include regulations or policy components. When performing ex-ante estimation of the mitigation potential of vehicle fuel efficiency improvement programmes, the following factors can have a substantial impact on magnitude and should be taken into account:

- Fuel prices, including subsidies or taxes;
- Capacity to maintain new technology;
- Expected technology improvement without the programme.

3.2.6 Boundary setting

Boundary will depend on the specific design of the programme. National programmes may target a large or sma-

Table 19

Dimensions of boundary setting for vehicle fuel efficiency improvement programmes

Dimension	Options for boundary setting
Geographical	National, regional
Temporal	Average life of vehicle, ~10–15 years
Upstream/downstream	Upstream emissions for electric vehicles or other alternative fuels and upstream emissions of baseline vehicles. Emissions from production of new vehicles
Transport subsector	Passenger, freight, specific type or use of vehicle (e.g. taxi, privately or publicly owned fleets)
Emissions gases	CO_2, CH_4

ll subset of the vehicle fleet. More local programmes may target a local subset. Upstream emissions should be included for electric vehicles.

3.2.7 Key methodological issues

The GHG impact depends upon the number of vehicles that adopt the new, fuel-efficient changes and the amount of fuel each vehicle can save thereby. Disaggregated data for variables pertaining to VKT and FE for different types of vehicles may be needed if direct measurement of fuel use is not possible. Specific methodologies focus on variables that are key to the measure, for example scrapping measures require knowledge of the age of scrapped vehicles and tyre replacement measures require the range of specific rolling resistance of tires within the fleet. A list of general issues to consider when selecting a methodology includes:

- How much will new technology improve vehicle FE compared with the existing fleet and with ‘business as usual’ future projections?
- Allowing for fleet turnover, how will the benefits of these improvements be realized over time in the on-road fleet?
- What unintended consequences (i.e. rebound effects) might the policy have that could reduce its benefits, for example, people keep older vehicles longer, import more used vehicles, or drive more because vehicle operating costs are less?

3.2.8 Double counting concerns

Other policies and actions taken to mitigate GHG emissions may have synergistic or interaction effects on fuel efficiency of vehicle fleets. Mitigation actions that affect the cost of fuel or of certain classes of vehicles can distort

Table 20

Actions with potential for double counting for mass transit investment mitigation actions

Mitigation action	May affect this variable
National fuel economy standard	Fuel/km
Fuel subsidies or tariffs	Fuel/km
Vehicle import fees or rebates	Fuel/km
Logistics measures	Fuel/tonne-km

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. In some cases a dynamic baseline (or a technology improvement factor) could account for the additional effects on fuel efficiency. Care should be taken in this regard if any of the following policies or actions is being implemented concurrently with fuel efficiency improvement programmes (see table 19).

3.3 DETERMINING THE BASELINE AND CALCULATING EMISSION REDUCTIONS

3.3.1 Analysis approach

The baseline scenario for fuel efficiency improvement programmes can be described as the overall fuel use by the targeted vehicles in the existing fleet. Baseline emissions are estimated by determining the total fuel use of each type of vehicle within the boundary or by determining the VKT by each vehicle type and applying an appropriate emission factor.

Current fuel use or travel and FE data serve as the basis for this baseline calculation, which must be projected into the future for ex-ante analysis and counterfactually projected to create a BAU scenario for ex-post analysis. Ex-ante analysis also requires a future projection of the mitigation action scenario to compare with the baseline scenario.

There are three general approaches for projecting or counterfactually projecting fuel use and travel activity for the baseline or fuel efficiency improvement programme scenarios. In some cases one approach may be used for the baseline and another for the mitigation scenario. The general approaches are as follows:

- Expert judgment based on historical trends, using time series data gathered ideally for at least 10 years – can be used for ex-ante projection or ex-post counterfactual projection situations. Should be combined with a model of fleet FE characteristics;
- Fleet turnover models that estimate the number of each type of vehicle by year;
- Economic projections and elasticity models that project technology uptake based on costs and benefits. No methodologies of this type were evaluated for this report.

Ex-post analysis also requires estimates of current mitigation scenario emissions, which are calculated based on the measured fuel use, or an activity measure such as VKT or tonne/km is multiplied by the respective emission factors, within the defined boundaries of the project. (One CDM methodology, for anti-idle devices, directly tracks the amount of time the device is in use, leading to a direct estimate of fuel saved.) Emission reductions, as always, are the difference between the project emissions (real or estimated ex-ante) and the baseline. Consideration of upstream emissions from electricity production is usually included in methodologies involving electric power.

3.3.2 Uncertainties and sensitivity analysis

The most uncertain variable in the emission reduction analysis of vehicle fuel efficiency improvement projects is usually the ex-ante estimate of the uptake of the new technology. There are also often 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 VKT.

Ex-post methodologies also have characteristic uncertainties related to the amount of change attributable to the project itself. For example, driver training or digital efficiency monitoring devices can have uneven effects depending on the driver. Also new technologies can result in the driver more closely monitoring fuel efficiency in the beginning until becoming accustomed to the change.

Box 3

Monitoring, reporting and verification of mobile air conditioning and transport refrigeration mitigation actions

Many light and heavy duty vehicles have refrigeration and/or air conditioning (RAC) systems. Greenhouse gas (GHG) emissions attributed to these systems can be considered as direct or indirect. Direct emissions result from the release of high global warming potential (GWP) gas refrigerants such as hydrofluorocarbons (HFCs) from these cooling systems. For example, HFC-134a, one of the most common refrigerants (used inter alia in mobile air conditioning), has a GWP of 1,430, and HFC-404A, commonly used in large refrigerated trucks, has a GWP of 3,922. Under the 2016 Kigali Amendment to the Montreal Protocol, 197 countries committed to cut the production and consumption of HFCs by more than 80 per cent over the next 30 years.1 Indirect emissions from vehicle RAC mainly result from the energy consumption needed to power these systems, which increases the overall energy consumption of the vehicle. While motor vehicle systems make up a small percentage of RAC emissions, it is important to be able to estimate the GHG contribution and the potential reductions from transport sector mitigation actions.

Initial emissions occur during the production and charging process as HFCs are produced and individual vehicle RAC systems are charged with refrigerant (initial charge). After charging the vehicle system holds the HFCs. The total amount of refrigerant in the vehicle fleet at any given time is called the stock. Annual leakage rates of refrigerant in transport refrigeration are high compared with other cooling applications because of the constant strain on system parts on the roads. Furthermore, the remaining refrigerant charge might be released during equipment or vehicle scrapping, etc., leading to additional emissions.

Structure of mitigation effects:

Direct emission reduction mitigation actions promote technologies that replace the conventional refrigerant, which will typically have high GWP, with low-GWP or zero-GWP refrigerants, such as natural refrigerants like carbon dioxide (CO_2) or propane (HC-290) or unsaturated HFCs (e.g. HFO-1234yf). Indirect emission reduction mitigation actions, on the other hand, focus on improving the energy efficiency of the refrigeration systems. This includes promoting adequately insulated refrigerated vehicles as determined by the k-factor values of the international ATP agreement.2 During operation, proper servicing and refrigerant recharging practices help to reduce leakages and thereby further reduce the climate impact. At the end-of-life of the mobile air conditioning system or the car itself, the refrigerant can be evacuated and stored for recycling or destruction.

Determining the baseline and calculating reductions:

A top-down bulk-based methodology can be developed by recording imported, produced and exported bulk HFCs and applying an emission factor. This can serve as a first step to indicate the potential for direct emissions or emission reductions. However, indirect emission reductions cannot be estimated this way.

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) has developed a generalized bottom-up methodology based on a unit-stock model for the RAC sector that can be applied to mobile systems. First the total stock of the RAC systems being considered is estimated. In the case of mobile or transport cooling this would be held in the fleet of vehicles (or refrigerated trucks) that use air conditioning or refrigerating systems. Then the direct and indirect emissions ('business as usual' scenario) and potential emission reductions (mitigation scenario) of a standardized unit of stock are estimated using the key variables below, which should be disaggregated, for example, by technology, refrigerant and other characteristics as needed to capture differences between scenarios:

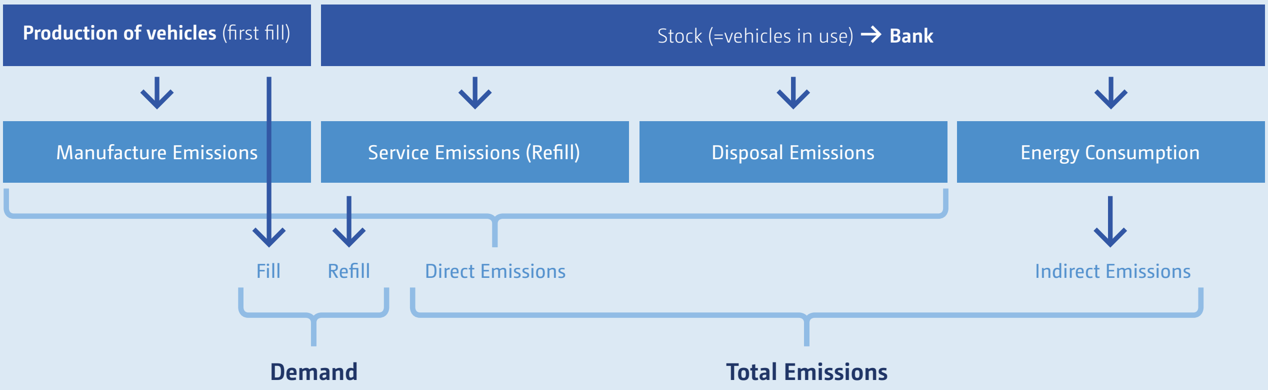
Continues on the next page

- Initial charge (kg) and the dominant refrigerant that is used in the system
- Manufacture emission factor (%)
- In-use emission factor (%)
- Disposal emission factor (%)
- Product lifetime
- Average cooling capacity (kW)
- Average coefficient of performance – the amount of cooling provided per energy used
- Cost per unit
- Expected future annual growth rates – uptake of new technology
- Runtime ratios of the systems (similar to average annual runtime hours)
- Emission factor for electricity and fuels to run system

Mitigated emissions are then calculated as the difference between the BAU scenario and the mitigation scenario as in other methodologies.

Figure 12

Causal chain of emissions from refrigeration and air conditioning



GIZ Proklima. See in particular the following modules:

Module 1 Inventory: https://www.giz.de/expertise/downloads/giz2014-en-NAMA-Handbook-Module-1_WEB.pdf

Module 5 Mitigation Scenarios: https://www.giz.de/expertise/downloads/giz2014-en-NAMA-Handbook-Module-5_WEB.pdf

Module 7 Measurement, Reporting, Verification: https://www.giz.de/expertise/downloads/giz2014-en-NAMA-Handbook-Module-7_WEB.pdf

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[1] <https://www.epa.gov/ozone-layer-protection/recent-international-developments-under-montreal-protocol>

[2] Agreement on the International Carriage of Perishable Foodstuffs and on the Special Equipment to be used for such Carriage (French and international abbreviation: ATP); available at: <http://www.unece.org/trans/main/wp11/atp.html>

[3] Go to <https://www.giz.de/expertise/html/4809.html> and find "NAMAs in the refrigeration, air conditioning and foam sectors", then click on "MORE" to see all volumes of the technical handbook.

3.4 GUIDANCE ON THE SELECTION OF ANALYSIS TOOLS FOR VEHICLE EFFICIENCY IMPROVEMENT PROGRAMMES

Higher degrees of accuracy can be obtained with more disaggregated locally derived data. While combining local data with defaults can yield benefits, using disaggregated default data alone may not be more accurate than aggregated default data. For example, highly disaggregated emission factors for various types of vehicles may be available. Using these factors without accurate values for trip length and fleet composition yields little improvement in accuracy over using average, more aggregated factors. Because the range of methodologies encompasses fuel use, VKT and fleet turnover variables, some variables listed in table 21 will not apply to a specific methodology.

The table below shows additional variables desirable for each higher level of accuracy.

Historically, fuel efficiency has been built into vehicle fleet emissions models such as MOVES, IVE or HBEFA, which became sophisticated enough to account for travel activity variables such as speed, stop and go, or even hills. These models incorporate fleetwide assumptions about fuel mix, technology evolution and uptake and were therefore less useful for estimating changes due to a fuel efficiency programme. Some models, such as HBEFA, do

Table 21

Additional variables for higher accuracy for vehicle fuel efficiency improvement programmes

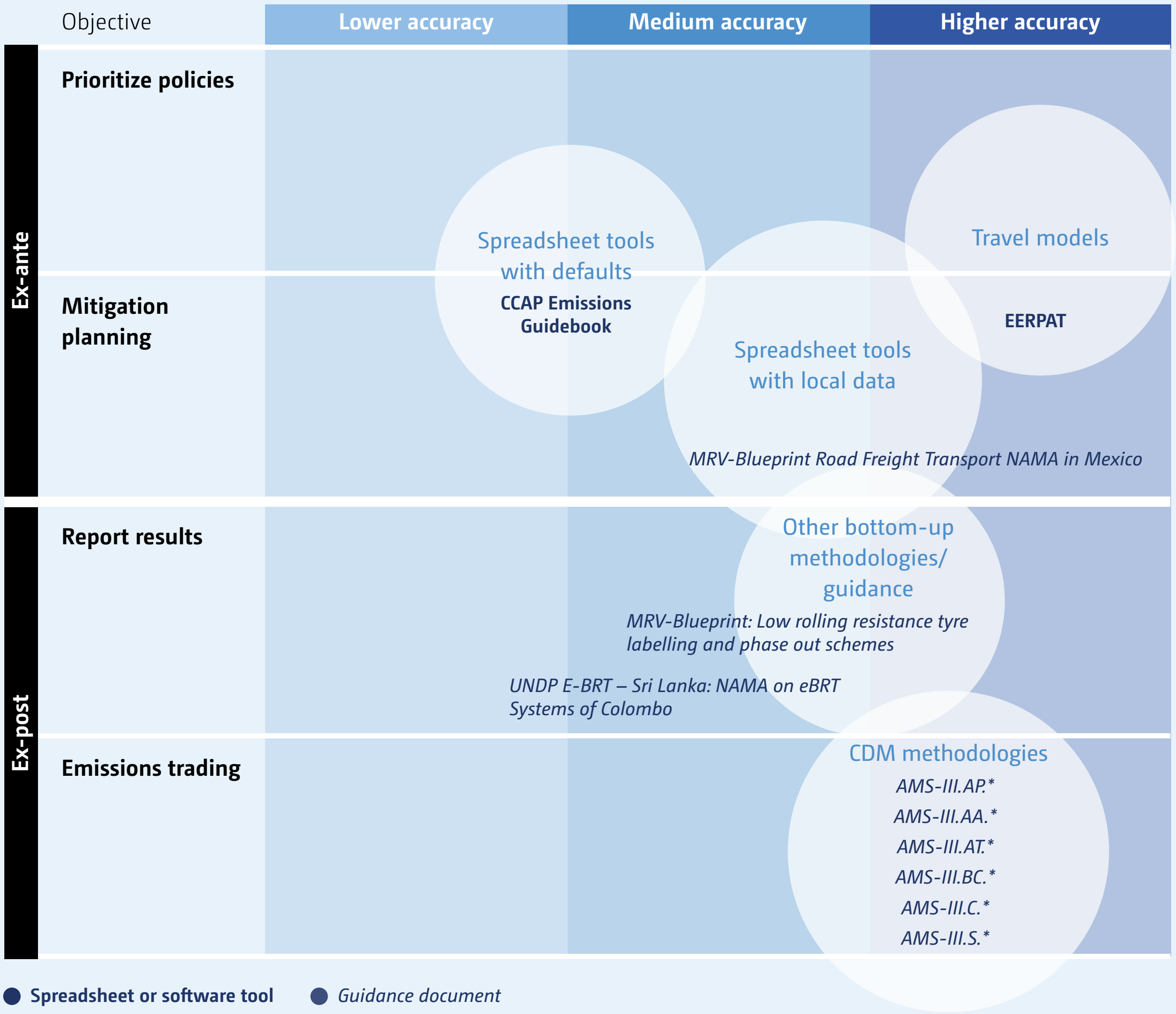
	Degree of local data disaggregation		
	Lower accuracy	**Medium accuracy**	**Higher accuracy**
Travel activity data	· Overall fuel use by vehicle type · Or: · Total vehicle stock (by type) · Total VKT by vehicle type (base year) · Total VKT by vehicle type (future-year projections) · Expected incremental change in cost of new vehicle (by type)	· Future-year projections of new vehicle sales (by vehicle type) · Scrappage/turnover rates or age distribution by vehicle type · Observed, sales-weighted new vehicle efficiency by vehicle type · Observed increase in cost of new vehicle (by type) · Observed increase in volume of imported used vehicles	· Mileage accumulation rates by vehicle type · “Rebound effect” – percentage increase in VKT due to decreased cost/km · Price of fuel (for rebound effect) · “Purchase effect” – expected shift in consumer purchases by vehicle efficiency or type in response to price differential · “Turnover effect” – expected slower rate of fleet turnover due to higher new vehicle cost · “Import effect” – expected increase in used imported vehicles due to higher new vehicle cost
Emission factors	· Average fuel economy of on-road vehicle fleet (by vehicle type) · Future-year projections of new vehicle efficiency by vehicle type	· Current and recent historical efficiency (test cycle) of new vehicles, by vehicle type to be regulated · Adjustment for actual on-road efficiency/emissions versus test cycle/certification efficiency · Future-year projections of new vehicle efficiency (baseline)	· Observed, sales-weighted new vehicle efficiency by vehicle type

have a version which allows different fleets to be simulated. The sketch planning tool EERPAT allows modification to its fuel efficiency defaults while maintaining the link with VKT inputs.

Some methodologies that were developed for the CDM or NAMAs focus on guidance to measure the changes from a programme or project promoting a single technology. Other methodologies offer a wider scope of application. As NAMAs and broader transport programmes spread, some spreadsheet methodologies were developed that incorporated assumptions about uptake of technologies, or allowed user inputs. Sri Lanka developed a simplified CDM-style methodology for GHG emissions as part of an overall project which also used the United Nations Development Programme Sustainable Development Evaluation Tool.

Figure 13

Navigating classes of available methods and associated tools for vehicle fuel efficiency improvement programmes



(*) AMS-III.AP.: Transport energy efficiency activities using post-fit idling stop device, AMS-III.AA.: Transportation energy efficiency activities using retrofit technologies, AMS-III.AT.: Transportation energy efficiency activities installing digital tachograph systems to commercial freight transport fleets, AMS-III.BC.: Emission reductions through improved efficiency of vehicle fleets, AMS-III.C.: Emission reductions by electric and hybrid vehicles, AMS-III.S.: Introduction of low-emission vehicles/technologies to commercial vehicle fleets

Table 22

Disaggregate emissions models for vehicle fuel efficiency improvement programmes

Ease of use/data collection: Highly resource and data intensive

Name	Application / summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
EERPAT	Non-spatial disaggregate model	Includes emissions module	U.S. Federal Highway Administration	Very good	Good	Complete defaults for United States – allows user input for other areas	Free

Figure 13 maps existing methodologies and tools for fuel efficiency improvement programmes according to their purpose (y axis) and level of accuracy (x axis).

3.4.1 Description of tool types

The following sections describe a number of tools that are available for estimating GHG emission reductions from fuel efficiency improvement mitigation actions. They are classified according to similarities in methodology.

3.4.2 Disaggregate emissions models

The EERPAT tool is a non-spatial policy analysis tool, designed to provide rapid analysis of scenarios that combine the effects of various policy and transportation system changes. In order to provide a quick response comparing many scenarios, it makes a number of simplifying assumptions (consistent with emissions and advanced regional travel demand modelling practice) that somewhat limit the detail and precision of its outputs compared with a properly set up MOVES 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.

3.4.3 Disaggregated bottom-up ex-post guidance

This consists of CDM methodology documents or other MRV guidance documents that detail the disaggregated variables that should be collected. The documents focus on delineating a specific type of mitigation action and often give precise methodologies on how to collect the appropriate variables to calculate emission reductions for them. CDM tools are primarily used ex-post because CDM ex-ante guidance is found only for additionality testing, which states that future trip length and mode share must be estimated outside of the methodology. Defaults are not usually included although default sources may be referenced. Some guidance documents associated with specific projects may have spreadsheets prepared for the case study.

There are two main types of methodologies. One type tracks the number of vehicles affected (or the VKT of affected vehicles) and applies an estimated new fuel efficiency obtained from a measured sample of individual affected vehicles. These methodologies have guidance on how to measure or calculate the new fuel efficiency after the mitigation action is applied on a vehicle. Another type of methodology measures change in fuel use of the overall fleet, usually for privately owned fleets of taxis or freight vehicles that have adopted the mitigation action. This methodology is found more in CDM projects as it is only usable ex-post.

Because there are many approaches to improving the FE of vehicles that lend themselves to CDM or NAMA designs, a number of methodologies have been developed. They differ mainly in the boundaries, for example, transit or truck, public or commercial fleets, etc., and in the specific attributes that affect the measure being monitored, such as the type of new tyres or hybrid technology. The general framework has even been extended to a methodology for improving fuel efficiency of large ships.

3.4.5 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. VKT estimates or actual fuel use must be entered by the user.

Table 23

Disaggregated bottom-up ex-post guidance for vehicle fuel efficiency improvement programmes

Ease of use/data collection – moderately resource and data intensive

Name	Application / summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
MRV-Blueprint: Low rolling resistance tyre labelling and phase-out schemes	Fitting trucks with lower rolling resistance tyres	Tyre-labelling and phase-out for heavy-duty trucks w/ GVW >3.5 tonnes (national level)	IFEU	Very good	Fair	Yes, for European Union fleet	Free
MRV-Blueprint Road freight transport NAMA in Mexico	Modernization programme (scrapping and finance)	Modernization of heavy-duty truck fleet (national level)	GIZ/ Wuppertal/ SEMARNAT	Very good	Very good	Yes, for Mexican fleet	Free
MRV methodology titled "Improvement of Fuel Efficiency for Taxies in Vietnam"	Improving fuel efficiency for taxis	Vehicle fuel efficiency measures Transit efficiency measures (higher occupancy rate/ lower non-passenger mileage)	GEC/JCM	Very good	Very good	None	Free
Reducing vessel emissions through use of advanced hull coatings	Ship fuel efficiency improvement	Retrofitting large freight or passenger ships	MGM Innova/ FReMCo Corp./ International Paint Ltd.	Excellent	Very good	None	Free
AMS-III.AP.: Transport energy efficiency activities using post-fit idling stop device	Devices to stop idling when vehicle not moving	Public transit fleets	UNFCCC	Very good	Very good	None	Free

Continues on the next page

Name	Application / summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
AMS-III.AA.: Transportation energy efficiency activities using retrofit technologies	Engine retrofit (replacement) with more efficient engine	Commercial passenger transport	UNFCCC	Very good	Very good	None	Free
AMS-III.AT.: Transportation energy efficiency activities installing digital tachograph systems to commercial freight transport fleets	Installing vehicle or engine tracking and recording systems	Centrally owned freight or passenger fleets	UNFCCC	Very good	Excellent	None	Free
AMS-III.BC.: Emission reductions through improved efficiency of vehicle fleets	Installing one or more: (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) Aerodynamic drag reduction measures (g) Transmission improvements (h) Retrofits that improve engine efficiency	Centrally owned freight or passenger fleets	UNFCCC	Very good	Fair	None	Free
AMS-III.C.: Emission reductions by electric and hybrid vehicles	New electric and/or hybrid vehicles that displace the use of fossil fuel vehicles	Passenger and freight transportation	UNFCCC	Very good	Very good	None	Free
AMS-III.S.: Introduction of low-emission vehicles/ technologies to commercial vehicle fleets	Introduce vehicles with lower emissions per kilometre	Includes lower emissions by means of electric or hybrid	UNFCCC	Good	Fair	None	Free
UNDP E-BRT – Sri Lanka: NAMA on eBRT Systems of Colombo	Substitution of electric buses for diesel in BRT system	Developed specifically for Sri Lanka project, could be adapted for other measures changing fuel efficiency	UNDP	Very good	Very good	Yes, values based on local study/ manufacturer data/ national or international averages	Free

Table 24

Simple bottom-up tools with mostly default data for vehicle fuel efficiency improvement programmes

Ease of use/data collection: Moderate to low

Name	Application / summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
CCAP Emissions Guidebook	Fuel efficiency incentives Anti-idling campaigns Vehicle scrappage feebates	Ex-ante tool; sketch planning estimates based on combining local data and defaults	CCAP	Good	Fair	Emission factors for United States fleet, other factors can be entered Uptake rates	Free

3.5 MONITORING

Performance of the mitigation action can be monitored by tracking key variables over time. CDM methodologies generally require annual monitoring. Fuel efficiency effectiveness of technologies should be measured at implementation and should in most cases remain unchanged. Uptake of technologies should be monitored annually to determine the penetration into the fleet. Measures that apply technology to individual privately owned commercial fleets can monitor penetration with cooperation from the owners. Broader government programs will keep records of scrapped vehicles or subsidies that are issued.

Table 25 presents a minimum list of key variables and recommended intervals for measurement if no other requirements are present, (e.g. CDM).

Table 25

Minimum indicator set for mass transit mitigation action

Category	Indicator	Normal monitoring frequency
Implementation indicator	Construction and operation of new transit line	One time or by construction phase
Performance indicators	Ridership on new line Traffic in corridor	Annual Annual
Impact indicators	Calculated passenger transport VKT by mode Latest emission rates by mode Calculated emissions in study area	5 years 5 years 5 years

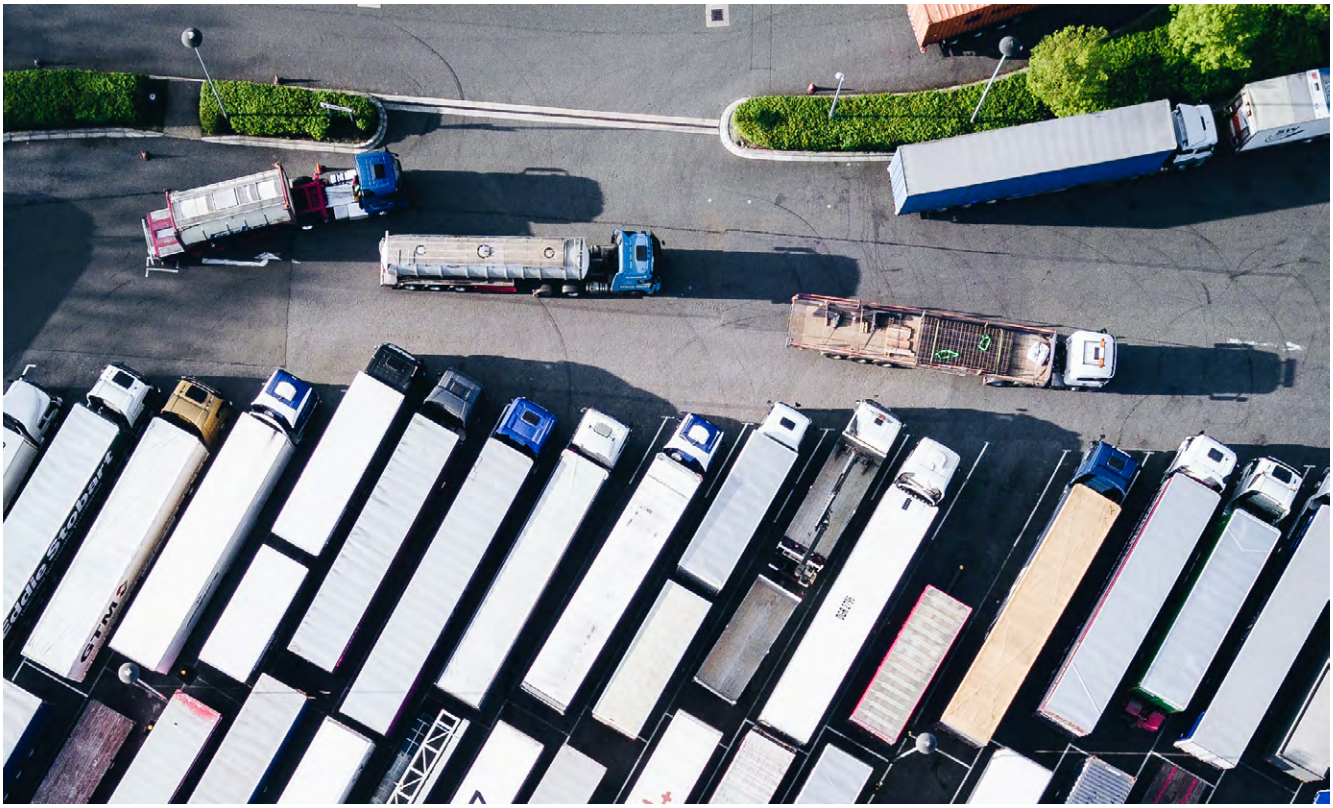
3.6 EXAMPLE – MEXICAN FREIGTH NAMA

The Mexican freight NAMA is a fuel efficiency mitigation action which has as its centrepiece the continuation of a programme of scrapping of trucks older than 10 years and replacing them with trucks less than 6 years old. When this is done it allows the owner to receive a subsidy of up to 25 per cent of the value of the new truck by the Mexican Fleet Modernization Program. There are also credits for users to finance newer fuel efficient trucks without scrapping an older one.

Under the existing programme an ex-post evaluation is used by Secretaría de Comunicaciones y Transportes and Instituto Nacional de Ecología y Cambio Climático to estimate the real GHG emission mitigation. Essentially, the calculation compares emissions of the scrapped truck, which represents the baseline, to the emissions of the replacement truck (based on the fuel efficiency and total kilometres travelled with the truck).

For ex-ante analysis the NAMA developed an MRV system that refines the old method to include a direct effect and an indirect effect (due to new trucks being used more than old). They also incorporated a fleet survival rate tool. Using these tools, they calculated that combining scrapping and credits for newer trucks would give a higher reduction potential than either programme alone.

Further details are available at:
http://transport-namas.org/wp-content/uploads/2014/10/TRANSfer_MRV-Blueprint_Truck_Scrapping_MX_draft.pdf



Chapter 4

ALTERNATIVE FUELS INCENTIVES, REGULATION AND PRODUCTION

4.1 DESCRIPTION AND CHARACTERISTICS OF ALTERNATIVE FUELS INCENTIVES, REGULATION AND PRODUCTION MITIGATION ACTIONS

This mitigation action type covers a range of projects and policies that displace liquid fossil fuels with liquid motor fuels from renewable sources or with gaseous fossil fuels. Measures that promote electric powered vehicles are included in section 3, vehicle energy efficiency, because liquid or gaseous fuels are used directly in vehicles and have specific methodologies associated with their production. This includes technologies, infrastructure and regulatory strategies for promoting biodiesel, other plant oils, bio-CNG (compressed natural gas), as well as fossil CNG and LNG (liquified natural gas). These actions are intended to reduce overall GHG emissions by increasing the use of less carbon-intensive fuels and decreasing the use of more carbon-intensive fuels to provide the energy required for travel activity. The reduced carbon intensity of the new fuels can be from reduced upstream emissions or from lower inherent carbon intensity, or both.

The outcomes of successful implementation of this mitigation action are expected to reduce the overall GHG emissions from a given amount of travel activity, when taking into account upstream and direct emissions.

Alternative fuels mitigation actions can create economic benefits in areas of production. There is also the potential for reduction of various toxic pollutants. However, if not properly designed alternative fuel mitigation projects could result in negative impacts on land use and food production or even displacement of persons. In fact, first generation biofuels have been found in some cases to actually be more emission intensive than conventional fuels if properly accounted. As a result, in the European Union the GHG emission savings from biofuels have to be at least 50 per cent to be eligible for support schemes (in accordance with the Renewable Energy Directive).

4.2 STRUCTURE OF MITIGATION EFFECTS

4.2.1 Cause-impact chain

Alternative fuels mitigation actions should result in measurable effects that are reflected in three key indicators in bottom-up models (ASIF approach). The expected changes in those variables will cause the desired outcomes. See figure 14.

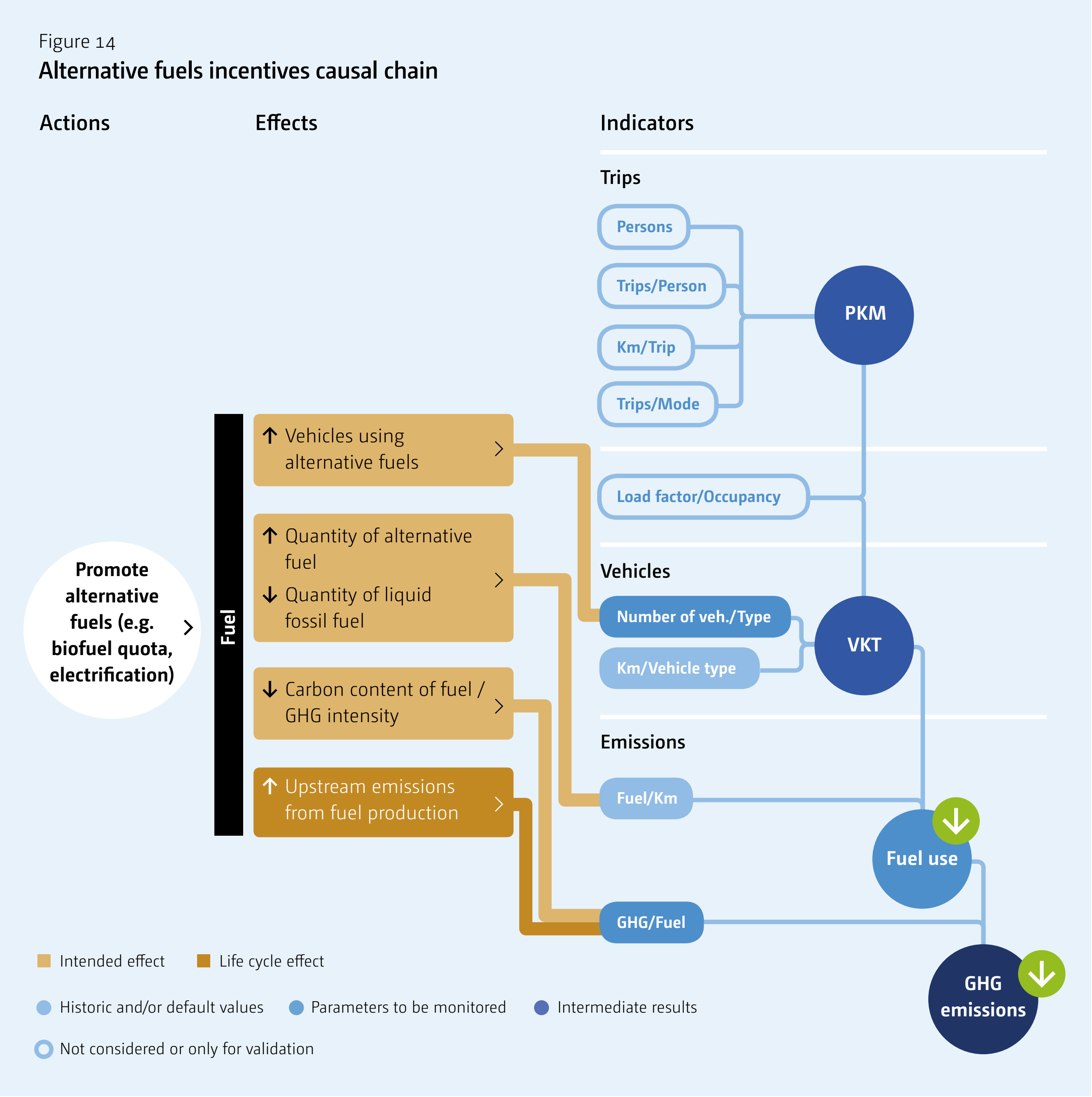
4.2.2 Key variables to be monitored

The key variables that are expected to change by alternative fuels mitigation actions are listed below, followed by the expected mechanism that causes them to change.

4.2.3 Monitor for intended effects

- Number of vehicles by fuel type;
- Fuel use – amount of fuel used, disaggregated by type of fuel, is the key indicator for this type of action because the amounts of the various types of fuels that are used will change. In some cases this will be measured directly and in other cases based on VKT of vehicles that use alternative fuels and relative fuel consumption of vehicle types;
- GHG/fuel – the GHG intensity per caloric output of each type of fuel must be determined;
- GHG/fuel – upstream emission from the production of fuel, charging infrastructure, etc., can vary greatly depending upon the process and type of fuel. This must be included in the overall GHG intensity.

Figure 14
Alternative fuels incentives causal chain



4.2.4 Interaction factors

The magnitude of change in the key variable of fuel use will be affected by the specific characteristics of the alternative fuels mitigation action. The economic and political context into which the alternative fuels are introduced is very important for actions in which uptake is determined mainly by the market as affected by incentives or taxes. In addition, some strategies impose quotas or portfolio standards for renewable or alternative fuels. For this reason the following factors need to be considered when performing ex-ante estimation of the mitigation potential of alternative fuels mitigation actions, if they are not part of the action itself:

- Incentive is designed to account for full fuel cycle GHG emissions;

Table 26

Dimensions of boundary setting for alternative fuels mitigation actions

Dimension	Options for boundary setting
Geographical	National, regional, local
Temporal	5 – 10, over 20 years for production projects
Upstream/downstream	Production process emissions for harvesting, refining, etc.; methane leakage
Transport subsector	Specific commercial or transit fleets, all vehicles capable of conversion or replacement
Emissions gases	CO_2, CH_4, N_2O (from production)

- Similar low-carbon standards/incentives adopted or proposed in neighbouring countries;
- Expected ability of fuel suppliers to produce and distribute low-carbon/GHG fuels;
- Expected ability of vehicle manufacturers to produce dedicated or bi-fuel vehicles.

4.2.5 Boundary setting

The boundary will depend on the type of mitigation action. Fuel production projects usually include the production area and the transportation use area. Vehicle conversion projects are more often limited to the use area, with upstream emissions incorporated into the emission factor.

Upstream balance of emissions/sinks should be included for the production of bio-fuels, as sinks contribute to the mitigation effect; other emissions such as methane leakage of LNG production may or may not be included depending upon the methodology. If this is done upstream emissions also have to be considered for the baseline fuels.

In the CDM methodologies the temporal boundary of a vehicle conversion projects is limited to the lifetime of the original fleet. Biofuel production can extend to the life of the project.

4.2.6 Key methodological issues

The GHG impact depends upon the reduced GHG intensity of the alternative fuels vs conventional fuels as well as the total amount of each fuel that is used to support transportation activity. Ex-ante prediction of the amount of fuels used is difficult for all methodologies. Calculating the upstream emissions can also be complicated and data intensive. Tracking the current fuel use is a straightforward challenge.

A list of specific issues to consider when selecting a methodology include:

- Is fuel use measured at the distribution point or the end user?
- What level of ex-ante estimation is needed?
- How effective will the action be at encouraging consumers to switch to different types of fuels?
- What are the full life cycle GHG emission impacts of the alternative fuels for which incentives are provided?

4.2.7 Double counting concerns

Other policies and actions taken to mitigate GHG emissions may have synergistic or interaction effects on the amount and type of fuel used or the make-up of the vehicle fleet.

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. Care should be taken in this regard if any of the following policies or actions are being implemented concurrently. In some cases a dynamic baseline can account for the effect without the al-

Table 27

Actions with potential for double counting for alternative fuels mitigation actions

Mitigation action	May affect this variable
Fuel economy standards	Amount of fuel used by type
Fuel subsidy removal	Amount of fuel used by typeFuel/km
Fuel efficiency incentives	Amount of fuel used by type
Vehicle scrapping schemes	Number of conventional vehicles
Taxes and tariffs on fossil fuels	Amount of fuel used by type

ternative fuel incentive; in other cases it may be better to analyse the combined effect of the actions rather than trying to allocate the reductions among the various mitigation actions.

4.3 DETERMINING THE BASELINE AND CALCULATING EMISSION REDUCTIONS

4.3.1 Analysis approach

Alternative fuel mitigation actions are analysed by determining the amount of conventional fuel that is or will be displaced by the alternative fuel. The respective emissions of the amount of conventional fuel and the amount of alternative fuels are calculated and the difference is the reduction attributed to the action. Two general approaches are used:

1. Top-down, mostly ex-post, based on directly measuring the amount of alternative fuel used (typically from fuel sales data), and assuming that it displaced the calorific equivalent of fossil fuel and corrected for vehicle efficiency changes due to fuel change, if applicable;
2. Bottom-up, mostly ex-ante, based on the distance travelled (used mainly for new vehicles projects or vehicle replacement projects). Bottom-up methods usually assume the same distance under baseline and mitigation scenarios and correct for variation in calorific content of fuels and for vehicle efficiency changes due to fuel change, if applicable. Also used ex-post for vehicle replacement projects that cover only a specific subset of vehicles, such as a taxi fleet, but do not have a great effect on fuel sales overall.

The baseline scenario for alternative fuel mitigation actions can be described as the mix of fuels that is currently in place or expected to occur under baseline policies. Current fuel sales data serve as the basis for this baseline calculation, which must then be projected into the future for ex-ante analysis and 'back cast' for ex-post analysis.

There are two general approaches for projecting or counterfactually projecting travel activity for baselines or alternative fuel mitigation action scenarios:

- Expert judgment based on historical trends, using time series data gathered ideally for at least 10 years – can be used for ex-ante projection or ex-post counterfactual projection situations. Should be combined with knowledge of fleet characteristics;
- Economic projections and elasticity models. No methodologies of this type were evaluated for this report.

Consideration of upstream emissions from fuel production varies between methodologies, depending on the type of fuel project that is being considered.

4.3.2 Uncertainties and sensitivity analysis

The first uncertainty in the emission reduction analysis of alternative fuel mitigation actions is usually the ex-ante estimate of the amount of fossil fuels that will be displaced by new supplies of alternative fuel from a mitigation action. In mitigation actions where a known number of vehicles are replaced, or new vehicles are introduced, this problem is less critical. It is also important to have a clear understanding of the availability and annual volume outputs of alternative fuels for these types of actions.

The other important uncertainty is estimating the life cycle emissions for alternative fuels. Biofuels can be cultivated and produced by different methods that result in a range of life cycle emissions. Proper analysis of feedstock production and transport as well as fuel production and distribution are crucial to determining the actual reductions of an action. Some widely accepted methods are available. Sustainability criteria according to the European Union renewable energy directive (directive 2009/28/EC) and the international standard on sustainability criteria for bioenergy (ISO 13065:2015) are two examples. There are also a number of voluntary schemes that certify sustainability criteria on biofuels.[7]

For conversion to CNG it is important to look at well-to-wheels emissions as a minimum. CNG conversions may come with CNG leakage and reduced catalytic activity for old fleets. A 2 per cent CNG leakage, which is within the range of potential performance of CNG conversions, can immediately negate the GHG emission benefits compared with gasoline. On the other hand, brand new vehicles with properly calibrated engines and systems designed to reduce leakage may produce the expected GHG emission reductions.

Table 28

Additional variables for higher accuracy for vehicle fuel efficiency improvement programmes

	Degree of local data disaggregation and context variables		
	Lower accuracy	**Medium accuracy**	**Higher accuracy**
Fuel sales data	• Current volume of transportation fuels sold in country, by fuel type • Forecast year volume of transportation fuels sold in country, by fuel type	• Current volume • Forecast year volume • Projected fuel cost differential versus conventional fuel after incentive, and net change in vehicle operating cost for consumer	• Current volume • Forecast year volume • Total volume of fuels sold within broader region, by fuel type (to examine diversion effects) • Analysis of whether alternative fuel demand would be new, or diverted from other existing uses • Maximum value of available alternative fuels
Vehicle and infrastructure data		• Fraction of existing vehicle fleet capable of using alternative fuel(s) targeted by policy • Extent to which renewable/low-GHG fuel infrastructure is deployed and fuel available	• Projected change in vehicle purchase price (for dedicated-fuel vehicles) and payback period given projected fuel prices • Differences in key performance attributes for alternative fuel versus conventional fuel vehicles (e.g. range, cargo capacity, safety)
Emission factors	• Default emission factors for fuel types	• Life cycle emissions associated with unit of fuel, by type	• Actual life cycle emissions considering production pathways used

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[7] See https://ec.europa.eu/energy/en/topics/renewable-energy/biofuels/voluntary-schemes.

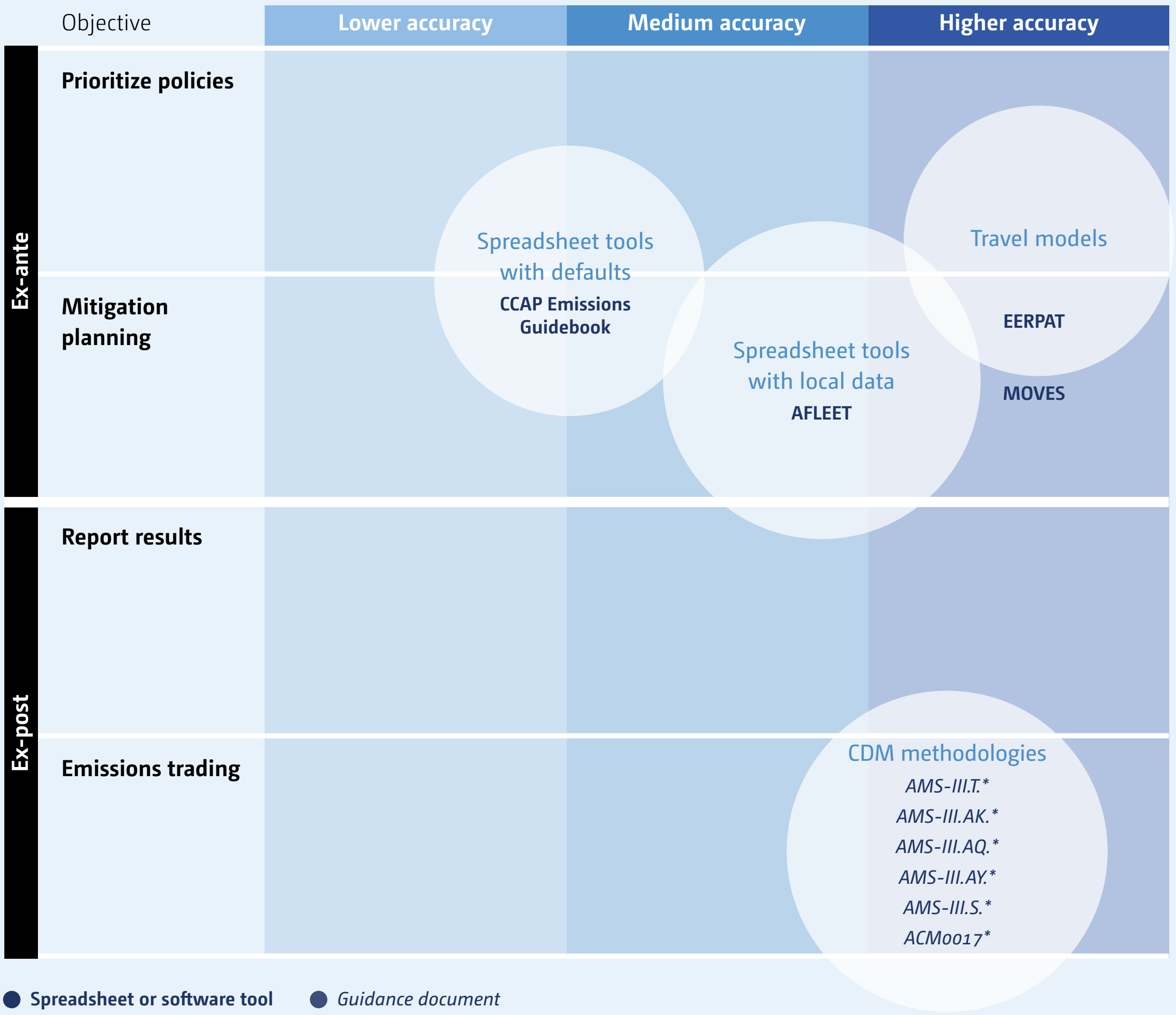
4.4 GUIDANCE ON THE SELECTION OF ANALYSIS TOOLS FOR ALTERNATIVE FUELS MITIGATION ACTIONS

Higher degrees of accuracy can be obtained with more disaggregated data, if some or all of the data are locally derived. While combining local data with defaults can yield benefits, using disaggregated default data alone is seldom more accurate than using aggregated default data. Estimating the penetration of alternative fuels can also require contextual data about the fleet and fuel infrastructure.

Evaluation methodologies for mitigation actions promoting alternative fuels have been developed under the CDM for several types of actions. Each methodology is fairly specific and limited in scope of application. Aside from CDM methodologies there exist some general tools that can be used for evaluating the emissions of different fuel mixes, given inputs of fuel use.

Figure 15

Navigating classes of available methods and associated tools for alternative fuels mitigation actions



(*) AMS-III.T.: Plant oil production and use for transport applications, AMS-III.AK.: Biodiesel production and use for transport applications, AMS-III.AQ.: Introduction of Bio-CNG in transportation applications, AMS-III.AY.: Introduction of LNG buses to existing and new bus routes, AMS-III.S.: Introduction of low-emission vehicles/technologies to commercial vehicle fleets, ACM0017: Production of biodiesel for use as fuel figure 15 maps existing methodologies and tools for mass transit investments according to their purpose (y axis) and level of accuracy (x axis).

4.4.1 Description of tool types

The following sections describe a number of tools that are available for estimating GHG emission reduction from alternative fuels projects. They are classified according to similarities in methodology.

4.4.2 Disaggregate emissions models

As described earlier, these are bottom-up models that calculate GHG emissions based on travel activity, fuel efficiency and emission factors. Each model has slightly different levels of disaggregation and data requirements.

The United States Environmental Protection Agency (EPA) supports the MOVES system. This is an emissions modelling system that estimates emissions for mobile sources at the national, county and project level for criteria air pollutants, GHGs and air toxics. The user must provide VKT data at the desired degree of disaggregation, including speed if available. Although the defaults included are for the United States fleet, given appropriate data on fuel types and fleet make-up, such as vehicle age distribution, types of vehicles, etc., the model can be modified to predict emissions in other regions. The 2015 version will automatically adjust fuel property changes based on user-made fuel property changes (e.g. ethanol), although this requires the user to have reliable life cycle data.

The EERPAT tool is a non-spatial policy analysis tool, designed to provide rapid analysis of many scenarios that combine effects of various policy and transportation system changes. In order to provide a quick response comparing many scenarios, it makes a number of simplifying assumptions (consistent with emissions and advanced regional travel demand modelling practice) that somewhat limit the detail and precision of its outputs compared to a properly set up MOVES implementation. Although this tool is most useful for developing ex-ante travel activity projections, those projections can be tested over different fuel type scenarios created by changing the vehicle mix assumptions; this can allow modelling of alternative fuels strategies.

The AFLEET (Alternative Fuel Life-Cycle Environmental and Economic Transportation) tool allows users to examine both the environmental and the economic costs and benefits of alternative fuel and advanced vehicles. It was developed for stakeholders to estimate petroleum use, GHG emissions, air pollutant emissions and cost of ownership of light-duty and heavy-duty vehicles using simple spreadsheet inputs. For a given scenario the user must input the characteristics of the fleet such as vehicle type and fuel or powertrain type (e.g. plug-in hybrid electric, biodiesel, CNG), then the annual mileage for each type. The tool calculates the emissions from each scenario, as well as cost saving information.

Table 29

Disaggregate emissions models for alternative fuels mitigation actions

Ease of use/data collection: Highly resource and data intensive

Name	Application / summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
MOVES	Emissions model	Requires VKT and speed inputs	US EPA	Very good	Fair	Defaults for USA – allows user input for other areas	Free
EERPAT	Non-spatial disaggregate model	Includes emissions module	US Federal Highway Administration	Very good	Good	Defaults for USA – allows user input for other areas	Free
AFLEET	Emissions and costs model for fleets	Fleet data and fuel costs	Argonne National Laboratory	Good	Good	Defaults for USA including WTW upstream emissions	Free

Table 30

Disaggregated bottom-up ex-post guidance for alternative fuels mitigation actions

Ease of use/data collection: Moderately resource and data intensive (may require agricultural production data)

Name	Application / summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
AMS-III.T.: Plant oil production and use for transport applications	Displacement of diesel with plant oils	Cultivation, production and use for transport	UNFCCC	Good	Fair	None	Free
AMS-III.AK.: Biodiesel production and use for transport applications	Displacement of diesel with bio-diesel	Cultivation, production and use for transport	UNFCCC	Good	Fair	None	Free
AMS-III.AQ.: Introduction of Bio-CNG in transportation applications	Use of CNG from biomass in transport	Cultivation, production and use	UNFCCC	Good	Fair	None	Free
AMS-III.AY.: Introduction of LNG buses to existing and new bus routes	Introduction of new LNG busses to existing or new routes	Must replace gasoline or diesel existing or planned vehicles	UNFCCC	Very good	Very good	None	Free
ACM0017: Production of biodiesel for use as fuel	Production, sale and consumption of blended biodiesel used as fuel	Cultivation, production and use	UNFCCC	Very good	Very good	None	Free
AMS-III.S.: Introduction of low-emission vehicles/technologies to commercial vehicle fleets	Introduce vehicles with lower emissions per kilometre	Includes lower emissions by means of alternative fuels	UNFCCC	Good	Fair	None	Free

4.4.3 Disaggregated bottom-up ex-post guidance

This consists of CDM methodology documents that detail the specific variables that should be collected. The documents give methodological guidance on how to collect these variables and how to calculate emissions using them. Because CDM is focused on documenting precise amounts of real values, CDM tools are primarily used ex-post. Each methodology is tailored to the specific type of fuel or the specific type of fleet where fuel will be used. Methodologies that focus on production offer careful definitions for conservatively estimating the actual amount of fuel produced and incorporating upstream emissions.

The four methodologies that focus on biofuels all look closely at the upstream characteristics of the fuel production in order to properly account for differences in agricultural and production process practices. Users must input data such as the amount of fossil fuels used to harvest, transport and generate the biodiesel or biogas fuels.

Methodologies for vehicle-centred actions focus on calculating emissions per passenger or tonne kilometre. They assume the same VKT for both old and new fleets and require inputs of the measured amount of fuel of each type, which is used in the baseline and mitigation scenarios.

4.4.4 Simple bottom-up tools with mostly default data

This is a spreadsheet program that accepts limited local data but offers default values for emissions based on experience in the United States. VKT estimates or actual fuel use must be entered by the user. It calculates the emissions based on default values for each type of fuel assuming standard upstream values for biodiesel and ethanol.

Table 31

Simple bottom-up tools with mostly default data for alternative fuels mitigation actions

Ease of use/data collection: Moderate to low

Name	Application / summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
CCAP Emissions Guidebook	Biodiesel Ethanol in fleets	Ex-ante tool; sketch planning estimates based on combining local data and defaults	CCAP	Good	Fair	United States emission factors for biodiesel and ethanol	Free

4.5 MONITORING

Performance of the mitigation action is monitored by tracking key variables over time. The monitoring frequency will vary, depending on the monitoring regimen and the budget available for data collection. Measures that focus on fuel production will have different monitoring challenges from measures that focus on introducing alternative fuel vehicles to the fleet. Production of alternative fuels will be monitored at the sites, which may be far from the areas that consume the fuel. Upstream emissions may require specialized agricultural or industrial knowledge to achieve reliable results, but there tools associated with CDM methodologies (e.g. ACM0017) which help in estimating upstream emissions. The number of vehicles using alternative fuels can be monitored at the private or commercial fleet level, or by government agencies managing a specific programme.

It is also suggested that information on implementation and performance be included in the monitoring plan to show progress before the full effects of the action may be apparent. Table 31 presents a minimum list of key variables and recommended maximum intervals for measurement if no other requirements are present (e.g. CDM).

4.6 EXAMPLE – PARAGUAY PLANT OIL PRODUCTION

The United States and Brazil have large national-level alternative fuel programmes in place that are monitored by the national government. The United States Department of Energy maintains the Alternative Fuels Data Centre, which tracks statistics at a detailed level.

However, at the CDM project level only one alternative fuels CDM project has been registered, Plant-Oil Production for Usage in Vehicles, Paraguay. This project was initiated in 2010 but no results have been reported on the CDM registry.

Table 32

Minimum indicator set for alternative fuel mitigation action

Category	Indicator	Normal monitoring frequency
Implementation indicator	Construction of plant Beginning new production Introduction of new vehicles	One time
Performance indicators	VKT of new vehicles Sales of alternative fuel	Annual Annual
Impact indicators	Total fossil fuel displaced Total GHG emission reduction	5 years 5 years

Chapter 5

INTER-URBAN RAIL INFRASTRUCTURE

5.1 DESCRIPTION AND CHARACTERISTICS OF INTER-URBAN RAIL INVESTMENTS

This mitigation action covers national or regional investments in long distance inter-urban rail infrastructure for passenger and/or freight. This includes programmes and projects for construction of new or additional lines and tracks, electrification of tracks, purchase of rolling stock, new stations or terminals, etc.

The outcomes of successful implementation of this mitigation action are expected to decrease the mode share of on-road passenger and freight modes, including trucks, private automobiles and buses, depending upon the focus and route. This leads to decreased car, bus and/or truck VKT and a subsequent decrease in fuel use and GHG emissions.

Inter-urban rail infrastructure mitigation actions are known to generate a number of sustainable development co-benefits such as decreased congestion, air pollution and noise due to fewer trucks and buses on the road in rural communities. It may lead to faster travel between urban areas. It can also lead to increased road safety by reducing traffic on rural highways.

5.2 STRUCTURE OF MITIGATION EFFECTS

5.2.1 Cause-impact chain

Inter-urban rail infrastructure mitigation actions should result in measurable effects that are reflected in indicator variables in bottom-up models (ASIF approach). Inter-urban rail can affect passenger and/or freight travel. Depending upon whether passenger transport or freight transport is being considered, the causal chain is shown in figure 16 and figure 17. The expected changes in those variables will cause the desired outcomes.

5.2.2 Key variables to be monitored

The key variables that are expected to change by inter-urban rail infrastructure mitigation actions are listed below, followed by the expected mechanism that causes them to change. A given project may not affect every variable if the appropriate mechanism of change is not present. For example if the technology of locomotives does not change, then fuel efficiency would not change. The variables listed below should be monitored as appropriate depending on whether freight or passengers are expected to be affected.

5.2.3 Monitor for intended effects

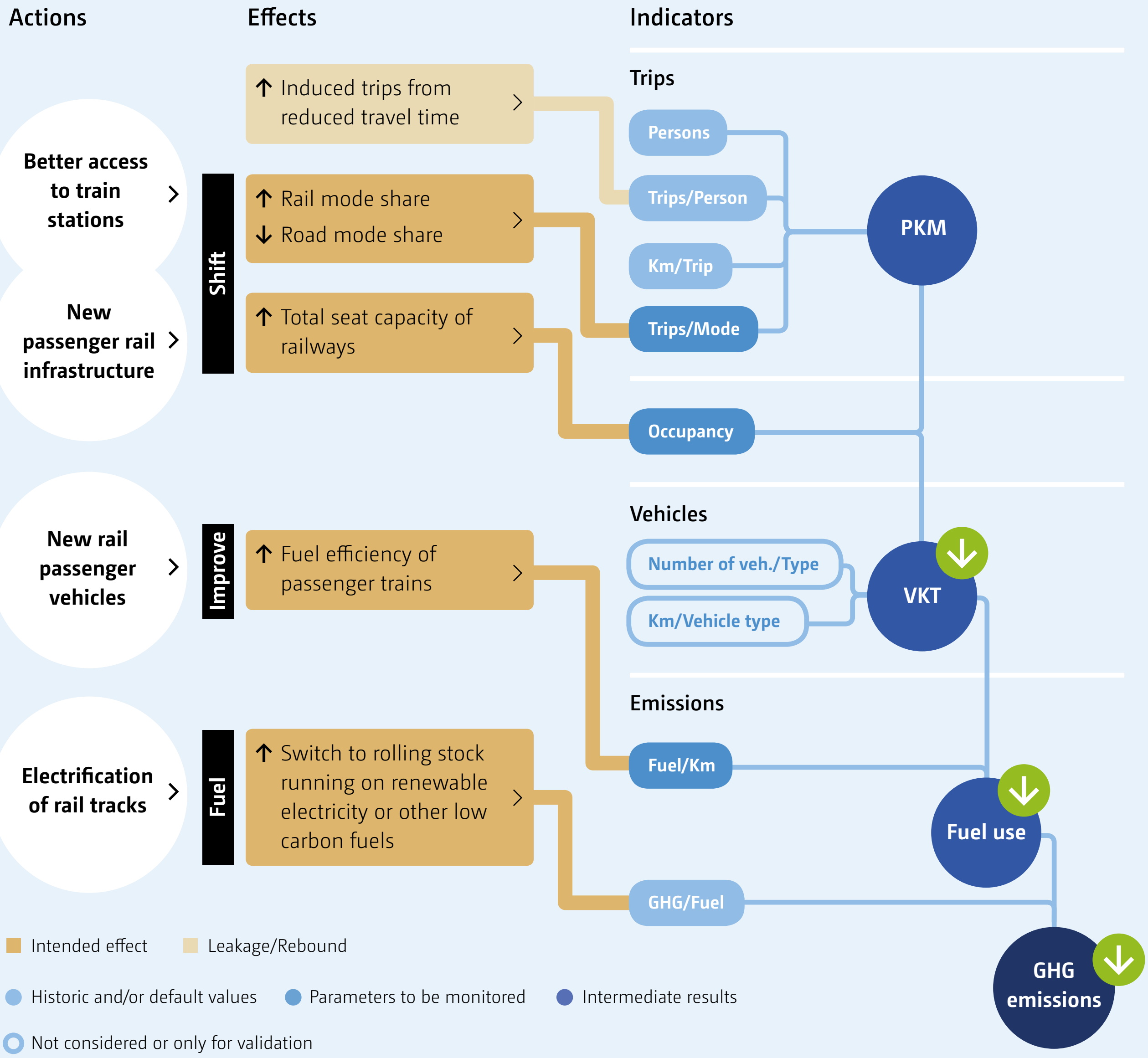
- Trips/mode – new improved rail infrastructure will attract trips previously made by car or bus;
- Tonnes/mode – new improved rail infrastructure will attract cargo previously transported by truck;
- Occupancy – rail passenger travel has higher capacity per vehicle than private automobile or bus;
- Load factor – the capacity of the rail mode vehicles could expand as a result of better infrastructure, which will lead to lower overall GHG emissions per tonne;
- Fuel/km – investment in newer train technology could improve fuel efficiency,
- GHG/fuel – electrification changes the fuel source and thus GHG/fuel, thus the overall decarbonization trajectory of the electricity sector will have a great effect on this variable.

5.2.4 May be monitored for leakage or rebound effects: [not highlighted by colour in figure 16 and 17]

- Trips/person – induced trips could be created owing to faster travel times or lower costs;
- Tonnes – induced freight tonnes could be created due to lower transport costs.

Figure 16

Inter-urban rail infrastructure (passenger) mitigation actions causal chain



5.2.5 Interaction factors

The magnitude of change in the key trips or tonnes/mode variables (the mode split) will be affected by the specific characteristics of the rail infrastructure that is built. To achieve maximum effects the action should be tailored to fit the national or regional context; for example, the best routes should be selected based on travel or market demand. Some ex-ante methodologies, such as travel demand models, may be able to quantitatively account for certain contextual factors. For other methods an economic cost analysis or a qualitative assessment using expert judgment may be needed. When performing ex-ante estimation of the mitigation potential of inter-urban rail infrastructure mitigation actions, the following factors can have a substantial impact on magnitude and should be taken into account:

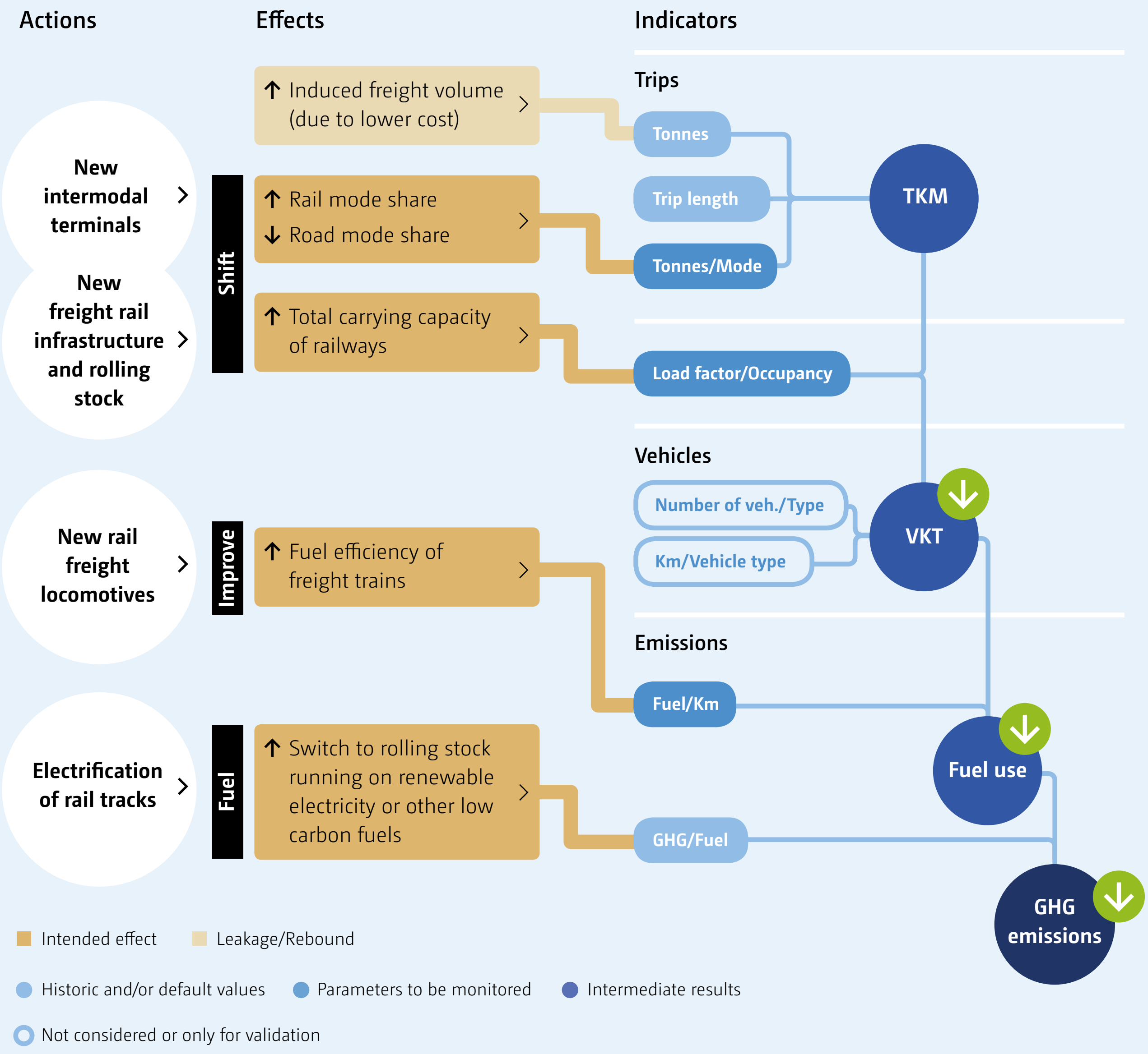


Figure 17

Inter-urban rail infrastructure (freight) mitigation actions causal chain

- Type of freight being moved; availability and location of trans-shipping and multi-modal facilities;
- Passenger accessibility to train stations at origin and destination; transit-supportive land use plans (TOD, parking, pedestrian access);
- Cost/speed/travel and handling time of road/air versus rail modes.

Table 33

Dimensions of boundary setting for inter-urban rail mitigation actions

Dimension	Options for boundary setting
Geographical	National, regional, specific rail corridor
Temporal	10–20 years
Upstream/downstream	Energy sector (electricity), may also consider infrastructure construction
Transport subsector	Passenger and /or freight transport
Emission gases	CO_2eq (may include CH_4, N_2O)

5.2.6 Boundary setting

The boundary will depend on the type of mitigation action. Fuel production projects usually include the production area and the transportation use area. Vehicle conversion projects are more often limited to the use area, with upstream emissions incorporated into the emissions factor.

Upstream balance of emissions/sinks are important to include for the production of bio-fuels, as sinks contribute to the mitigation effect, other emissions such as methane leakage of LNG production may or may not be included depending upon the methodology. If this is done upstream emissions also have to be considered for the baseline fuels.

In the CDM methodologies the temporal boundary of a vehicle conversion projects is limited to the lifetime of the original fleet. Bio-fuel production can extend to the life of the project.

5.2.7 Key methodological issues

The GHG impact depends upon the change in mode shares from road to rail travel. A list of specific issues to consider when selecting a methodology include:

- Collecting accurate travel activity data by mode – rail data may be centralized but road data may require surveys
- Estimating the ex-ante future and BAU mode shares of passengers or freight
- Establishing accurate emission factors for truck versus rail travel on a tonne/km or passenger/km basis, including effects of new technology
- Determining any induced travel
- Attributing shift to particular investments versus external factors such as fuel prices

5.2.8 Double counting concerns

Other policies and actions taken to mitigate GHG may have synergistic or interaction effects on the modal share and efficiency of travel activity.

This can lead to difficulty in attributing the reduction to a particular action or to counting the same tonnes more than once for different actions. Care should be taken in this regard if any of the following policies or actions is being implemented concurrently. In some cases the effects can be incorporated in a dynamic baseline (BAU); in other cases it may be better to analyse the combined effect of the actions rather than trying to disaggregate the reductions.

Table 34

Actions with potential for double counting for inter-urban rail mitigation actions

Mitigation action	May affect this variable
Fuel cost (taxes or subsidy removal)	Mode share of passengers or freight
Logistics facilities investment	Induced trips, mode share
Congestion pricing	Mode share of passengers or freight
Fuel economy standard	Emission factor for road modes compared with rail

5.3 DETERMINING THE BASELINE AND CALCULATING EMISSION REDUCTIONS

5.3.1 Analysis approach

The baseline scenario for inter-urban rail infrastructure mitigation actions can be described as the existing mode shares of inter-urban passenger and freight travel and the projected BAU share given existing capacities and plans for expansion of rail and road infrastructure.

The baseline emissions from the transportation of passengers and cargo between urban centres are calculated based on the amount of people or cargo transported, the distance of the baseline trip between origin and destination and a baseline emission factor per passenger or tonne kilometre transported. Measurement of current travel activity data serves as the basis for this baseline calculation, which must then be projected into the future for ex-ante analysis and for a counterfactual baseline for ex-post analysis. The mitigation scenario activity in passengers or tonnes is typically assumed to be the same amount as the baseline but shifted to more efficient modes. Emission factors for the new modes and revised distances using the new rail infrastructure are applied under the mitigation scenario.

There are three general approaches for projecting or counterfactually projecting the amount of future travel activity for baselines or rail investment scenarios:

- National- or regional-scale travel models;
- Expert judgment based on historical trends, using time series data gathered ideally for at least 10 years;
- Survey or data collection from rail passengers or shippers.

Ex-post analysis also requires estimates of current emissions, which are calculated based on monitored travel activity and respective emission factors within the defined boundaries. In practice, many methodologies first calculate emissions per passenger or tonne kilometre for the competing road and rail modes then look at modal shift. Emission reductions, as always, are the difference between the project emissions (real or estimated ex-ante) and the baseline.

Consideration of upstream emissions from electricity production is included in methodologies. Construction emissions are not included in most methodologies but are optional in some.

Table 35

Level of disaggregation of key variables

	Degree of local data disaggregation and context variables		
	Lower accuracy	Medium accuracy	Higher accuracy
Travel activity data	· Total vehicle trips · Forecast change in passengers or tonnes to rail · Average passengers or tonnes per road vehicle and rail vehicles* · Average trip length*	· Vehicle trips in analysis corridor or area by vehicle type · Vehicle trip length by vehicle type · Proposed change in car/bus/truck VKT from feeder operations · Forecast change in rail tonnage	· Total passenger trips or tonnes shipped in analysis area · PKM or TKM in analysis area by vehicle type · Passengers or tonnes/vehicle by vehicle type · Proposed change in VKT from feeder operations (by vehicle type) · Forecast change in passengers or tonnes/mode · Trip lengths of new shifted trips by mode (incl feeder) · Prior mode of cargo
Emission factors	· Average emission factors *	· Emission factors by vehicle type and speed*	· Forecast change in VKT by vehicle type (modelled)** · Emission factors for rail vehicles · Construction emission of new infrastructure**

*=default OK, **= optional item) for inter-urban rail mitigation actions

5.3.2 Uncertainties and sensitivity analysis

The most uncertain variable in the emission reduction analysis of inter-urban rail infrastructure mitigation actions is usually the ex-ante estimate of new ridership/freight movement on the rail line. The capture of passenger trips by rail mode can come from cars or from buses, so accurate mode split data are important. For freight the vehicle fleet (and age) of trucks is important. Predicting mode split depends on the attractiveness of the rail line relative to alternative modes, which is highly context dependent and differs for freight and passenger situations.

In contrast, ex-post methodologies are fairly simple, based on monitoring and assuming that the change in mode share is due to the project.

The potential for rebound effects is also difficult to estimate ex-ante, although economic models may offer some guidance as to the elasticity of travel versus cost.

5.4 GUIDANCE ON THE SELECTION OF ANALYSIS TOOLS FOR INTER-URBAN RAIL INFRASTRUCTURE MITIGATION ACTIONS

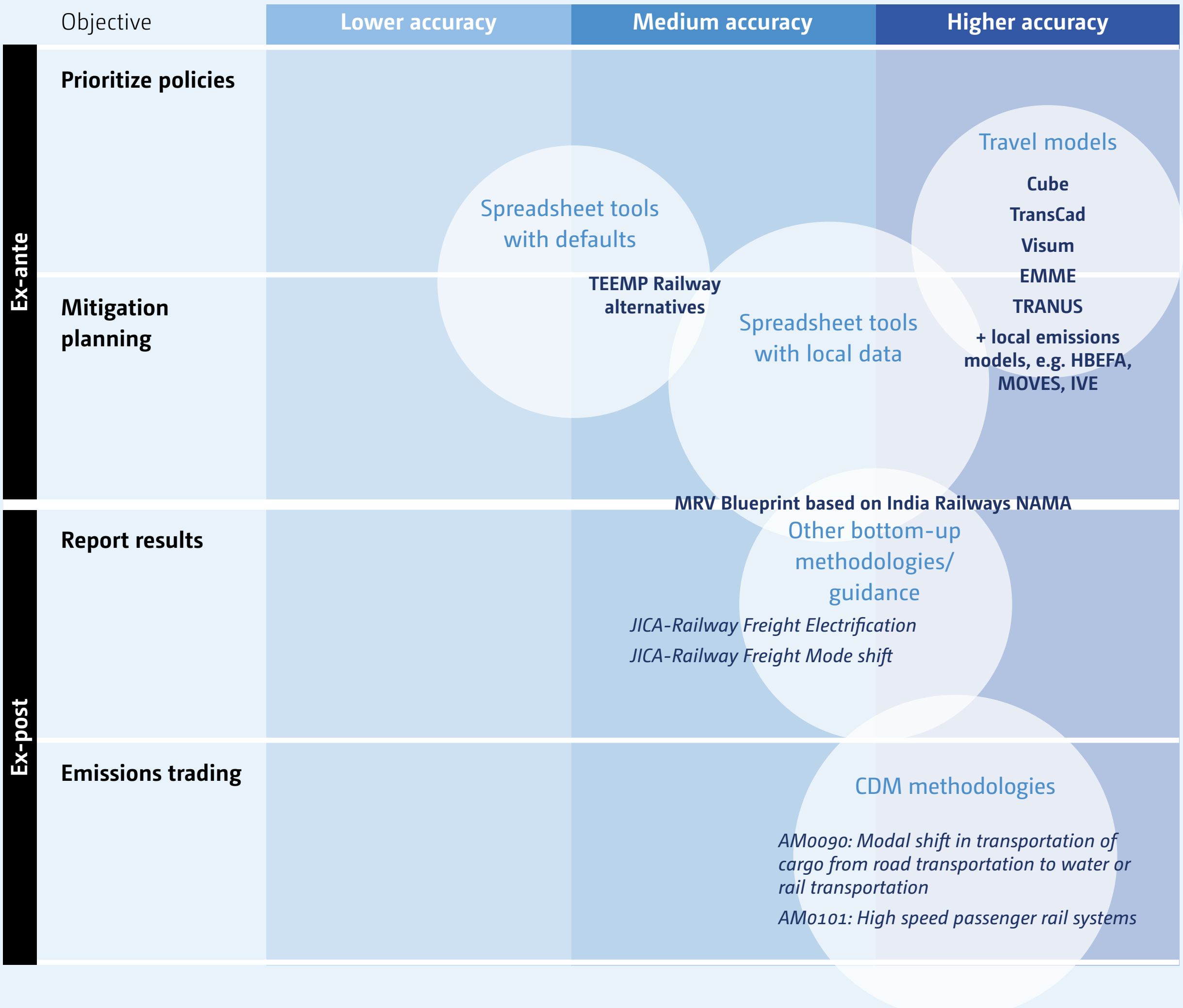
Higher degrees of accuracy can be obtained with more disaggregated data, if some or all of the data are locally derived. While combining local data with defaults can yield benefits, using disaggregated default data alone is seldom more accurate than using aggregated default data. Table 35 shows the level of data disaggregation that is desirable for each general level of accuracy.

There are two rail-specific transport analysis methodologies for GHG analysis under the CDM, and the Japan International Cooperation Agency (JICA) developed three more simplified methods based on CDM. TEEMP (Transport Emissions Evaluation Models for Projects) has developed a rail mode shift sketch planning module that accommodates freight or passengers. In addition, a methodology for monitoring a national rail programme in India was developed for the Asian Development Bank and India Railways. Travel demand modelling can also be used in areas where regional or national models are available, although models for freight are not as common as for passenger travel. Commercial software packages have passenger and freight modelling capabilities that include rail modes.

Figure 18 maps existing methodologies and tools for freight modal shift projects according to their purpose (y axis) and level of accuracy (x axis).

Figure 18

Navigating classes of available methods and associated tools for inter-urban rail infrastructure mitigation actions



● **Spreadsheet or software tool** ● *Guidance document*

5.4.1 Description of tool types

The following sections describe a number of tools that are available for estimating GHG emission reduction from transit projects. They are classified according to similarities in methodology.

5.4.2 Travel demand models

These are spatial interaction models that calculate VKT disaggregated by mode, time of day and speed. Trip lengths are based on location of origins and destinations. Mode choice can be modelled based on interaction of origins, destinations and transport systems. Induced trips can be modelled using a capacity restraint formula (activity models may have more sophisticated methods). With appropriate submodules some models can include freight, transit and NMT. Some models can include land use simulations as well. Important disaggregated variables cascade through analysis. Some defaults may be included and models include the ability to change any variable. Models are calibrated by entering local data from detailed travel surveys and comparing the model output to known results. This option is an accurate methodology for forecasting future travel activity parameters if a well-calibrated mode choice module that includes rail is part of the model. A freight model is needed if shifting the mode of freight trips is part of the mitigation action.

Typically, highly disaggregated activity data from travel demand models are input to a separate emissions model calibrated to national or supranational fleets. Some software packages incorporate emission factors from various sources for an extra cost. External standard emissions models that accept highly disaggregated inputs include MOVES, HBEFA and IVE. Emissions models also have to be adapted to local or at least country-specific circumstances regarding, for example, the underlying fleet composition and emission factors to deliver meaningful results. Travel model outputs can, however, also be aggregated and emissions calculated with simpler emission factors.

Table 36

Travel demand models for inter-urban rail mitigation actions

Ease of use/data collection: Highly resource and data intensive

Name	Application / summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
Cube	Passengers and commodity flow	Multimodal passenger and truck freight	Citilabs, Inc.	Excellent	Paid training offered	Internal parameters*	High
TransCad	Commodity flow	Multimodal passenger truck and rail freight	Caliper Corporation	Excellent	Paid training offered	Internal parameters*	High
VISUM	Passenger trips and "tour based" freight model	Multimodal	PTV Group	Excellent	Paid training offered	Internal parameters*	High
EMME	Travel activity	Unknown	INRO Software	Excellent	Paid training offered	Internal parameters*	High
TRANUS	Travel activity	Multimodal passenger only	Modelistica	Very good	Fair	Internal parameters*	Free

*for example friction factors, mode choice curves, and other coefficients for internal sub-models

Table 37

Disaggregated bottom-up ex-post guidance for inter-urban rail mitigation actions

Ease of use/data collection: Moderately resource and data intensive

Name	Application / summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
MRV-Blueprint: India Railways NAMA	National rail infrastructure programme NAMA	Passenger and freight mode shift from road or air modes	Grütter Consulting	Very good	Good, brief recommendations for data sources at national level	No	Free
AM0090 Proposed Version 03.1	Shift cargo among trucks barges, ships and trains	Ex-post, upstream including construction, electric grid factor	UNFCCC	Good	Brief 'measurement procedures' for all variables	Defaults emission factors for diesel for trucks, barges and ship fuel oils	Free
AM0101 High speed passenger rail systems	Passenger rail system >200kph	Ex-post, upstream electric grid factor, includes shift from air travel	UNFCCC	Very good	Very good	Default emission factors for air travel	Free

5.4.3 Disaggregated bottom-up ex-post guidance

This consists of CDM methodology documents or other MRV guidance documents that detail the disaggregated variables that should be collected. The MRV blueprint methodology looks at the entire rail sector, freight as well as passenger transport and not just at an individual new line. This is different from CDM project-based approaches where a new line or investment is looked at as a stand-alone action. All the methodologies calculate the emissions PKM or TKM of the different modes and apply a mode split factor, either measured or based on surveys.

All the documents describe the required travel activity variables and give precise methodological guidance on how to collect them and how to calculate emissions using

Table 38

Partially aggregated bottom-up spreadsheet tools with defaults for inter-urban rail mitigation actions

Ease of use/data collection: Moderate

Name	Application / summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
TEEMP Railway alternatives	Rough ex-ante assessment based on shift of passengers and/or freight between road and rail	Manual entry of expected mode shift by percent	Clean Air Asia/ ITDP/ADB	General guide for all spreadsheets	Some guidance with defaults	Emission factors for passenger and tonne kilometre for highway and rail Defaults for trip lengths	Free

Table 39

Simple bottom-up tools with mostly default data for inter-urban rail mitigation actions

Ease of use/data collection: Moderate to low

Name	Application / summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
JICA Railway electrification	GHG emission from electrification of rail	Includes mode shift effects Includes upstream grid factor	JICA	Limited	Fair	Refers to appendix	Free
JICA Railway (Freight) mode shift	Mode shift of freight from truck to rail	Includes upstream grid factor	JICA	Limited	Fair	Refers to appendix	Free
JICA Railway passenger mode shift	Aimed more at within urban areas but works for inter-urban rail	Includes mode shift effects Includes upstream grid factor	JICA	Limited	Fair	Refers to appendix	Free

them. Because CDM is focused on documenting precise amounts of real values, CDM tools are primarily used ex-post. Ex-ante BAU is estimated following the same general approach but not described in detail in CDM methodologies. Sometimes induced trips may be estimated using this methodology. Defaults and spreadsheets are not included, although default sources may be referenced.

5.4.4 Partially aggregated bottom-up spreadsheet tools with defaults

This is a spreadsheet-based tool that calculates the reduction from a mode shift between rail and highway using default values. It requires the user to enter the passenger and freight data either as PKM/TKM or in terms of units and trip lengths. It has a section for calculating the construction emissions for rail projects.

5.4.4 Aggregated bottom-up guidance tools

These are guidance documents that offer a framework of equations for calculating GHG emission reduction from mode shift. These methodologies are based upon and similar to the CDM methodologies in that they use emissions per PKM and TKM but they offer less data collection guidance.

5.5 MONITORING

Performance of the mitigation action should be monitored by tracking key variables over time. The monitoring frequency will vary, depending on the monitoring regimen and the budget available for data collection. Official passenger and freight data should be obtained from railway operators, which may or may not be government owned depending on the national circumstances. Key mode share and trip length data can require transport surveys that may not be possible on an annual or biannual basis. Although new methods such as mobile phone tracking can substitute for surveys in some instances, many organizations cannot be assumed to have reliable data for all variables annually. However, different variables can be updated at different intervals.

Table 40

Minimum indicator set for Inter-urban rail mitigation action

Category	Indicator	Normal monitoring frequency
Implementation indicator	Completion of new rail line or facility	One time or by construction phase
Performance indicators	Mode shift in percent	Annual
	Annual passengers or tonnes of cargo by mode	Annual
Impact indicators	Calculated passenger or cargo tonne kilometres by mode	5 years
	Latest emission rates by mode	5 years
	Calculated emissions in study area	5 years

Implementation and performance data can show progress before the full effects of the action may be apparent. The table below presents a minimum list of key variables and recommended maximum intervals for measurement if no other requirements are present (e.g. CDM).

5.6 EXAMPLE – INDIA RAILWAYS NAMA

A methodology was developed for MRV of a national-level railway NAMA. The NAMA includes six dedicated freight corridors, double, triple or quadruple tracking of various saturated corridors and technology upgrades and new rolling stock. Total investment of nearly USD 800 billion is contemplated.

The MRV methodology looks at the entire rail sector, covering all inter-urban rail operations in India. Urban services are not included. It looks at direct and indirect effects including construction and upstream fuel production. Two baselines are examined, a ‘frozen’ baseline and a dynamic BAU with some rail growth. The ex-ante estimate for the entire NAMA using the frozen baseline is a reduction of 152 Mt CO_2 eq per annum between 2012 and 2030.

Further details are available at:
http://transport-namas.org/wp-content/uploads/2014/10/TRANSfer_MRV-Blueprint_Railway-NAMA_India_draft.pdf

Chapter 6

SHIFT MODE OF FREIGHT TRANSPORT FROM ROAD TO RAIL OR WATER

6.1 DESCRIPTION AND CHARACTERISTICS OF FREIGHT MODAL SHIFT MITIGATION ACTIONS

This mitigation action includes activities that result in modal shift in transportation of a specific cargo (excluding passengers) from road transportation using trucks to water transportation using barges or ships or rail transportation.

This mitigation action covers investments that increase the capacity and/or decrease the cost of rail or water transport modes. This typically includes infrastructure such as rail lines, stations or yards and rolling stock as well as intermodal rail hubs and port facilities, river channel projects, ship or barge fleets, etc. The investments may include new vehicles that are more efficient than the old fleet, which increases the emission reduction effect of the modal shift.

The outcomes of successful implementation of this mitigation action are expected to decrease mode share of truck cargo and increase rail or waterborne cargo share, in some cases for a specific type of cargo as freight shift is highly dependent upon the type of good. This leads to decreased TKM moved by truck, decreased truck VKT and a shift of TKM to more efficient rail or water modes, resulting in decreased fuel use and GHG emissions.

Shifting freight from truck mode to rail or water can generate sustainable development co-benefits such as decreased congestion and noise due to fewer trucks on the road. It can also lead to increased road safety by reducing traffic. Reduced toxic air pollution can also be a benefit, especially if freight is moved to electric rail.

6.2 STRUCTURE OF MITIGATION EFFECTS

6.2.1 Cause-impact chain

Freight mode shift actions result in measurable effects reflected in ASIF indicators, but the causal chain model is slightly different from passenger transport. Mitigation actions in the form of investments in new infrastructure in essence reduce the cost per unit of transporting freight using the target modes. However, many factors go into the cost calculation. The actual choice of mode is based on a combination of four categories of cost factors as described below:

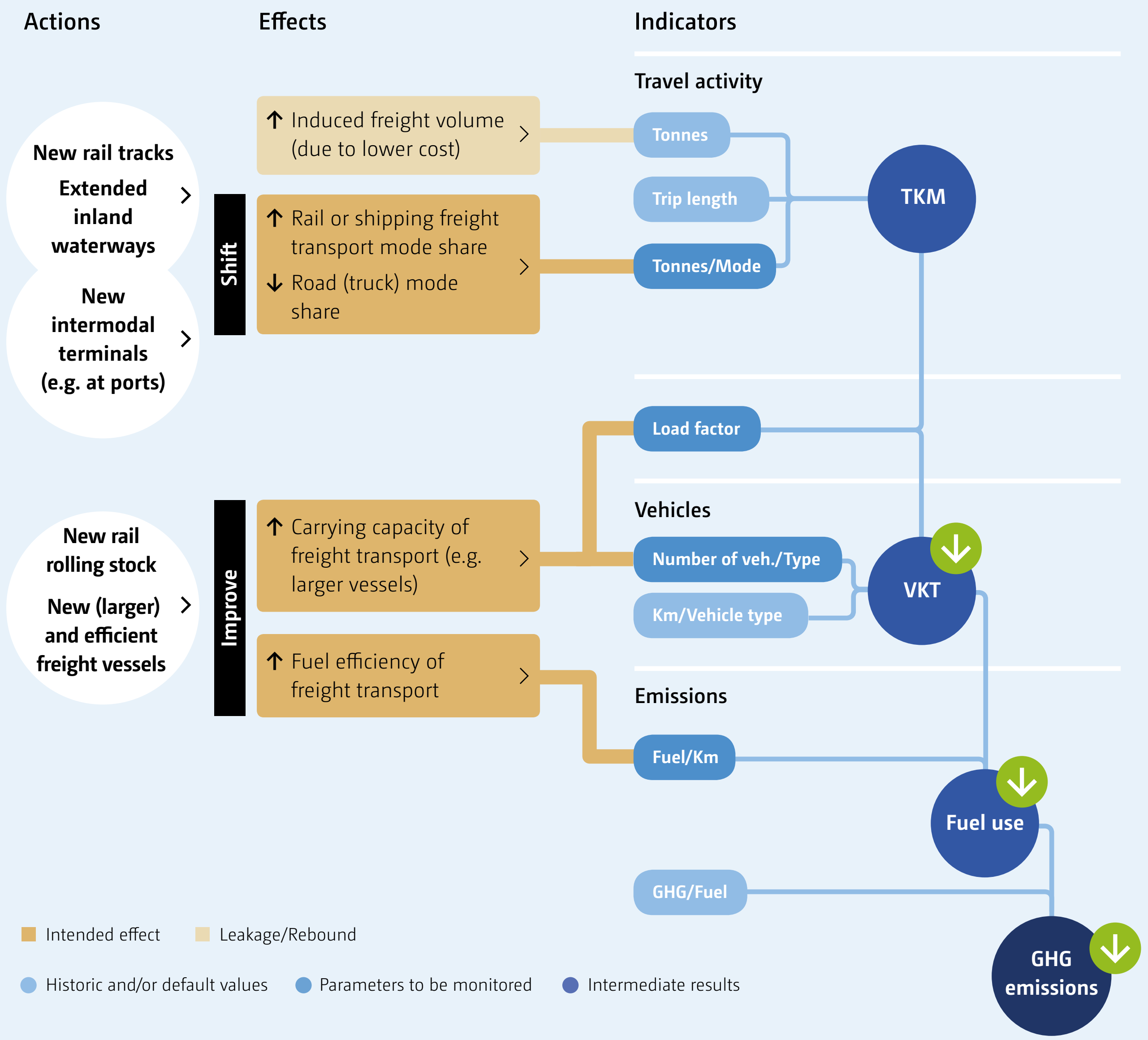
1. goods characteristics – these include physical characteristics of goods such as the type of commodity, the size of the shipments, weight, density and the value of the goods;
2. modal characteristics – speed of the mode, mode reliability, network accessibility and the capacity;
3. total logistics cost – inventory costs, loss and damage costs, and service reliability costs;
4. overall logistics characteristics – length of haul and the shipment frequency, intermodal transfers and feeder trips, empty return trips or repositioning of empty containers.

Trip length depends on the origin and destination of the specific type of freight that is transported. Similarly the load factor will vary with the type of freight and the mode chosen.

If the elasticity of demand is sufficient the decreased cost can result in increased total freight and more economic activity as a rebound effect, eroding some of the GHG emission benefits.

The expected changes in those variables will cause the desired outcomes. See figure 19.

Figure 19
Freight modal shift causal chain



6.2.2 Key variables to be monitored

The key variables that are expected to change by freight mode shift actions are listed below, followed by the expected mechanism that causes them to change. A given project may not affect every variable if the appropriate mechanism of change is not present. For example, if the investments do not affect the number of rail or water vehicles, but only the cost or some other factor, then historical/default values can be used.

6.2.3 Monitor for intended effects

- Tonnes/mode – new improved freight infrastructure will attract cargo transported by truck mode;
- Load factor – the throughput capacity of the water or rail mode vehicles could expand due to better infrastructure, for example intermodal terminals, which will lead to lower overall GHG emissions per tonne;

- Number of vehicles/type – new rolling stock or vessels may be added to the fleet;
- Fuel use – new vehicles, for example electric trains, may have different fuel efficiencies;
- Type of freight – it may be necessary to disaggregate variables by the type of freight, as different types will have different load factors, etc.

6.2.4 May be monitored for leakage or rebound effects: [not highlighted by colour in figure 19]

- Tonnes/mode – induced freight tonnes can be created owing to lower transport costs (see four cost factors above), regulatory policies that mandate certain modes could under some circumstances suppress total freight;
- Km/tonne – lower costs can sometimes lead to longer trip lengths because longer trips can be made for the same cost of previous short trips;
- Fuel/km – could increase for road freight if trucks become under-utilized as a result of mode shift

6.2.5 Interaction factors

The magnitude of change in the key variables will be affected by the specific characteristics of the freight mode shift action. To achieve the best effects the action will be designed to fit the national or regional context. Some methodologies, transport or travel demand models, for example, may be able to quantitatively account for certain contextual factors. For other methods a qualitative assessment using expert judgment may be needed. When performing ex-ante estimation of the mitigation potential of a freight mode shift action, the following factors can have a substantial impact on magnitude and should be taken into account:

- Emission rate per tonne/km of the train or water modes;
- Cost of alternate modes using four categories of cost;
- Cross modal elasticity of demand;
- Speed/travel time of modes;
- Availability and location of transshipping and multimodal facilities;
- Relative load factors before and after modal shift.

6.2.6 Boundary setting

Water or rail are usually best for long distance freight transport, thus the project will be best analysed at the national or regional level. Often a specific corridor such as a river is singled out for investment, which can be used as the boundary while considering the feeder routes leading into it.

Table 41

Dimensions of boundary setting of freight modal shift mitigation actions

Dimension	Options for boundary setting
Geographical	National, regional, specific freight corridor
Temporal	10–20 years
Upstream/downstream	Energy sector (conventional fuels, electricity, biofuels), may also consider infrastructure construction
Transport subsector	Freight transport
Emissions gases	CO_2eq (may include CH_4, N_2O)

Upstream emissions from electricity generation should be included if the rail is powered electrically. However, if the mitigation action of the project aims solely at the switch to electric energy, that is, if rail freight is part of the baseline and the only difference is energy source, then the analysis should consider methodologies under fuel switching (action type 4).

Large projects such as a port or new rail lines and yards may have substantial construction emissions, which should be considered as part of the life cycle emissions and factored into calculations. In this case it may be necessary to compare with baseline construction emissions if the BAU scenario includes new highways or similar investments.

6.2.7 Key methodological issues

The GHG emission impact depends on the specifics of the project that make water or rail a more viable choice for freight transport compared with truck. These need to be considered carefully in any ex-ante analysis. Variables pertaining to the value of the freight, the time sensitivity and the location of origins and destinations become important when estimating the potential for mode shifting. Consideration of the end distribution characteristics of the cargo, for example, whether it is delivered to a single factory or to multiple small stores, also affects the mode choice. Other issues to consider when selecting a methodology include:

- Attributing shift to a particular policy or investment – how much does that policy affect the mode choice compared with other factors;
- Determining whether the cargo would have gone by truck without the project – some cargo will naturally go by water or rail owing to bulk, lack of time sensitivity, etc.
- Using correct emission factors for rail or ship – are default factors appropriate or are local emission factors per kilometre or per tonne different from typical values because of unique vehicles or geography, feeder requirements, etc.? If electric rail is used CO_2 emission factors of grid electricity specific to the national or regional grid have to be used;
- Accounting for truck feeder transport to and from rail or ship. If there is a substantial cost savings for water or rail, cargo may be attracted from more distant areas via feeder trucks;
- Specific characteristics of the non-road modes including empty return factors, size of vessels (larger vessels may have adverse environmental impacts such as river dredging, pollution from dirty bunker fuels, etc., leading to political opposition).

6.2.8 Double counting concerns

Other policies and actions taken to mitigate GHG emissions may have synergistic or interaction effects on freight mode shift actions. 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. Care should be taken in this regard if any of the policies or actions listed in table 42 is being implemented concurrently with the freight mode shift action.

Table 42

Actions with potential for double counting of freight modal shift mitigation actions

Mitigation action	May affect this variable
Fuel cost (taxes or subsidy removal)	Mode share
Logistics facilities investment	Induced trips, mode share
Fuel economy standards or measures for trucks	Mode share, truck transport costs
Improved logistics practices (e.g. alliances of small truckers)	Mode share, truck transport costs

6.3 DETERMINING THE BASELINE AND CALCULATING EMISSION REDUCTIONS

6.3.1 Analysis approach

The baseline scenario for freight mode shift actions is that the freight is transported by trucks over roadways. The baseline emissions from the transportation of the cargo are calculated based on the amount of cargo transported, the distance of the baseline trip between origin and destination for transportation of cargo by trucks and a baseline emission factor per TKM of cargo transported. Measurement of current freight movement data serves as the basis for this baseline calculation, which must then be projected into the future for ex-ante analysis and counterfactually projected for ex-post analysis. The mitigation scenario freight activity in TKM is typically assumed to be the same amount as the baseline but shifted to more efficient modes. Emission factors for the new modes and revised distances are applied under the mitigation scenario.

There are four general approaches for projecting or counterfactually projecting the amount of future freight activity for baselines or mode shift scenarios:

- National or regional freight models – based on commodity flow and/or spatial inputs;
- Growth factor methods based on direct economic projections;
- Expert judgment based on historical trends, using time series data gathered ideally for at least 10 years;
- Survey or data collection from shippers including stated preference surveys.

Ex-post analysis also requires estimates of current emissions, which are calculated based on the measured freight movements and respective emission factors within the defined boundaries. In practice, many methodologies determine emissions per TKM of freight (including return factors) for various modes then look at modal shift. Emission reductions, as always, are the difference between the project emissions (real or estimated ex-ante) and the baseline.

Consideration of upstream emissions from electricity production is included in methodologies. Construction emissions are not included in some methodologies but are optional in others.

6.3.2 Uncertainties and sensitivity analysis

The most uncertain variable in the emission reduction analysis of freight mode shift projects is usually the ex-ante estimate of mode split and demand for new freight activity. Mode split depends on the relative attractiveness to shippers of the various modes and can vary depending on the type of cargo. Demand can be projected by commodity production models in developed countries, but such data are often very uncertain in dynamically developing countries. Different methodologies address baseline setting in various ways to accommodate this uncertainty.

In contrast, ex-post methodologies are fairly simple, assuming that the change in mode share is due to the project.

The potential for rebound effects is also difficult to estimate ex-ante, although economic models may offer some guidance as to the elasticity of freight transport versus generalized cost.

6.4 GUIDANCE ON THE SELECTION OF ANALYSIS TOOLS FOR FREIGHT MODAL SHIFT PROJECTS

Higher degrees of accuracy can be obtained with more disaggregated data, if some or all of the data are locally derived. While combining local data with defaults can yield benefits, using disaggregated default data alone is seldom more accurate than using aggregated default data. Table 43 shows the level of data disaggregation that is desirable for each general level of accuracy.

There are a few freight transport analysis methodologies for GHG emission analysis under the CDM. The TEEMP project has also developed a rail mode shift sketch plan-

Table 43

Level of disaggregation of key variables of freight modal shift mitigation actions

	Degree of local data disaggregation and context variables		
	Lower accuracy	**Medium accuracy**	**Higher accuracy**
Transport activity data	· Total freight vehicle trips · Forecast change in truck tonne-km to rail or ship · Average tonnes per truck and rail/ship vehicles* · Average trip length*	· Freight vehicle trips in analysis area by vehicle type · Freight vehicle trip length by vehicle type · Proposed change in truck VKT from feeder operations · Forecast change in rail or ship tonnage	· Total tonnes shipped in analysis area · TKM in analysis area by vehicle type · Tonnes/vehicle by vehicle type · Proposed change in freight VKT from operations (by vehicle type) · Forecast change in tonnes/mode · Trip lengths of new freight trips by mode (including feeder) · Prior mode of cargo
Emission factors	· Average emission factors per tonne-km *	· Emission factors by vehicle type and speed*	· Forecast change in truck VKT by vehicle type (modelled)** · Emission factors for rail or ship vehicles · Construction emission of new infrastructure**

*=default OK, **= optional item)

ning module that accommodates freight. Transport demand modelling practice for freight is not as widespread as for passenger travel, although commercial software packages have freight capabilities that include rail.

Figure 20 maps existing methodologies and tools for freight modal shift projects according to their purpose (y axis) and level of accuracy (x axis).

6.4.1 Description of tool types

The following sections describe a number of tools that are available for estimating GHG emission reduction from freight mode shift mitigation actions. They are classified according to similarities in methodology.

6.4.2 Freight demand models

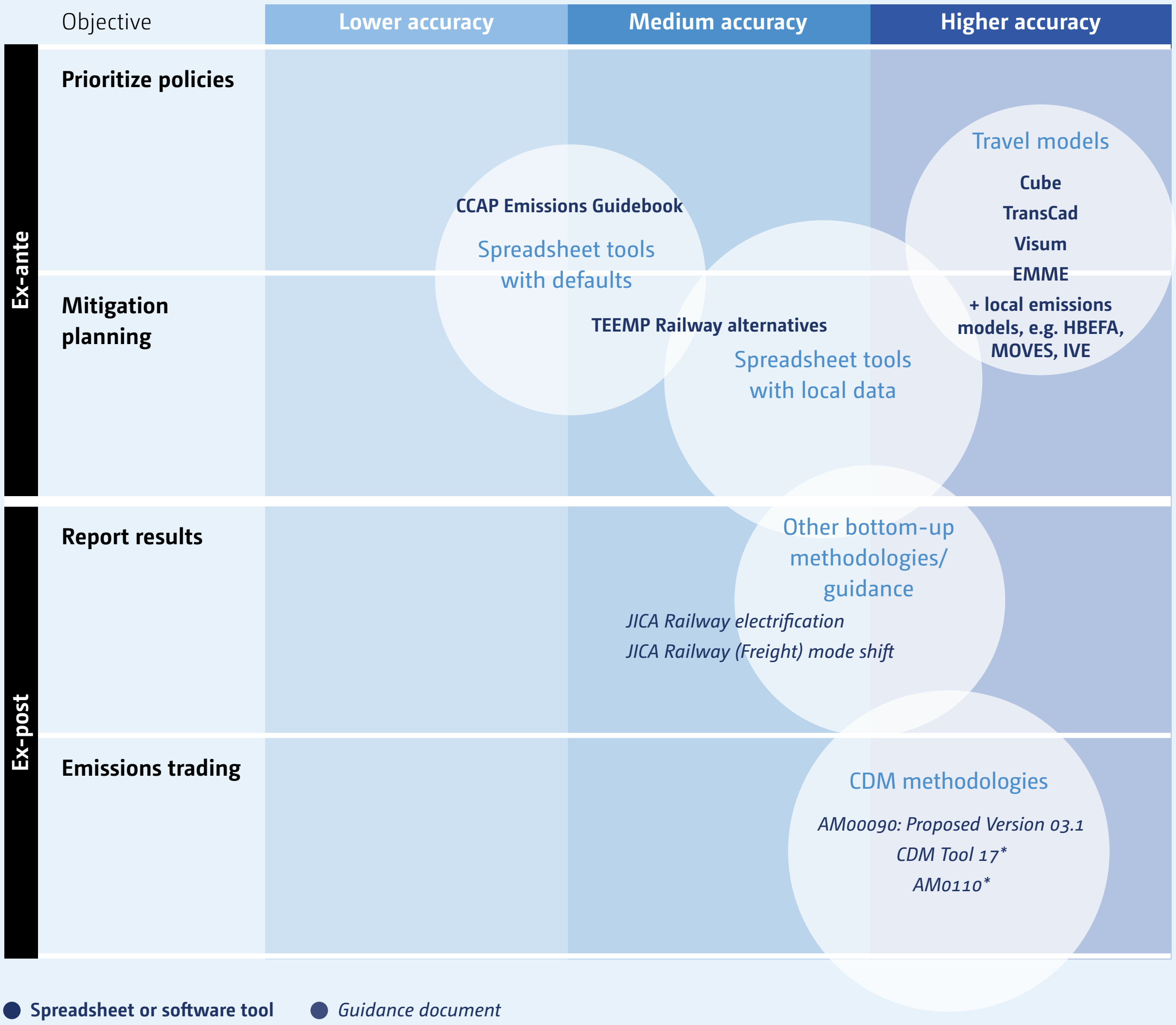
Freight demand is mostly found as a component of a larger travel demand forecasting model. The freight components typically focus on truck flows to forecast the demand for intercity corridors or for regional systems planning. Some national- or state-level government agencies will prepare a commodity-based freight model. This methodology uses flows of commodities between various industries to be reflected through a series of freight decision-making models resulting in flows of trucks, trains, etc. Commercial travel modelling software such as Cube or TransCad can be used to develop commodity generation and distribution models based on employment factors or other industry data. Such models may also have multi-modal capabilities to allocate freight to the various cargo transport modes. This option is an accurate methodology for forecasting future travel activity parameters if a well-calibrated mode choice module that includes rail is part of the model.

As with passenger models, disaggregated activity data from freight demand models are input to a separate emissions model calibrated to national or supranational fleets. External standard emissions models that accept highly disaggregated inputs include MOVES, HBEFA and IVE. In this case the emissions model should be adapted to specific circumstances regarding the underlying fleet composition. Travel model outputs can, however, also be aggregated and emissions calculated with simpler emission factors.

6.4.3 Disaggregated bottom-up ex-post guidance

This consists of CDM methodology documents or general guidance documents that provide formulas for GHG emissions calculations and detail the disaggregated variables that should be collected. These methodologies calculate the emission factor per TKM for each mode of freight transport. Guidance is given for calculating these values using historical data, surveys or, in the case of CDM tool 17,

Figure 20
Navigating classes of available methods and associated tools of freight modal shift mitigation actions



(*) CDM Tool 17: Baseline emissions for modal shift measures in inter-urban cargo transport; AM0090: Modal shift of cargo from road to water or rail transportation; AM0110: Large-scale Methodology: Modal shift in transportation of liquid fuels Version 01.0.0

Table 44

Travel demand models for freight modal shift mitigation actions

Ease of use/data collection: Highly resource and data intensive

Name	Application / summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
Cube	Commodity flow	Truck	Citilabs, Inc.	Excellent	Paid training offered	Internal parameters*	High
TransCad	Commodity flow	Truck and rail	Caliper Corporation	Excellent	Paid training offered	Internal parameters*	High
VISUM	"Tour based" freight model	Multimodal	PTV Group	Excellent	Paid training offered	Internal parameters*	High
EMME	Travel activity	Unknown	INRO Software	Excellent	Paid training offered	Internal parameters*	High

*for example friction factors, mode choice curves, and other coefficients for internal sub-models

for using provided default CO_2/TKM values. The emission factors are applied to the measured total TKM per mode.

The documents often also supply methodologies on how to collect these variables, emphasizing the most conservative assumptions. Because CDM is focused on documenting precise amounts of real values, CDM tools are primarily used ex-post. Users are referred to the "Combined tool to identify the baseline scenario and demonstrate additionality" for general ex-ante guidance. Some defaults are included. No spreadsheet is provided.

6.4.4 Partially aggregated bottom-up spreadsheet tools with defaults

This is a spreadsheet-based tool that calculates the reduction from a mode shift between rail and highway using default values. It requires the user to enter the passenger and freight data either in TKM or in terms of units and trip lengths. It has a section for calculating the construction emissions for rail projects.

6.4.5 Aggregated bottom-up guidance tools

The JICA documents offer a framework of equations for calculating GHG emission reduction from mode shift. One is specific to the electrification of rail lines, including new or existing electric rail, and the other is more general and offers guidance for monitoring any action designed to increase rail mode share of freight. These methodologies are based upon and similar to the CDM methodologies in that they use emissions per PKM and TKM but they offer less data collection guidance.

The CCAP Transportation Emissions Guidebook has a spreadsheet tab for a simple calculation of mode shift between truck and rail. Users input the TKM values and can use default emission factors or input their own emission factors per TKM.

Table 45

Travel demand models for freight modal shift mitigation actions

Ease of use/data collection: Highly resource and data intensive

Name	Application / summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
AM0090 Proposed Version 03.1	Shift cargo among trucks barges, ships and trains	Ex-post, upstream including construction, electric grid factor	UNFCCC	Good	Brief "Measurement procedures" for all variables	Default emission factors for diesel for trucks, barges and ship fuel oils	Free
CDM Tool 17: Baseline emissions for modal shift measures in inter-urban cargo transport	Modal shift from road to waterborne (using barges or domestic ships) or rail transportation	Ex-post, no upstream emissions except electric grid factor	UNFCCC	Good	Brief "Measurement procedures" for only some variables	Default emission factors for rail, water and road disaggregated by some cargo types	High
MRV-Blueprint: India Railways NAMA	National rail infrastructure programme NAMA	Passenger and freight mode shift from road or air modes	Grütter Consulting	Very good	Good, brief recommendations for data sources at national level	No	High
AM0110 Large-scale methodology: Modal shift in transportation of liquid fuels Version 01.0.0	Shift in mode of transportation of liquid fuels from road transportation using trucks to pipeline transportation	Ex-post, includes upstream electric emissions, trucks to transport fuel for pipeline and land use changes from pipeline	UNFCCC	Good	Brief "Measurement procedures" for only some variables	Includes a single default value for truck fuels	High

Table 46

Partially aggregated bottom-up spreadsheet tools with defaults for freight modal shift mitigation actions

Ease of use/data collection – moderate

Name	Application / summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
TEEMP Railway alternatives	Shift of passengers and/or freight between road and rail	Manual entry of expected mode shift by percent	Clean Air Asia/ITDP/ADB	General guide for all spreadsheets	Some guidance with defaults	Emission factors for passenger and tonne kilometre for highway and rail Defaults for trip lengths	Free

Table 47

Simple bottom-up tools with mostly default data for freight modal shift mitigation actions

Ease of use/data collection: Moderate to low

Name	Application / summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost of tool
JICA Railway electrification	GHG reduction from electrification of rail	Includes mode shift effects Includes upstream grid factor	JICA	Limited	Fair	Refers to appendix	Free
JICA Railway (Freight) mode shift	Mode shift of freight from truck to rail	Includes upstream grid factor	JICA	Limited	Fair	Refers to appendix	Free
CCAP Emissions Guidebook	Mode shift from truck to rail or barge	Ex-ante tool; sketch planning estimates based on reduction in number of trucks (and/or change in loading)	CCAP	Good	Fair	United States energy and emission factors for trucks	Free

6.5 MONITORING

Performance of the mitigation action can be monitored by tracking key variables over time. The monitoring frequency will vary, depending on the monitoring regime and the budget available for data collection.

Implementation and performance metrics should be included in the monitoring plan to show progress before the full effects of the action may be apparent. Freight movement is generally done by private companies so proprietary data may need to be requested for monitoring purposes. If this is not available default data will have to be found. Official government statistics can be used if they are deemed transparent and reliable and offer the degree of disaggregation required. Incentives for carriers to report data should be considered, as proprietary data for total tonnes moved by mode and fuel use by mode will provide the most accurate estimates.

Table 48 presents a minimum list of key variables and recommended maximum intervals for measurement if no other requirements are present (e.g. CDM).

Table 48

Minimum indicator set for freight modal shift mitigation actions

Category	Indicator	Normal monitoring frequency
Implementation indicator	Construction of new rail or water infrastructure	Onetime or by construction phase
Performance indicators	Mode shift in percent Annual tonnes of cargo by mode	Annual Annual
Impact indicators	Calculated passenger or cargo tonne kilometres by mode Latest emission rates by mode Calculated emissions in study area	5 years 5 years 5 years

6.6 EXAMPLE – SWITCHING FREIGHT TO SHORT SEA SHIPPING

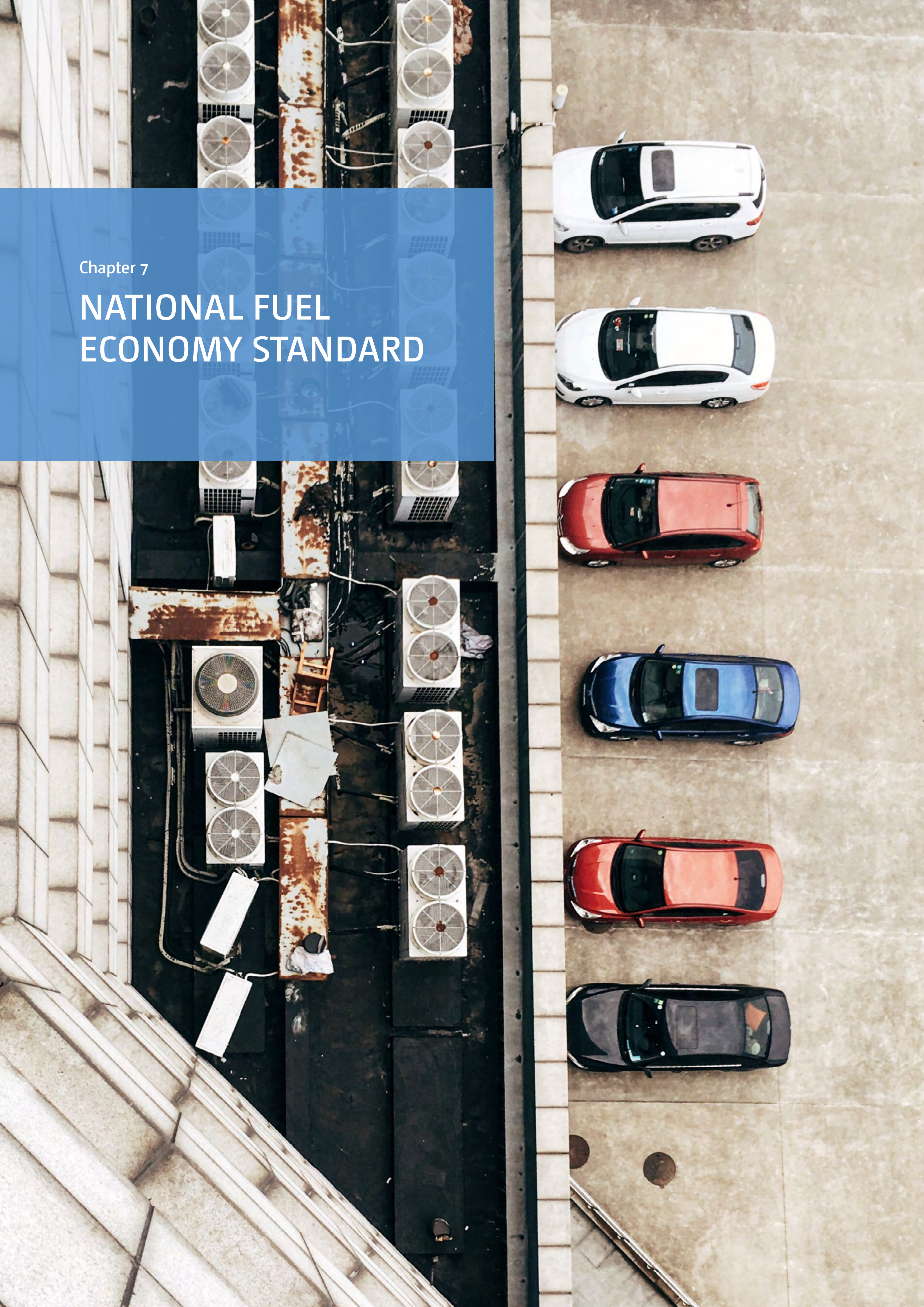
An example of a freight mode shift project was the development of waterway infrastructure to shift freight transport from road to waterways. This project had been developed and implemented in Brazil by ArcelorMittal Tubarão, a company specializing in the production of slabs and hot rolled steel coils. CDM methodology AM0090 was chosen to estimate the mitigation outcomes of the project. According to this methodology, annual TKM of cargo transported by the newly developed infrastructure was monitored and used to estimate baseline and project emissions.

Baseline emissions were estimated using the following variables: transportation distance (from origin to destination point) by road using trucks, baseline emission factor and cargo volume (assuming the same amount of cargo transported by the newly developed infrastructure). Baseline emission factor was a default emission factor in g CO_2/TKM available in the AM0090 methodology.

Data on the consumption of fuel by ocean barges were monitored along with the amount of cargo transported by the barges. The two amounts are multiplied to estimate baseline emissions, as described above. The difference between project emissions and baseline emissions equals the emission reductions that the implementation of the project brings about.

The project shifts the transportation of around 1,100,000 tonnes of coils per year from road transportation by trucks to ocean shipping by barges, leading to estimated emission reductions of around 120,000 t CO_2/year.

Further details are available at
http://cdm.unfccc.int/methodologies/PAmethodologies/pnm/byref/NM0320



Chapter 7

NATIONAL FUEL ECONOMY STANDARD

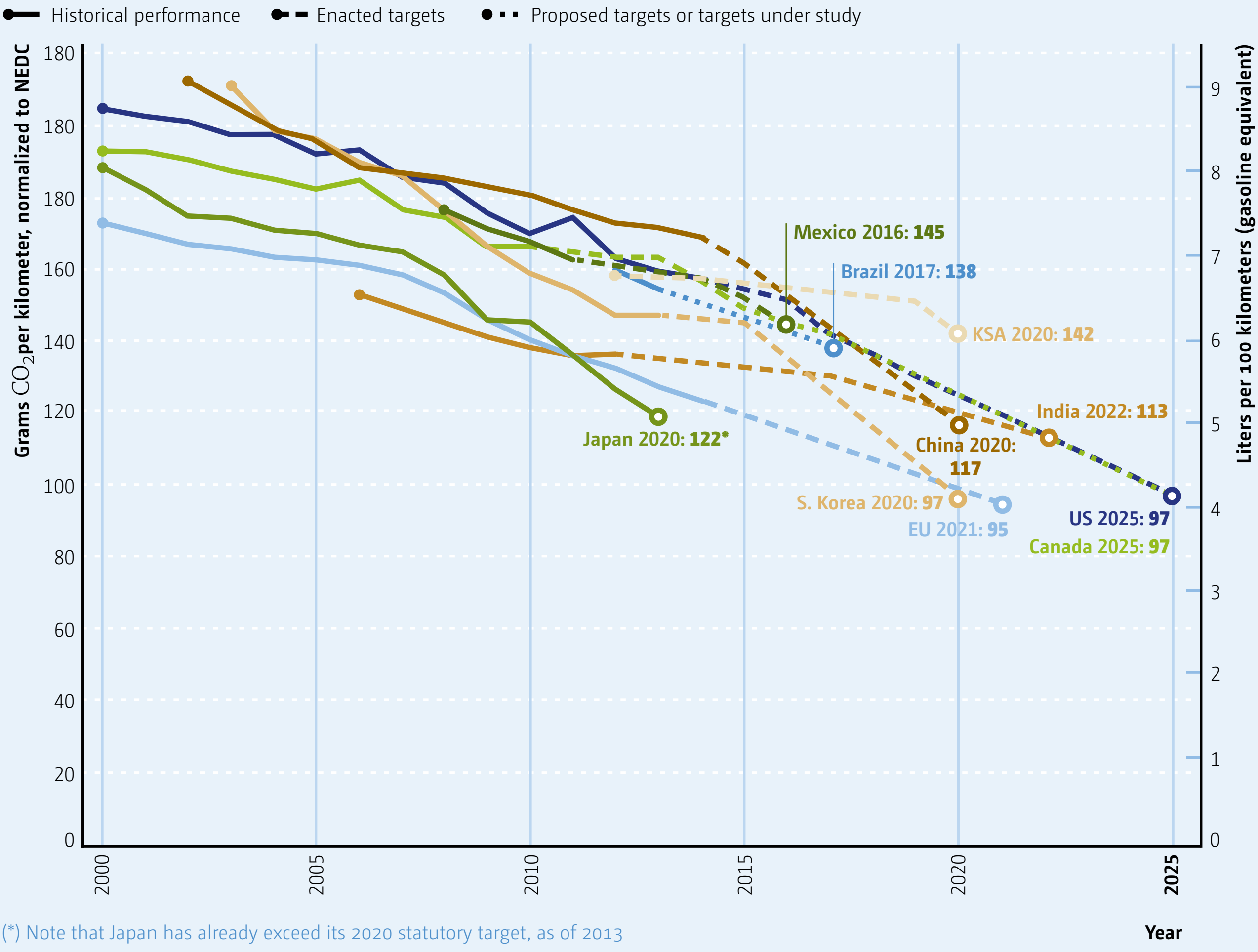
7.1 DESCRIPTION AND CHARACTERISTICS OF GREENHOUSE GAS/FUEL ECONOMY STANDARDS FOR LIGHT-DUTY VEHICLES

One of the main instruments available to policymakers to achieve significant improvements in FE from light-duty vehicles is through implementation of FE or GHG emissions standards regulations. These standards require new light-duty vehicles to achieve lower fuel consumption and emissions over time through continued development and application of fuel-efficient technologies. Adoption of such standards results in a market shift towards vehicles that are increasingly fuel-efficient, consuming less fuel per kilometre driven and thus emitting less GHG.

GHG and FE standards are set based on a vehicle attribute – typically either the size or the weight. Each automotive manufacturer should meet a target value based on the light-duty vehicle fleet that it sells; compliance with the target by each manufacturer ensures that the entire national fleet of new vehicles achieves the desired reductions in GHG emissions and fuel use. Because targets are designed with increased stringency over time, the fleet becomes more efficient every year. In addition, because the standards mandate no specific technology, fuel or ve-

Figure 21

Passenger car sales CO_2 emission targets and sales weighted averaged actual fleet historical performance (ICCT, 2016)



(*) Note that Japan has already exceed its 2020 statutory target, as of 2013 hicle type/size, manufacturers can choose the technology pathway that is most suitable to their business plan while respecting local consumer preferences.

New light-duty vehicle GHG emission and FE standards regulations are policies typically set at the national level. The regulated entities are vehicle manufacturers and importers of all new vehicles intended for sale within the country. These regulations typically span 3 to 8 years, and additional regulatory phases are commonly applied to continue the policies. Figure 21 shows the evolution of sales-weighted CO_2 emissions from the passenger car fleets of 10 countries with GHG or FE standards in place today.

Successful implementation of new vehicle GHG/FE standards means that more efficient vehicles are incorporated into the fleet, thereby reducing the fleet average fuel consumption. Globally, the application of stringent GHG/FE standards in key regions is expected to attenuate and even offset growth in vehicle activity and vehicle sales numbers to reduce overall GHG emissions from the transport sector. The methodology presented in this section for the MRV of such standards considers both the ex-ante definition of new vehicle standards and the ex-post assessment of how standards are impacting actual GHG emissions.

7.2 STRUCTURE OF MITIGATION EFFECTS

7.2.1 Cause-impact chain

Adoption of new vehicle GHG/FE standards brings measurable reductions in GHG emissions and fuel consumption for the average light-duty vehicle via increased adoption of fuel-efficient technologies. This improvement, coupled with new vehicle sales – which have been showing significant growth in most emerging economies – and activity, have the potential to significantly reduce fleetwide GHG emissions compared with BAU conditions; those reductions can be assessed applying bottom-up models based on CO_2 emission factors, number of vehicles and vehicle activity. This measurable fuel consumption and GHG emission reduction found in regulated average new vehicles would reduce the overall vehicle fleet GHG emission impact as described in figure 22.

Adopting new vehicle GHG/FE standards regulations would provide the following direct and indirect benefits with respect to the baseline scenario:

- Reduce the fleet average emissions of CO_2 and fuel consumed per kilometre driven for the fleet covered;

Box 4

Vehicle energy measurement units

Many metrics can be used to describe the amount of fuel, energy and GHG emissions generated by unit of distance traveled by a vehicle. Selection of the metric is driven by the intention of the policy to either reduce fuel use or GHG emissions (e.g. as part of NAMAs).

Fuel economy measures distance traveled per unit of fuel consumed. The most common metrics are kilometers per liter (km/L) and miles per gallon (mpg) in the U.S.

Fuel consumption is the reciprocal of fuel economy, and measures fuel consumed per distance traveled. It is usually expressed in liters per 100 kilometers (L/100 km), and it is used in Europe, for example.

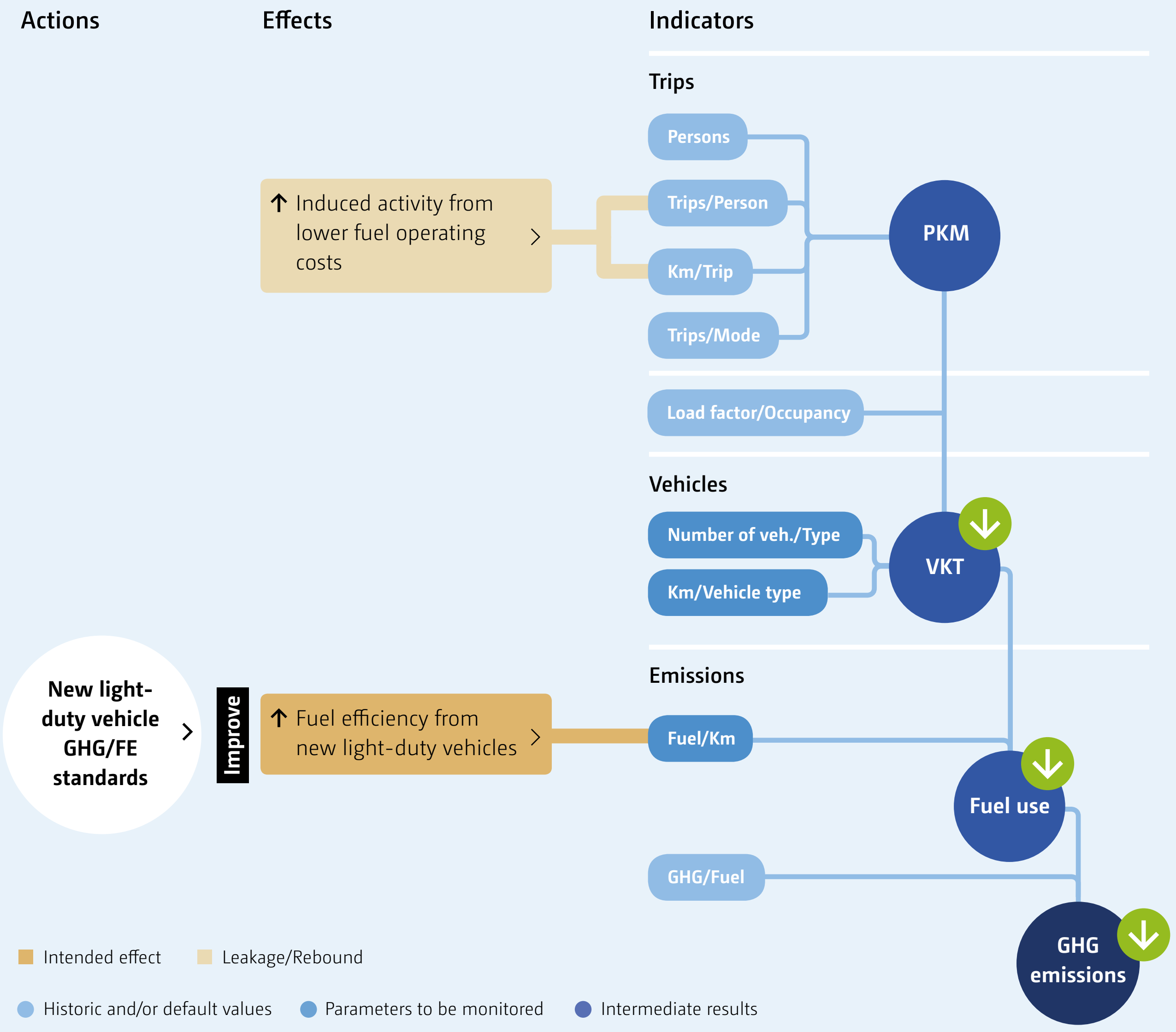
GHG/CO_2 emissions measures GHG or CO_2 emissions per distance traveled, expressed as grams of pollutant per kilometer or mile. The metric can be expressed in grams of CO_2 or CO_2-equivalent per unit distance (gCO_2/km or gCO_2eq/km). A CO_2-equivalent (CO_2e) metric incorporates emissions of non-CO_2 pollutants, using the global warming potential (GWP) to translate their impact to CO_2 equivalency. Primary GHGs besides CO_2 are methane (CH4), nitrous oxide (N_2O), and fluorinated gases (F-gases).

Energy consumption (EC) measures the energy consumed per distance traveled, for example in megajoules per kilometer (MJ/km). Despite being a less common metric, it is relevant as a fuel-neutral metric across different fuel types and vehicle technologies. Vehicle energy consumption is the metric used in Brazil’s vehicle efficiency standards policy.

- Reduce the total annual contribution of GHG emissions from the transport sector;
- Reduce fuel consumption from the transport sector and potentially fuel imports;
- Reduce emissions of GHGs and pollutants generated by oil extraction, and fuel production and distribution;
- Accelerate adoption of advanced efficiency technologies and potentially incentivize the transition to electric mobility and zero emissions. As the standards become more stringent over time, the most advanced fuel-efficient technologies are required. Estimates by EPA in the United States show that the most stringent GHG/FE standards in 2025 would require increased adoption of hybrid and battery electric vehicles to meet future standards (EPA, 2016). Other complementary policy instruments can be deployed to increase the rate of adoption via direct taxation incentives or indirect incentives such as easier access to high occupancy lanes or parking spots.

Figure 22

New vehicle fuel economy and greenhouse gas emission standards causal chain



7.2.2 Key variables to be monitored

GHG/FE standards refer to a GHG or fuel efficiency target level to be achieved by vehicle manufacturers in a given year. Manufacturers and importers are the regulated entities. Applying the regulations to a reduced set of stakeholders rather than individual consumers both ensures compliance and simplifies enforcement of the standards. Thus, the key variable to be monitored when designing and implementing a new vehicle GHG/FE standard is the performance of each manufacturer with respect to its target. As GHG/FE standard targets are more stringent over time, monitoring is required on an annual basis. Other variables that affect the actual GHG emissions of the sector are new vehicle sales volume and vehicle activity.

7.2.3 Monitor for intended effects

New Vehicle GHG or FE Standards

Under a new vehicle GHG or FE standard each automotive manufacturer has a GHG/FE target value for its light-duty vehicle fleet sold into the market for a given year. Targets can be designed in two ways: as manufacturer fleet average target values or as individual (per-vehicle) maximum target values.[8] Fleet-average target designs incentivize the manufacturer to offer very efficient models to balance out the less efficient ones. Fleet average targets facilitate setting of strong targets as they give flexibility to manufacturers to reach them. And because they provide an incentive for technology to keep improving, they ease the process of increasing standard stringency over time. Per-vehicle maximum target designs restrict the sale of models that have fuel consumption above some level; they are restrictive to manufacturers but are easier to implement and monitor. Due to the restrictive nature of this design, per-vehicle targets are required to be less stringent compared to average targets to avoid imposing bans on a wide range of models. Such standards also offer a limited incentive for further investment in efficiency technology development.

Most countries with regulated vehicle fleets have adopted fleet average standards designs– as shown in figure 21; Saudi Arabia's FE program design is an interesting example in that it applies fleet average targets for new vehicles sales and per vehicle maximum targets for its used import vehicle sales (SASO, 2016).

Each target is designed as a linear function of vehicle footprint[9] or vehicle weight, with less stringent targets for larger or heavier vehicles. Using these metrics helps to specifically target vehicle efficiency technologies and avoid impacting consumer choices and manufacturer competitiveness. The targets may be expressed in grams of CO_2 or CO_2-equivalent per unit distance (gCO_2/km or gCO_2eq/km), distance driven per litre of fuel consumed (km/L), or fuel consumed for certain distance (L/100km).
The targets are tightened over time. The rate of annual target improvement ranges between 3.5 to 6.0%. Increasing annually the stringency of the target implies that the fleet becomes more efficient year by year as new targets are set and new (more efficient) vehicles are phased in to meet them. While the new vehicle fleet average efficiency improves annually, older and less efficient vehicles are retired from the fleet, improving the overall vehicle stock fleet average fuel efficiency.

Number of vehicles

The number of new vehicles entering the fleet each year (i.e., new vehicle sales) is used as an input to calculate the total new vehicle fleet contribution to GHG emissions and fuel consumption. Individual manufacturer new vehicles sales are also used as inputs to calculate performance with respect to the GHG/FE targets and to determine compliance with the standards. It should be noted that new vehicle fuel economy standards does not regulate the number of vehicles sold.

Monitoring the current vehicle fleet size (or vehicle stock), via national vehicle registration data or other sources, is required to provide absolute GHG emissions and fuel con-

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[8] As an example, Chinese light-commercial vehicle fuel consumption standards regulation use a per-vehicle efficiency approach. While this can be a useful approach for GHG/FE standards, this document is intended to support best practices to reduce fuel consumption and GHG emissions from new vehicles, and therefore the text focuses on a sales-weighted regulatory design.

[9] The footprint of a vehicle is defined as the area circumscribed by the vehicle's wheelbase and average track width (i.e., footprint equals wheelbase times average track width).

sumption by the baseline fleet; it is also needed for calculating the relative impact of the intended action. Vehicle retirement rates are needed to estimate the outflow of vehicles from the vehicle stock and to provide an estimate of the current vehicle stock. Vehicle retirement rates are mathematical functions that describe the probability of finding a vehicle operating after certain age. A new vehicle is much more likely to be found operating (and contributing to the GHG inventory) after year one of entering the fleet than a vehicle that entered the fleet 30 years ago.

Vehicle activity
Vehicle activity, in km traveled per vehicle per year or VKT, is used as an input for calculating total fleet fuel consumption and GHG emissions. Typically the input comes as an average value by vehicle type (e.g. light-duty, heavy-duty, urban buses, taxis) from national statistical data from national road or transit authorities. This input does not require active monitoring as part of the standard design or MRV ex-ante and ex-post activities, but it is recommended to observe official publications for significant changes on fleet average VKT values. VKT changes with vehicle age and/or efficiency; VKT degradation curves can be developed to account for that, or can be adopted from similar markets.

7.2.4 May be monitored for leakage or rebound effects

One known negative indirect effect of new vehicle GHG/FE standards for light-duty vehicles is the potential increase in vehicle activity due to drivers experiencing lower fuel consumption and lower driving operating cost. This is known as rebound effect.

7.2.5 Interaction factors

The most important factors affecting the magnitude of the fuel consumed and GHG emitted by the fleet are the design of the GHG/FE standards, and the extent and activity of the vehicle fleet. The table below presents a summary of those factors and GHG effects.

Table 49
Factors that affect key GHG/FE standards variables

Factor	Changes	Reasons for the change and effects on total GHG
GHG/FE regulatory design	GHG target design and rate of annual improvement	More stringent GHG targets with higher annual improvement rates would result in lower total GHG emission reductions. Ambitious GHG targets and annual rates of GHG improvement would have to be evaluated against a realistic assessment of the ability of the regulated party to achieve the targets via available technologies and costs
Vehicle activity	VKT changes due to rebound effect	Lower fuel operating costs due to more efficient vehicles may incentivize the consumer towards higher vehicle activity. This would offset to various degrees the reduction in total GHG emissions from new vehicle efficiency improvements
Fleet size	Increase in the number of vehicles in the fleet	Rapidly growing vehicle markets will face more difficult challenges reducing the total GHG emissions than more saturated markets, but effective regulations will lead to bigger GHG reductions compared with BAU. GHG/FE standards are not designed to affect vehicle sales. Other policy instruments, such as vehicle taxes, can have an impact on fleet growth and replacement rates. In regions where imports of used vehicles are significant compared with new vehicle sales the impact of those vehicles on total GHG emissions has to be estimated

7.2.6 Boundary setting

The boundary setting of MRV on GHG/FE standards is closely linked to the regulatory scope. The technical scope of the regulation calls for defining what type of vehicles would be covered under the standard and for how long.

The common practice is to develop light-duty vehicle fuel economy regulations independent of other vehicle types. Light duty vehicle standards can be developed with independent targets for passenger cars and for other larger vehicles like pick-up trucks, as done in the US. Another option is to have independent regulations for passenger cars and for light commercial vehicles, as implemented in Europe. While these vehicle types are similar enough to warrant a consistent regulatory approach, different efficiency or GHG targets are warranted for vehicles to support the work-based functionality (towing and load requirements) of light-trucks and light commercial vehicles.

For other vehicle types, such as heavy-duty vehicles, separate GHG/FE standard regulations with different design elements could be conceived. The regulation of heavy-duty vehicles, which span over a wider range of vehicle types, uses, and drive cycles (e.g. long-haul trucks, refuse trucks, delivery trucks), requires a very different approach and different technology packages are available for different vehicle types and uses. The decision on sectorial boundaries depends on the specific country vehicle class definitions.

The temporal boundary of MRV should go beyond the regulatory implementation timeline. The regulatory implementation typically covers 3 to 8 years periods, typically with the intent to continue progress in reduction of GHG emission over subsequent regulatory phases. The analysis of the effect of the regulation on GHG emissions and fuel consumed should cover a longer timeframe as the useful life of vehicle is 15 to 30 years and the peak benefit of standards adoption on GHG emissions is reached around 10–15 years into the program (once the older inefficient fleet is retired). Thus, for MRV on new-vehicle GHG/FE standards, a longer boundary is recommended.

In summary, the boundaries, scope and targets for new-vehicle GHG/FE standards are as follows (table 50):

7.2.7 Key methodological issues

The main issues for quantifying GHG emission reductions are related to data availability and defining some key as-

Table 50

Dimensions of boundary setting for new-vehicle GHG/FE standards

Dimension	Options for boundary setting
Geographical	National- or regional-level regulation (large states have also effectively regulated passenger vehicle GHG emissions, but federal regulations are more common)
Temporal Boundary	GHG/FE standards policy enforcement: 3–20 years. It can be split into 3 to 5-year phases with interim reviews between phases Ex ante assessment of a policy proposal should consider a longer time frame as the benefits reach peak values around 15 years after the end of the last regulatory period
Transport sub-sector	Depending on vehicle classification pertaining to the regulation, the MRV system would cover manufacturers and importers of new passenger cars and/or light commercial vehicles/light trucks for sale in the country
Emissions gasses	CO_2 emissions and possibly CH_4, N_2O and fluorinated gases (F-gases). (F-gas emissions used as air conditioning refrigerants have a high range of GWPs) erants have a high range of GWPs)
Sustainability effects	Reduced fuel consumption and improved energy security. Upstream emissions of black carbon, NO_X and SO_X in countries that refine petroleum or other fossil fuels into automotive fuels

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[10] Fluorinated gases used as air conditioning refrigerants have a high range of GWPs.

sumptions for the inventory model. Markets that allow used vehicle imports introduce challenges with respect to defining vehicle stock and retirement rates. The MRV design process should consider the following challenges:

- Data availability on new-vehicle CO_2 emissions or fuel economy for all new models sold in the market in a given year.
- Data availability on new-vehicle sales, and as granular as possible, i.e., model-by-model basis.
- Data availability on fuel requirements, vehicle size and weight, key technology components of models sold in the market.
- Data availability on vehicle stock, which usually comes from annual vehicle registration data.
- Availability of national curves for vehicle retirement rate and national VKT deterioration curves by vehicle age.
- Vehicle sales growth assumptions based on economic activity indicators that can change due to global market fluctuations.
- Data availability on FE and sales for used vehicle imports in markets that allow it.

7.2.8 Double counting concerns

New vehicle GHG and fuel economy standard regulations are designed to incentivize manufacturers to offer the most technologically efficient vehicles in the market. Policies and programs designed to incentivize the demand of more efficient vehicles are important complementary measures to take into consideration and action. The main complementary policies/programs are:

- New vehicle fuel economy and/or CO_2 labeling programs. Labeling programs inform the consumer about the efficiency of the vehicle, potentially influencing the decision to purchase a more efficient one. Labeling programs that include information on annual fuel costs can help relate policy impacts to consumer decisions.
- Fiscal incentives linked to fuel efficiency. Fiscal incentives can be designed to influence consumer choice by attaching larger fiscal loads to the least efficient vehicle models. By providing consumers with additional incentives to choose the more efficient models overall, fiscal incentives can both assist manufacturers in meeting regulatory targets and regulators in achieving sector targets. Incentives can be designed as taxes, fees and rebates, and can be linked to different fiscal instruments including import taxes or fees, registration fees, annual operating fees or taxes, or toll roads. The reader should be made aware of two tools, Fuel Economy Policies Implementation Tool (FEPIT) developed by the International Energy Agency and the ICCT's Feebate simulation Tool, to estimate the impact of fiscal policies, and other policy instruments, on average fuel economy values of new passenger vehicles. Fiscal policies addressed by FEPIT are registration, circulation and fuel taxes (IEA/FEPIT, 2016). The ICCT's Feebate tool focuses on design of CO_2-based taxation programs for vehicles (ICCT, 2014).

GHG and fuel reductions from the adoption of label programs and the standards are measured by new vehicle sales and their efficiency, which comes from a single source: manufacturer's reports to regulators. To avoid double counting of benefits, some level of coordination between the managers of each program (standards, label and taxes) is required aiming at identifying what achieved GHG benefits can be assigned to each program and how to report it for MRV purposes.

Other policies that affect key variables that affect total GHG emissions from LDVs but that are out of the scope of this type of mitigation are fuel prices and fuel taxation policies. Fuel prices can change due to crude oil market price changes, and due to national or regional fuel taxation policy changes. Fuel price variations may influence not only consumer decisions on new vehicle purchases, but also manufacturers product planning, inducing an impact in actual (ex-post) new vehicle sales-weighted fleet average fuel economy values. Fuel price variations my also affect overall fleet size and activity, factors that contribute to total GHG and fuel consumption. Fuel price effects on total GHG emissions and fuel consumption are specifically addressed as part of the sensitivity analysis under the Mitigation Action type 8: Pricing Policies.

7.3 DETERMINING THE BASELINE AND CALCULATING EMISSION REDUCTIONS

7.3.1 Analysis approach

Developing the baseline scenario annual contribution of GHG emissions from the light-duty vehicle fleet and calculating the emission reductions due to GHG/FE standards implementation involves two main activities:

1. Calculating the fleet average GHG emissions of new vehicles for a baseline year;
2. Developing a model to calculate and compare fleetwide GHG emissions and fuel consumption under a BAU scenario and an intervention or regulated scenario.

The ex-ante and ex-post analyses share some of the inputs, but ex-post analysis can make use of actual vehicle fleet changes in terms of new vehicle fleet average CO_2 values and sales numbers. Ex-ante and ex-post fuel sales information can be used to recalculate vehicle activity. Ensuring real-world FE and GHG emissions performance of the new fleet and estimating the corresponding impact on total GHGs emitted would require a dedicated study that can be envisioned and designed in the early stages of policy and/or MRV development.

7.3.2 Determination of baseline new vehicle fleet-average greenhouse gas emissions

The objective of this first step is to have a precise evaluation of the fleet-average FE and GHG emissions generated by the new vehicle fleet that is entering the national market during a given year or period of evaluation (model year or fiscal year) before standards are imposed. The main output of this step is a pair of values: the first one is the new vehicle fleet-average FE or GHG emissions value ($g\ CO_2/km$ or equivalent metric); and the second one is the new vehicle fleet average reference parameter, either vehicle mass or vehicle size, used to define the target.

The new vehicle fleet average CO_2 emissions value is calculated as sales-weighted average[11] CO_2 emissions, in g/km, or equivalent metric; it represents the average CO_2 emissions rate, or efficiency, of all new vehicles entering the fleet during a period of time, that is, the baseline year. The reference parameter typically used is either fleet sales-weighted average mass (in kg) or the fleet sales-weighted average footprint (in m^2).

Calculating the fleet sales-weighted average GHG/FE requires two main sources of data:

- Model-by-model certification values for either CO_2 emissions, FE or fuel consumption, and reference parameter data (vehicle weight or footprint);
- Model-by-model sales data during defined regulatory cycle (calendar year, fiscal year or model year).

Ideally, model-by-model certification data on CO_2 (or FE), vehicle parameters and sales would come from the same source, either a government institution or an industry source. In cases where part of the data is not available there are options to supplement the data, albeit at the cost of introducing uncertainties. Options include focusing on the top sales vehicle models covering as much market as possible, or using international CO_2 emissions data after extremely careful matching of vehicle models.

7.3.3 Fleetwide greenhouse gas emissions model development

Construction of the fleetwide GHG emissions model is required to estimate BAU scenario GHG emissions and the relevant intervention scenario emissions to be able to estimate the emission reduction potentials of the GHG/FE standard. Data requirements are as follows:

- Calculated fleet average CO_2 emissions or FE (CO_2/km or equivalent metric). Single value for average new vehicle in a given year;
- Vehicle stock/registration data;

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[11] Sales-weighted average values represent more closely the average emissions of the evaluated vehicle fleet, either a national fleet or a manufacturer fleet. As an example, let us assume a market where only two vehicle models are sold, a compact car that emits 100 g CO_2/km and a sport utility vehicle (SUV) that emits 300 g CO_2/km. Let us assume that 9000 units of the compact car and 1000 units of the SUV are sold during a given year. Sales-weighted average CO_2 is calculated by adding up the product of CO_2 emissions times sales numbers for each model, and then dividing by total sales: $(9000*100gCO_2/km+1000*300gCO_2/km)/(9000+1000) = 120\ g\ CO_2/km$, which better represent the average vehicle for that fleet of 10000 vehicles sold that year.

- Vehicle fleet average activity data and activity deterioration curves;
- Vehicle activity change assumptions due to GHG/FE standards (rebound effect);
- Vehicle survival rate or retirement curves;
- Data needed to project fleet growth: GDP, population and other economic activity growth indicators;
- Defined time window for the analysis.

The annual rate of CO_2 emissions from the passenger vehicle fleet can be estimated for a given year by multiplying the sales-weighted average CO_2 emission value (g/km) times vehicle activity (km/year), times the number of vehicles entering the fleet and survival rates.

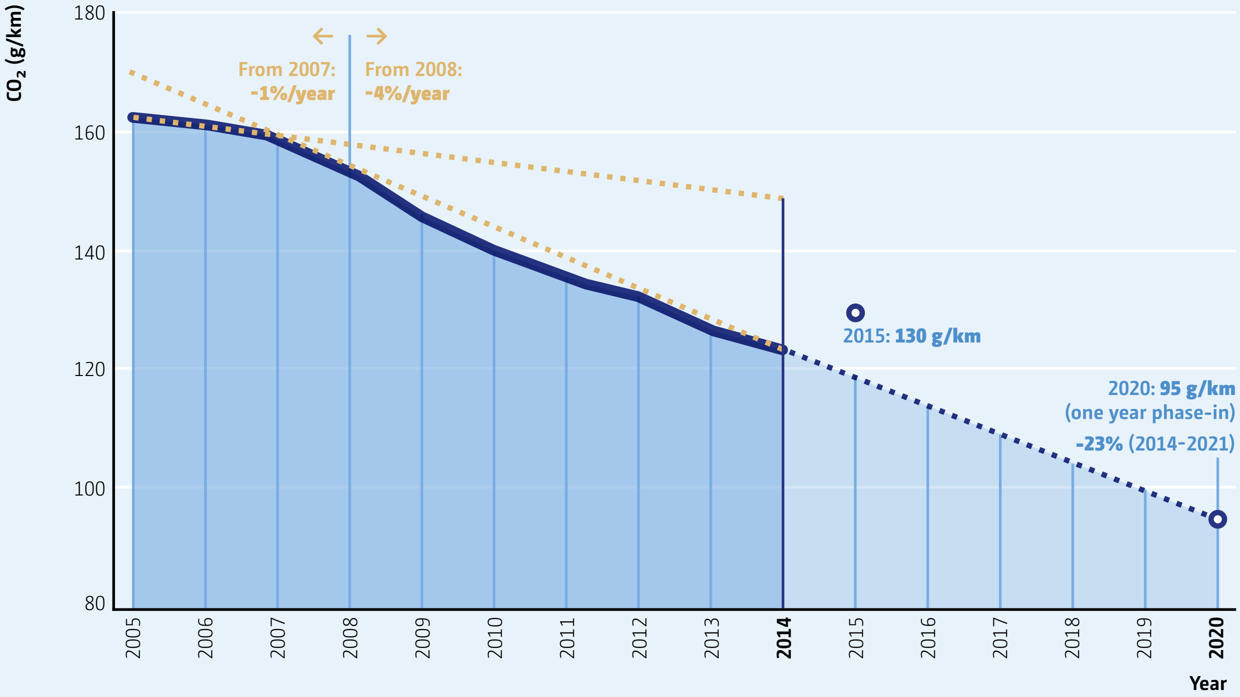
Under ex-ante evaluations, there are only two main methodological differences in fleetwide CO_2 emissions between the BAU and the regulated scenario: (a) the fleet-average CO_2 value would change under the regulated scenario based on FE/GHG standard design stringency and timelines; and (b) VKT average values would be affected under the regulated scenario due to the rebound effect. The remaining model inputs should remain the same for both scenarios. Consequently, the impact of a new vehicle FE standard requires defining policy scenarios and assessing their effects compared with the BAU scenario. Under ex-post evaluations the models are basically the same, but actual values can be used for fleet-average CO_2 emissions and new vehicle sales, while corrections may be made to VKT and vehicle stock.

7.3.4 Greenhouse gas/fuel efficiency standard design and timelines

Defining the new-vehicle GHG or FE standard is not part of the MRV process, but is the most important input that comes from the GHG/FE policy design process, affecting the overall impact of this type of mitigation action. There are important connections between the policy development activity and the MRV process: the first is that new vehicle GHG/FE standard policy development and adoption are the

Figure 23

Historic progression of passenger car fleet average CO_2 emission standards and fleet performance



Blue-white dots indicate regulated targets. The thick blue line shows the actual performance of the regulated fleet, while the dotted line shows the trend towards future targets. (ICCT) primary reason for this type of mitigation, that is, no mitigation without an adopted standard; second, important synergies exist between GHG/FE policy development and MRV development for NAMAs, as all the analysis required for MRV is also included within a wider analysis required for policy development, (e.g. cost-benefit analysis). Analysis tools, data and modelling inputs and outputs can be shared and made consistent for both national policy development and NAMA purposes.

The regulated scenario requires new-vehicle GHG/FE targets for the projected fleet. Those regulatory targets are used as inputs for those years covered under the regulatory timeline. Figure 22 shows an example for CO_2 standard target evolution for European Union passenger cars in place since 2008. European Union targets change over time and exhibit a rate of annual improvement of around 4 per cent per year, from 130 g/km for 2015 to a target of 95 g/km by 2020/21. The difference between fleet targets values and achieved fleet performance values illustrates the different inputs for ex-ante (target) and ex-post (achieved) evaluations.

7.3.5 Real-world greenhouse gas/fuel efficiency performance of new vehicles

New-vehicle real-world CO_2 emissions and FE could be corrected as part of an ex-ante analysis to better reflect the performance of the new vehicles in the local market, better predict their impact on the GHG inventory model, and, more importantly, better estimate the fuel consumption reduction, which is a key input for regulatory cost payback analysis. The new vehicle CO_2 emissions data used in the ex-ante model to estimate fleet average CO_2 emission values come from laboratory test carried out under specific driving conditions. Those driving conditions may not entirely represent the driving behaviour of the local market, often resulting in a gap between laboratory and real-world CO_2 emissions (Tietge et al., 2015). For ex-ante analysis, real-word GHG/FE adjustment factors can be included in the model to account for that effect on total benefits. This adjustment helps to better reflect the performance of the new vehicles in the local market, better predict their impact on the GHG inventory model, and more importantly, better estimate the fuel consumption reduction, which is a key input for regulatory cost payback analysis.

7.3.6 Ex-post analysis

Several levels of corrections can be carried out to estimate the effects of this intervention compared with the effect calculated with ex-ante data. Achieved or measured data inputs available for ex-post analysis are as follows:

- Achieved new vehicle fleet-average GHG/FE values, which tend to be better than the targets, as manufacturers tend to over-comply with the regulation;
- Actual new vehicle sales can be used and fleet growth can be better modelled;
- Actual fuel consumption at the pump can be used via top-down models to estimate the impact of the regulation in terms of total fuel use and GHG emitted, or to correct fleet activity data;
- Ex-post inputs can also include updated VKT and rebound effect assumptions, from dedicated studies on vehicle activity planned in parallel with regulatory and MRV development.

Ex-post analysis could benefit from a national study to measure the performance of a sample of new vehicles and determine the magnitude of the actual laboratory to road FE gap to better reflect CO_2 improvements of this type of intervention. Note that a measured gap has been reported only in the United States and Europe.

7.3.7 Uncertainties and sensitivity analysis

Uncertainties for calculating the ex-ante impact of this type of mitigation action arise from input availability and quality. Uncertainties can be found in key variables as well as external variables that are not directly affected by the mitigation action but that impact its outcome, such as fuel price variations. Lack of available data regarding local VKT values, and retirement and VKT degradation curves, as well as stock numbers and used imports generate uncertainties that ought to be declared for ex-ante reporting. Table 51 lists the main uncertainties for ex-ante BAU and intervention scenario accounting.

The most important ex-ante sensitivity analysis could consider:

- Projected new vehicle fleet-average CO_2 emission values under a BAU scenario, including three cases: no

Table 51

Main GHG/FE modeling uncertainties

Variables	BAU	Intervention
New vehicle fleet average CO_2	Uncertainty on projected new fleet average CO_2 values. Future values could be affected by vehicle market response to fuel pricing variations.	Uncertainties from sales weighted average determination (quality and quantity of available data). Uncertainties due to deviation of new-vehicle GHG/FE data vs. real-world performance data Future values could be affected by vehicle market response to fuel pricing variations.
New vehicle numbers	Fleet growth is dependent on growth modelling assumptions, GDP and/or population.	
In-use vehicle stock numbers	Uncertainties arise from data quality and availability of retirement curves. Vehicle outflows (retirement) data are typically unavailable, relying on international default curves.	
Used imports numbers	Uncertainties arise from data quality and availability	
Vehicle activity	Uncertainties due to data quality and rebound effect assumptions	

improvement with respect to baseline year value, a moderate decline case and moderate improvement case;

- Rebound effect on vehicle activity could be modelled under a mid, high and low case based on data found in technical literature.

7.4 GUIDANCE ON THE SELECTION OF ANALYSIS TOOLS FOR NEW VEHICLE GREENHOUSE GAS AND FUEL ECONOMY STANDARDS FOR LIGHT-DUTY VEHICLES

Modelling the impact of new-vehicle GHG/FE standards on total GHG emissions entails a straightforward bottom-up approach that requires paying special attention to the input variables involved. The main variables for ex-ante analysis are new vehicle fleet-average CO_2 emissions value (emission factor), new vehicle sales and in-use vehicle fleet (vehicle numbers) and average VKT (average vehicle activity data). The table below presents a list of variables and where to use aggregated and disaggregated data.

Tool selection for ex-ante and ex-post analysis is simple as most analyses are based on traditional bottom-up models, with a fleet average input value for new-vehicle CO_2, a number of vehicles input and activity input.

Although GHG/FE standards for light-duty vehicles have been successfully implemented in several countries as national efforts to reduce fuel consumption and GHG emissions, this is the first time that a comprehensive baseline and monitoring methodology for the assessment of GHG/FE standards for light-duty vehicles has been written up. Figure 24 maps the few existing methodologies and tools for new vehicle FE standards according to their purpose (y axis) and level of accuracy (x axis). As at the time of writing this compendium, there are no CDM methodology documents or general guidance documents covering GHG/FE standards. However, a new and more detailed light–duty vehicle fuel economy and CO2 emissions standards evaluation guide has recently been developed by ICCT for GIZ (Posada et al., 2017).

Table 52

Level of disaggregation of key variables

	Degree of local data disaggregation		
Variable	**Lower accuracy**	**Medium accuracy**	**Higher accuracy**
New vehicle fleet-average CO_2 emissions	Fleet-average values obtained from total fuel sales data via top-to-bottom analysis This can be used to estimate the value corresponding to the current in-use stock of vehicles Not recommended for new vehicles.	Fleet average CO_2 values from partial new vehicle fleet databases: data on the top x% vehicle models sold in target market Fleet-average CO_2 values based on aggregated new vehicle databases, i.e., by vehicle segment (small car, medium car, large car, sports, van), or by vehicle manufacturer	Fleet-average CO_2 values would be ideally calculated from disaggregated, model-by-model, vehicle databases sourced from manufacturers or government officials, or from commercial vehicle market analysis companies
Vehicle numbers: new vehicle sales, stock and used imports	Total vehicle numbers are helpful for overall fleet consumption and very basic estimates Stock numbers and used imports may be available as aggregated values only	Sales numbers may be available by manufacturer or by segment. This can be used for cross validation of other data sources Used vehicle import numbers by vehicle segment (cars and light trucks) may be available from government agencies	Disaggregated model-by-model sales data are ideal for new vehicles
Vehicle numbers: new vehicle sales, stock, and used imports	Average vehicle activity for light-duty vehicles is a single value input for this type of MRV analysis. Some level of disaggregation can be found for two LDV types: light passenger cars and light trucks However, how VKT data are determined affects the accuracy of the model output:		
	Lower modeling accuracy if VKT is adapted from other markets when not available in local market	Medium modeling accuracy if the VKT value use has been corrected to local markets based on total fuel use or any other statistical method	Higher modeling accuracy is obtained if the VKT comes from a recent study on local market vehicle activity. This is ideal for ex-post analyses

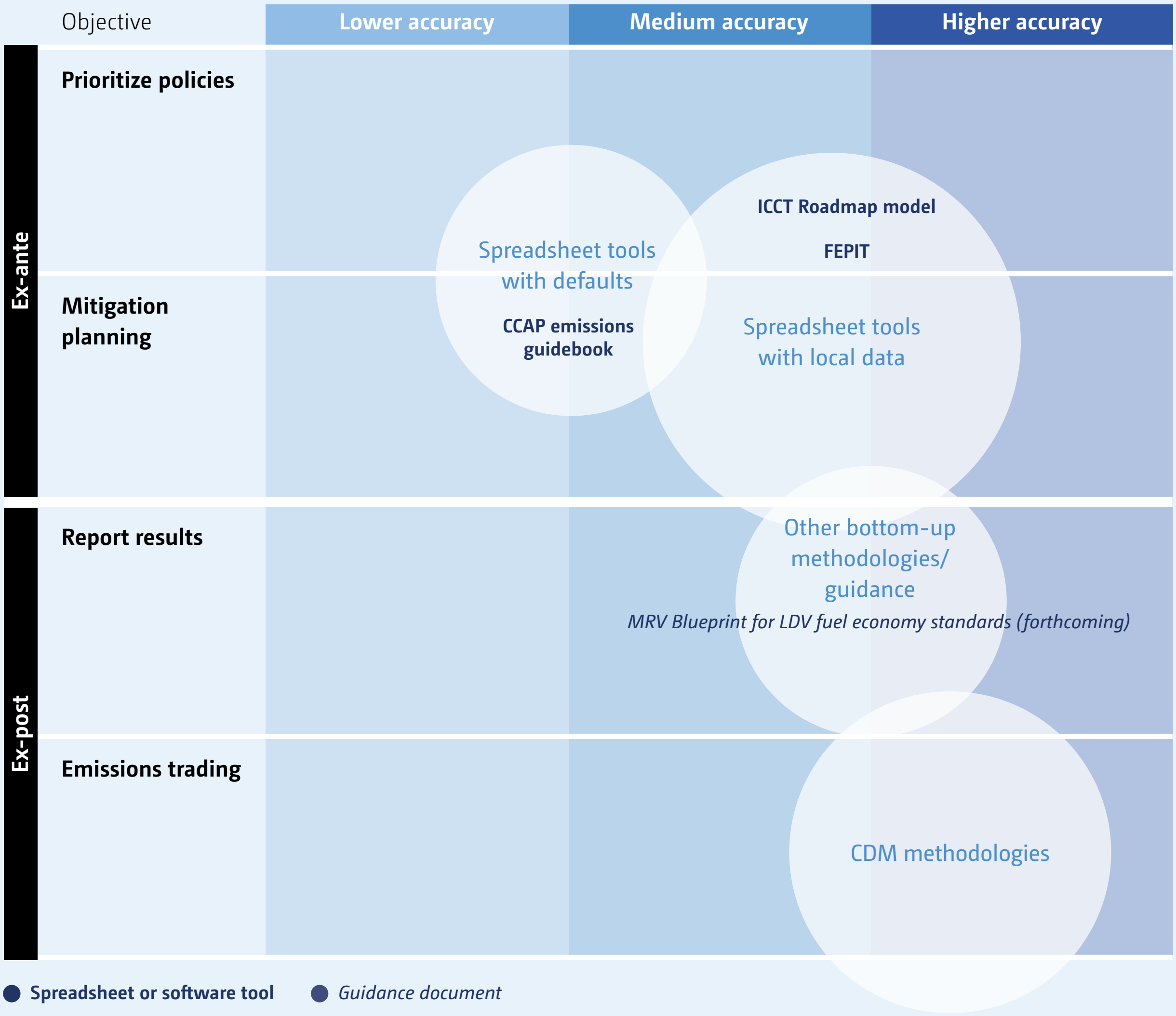
7.4.1 Description of tool types

Modelling tools are typically developed as Excel spreadsheet models, easy for users to adapt to specific markets. Where most modelling tools may differ is in the calculation of new vehicle fleet-average CO_2 emission values depending on data granularity. The other differentiation aspect is the ability to estimate the impact of the GHG/FE standard with respect to total fleet stock, current and new vehicles, including retirement rates and VKT degradation factors and real-world GHG/FE adjustments.

As an example FEPIT requires new vehicle sales and CO_2 emissions data input by segment, and the model calculates the new vehicle fleet average CO_2 value and fleetwide GHG emissions. Vehicle data by segment can also be used with the tool by the regulator to develop other complementary policies such as CO_2-based taxation programmes. GHG/FE regulatory targets can be input as a percentage of annual reduction targets. FEPIT, however, does not account for the in-use fleet stock numbers and FE values, and has no options for accounting for used vehicle imports or a real-world GHG/FE gap. This is a significant limitation of FEPIT, as the impact of the new vehicle GHG/FE standard (i.e., regulated vs. BAU scenarios) is reduced to new vehicles only, which

Figure 24

Navigating classes of available methods and associated tools for new vehicle fuel economy standards



greatly underestimates the positive impact of an efficient new vehicle fleet as older, inefficient vehicles are retired from the stock fleet.

Another example of an available bottom-up tool for studying the effect of adopting new vehicle GHG/FE standards is the Global Transportation Roadmap model, developed by ICCT as an accounting tool for the global impact of GHG and FE policies. It can be adapted as a preliminary impact assessment tool during early MRV development stages. The main difference from FEPIT is that the new vehicle GHG/FE value is input by vehicle type (light-duty vehicle being the relevant one for this MRV), and as a single number, by year, as opposed to annual improvement rates. The Roadmap tool also has a pre-loaded set of country data on VKT and fleet numbers from 11 countries and regions that the user can adapt to their local needs. This tool includes in-use fleets in the GHG inventory calculation, accounting for the retirement of older inefficient vehicles. Other relevant policies that can be studied with the Roadmap tool are electric vehicle adoption, mode shift and fuel and electric grid decarbonization.

A simpler bottom-up publicly available model is the CCAP Transportation Emissions Guidebook. The purpose of the guidebook is to provide basic rules of thumb providing

Table 53
GHG/ FE inventory models

Name	Summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost
FEPIT	Estimates the impact of policy measures on the average fuel economy of newly registered cars	LDV fuel economy standards (FE) CO_2-based vehicle registration tax/ feebate scheme CO_2-based vehicle circulation tax/ feebate scheme Fuel taxation	IEA	Very good	No	Yes Global FE imrpovement rates Predefined target values Predefined vehicle segments FE values	Free
ICCT Roadmap	Shows trends and assessed emissions and energy-efficiency implications of different policy options on GHG and pollutant gases	GHG/FE standards Modal shift Lower carbon fuels EV adoption	ICCT	Very good	No	Yes GHG emission factors for all sectors Predefined country values for fleet stock and growth	Free
CCAP Emissions Guidebook	Fuel efficiency incentives Anti-idling campaigns Vehicle scrappage Feebates	Ex-ante tool; sketch planning estimates based on combining local data and defaults	CCAP	Good	Fair	Emission factors for United States fleet, other factors can be entered Uptake rates	Free
FESET	Assessment of adopting FE/ CO2 emission standards in new vehicles	National standards BAU vs. mitigation action evaluation Ex ante and ex post evaluations	ICCT	Good – see Light–Duty Vehicle Fuel Economy and CO2 emissions Standards Evaluation Guide	Fair	Vehiclel activity VKT degradation Retirement rate curves Real-world FE gap Rebound effect	Free

rough emission reduction estimates from a wide range of transportation, fuel and land use measures. The guidebook has a significant amount of default data based on United States transport characteristics, requiring careful consideration when adopting it to other countries.

ICCT developed a new bottom-up tool for this chapter focusing on the evaluation, ex-ante and ex-post, of adopting new vehicle FE or CO_2 emission standards on light-duty vehicles. The ICCT tool on vehicle GHG/FE standards evaluation (FE Standards Evaluation Tool (FESET)) provides a simple bottom-up evaluation method split into several sections. The first section is focused on fleet-average CO_2 emissions value determination and requires a detailed fleet database; however, if not available, a simplified database or even a single fleet-average value could be used as the input for the subsequent relevant sections. The second section allows for the input of annual fleet CO_2 targets. The third section provides the total annual fleet CO_2 emissions calculation inventory, including fleet numbers (historical and projected); vehicle activity; vehicle retirement curves; predefined curves for activity degradation; vehicle retirement curves; real-world FE gap; and VKT rebound effects. The fourth section covers ex-post analysis, and allows the user to input achieved fleet-average CO_2 emission values, actual registration numbers and any other modelling updates produced after ex-ante analysis. The final section, outputs, provides a summary of fleet CO_2 emission results for ex-ante and ex-post analysis. A detailed description of this model is provided in the "Light-Duty Vehicle Fuel Economy and CO_2 Emissions Standards Evaluation Guide" (Posada et al., 2017).

Models and most numerical tools use granular CO_2 emissions and sales data as the input to estimate the new vehicle CO_2/FE fleet-average value. Thus, the first step to adapt/develop ex-ante inventory tools for GHG/FE standard mitigation is to perform an accurate assessment of the performance of the baseline new vehicle fleet. From that point onwards the MRV analysis could make use of FEPIT, the ICCT Roadmap, FESET or any developed GHG accounting models to evaluate this type of mitigation.

Table 53 presents a qualitative estimation of the level of effort and technical capacity required to use the methodologies.

7.5 MONITORING

Periodic evaluation of key components of the mitigation action is required to track performance. The implementation of the new vehicle GHG/FE standard regulation for light-duty vehicles is the starting point for the MRV of this type of mitigation action. The standards regulation itself contains the timeline of adoption, evaluation cycles and the expected targets, limiting modelling assumptions and reducing the uncertainty for ex-ante analysis.

Performance indicators are based on ex-ante regulatory targets, while the ex-post work can be performed following regulatory compliance evaluation. New vehicle sales can also be provided by regulators, or obtained directly from manufacturers or commercial data vendors. Changes to VKT values can be revisited during the preliminary regulatory and mitigation design phases, and can also be planned for update as part of the mitigation development.

Impact indicators on GHG emissions and fuel consumption are the result of the CO_2 emissions and FE data provided by regulators, and updated vehicle fleet numbers and VKT values. In that regard, impact indicators can be presented

Table 54
Minimum indicator set for new vehicle GHG/FE standards mitigation actions

Category	Indicator	Normal monitoring frequency
Implementation indicator	Adoption of GHG/FE standard	Upon regulatory adoption, and for each new regulatory phase
Performance indicators	New vehicle GHG/FE sales-weighted average values	Annually, after each regulatory cycle
	New vehicle sales	Annually, after each regulatory cycle
	VKT fleet average values	In preparation for new regulatory cycles
Impact indicators	Fuel consumption	Annual, information from total gasoline and diesel used for passenger vehicles
	Final GHG results	Annually or after each compliance cycle along the extension of the regulatory timeline

annually or after the end of the regulatory cycle. Impact indicators would be affected by the accuracy of VKT values, which suggests that even though the ex-ante analysis can be carried out with default values from other markets, a study of national VKT values would increase the accuracy of ex-post evaluations.

It should be noted that monitoring and reporting activities can be supported by those regulators at the national level that oversee GHG/FE standards compliance. A memorandum of understanding between the branches of the government in charge of the standards, as well as with international verification bodies, can benefit its adoption by allowing access to disaggregated actual data produced during the regulatory cycles. The implementation process could benefit from synergies with local governments by providing access to data or developing better mechanisms to monitor the fleet, via studies on vehicle activity and real-world consumption of fuels. These measures have the potential for local capacity development (i.e. local research organizations can be tasked with updating or developing national VKT and real-world consumption data) adding to societal benefits.

Regarding verification activities, two actions that can complement each other are worth mentioning. From a national regulatory perspective, the promise of environmental and economic benefits from new vehicle GHG/FE standards requires policy enforcement through an effective vehicle emissions verification programme to ensure that regulations are effectively implemented. The focus of enforcement programmes is to verify that the information provided by manufacturers is accurate, thus achieving the policy targets set by the regulation. From a UNFCCC perspective, verification would go beyond regulatory compliance, which is laboratory based, and into real-world GHG emissions. Thus, a carefully crafted verification component would include considerations to make sure real-world CO_2 emission reductions and fuel savings are achieved. This may entail developing local technical capacity, laboratories, testing methods and staff training, planned in parallel with mitigation action implementation. Financing would be required for developing local capacities.

7.6 EXAMPLE – IMPACT OF NEW VEHICLE CO_2 STANDARDS IN MEXICO

Mexico is the second largest market for new passenger vehicles in Latin America and has been setting records for growth of vehicle sales, with 1.6 million new cars and light trucks sold in 2016. In 2013, the Secretary of Environment and Natural Resources adopted the standard NOM-163-SEMARNAT-ENER-SCFI-2013, which set mandatory manufacturer-fleet average emission limits for CO_2 from new light-duty vehicles for the years 2014 to 2016, with voluntary targets for 2012 and 2013. The new vehicle fleet-average CO_2 emissions changed from 151 g CO_2/km in 2012 to an estimated 136 g CO_2/km in 2016, a 10 per cent improvement.[12] Ex-ante impact analysis using the FESET tool developed for this project, and adapted to Mexico's passenger vehicle fleet targets (excluding the light-truck fleet), shows that by 2050 the benefit of the 2014–2016 standard is expected to reduce the total CO_2 emitted from 64 Mt/year to 58 Mt/year, including real-world adjustments.

Mexican regulators are currently working to develop the next phase of the light-duty vehicle GHG/FE standards. In the most ambitious scenario studied, the fleet average FE for model year 2025 vehicles would achieve 108 g CO_2/km, a 28 per cent reduction on fleet-average fuel consumption from 2016 levels (Posada et al., 2017).

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[12] The fleet-average CO_2 emission value for 2012 was calculated by ICCT from ex-post data. The 2016 value was estimated based on regulatory targets and projected fleet characteristics. Official fleet-average CO_2 emissions data were not available at the time of writing.


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Chapter 8

FUEL PRICING POLICIES

8.1 DESCRIPTION AND CHARACTERISTICS OF FUEL PRICING POLICIES

This mitigation action focuses on policies and actions that increase fossil fuel prices (e.g. gasoline or diesel prices) in order to reduce GHG emissions from the transport sector. The chapter is based on the publication Transport Pricing Guidance (ICAT, 2017) (hereinafter referred to as the transport pricing guidance).

In many countries, current fuel prices often fail to reflect the marginal costs of transport activities, which is economically inefficient and raises fairness issues. Policies that raise fuel prices, if implemented correctly, are highly effective in reducing transport sector emissions. Two different types of fuel price changes may be considered:

- Increased fuel tax or levy: An increase in the tax or levy imposed on each unit of vehicle fuel, which may include general taxes that apply to many goods and special taxes specific to all or some vehicle fuels;
- Fuel subsidy removal: Removal of subsidies that reduce the price of vehicle fuel below its fair market cost.

All things being equal, increased fuel prices can be expected to result in reduced vehicle travel and increased switching to more efficient or alternative-fuelled vehicles to reduce fuel costs of travellers. These impacts on the mode and frequency of travel directly affect fuel consumption and GHG emissions. In this chapter, impacts of fuel price changes are assessed with ex-ante methods only, using specific price elasticity values to predict changes in transport demand and related GHG emission reductions compared with the projected baseline emissions. Own-price elasticities quantify how fuel demand changes when fuel prices rise, while cross-price elasticities quantify how the demand for other transport modes change when fuel prices rise (i.e. mode shift).

Implementing fuel pricing policies can generate sustainable development (co-)benefits such as decreased congestion and noise, increased road safety and reduced air pollution (i.e. through reduced vehicle travel and mode shift), as well as increased revenue (e.g. through increased fuel tax). On the other hand, fuel pricing policies should be designed in such a way that their impact on low-income households is adequately buffered, for example by moving from general fuel subsidies to targeted subsidies for low-income groups.

In the transport sector, pricing policies do not need not be restricted to fuel prices, but can also target infrastructure (e.g. road pricing such as road tolls or congestion pricing) or vehicles (purchase incentives for more efficient vehicles) (see chapter on vehicle purchase incentives and road pricing in: ICAT, 2017). However, in this chapter only fuel pricing policies are considered.

8.2 STRUCTURE OF MITIGATION EFFECTS

Two approaches are described in this chapter: the simple Approach A (top-down method with energy use data) and the more complex Approach C (bottom-up method with travel activity data) (see section 8.3 below). The terminology follows the transport pricing guidance, which sets out three distinct approaches (Approaches A, B and C). Approach B is not discussed in this chapter of the compendium – it follows the same method as for Approach A, but instead of analysing a fuel mix, Approach B can distinguish between specific fuels (i.e. gasoline and diesel).

8.2.1 Cause impact chain

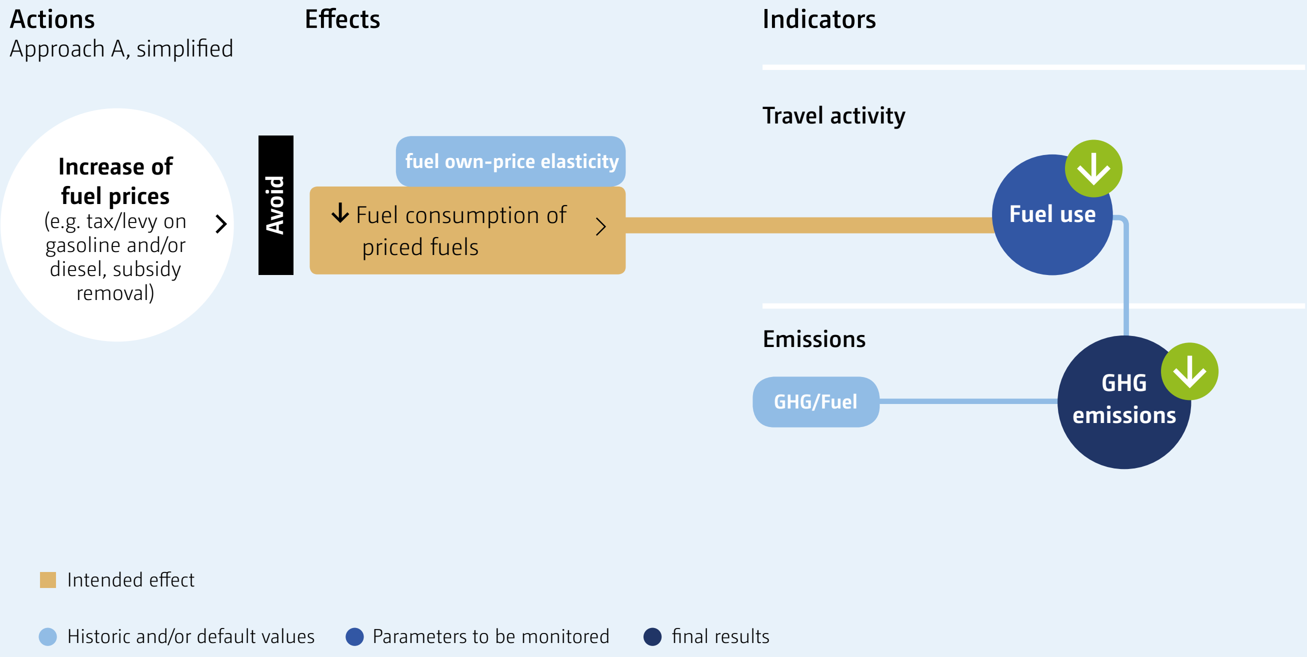
A fuel price increase may encourage motorists to drive less, to drive more efficiently (i.e. accelerating more smoothly and reducing speeds) and/or to choose more fuel-efficient or alternatively fuelled vehicles or modes of transport when possible. This leads to reduced fuel use and possibly to mode shifts, which will decrease transport emissions. Although not covered in the transport pricing guidance in detail, it is recommended that the increased revenue availability and the use of revenues be taken into account in the interpretation of results.

For the simple Approach A, the single effect of the fuel pricing policy that is assessed is the reduced fuel consumption of the relevant fuels due to the reduced fuel demand (indicator: own-price elasticity). Figure 25 illustrates the causal chain for this effect.

Figure 25

Fuel pricing policy causal chain: Simple Approach A from Transport Pricing Guidance (ICAT, 2017)

Note: This figure deviates slightly in structure from analogous figures in other chapters of this volume since it is closely linked to the design and wording of the Transport Pricing Guidance.



The more complex Approach C assesses reduced fuel consumption of the relevant fuels, as well as changes in the modal split of the transport system. Accordingly, more indicators have to be taken into account, such as fuel use per mode, own- and cross-price elasticities, load factors and PKM shares. Figure 26 illustrates these effects.

8.2.2. Key variables to be monitored

The fuel pricing policy is expected to lead to changes in several key variables listed in table 55 (fuel use, load factors/occupancy, PKM per mode and emission factors per PKM/mode). Further important key variables are the price elasticities (own- and cross-price), which may change over time independent from the pricing policy. The column "Approach" specifies the approach in the transport pricing guidance for which the key variables have to be monitored. The column "change mechanism" describes the expected cause for the change of the key variable.

8.2.3. Interaction factors

In order to achieve an effective fuel pricing policy, the policy needs to be appropriately designed for the national and regional circumstances. There are interaction factors which will influence these circumstances and thereby affect the impacts. Some interaction factors that need to be considered when implementing the transport pricing guidance, as well as examples of how they change the national and regional circumstances, are described in table 56.

Figure 26

Fuel pricing policy causal chain More complex Approach C from Transport Pricing Guidance (ICAT, 2017)

Note: This figure deviates slightly in structure from analogous figures in other chapters of this volume since it is closely linked to the design and wording of the Transport Pricing Guidance.

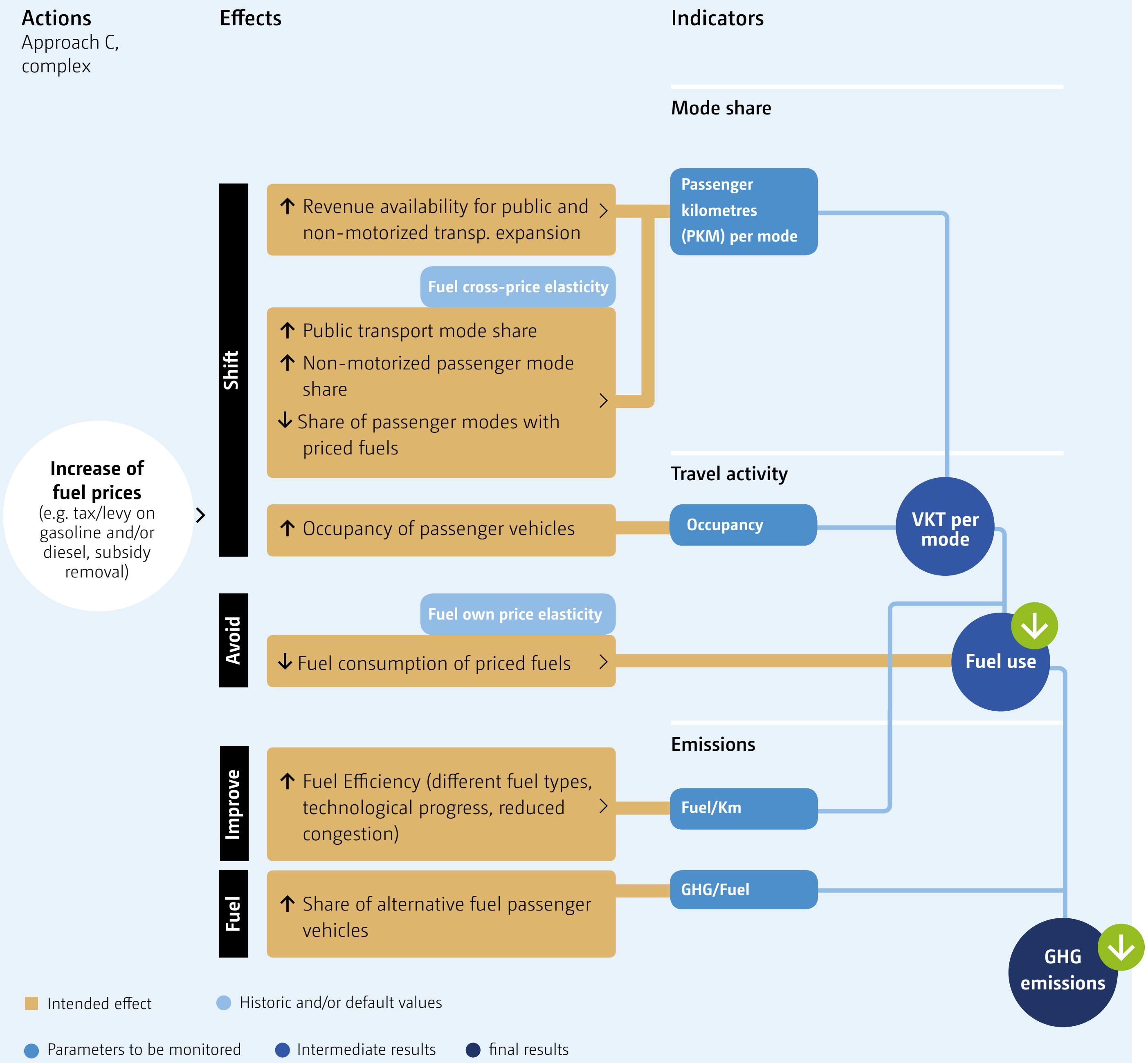


Table 55

Key variables to be monitored for the fuel pricing policy

Key variable	Approach	Change mechanism
Fuel use	A, C	Increased fuel prices will lead to reduced transport demand for modes using the relevant fuels
Load factor/occupancy	C	Increased fuel prices will lead to higher load factors (i.e. carpooling) and higher occupancy (i.e. in public transport)
Passenger kilometres per mode	C	Increased fuel prices will lead to a different modal split
Emission factors per PKM/ mode	C	Increased fuel prices will lead to a different modal split with different emission factors
Fuel own-price elasticity	A, C	Over time, the habits, behaviour and priorities of people may change, which will impact the price elasticities. This change mechanism is not directly influenced by the fuel pricing policy, but the price elasticities should still be monitored as key variables
Fuel cross-price elasticity	C	Over time, the habits, behaviour and priorities of people may change, which will impact the price elasticities. This change mechanism is not directly influenced by the fuel pricing policy, but the price elasticities should still be monitored as key variables

Table 56

Interaction factors that affect fuel pricing policies

Factor	Examples of Change
Maintenance, operation and investment in new infrastructure	· The use of revenues can influence the effect of the fuel pricing policy: · If the revenues are invested in activities that tend to increase emissions, such as general government spending, building or extension of roadways, the net emission reductions from the policy may be considerably reduced or the policy may lead to higher overall emissions · If the revenues are invested in activities that tend to decrease emissions, such as investments in public transport or schemes to promote low-emission vehicles, the emission reductions may be increased owing to easier and more convenient mode shift
New technologies entering the market	· Incentive programmes may influence adoption of new technologies (e.g. to promote electric vehicles or biofuels) · Changes in import regulation may change prices and availability
Technology improvements	· Health and safety measures can influence the age structure and thus the overall efficiency of the fleet (e.g. introduction of mandatory regular vehicle inspection) · National fuel efficiency standards can influence vehicle technology
Development of customer preferences	· Awareness-raising measures and education can enhance environmental concerns

8.2.4. Boundary setting

The scope of assessment can generally cover passenger and freight transport when applying the simple Approach A. For the more complex Approach C, the scope covers passenger transport only within the scope of the transport pricing guidance, to keep it within manageable complexity. However, analogous approaches could also be used for freight transport.

It is feasible to assess the fuel pricing policy at the national level with a national own-price elasticity of the relevant fuels. If mode shifts (and hence cross-price elasticities) are considered, the geographical boundaries should be restricted to the regional or urban context, since the mode shifts strongly depend on the availability of alternative modes (e.g. public transport).

Upstream emissions from electricity generation should be included if mode shifts towards electrically powered rail transport are considered in the assessment. An estimation of emission reductions resulting from the use of revenues generated from the fuel pricing policy (e.g. investment in sustainable transport systems) should be included if possible, although guidance on this is not provided in the transport pricing guidance.

Table 57 gives an overview over the boundary setting options for Approaches A and C.

8.2.5. Key methodological issues

In the transport pricing guidance, the assessment of impacts of a fuel pricing policy on the GHG emissions of the transport sector requires a certain simplification of the complex transport system. Therefore, the following methodological issues have to be considered, and at least to be qualitatively assessed:

- Use of revenue generated by the fuel pricing policy: The use of revenues from fuel levies has a significant influence on GHG impacts and should be at least qualitatively assessed (e.g. if spent on extending the road network, it may lead to higher emissions, whereas if spent on public transport infrastructure or low-carbon transport modes, it may lead to lower emissions);
- High uncertainties: It is important to be transparent about uncertainties, including indicating ranges for the results instead of single values, and undertaking plausibility checks;

Table 57

Dimensions of boundary setting for fuel pricing policies

Dimension	Options for boundary setting
Geographical	Approach A: national Approach C: regional, urban
Temporal	5–10 years
Upstream/downstream	Upstream: energy sector (conventional fuels, electricity, biofuels)
Transport subsector	Approach A: passenger and freight transport Approach C: passenger transport only
Emissions gases	CO_2
Fuels	Approach A: fuel mix Approach C: gasoline, diesel and electricity (more fuels may be included)

- Rebound effects: Rebound effects can occur when, for example, an increase in energy efficiency stimulates more vehicle travel which offsets some of the potential GHG emission reductions or energy savings. Those effects should at least be qualitatively assessed;
- Social equity: Avoid placing a larger tax burden on the lower-income population by using revenues partially in ways that benefit disadvantaged groups, including investments in affordable transport modes.

8.2.6. Double counting concerns

Other policies and actions that mitigate GHG emissions may have similar effects to the fuel pricing policy. As a result, attributing a GHG reduction to a particular policy or action can be difficult, which can also lead to double counting of reductions. The following policies and action are examples that can affect similar variables to the fuel pricing policy:

- Other transport pricing policies (e.g. carbon taxes, road pricing, parking pricing);
- Investments in transport infrastructure (e.g. public transport, bike lanes);
- Fuel economy standards or measures;
- Subsidies or other measures to promote renewable energy (e.g. biofuels, renewable electricity);
- Subsidy of public transport.

8.3 DETERMINING THE BASELINE AND CALCULATING EMISSION REDUCTIONS

8.3.1. Analysis approach

In a first step, the baseline scenario is determined (see ICAT, 2017). The baseline scenario for an ex-ante assessment of a fuel pricing policy is based on fuel demand and current fuel prices (i.e. current taxes, subsidies) for a base year. From this, base year emissions are calculated given the fuel consumption for the base year and appropriate emission factors. Depending on the approach, fuel consumption data are derived with top-down energy use data (e.g. total fuel used in TJ, for Approach A) or estimated with bottom-up travel activity data (e.g. distance travelled, for Approach C). The baseline scenario corresponds to the projection of the base year emissions over future years (e.g. using projections of population growth as a simple proxy). The baseline assumes no change in overall fuel pricing policy. Guidance is also provided for more sophisticated methods of baseline projection.

In the second step, the impact of the fuel pricing policy on fuel demand is analysed. First, as a result of the higher fuel prices, the demand for the relevant fuels is expected to decrease. This impact is estimated based on own-price elasticity values, which are relevant for both Approach A and Approach C. The own-price elasticity is the percentage change of a good’s demand divided by the percentage change of that good’s price. In other words, own-price elasticities quantify how fuel demand changes when fuel prices rise. Own-price elasticities are applied to aggregate fossil fuel consumption (of private cars, buses, trains, etc.). It is recommended that country-specific elasticity values are used (empirically or statistically derived), but the transport pricing guidance also provides default elasticity values that can be used depending on the current fuel prices and current average incomes per capita. Second, the higher fuel prices may also lead to shifts towards other transport modes. This effect is estimated with cross-price elasticities in Approach C. Cross-price elasticities quantify how the demand for other transport modes changes when fuel prices for road transportation rise. The cross-price elasticities are applied to PKM driven with private cars, in order to find the magnitude of the shift towards PKM with public transport (bus or rail). Similar to the own-price elasticities, the guidance recommends the use of country-specific cross-price elasticity values, but also provides default values.

In the final step, the GHG impact is determined by comparing the baseline scenario with the policy scenario. The policy scenario is the scenario based on the change of fuel demand due to the fuel pricing policy. The policy scenario is determined using the appropriate elasticity values and the price change introduced by the pricing policy.

Ex-post assessments are conducted in a similar way to the ex-ante assessments, but based on historical, monitored data rather projected data.

Upstream emissions from electricity production are included in the methodology.

8.3.2. Uncertainties and sensitivity analysis

The uncertainties of the price elasticity values tend to dominate overall accuracy of the estimated GHG impacts. Further processes subject to uncertainties are (baseline) activity data estimation, emission factor estimation, estimation of other conversion factors and the projection of baseline scenarios. The uncertainty may increase through interaction factors such as rebound effects or new technologies (see section 8.2 above).

Because of the high uncertainties, it is important to fully understand the limitations in accuracy and the sensitivity of the results of the assessment. Practitioners should always be transparent about high uncertainties in the results and interpretations. Furthermore, the conditions of applicability should be assessed, the parameters and results should undergo a plausibility check, and if possible the results should be indicated as ranges rather than single values. If possible, an ex-post assessment should be conducted at a later point in order to evaluate the results of the ex-ante assessments and see whether the elasticity values used have changed (see the transport pricing guidance for more information).

Table 58

Level of disaggregation of key variables of fuel pricing policies (based on ICAT, 2017)

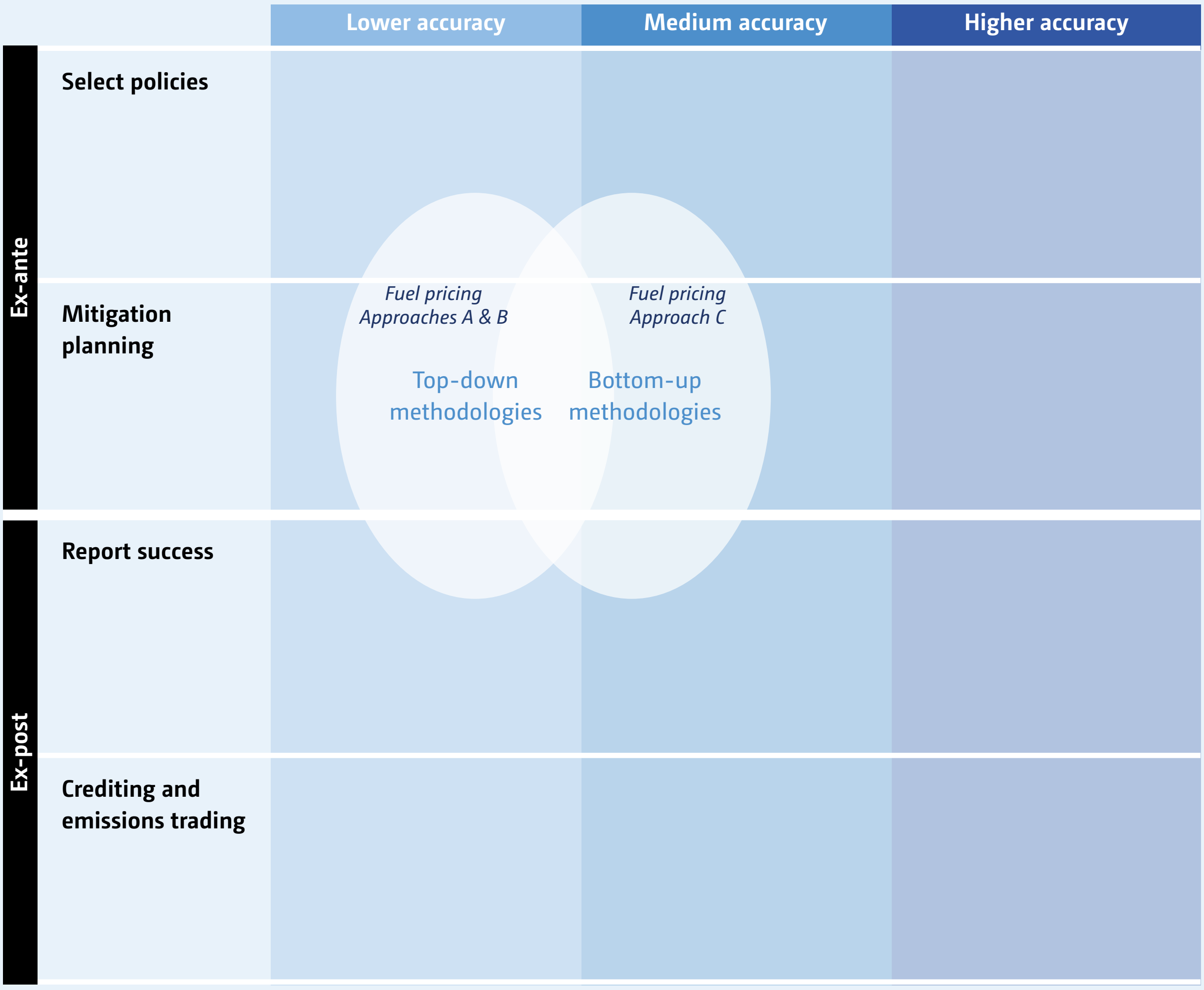
	Degree of local data disaggregation		
Transport activity data	**Lower accuracy (equivalent: Approach A)**	**Lower to medium accuracy (equivalent: Approach C)**	**Medium to higher accuracy (equivalent: extended version of Approach C, considering several fuels and modes with country-specific or local data)**
Transport activity data	Top-down energy use data: · Total fuel consumption in the transport sector (fuel mix) · Default own-price elasticity value	Bottom-up travel activity data and top-down energy use data (top-down if bottom-up is not available): · Passenger kilometres per mode · Load factors/occupancy per mode · Fuel consumption per mode · Default or country-specific own-price elasticity values · Default or country-specific cross-price elasticity values	Bottom-up travel activity data only: · Passenger kilometres per mode · Load factors/occupancy per mode · Fuel consumption per VKT/PKM per mode · Country-specific own-price elasticity values · Country-specific cross-price elasticity values
Emission factors	· Average emission factors per fuel consumption	· Specific emission factors by fuel and mode	· Specific emission factors by fuel and mode

8.4 GUIDANCE ON THE SELECTION OF ANALYSIS TOOLS FOR TRANSPORT PRICING POLICIES

The accuracy of the assessments in the transport pricing guidance strongly depends on the level of disaggregation and accuracy in transport activity data and on the appropriateness of the chosen price elasticity values. Due to the use of price elasticities, accuracy is generally low to medium. Higher degrees of accuracy can generally be obtained with disaggregated data on a higher level of disaggregation and accuracy, and if data are derived on a country-specific basis (at the national or regional level). Table 58 shows data setting that is desirable for each level of accuracy.

There are no transport pricing methodologies under the CDM. Figure 27 maps the transport pricing policies guidance according to their purpose (y axis) and level of accuracy (x axis).

Figure 27
Available methods and tools for transport pricing policies



● **Fuel pricing methods are Guidance documents, not spreadsheet or software tools.** ● *Guidance document*

Approach A estimates the GHG impacts of a pricing policy for the sum of gasoline- and diesel-related emissions from a country's transport sector, and is appropriate for users with undifferentiated fuel mix data. On the other hand, Approach C estimates the GHG impacts for passenger transport separately for passenger cars, bus- and rail-based public transport for users who have differentiated fuel mix data and data on PKM for the different modes. Table 59 gives an overview of the two approaches.

8.4.1. Fuel pricing Approach A

Approach A estimates the impact of fuel pricing policies on GHG emissions in the road transport sector (covering passenger and freight). The general procedure for estimating the GHG impacts is explained in section 8.3 above and in the sections about baseline scenarios and GHG impact assessment of the transport pricing guidance. Key elements of the approach are as follows:

1. Baseline emissions: users estimate baseline emissions with simple top-down energy use data (e.g. total fuel used in TJ). Default emission factors and methods for projection are provided in the guidance;
2. Demand impacts: users estimate the impacts of increasing fuel prices on fuel demand with own-price elasticities. If possible, country-specific elasticity values should be used or developed, but the guidance also provides default values;

Table 59

Fuel pricing policy assessments based on: ICAT, 2017)

Name	Summary	Scope	Developer	Methodology documentation	Data collection guidance	Defaults provided	Cost
Transport Pricing Guidance – Approach A	Estimates the impact of fuel pricing policies on GHG emissions in the road transport sector	Fuel tax or levy, subsidy removal National or regional assessment Passenger and freight transport Fuel mix (gasoline and diesel)	INFRAS for ICAT	Very good	Yes [although very short]	Yes National fuel own-price elasticities Net calorific values, fuel densities, emission factors	Free
Transport Pricing Guidance – Approach C	Estimates the impact of fuel pricing policies on GHG emissions in the passenger transport sector and in the transport system (mode shifts)	Fuel tax or levy, subsidy removal Regional or urban assessment Passenger transport only Specific fuel differentiation (gasoline and diesel) Mode shifts towards public transport (bus and rail)	INFRAS for ICAT	Very good	Yes [although very short]	Yes National gasoline and diesel own-price elasticities National fuel cross-price elasticities Load factors Specific fuel consumption per VKT Net calorific values , fuel densities, emission factors	Free

3. GHG impacts: Approach A only assesses the GHG reductions due to the fuel pricing policy in road transportation (no mode shift) by comparing the baseline scenario with the policy scenario;

4. Input data: Approach A can be conducted with minimal data availability (see table 60).

Table 60

Overview of data requirements with Approach A (ICAT, 2017)

Analysis steps (Approach A)	Input data required
Estimating base year emissions, Projecting the baseline scenario	· Activity data (fuel consumption, fuel mix) · Emission factors for relevant fuels · Population/GDP data, including projected data · Further data if advanced projection methods are used
Estimating GHG impacts	· Country-specific fuel own-price elasticity or default value from guidance · Annual average prices of relevant fuels · Annual average per capita income in considered country · Price change due to fuel pricing policy

8.4.2. Fuel pricing Approach C

Approach C estimates the impact of fuel pricing policies on the GHG emissions of the passenger transport sector and the transport system (mode shifts), and is more complex than Approach A. The higher level of detail allows for a more comprehensive interpretation of results. For instance, the estimation of the changes in fuel demand are partly based on bottom-up assessments and thereby on the change in PKM per mode leading to fuel demand. However, the general procedure for estimating the GHG impacts is similar for both approaches, and it is explained in section 8.3 above and in the sections about baseline scenarios and GHG impact assessment of the transport pricing guidance. Key elements of the approach are as follows:

1. **Baseline emissions:** users estimate baseline emissions using a combination of top-down energy use data (e.g. total fuel used in TJ) and bottom-up travel activity data (e.g. distances travelled). Default emission factors and methods for projection are provided in the guidance;
2. **Demand impacts:** users estimate the impacts of increasing fuel prices on road transport fuel demand with own-price elasticities. In addition, mode shifts towards public transport are estimated with cross-price elasticities. If possible, country-specific own- and cross-price elasticity values should be used or developed, but the guidance also provides default values;
3. **GHG impacts:** Approach C only assesses the GHG reduction in road transportation and the potential GHG increase in public transport (through mode shifts) by comparing the baseline scenario with the policy scenario;
4. **Input data:** Approach C has higher data requirements than Approach A (see table 61).

8.5 MONITORING

The impact of fuel pricing policies cannot be measured directly, as fuel consumption and transport demand depend on many more factors than fuel price. However, tracking key variables over time allows users to assess whether the expected impact in terms of reduction of fuel consumption and emissions is visible in the top-down data.

The frequency of monitoring is dependent on user re-

Table 61

Overview of data requirements with Approach C (ICAT, 2017)

Analysis steps (Approach C)	Input data required
Estimating base year emissions, Projecting the baseline scenario	· Activity data: · Energy use data (fuel consumption per mode – gasoline, diesel, electricity) · Travel activity data (passenger kilometres per mode, load factors/occupancy per mode, etc.) · Emission factors per fuel and per mode (all considered fuels, all considered modes) · Population/GDP data for projection · Further data if advanced projection methods are used
Estimating GHG impacts	· Country-specific fuel own-price elasticity or default value from guidance · Country-specific fuel cross-price elasticities per mode or default value from guidance · Annual average prices of relevant fuels · Annual average per capita income in the country · Price change due to fuel pricing policy

sources and capabilities, data availability, feasibility, and the requirements regarding accuracy of the estimation of mitigation impacts. The monitoring plan should take these limitations and needs into account, and may follow an iterative process towards improving data availability. Where monitoring indicates that the assumptions used in the ex-ante assessment are no longer valid, users should document the changes and incorporate the monitored values when updating ex-ante estimates or estimating ex-post GHG impacts.

Table 62 presents a minimum list of key variables and recommended maximum intervals for measurement.

Table 62

Minimum indicator set for fuel pricing policies (ICAT, 2017)

Category	Indicator	Normal monitoring frequency
Implementation indicator	Legal implementation of pricing policy	One time
Performance indicators	Reduction in fuel consumption Reduction of VKT (road)	Annual
	Mode shift in per cent Vehicle fleet composition: · Share of road transport LDV/HDV vs. rail transport · Number of trips per mode · Number of cars on roadways	5 years
	Revenue generated	Annual
Impact indicators	Latest emissions data by mode	Annual
	Calculated emissions in study area	Annual

8.6 EXAMPLE – Fuel pricing impacts

At the time of writing, the first draft of the transport pricing guidance had recently been released and the guidance had not yet been applied in a country or region. However, it provides illustrative examples and these are summarized in the following paragraphs.

A government plans to implement a national fuel levy on gasoline and diesel that will be targeted at light-duty vehicles in the form of a fixed sum per litre, higher for gasoline than for diesel. The national energy balance breaks down total fuel use by sector, and the transport sector is a major source of demand with an annual energy use of 782,000 TJ. The Ministry of Transport knows that this quantity comes from liquid fuels, but there is no breakdown by specific fuel type. Still, the ministry wishes to calculate the emission reductions from implementing the fuel levy. Therefore, it chooses to apply Approach A from the transport pricing guidance.

The ministry starts by calculating the base year emissions for 2015 by multiplying the energy use with appropriate emission factors for gasoline and diesel. It assumes that gasoline and diesel consumption is equally distributed (each 50 per cent). Base year emissions amount to 56 Mt CO_2. Subsequently, it plans to project the base year result to the years between 2016 and 2020. They use population as a proxy, estimate an average fuel consumption and emission amount per capita, and project fuel consumption and emissions according to the expected development of population. Emissions are expected to rise by about 7 per cent and to reach 60 Mt CO_2 by 2020.

In the next step, the ministry needs to estimate the demand impacts of the national fuel levy. Since no domestic studies are available in the country and there is insufficient capacity to conduct a study, the ministry decides to apply the default elasticity values provided in the transport pricing guidance. It is aware that the default values are subject to high uncertainties. In the country, the mean average income amounts to USD 13,000 per capita and the (annual mean) average fuel price is equal to USD 0.50 per litre in 2015. According to the transport pricing guidance, the default own-price elasticity value is 0.24.

Finally, the ministry estimates the GHG impacts of the national fuel levy. The overall fuel price increase amounts to 4.5 per cent (5 per cent for gasoline, 4 per cent for diesel). By multiplying the fuel own-price elasticity value (0.24) with the relative price increase (4.5 per cent), the ministry finds the relative emission reduction of 1.1 per cent. Accordingly, as a result of the introduced fuel levy the baseline emissions of 56 Mt CO2 in 2015 are reduced by about 0.62 Mt CO2 and the baseline emissions of 60 Mt CO2 in 2020 by about 0.66 Mt CO2.

The ministry then creates a monitoring plan, sets up a reporting system and makes provisions for conducting an ex-post assessment (e.g. 5–10 years later). It also plans to conduct a domestic study on fuel own-price elasticities in the country.

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MRV-Blueprint: India Railways NAMA <http://transport-namas.org/wp-content/uploads/2014/10/TRANSfer_MRV-Blueprint_Railway-NAMA_India_draft.pdf>

AM00090 Proposed Version 03.1 <https://cdm.unfccc.int/Panels/meth/meeting/11/049/mp49_an07.pdf>

AM0101 High speed passenger rail systems <https://cdm.unfccc.int/methodologies/DB/0U42CLZRFTEERYLAB4SZ87ERW84ZUT>

Partially aggregated bottom-up spreadsheet tools with defaults for inter-urban rail mitigation actions

TEEMP Railway alternatives <http://cleanairasia.org/transport-emissions-evaluation-model-for-projects-teemp/>

Simple bottom-up tools with mostly default data for inter-urban rail mitigation actions

JICA Railway electrification <https://www.jica.go.jp/english/our_work/...att/M06_Railway_Freight_Elec_E.pdf>

JICA Railway (Freight) mode shift <https://www.jica.go.jp/english/our_work/climate.../M05_Railway_Freight_MS_E.pdf>

JICA Railway passenger mode shift <https://www.jica.go.jp/english/our_work/.../M03_Railway_Passenger_MS_E.pdf>

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Travel demand models for freight modal shift mitigation actions
Cube <http://www.citilabs.com/software/cube/>
TransCad <http://www.caliper.com/tctraveldemand.htm>

VISUM <http://vision-traffic.ptvgroup.com/en-us/products/ptv-visum/>

EMME <https://www.inrosoftware.com/en/products/emme/>

Disaggregated bottom-up ex-post guidance for freight modal shift mitigation actions

AM00090 Proposed Version 03.1 <https://cdm.unfccc.int/Panels/meth/meeting/11/049/mp49_an07.pdf>

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