A. ForFITS: coverage, methodology and input data

Coverage

ForFITS covers aspects of the transport system ranging from non-motorized passenger transport to freight pipelines. Table A.1 explains the ranges of parameters covered in ForFITS and introduces (in capital letters) some of the terminology used in the model. Figure A.1 and Figure A.2 give tables — one for passenger and one for freight transport — that depict the modal and submodal characteristics outlined in Table A.1. [1]

Table A.1 ForFITS coverage and terminology

Coverage	Details
2 transport SERVICES	PASSENGER and FREIGHT
2 AREAs in each REGION	Indicated as AREA I and AREA II of each REGION (i.e. the transport systems under consideration)
2 ZONES in each AREA and REGION	Indicating (for large freight transport) whether the origin or destination of the movement is inside or outside the boundaries of the transport system under consideration (AREA and REGION)
9 transport MODES	Non-motorized transport (NMT) TWO WHEELERS: personal private vehicles and public transport vehicles for passenger transport, and freight two wheelers THREE WHEELERS: personal private vehicles and public transport vehicles (e.g. autorickshaws) for passenger transport, and freight three wheelers Light Duty road Vehicles (LDVs): includes cars in personal passenger transport, taxis in public personal transport, and light commercial vehicles in freight transport Navigation VESSELS: private personal vessels and vessels used for public transport for passenger services; large-freight inland waterway vessels (LF IWW), short-sea shipping (LF SHORT SEA) and large-freight deep-sea/maritime vessels (LF MARITIME) LARGE ROAD vehicles, includes buses and large buses for passenger transport, large-freight medium duty trucks (LF MDT) and large-freight heavy duty trucks (LF HDT) in freight transport RAIL: public rail passenger transport and freight AIR: passenger and freight Freight PIPELINES
6 VEHICLE CLASSES	Identified by the letters A to F, as VCLASS A, VCLASS B, VCLASS C, VCLASS D, VCLASS E and VCLASS F and subgrouped to identify specific submodes within the main modes

[1] This is further elaborated in section C which focuses on the Excel interface.

Coverage	Details
	In PASSENGER NMT, VCLASS A is used for walking, VCLASS B for cycling, VCLASS E and F for public transport (VCLASS C and D are not used); FREIGHT NMT is not considered VCLASS A to D identify personal vehicles for PASSENGER TWO WHEELERS, THREE WHEELERS and LDVS, while VCLASS E and F are used for public transport; there are no submodes in freight for these three modes For PASSENGER transport, VCLASS A to D identify personal VESSELS, while VCLASS E and F are used for public transport VESSELS; FREIGHT VESSELS are composed by LF IWW (VCLASS A), LF SHORT SEA (VCLASS B) and LF MARITIME (VCLASS C to F) VCLASS A to F identify public transport LARGE ROAD PASSENGER vehicles; VCLASS A to C correspond to LF MDT and VCLASS D to F correspond to LF HDT VCLASS A to F identify public transport RAIL PASSENGER vehicles; LF RAIL corresponds to FREIGHT RAIL, VCLASS A to F) VCLASS A to F identify AIR PASSENGER vehicles; LF AIR corresponds to FREIGHT AIR, VCLASS A to F VCLASS A to F identify FREIGHT PIPELINES
10 FUEL BLENDs	NMT BLEND, GASOLINE BLEND, METHANE BLEND, LPG BLEND, DIESEL BLEND, DME BLEND, HYDROGEN BLEND, ELECTRICITY MIX, KEROSENE BLEND, and PIPELINE BLEND, some of which are associated with specific modes
31 POWERTRAIN technologies	GASOLINE positive ignition (PI) internal combustion engine (ICE), GASOLINE PI ICE-HYDRAULIC HYBRID, GASOLINE PI ICE-ELECTRIC HYBRID, METHANE PI ICE, METHANE PI ICE-HYDRAULIC HYBRID, METHANE PI ICE-ELECTRIC HYBRID, LPG PI ICE, LPG PI ICE-HYDRAULIC HYBRID, LPG PI ICE-ELECTRIC HYBRID, DIESEL compression ignition (CI) ICE, DIESEL CI ICE-HYDRAULIC HYBRID, DIESEL CI ICE-ELECTRIC HYBRID, DME CI ICE, DME CI ICE-HYDRAULIC HYBRID, DME CI ICE-ELECTRIC HYBRID, HYDROGEN ICE, HYDROGEN ICE-HYDRAULIC HYBRID, HYDROGEN ICE-ELECTRIC HYBRID, fuel cells (FC) , FC-ELECTRIC HYBRID, ELECTRIC, GASOLINE PI ICE-ELECTRIC HYBRID PLUG-IN, METHANE PI ICE-ELECTRIC HYBRID PLUG-IN, LPG PI ICE-ELECTRIC HYBRID PLUG-IN, DIESEL CI ICE-ELECTRIC HYBRID PLUG-IN, DME CI ICE-ELECTRIC HYBRID PLUG-IN, HYDROGEN ICE-ELECTRIC HYBRID PLUG-IN, FC-ELECTRIC PLUG-IN HYBRID, potentially relevant and available for all modes except NMT, AIR and PIPELINES NO POWERTRAIN, only for NMT KEROSENE TURBINE, only for AIR PIPELINE PUMP, only for PIPELINES
26 AGE classes	Numbered from 0 to 25, using the following notation: ZERO, I, II, III, IV, V, VI, VII, VIII, IX, X, XI, XII, XIII, XIV, XV, XVI, XVII, XVIII, XIX, XX, XXI, XXII, XXIII, XXIV, XXV

Figure A.1 ForFITS: Modal and submodal characteristics – passenger transport

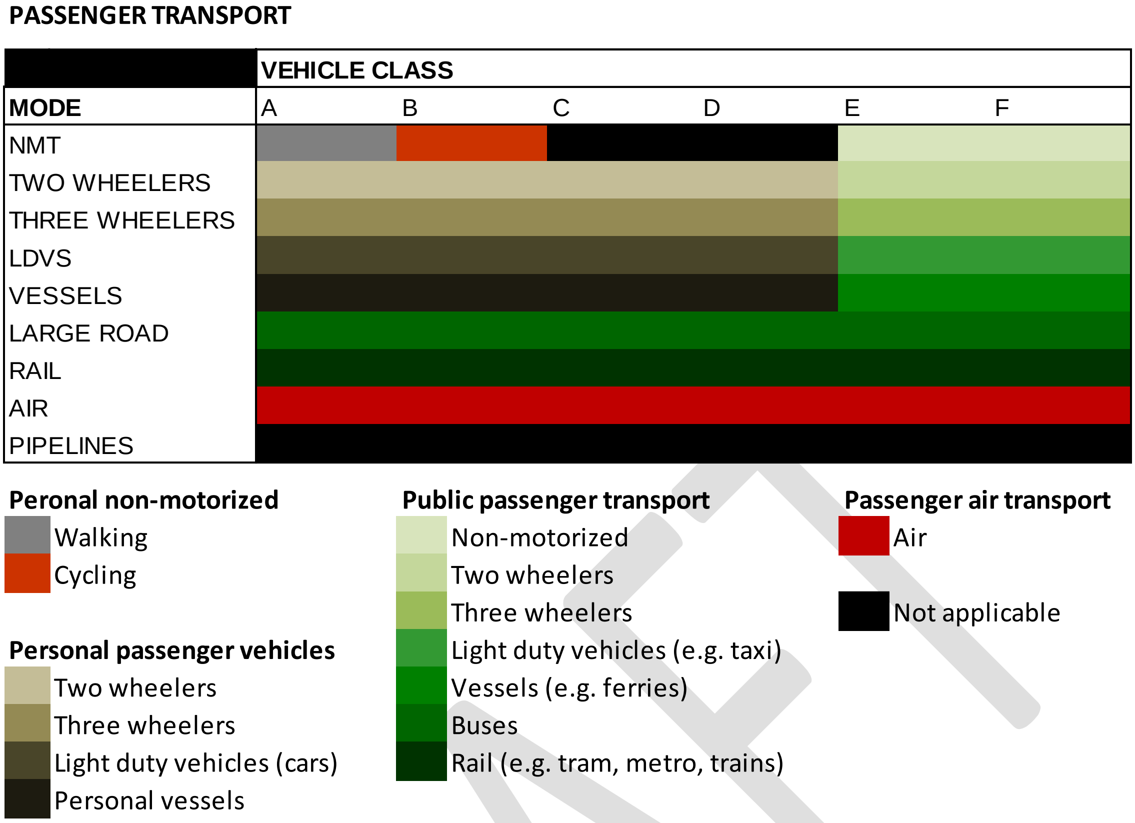
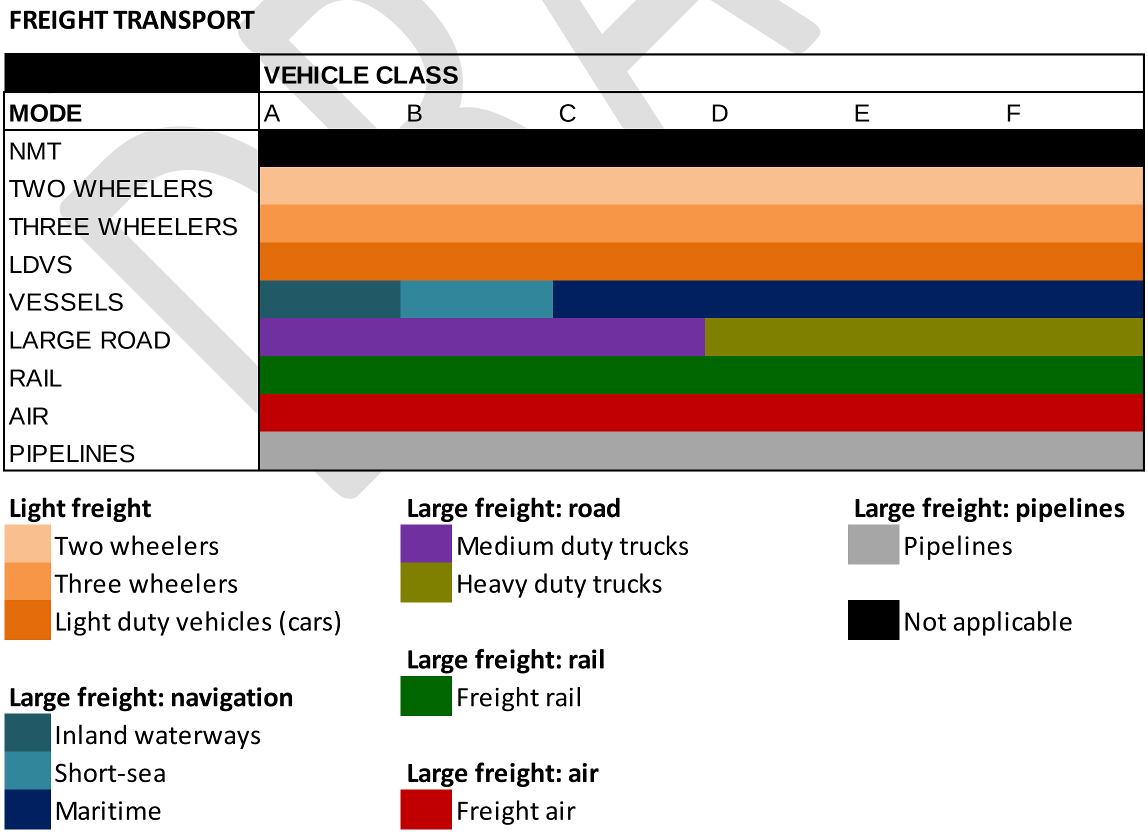


Figure A.2 ForFITS: Modal and submodal characteristics – freight transport



Methodology

Estimating fuel consumption and CO_2 emissions from transport activity

Fuel consumption

The evaluation of fuel consumption from existing information on transport activity and vehicle characteristics is calculated using an approach based on the decomposition of Fuel use into transport Activity, energy Intensity and Structural components, such as the type of transport service (passenger versus freight), mode, vehicle class and powertrain group (generally called ASIF). The main equation is as follows:

$$\sum_i F_i = A \sum_i \left(\frac{A_i}{A}\right)\left(\frac{F_i}{A_i}\right) = A \sum_i S_i I_i = F$$

Where: F	is total fuel use in a sector
A	is overall sectoral activity (vkm)
$\frac{A_i}{A} = S_i$	is overall sectoral activity (vkm)
$\frac{F_i}{A_i} = I_i$	is the energy intensity, expressed in energy required per vehicle km, of each vehicle category i (e.g. average fuel consumption per km of vehicles performing a given type of service and belonging to a given mode, a given vehicle class and a given powertrain group)

CO_2 emissions

The assessment of emission estimates from fuel consumption is addressed by the multiplication of the energy used by emission factors reflecting the characteristics of the fuels with respect to tank-to-wheel and well-to-tank emissions. In this case, the ASIF equation is extended as follows:

$$\sum_i F_i EF_i = A \sum_i \left(\frac{A_i}{A}\right)\left(\frac{F_i}{A_i}\right)\left(\frac{EF_i}{F_i}\right) = A \sum_i S_i I_i EF_i = E$$

With:

$$EF_i = \sum_j \left(\frac{EF_{ij}}{F_{ij}}\right)\left(\frac{F_{ij}}{F_i}\right)$$

Where:

E	is total emissions use in a sector
A	Is overall sectoral activity (vkm)
$\frac{A_i}{A} = S_i$	is the sectoral structure (by service, mode, vehicle class and powertrain group)
$\frac{F_i}{A_i} = I_i$	is the energy intensity (by service, mode, vehicle class and powertrain group)
EF_{ij}	is the emission factor per unit of energy for the energy carrier or fuel j used in the service, mode, vehicle class and powertrain group i

Estimating transport activity over time

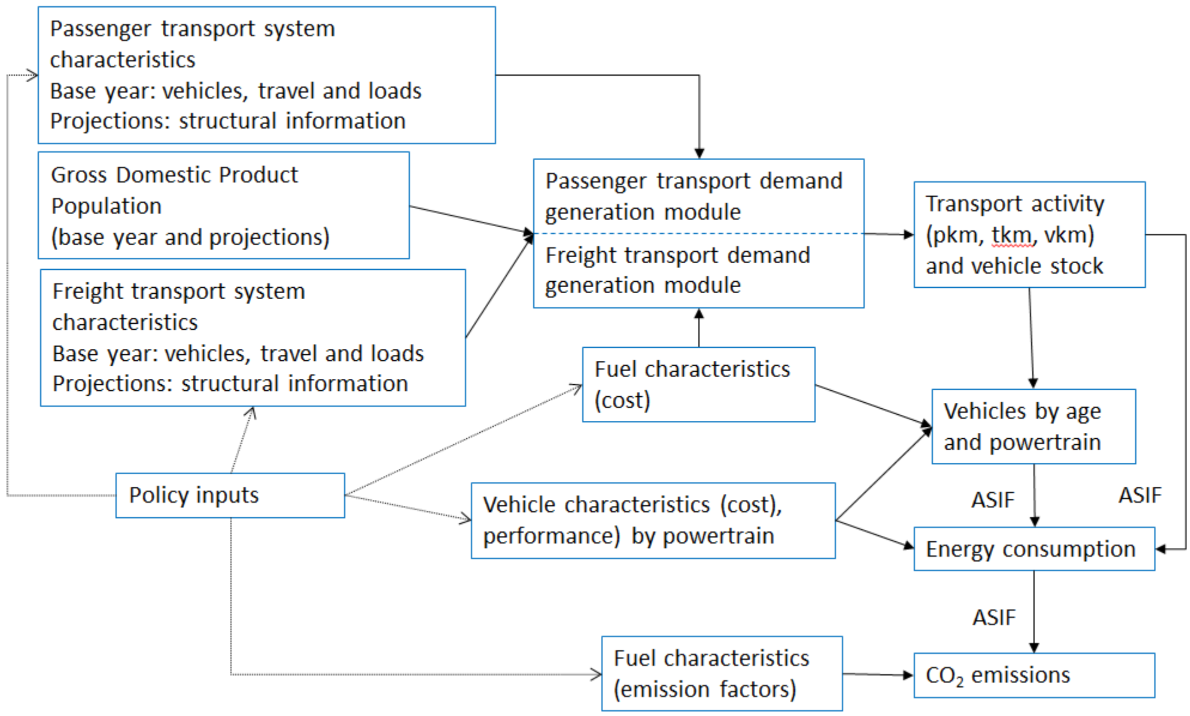
In ForFITS, the ASIF equation, extended to CO_2 emissions, takes into account the classification of transport services, modes, vehicle classes and powertrain groups (also includes information on vehicles by age, as defined by characteristics of different vintages).

In developing long-term projections, however, the vehicle-based ASIF approach is supplemented with relationships that link economic parameters with transport-related ones (such as changes in the cost of travel with variations in travel per vehicle, or changes in income per capita with variations in vehicle ownership), as well as other specific methodologies (i.e. choice models) that apply only to specific subsets of the data.

This is why ForFITS combines characteristics of the transport system in a base year with inputs on the evolution of demographic parameters, economic variables, vehicle and fuel characteristics, as well as structural aspects of the passenger and freight transport systems (including a number of policy inputs) to generate transport activity, vehicle, fuel consumption and CO_2 emission estimates.

Figure A.3 provides a synthetic description of the calculation flow outlined above and also highlights the links associated with the ASIF calculations.

Figure A.3 ForFITS: *simplified model structure*



In ForFITS, transport demand is largely determined by the relationship linking GDP and GDP per capita with vehicle ownership, pkm and tkm. Figure A.4, Figure A.5 and Figure A.6 show three examples of this. Figure A.4 contains: i) historical data on personal passenger vehicle ownership as a function of GDP per capita; and ii) the default drivers used in ForFITS for characterizing this relationship. Figure A.5 refers to the relationship between GDP per capita and the pkm share of personal passenger vehicles in the total pkm of personal motorised passenger vehicles and public passenger transport (excluding air transport). It shows historical values and the default driving patterns adopted in ForFITS (dotted blue lines). Figure A.6 illustrates the default assumptions of ForFITS for the share of pkm of air passenger transport as a function of GDP per capita.

Results characterizing each mode and vehicle class also depend on: i) parameters affecting the driving cost of different vehicle types and the cost of different powertrain options; ii) information for understanding the changes associated with shifts to/from private vehicles from/to public transport (see Box A.1); and iii) parameters that consider the effect of behavioural changes associated with environmental consciousness.

Box A.1 Effects from changes to the "Passenger transport system index"

The "passenger transport system index" is an instrument that was specifically developed in ForFITS to help understand the changes in the passenger transport system associated with shifts to/from private vehicles from/to public transport (i.e. modal shift in passenger transport).

The index is closely related with the shares of pkm on personal and public passenger transport (excluding air). Its conception exploits the information published in the Mobility in Cities Database (UITP, 2006) to identify development patterns, as functions of GDP per capita, of the modal share of motorized private vehicles in the total of personal and collective passenger transport vehicles (Figure A.5). A similar approach was suggested in IEA, 2008.

An index of 0 is associated with a share of pkm on personal vehicles that tends to 1 (100%) when GDP per capita increases. An index of 0 reflects high shares of the average vehicle travel of personal vehicles, and higher-than-average personal vehicle ownership (towards the "high driver" in Figure A.4). In developed countries, this is the case of low population density areas, such as rural areas and/or urban agglomerations developed horizontally, with significant urban sprawl, and where the transport system is composed mainly of personal vehicles. A low transport characteristic index is also very likely to be associated with relatively low taxation of fuels and personal vehicles.

On the other hand, an index of 1 is associated with an evolution of the share of pkm on collective passenger transport vehicles of 100%, while pkm on personal vehicles is reduced to 0% (below the bottom blue dotted line of Figure A.5). This is an extreme case where the transport system fully operates on public transport. A high transport characteristic index (e.g. close to 0.7, as in the case of the bottom blue dotted line of Figure A.5) tends to correspond to urban areas with: i) high population densities; ii) a policy framework that does not promote the use (and sometimes the ownership) of personal vehicles (e.g. via parking fees, access restrictions, road pricing, and/or relatively high taxes on personal vehicles and fuels); iii) land use polices and sometimes geographical and/or other constraints that encourage the vertical development of the city; and iv) appealing, widely available and high-quality public transport. High values of the "transport characteristic index" are also associated with an average travel per vehicle for personal passenger vehicles that is roughly half of the value observed for areas characterized by low indexes, and lower-than-average personal vehicle ownership levels (towards the "low driver" in Figure A.4).

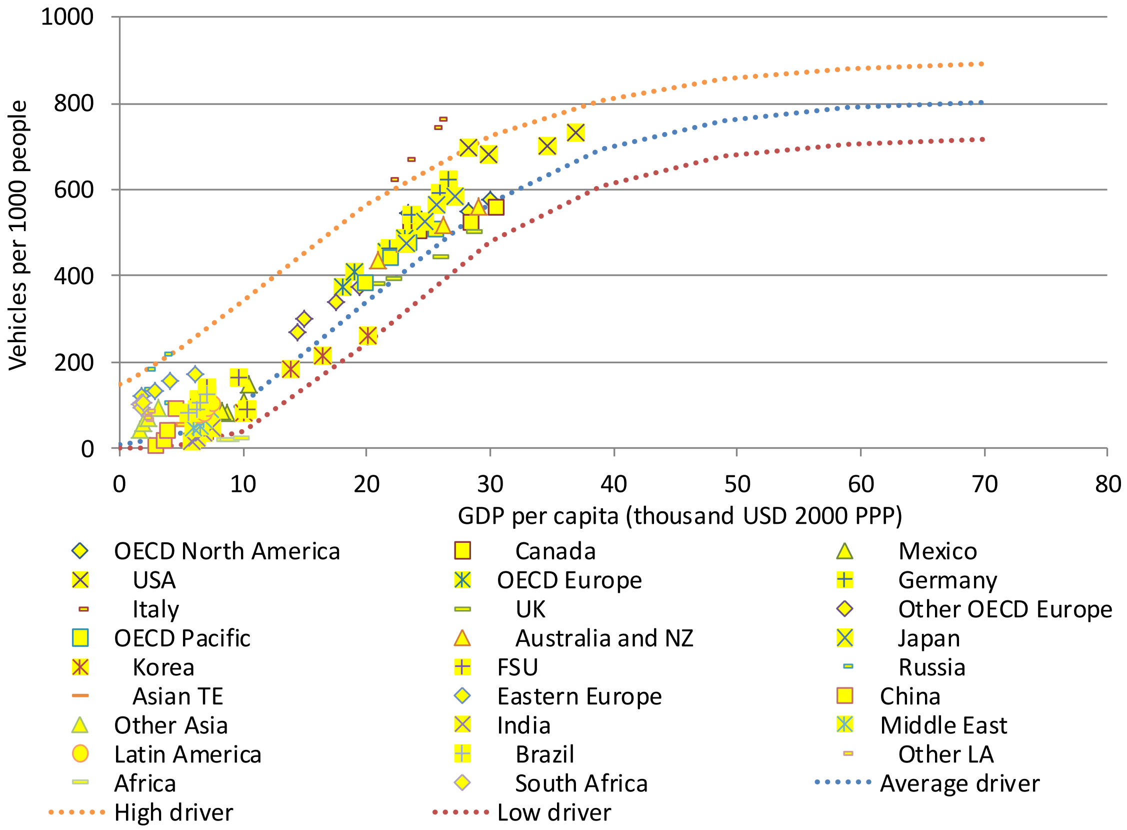
Motorized personal passenger transport vehicles

For motorized personal passenger transport vehicles (namely cars and motorcycles), the vehicle stock is estimated using S-curves (similar to those described by Dargay et al., 2007 for the whole vehicle fleet) describing vehicle ownership as a function of GDP per capita (Figure A.4). In ForFITS, such curves are modified over time by the "transport characteristic index", the "environmental culture index" (the latter considers the effects of behavioural changes associated with increasing environmental consciousness), and the cost of driving per vkm.

The average vehicle travel of personal passenger transport vehicles is estimated on the basis of the base year input and the variation of the following driving parameters: the cost of driving (an increment in the cost of driving per vkm is assumed to result in a reduction of the use of private vehicles; cross effects representing the influence of changes in the cost of modes competing with personal vehicles are also considered), the "passenger transport characteristic index" (due to the tendency to observe higher values of the average travel per personal passenger vehicle in regions with low population densities, such as rural areas and horizontally developed urban agglomerations, and/or in regions where fuel taxation tends to be lower than the global average), and the personal income (small effect).

For personal motorized road modes (average vehicle load), the variation in the number of passengers per vehicle is assumed to depend on the evolution of the vehicle ownership over time.

Figure A.4 Personal vehicle ownership (two wheelers, three wheelers and LDVs)



Sources: elaboration of information collected from national statistical offices and international databases, building on those referenced in UNECE, 2012

Public transport

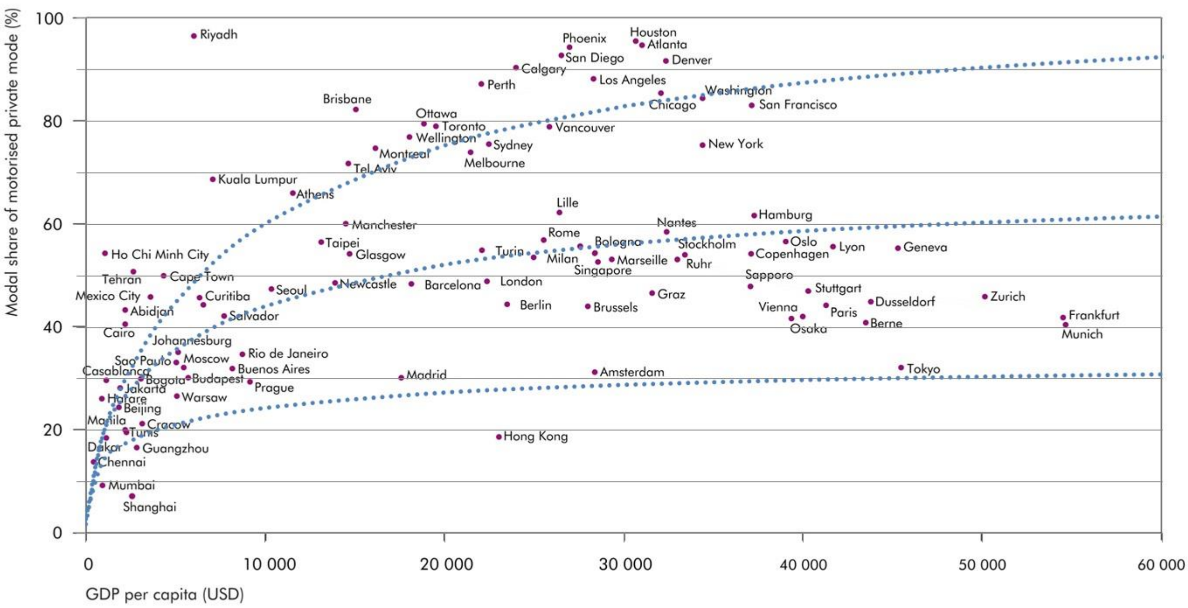
For public passenger transport vehicles, the vehicle stock results from the estimation of the total passenger travel (pkm) on collective passenger transport vehicles, the average vehicle load (people per vehicle) and the average travel per year of the vehicles.

The total passenger travel on public passenger transport vehicles is derived from the share of pkm on public transport in the base year, its evolution over time and the estimations on pkm obtained for personal passenger vehicles. The pkm share of transport on personal motorised passenger vehicles (in total pkm of personal motorised passenger vehicles and public passenger transport, excluding air transport) is expressed as a function of GDP per capita (Figure A.5), as modified by changes in the "passenger transport characteristic index" and the evolution of the cost of driving for public transport and the competing passenger transport "driving modes" (i.e. personal motorised passenger vehicles and air, in ForFITS).

The share of passenger travel on different public transport modes (buses, rail, etc.) depends on exogenous inputs.

ForFITS is designed to transfer variations of pkm (on public transport vehicles) that are beyond certain load and travel ranges (i.e. between a minimum and maximum variation of passenger load and average travel per vehicle) to the corresponding vkm and vehicle stock. In order to avoid steps in the modelling results, default data are such that all changes in pkm are entirely reflected in changes to the vehicle stock.

Figure A.5 Pkm share of transport on personal motorised passenger vehicles in total pkm of personal motorised passenger vehicles and public passenger transport (excluding air transport)



Sources: elaboration of UITP, 2006 (cited by IEA, 2008)

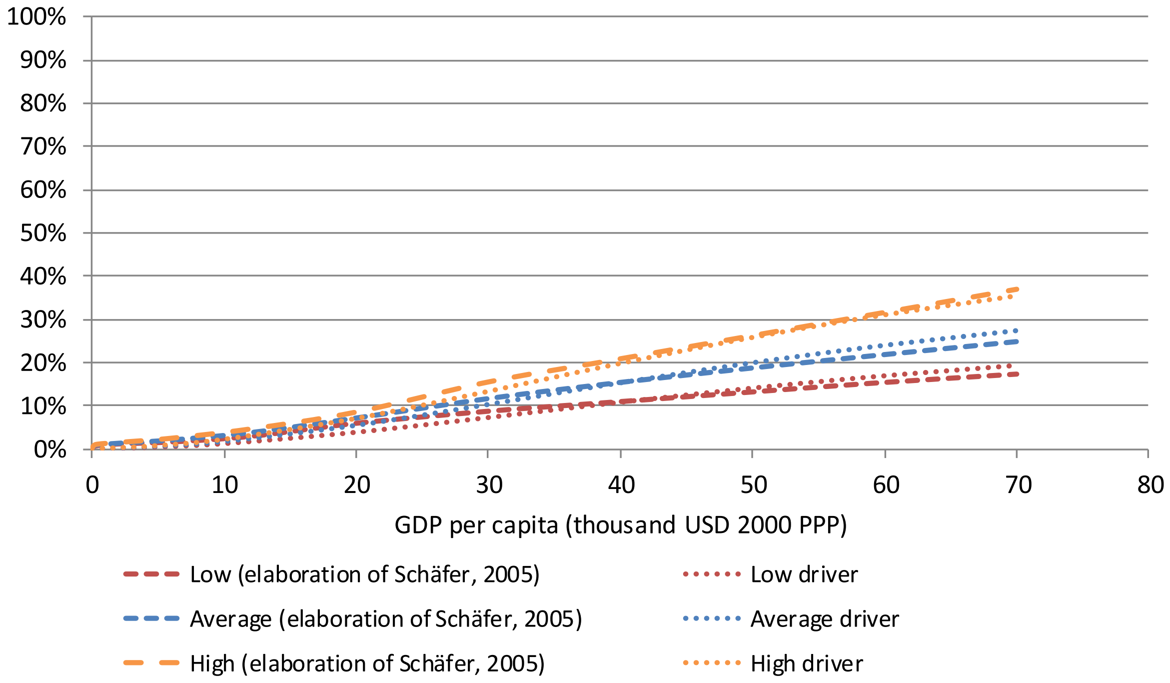
Air passenger transport

The vehicle stock for air transport vehicle is also estimated from of the total passenger travel (pkm), the average vehicle load (people per vehicle) and the average annual distance travelled by the vehicles.

The total passenger travel of air passenger transport vehicles is derived from the share of pkm on air transport in the base year, its evolution over time and the estimations on pkm obtained for personal passenger vehicles. The pkm share over time is evaluated on the basis of the effects of GDP per capita (Figure A.6), changes due to the "passenger transport characteristic index" and the "environmental culture index", and the evolution of the cost of driving for air transport and the competing passenger transport "driving modes" (i.e. personal vehicles and air, in ForFITS).

As in public transport, ForFITS is designed to transfer variations of pkm (on air transport vehicles) that are beyond certain load and travel ranges (i.e. between a minimum and maximum variation of passenger load and average travel per vehicle) to the corresponding vkm and vehicle stock. Default data are such that all changes in pkm are entirely reflected in changes to the vehicle stock.

Figure A.6 Pkm share of air transport in total pkm



Sources: elaboration of Schäfer, 2005

Freight

For large freight vehicles (including LARGE ROAD, RAIL vehicles, VESSELS, AIR and PIPELINES), the vehicle stock is estimated on the basis of the total freight travel (tkm) on freight vehicles, the average vehicle load — encompassing the effects of loads on laden trips and empty running — and the average annual travel of the vehicles.

The total freight travel (tkm) is evaluated from the product of transport volumes (tonnes lifted) and the average haul length: the latter assumed to be constant for each distance class characterising the travel of vehicles belonging to each large-freight submode.

The total amount of tonnes lifted (transport volume) by large freight is assumed to be proportional to GDP and directly affected by economic growth. This is consistent with the idea that, without significant structural changes in the economy, growth in total freight travel tends to closely follow the growth of GDP. This reflects observations that there were no clear signs of decoupling of transport volume growth from economic growth (for Europe, see for instance EEA, 2008).

Structural changes affect the large freight transport system and can result in modal shifts. The structural modifications taken into account include changes to:

i) the shares of tonnes lifted by transport zone for each area, reflecting whether the economy is more or less export-oriented than in the base year)

ii) the shares of tonnes lifted by haul distance for each transport zone and goods type, reflecting changes in the origin and destination of goods, either within the transport system (e.g. because of changes in sourcing) or beyond it (e.g. because of structural changes in the export destination);

iii) the shares of tonnes lifted by good type for each area and transport zone, reflecting changes in the type of products processed and manufactured within the system boundaries; and

iv) the shares of tonnes lifted by large-freight submode for each area, transport zone and transport distance, reflecting changes in the competitiveness of one mode over another (e.g. due to the construction of new infrastructure).

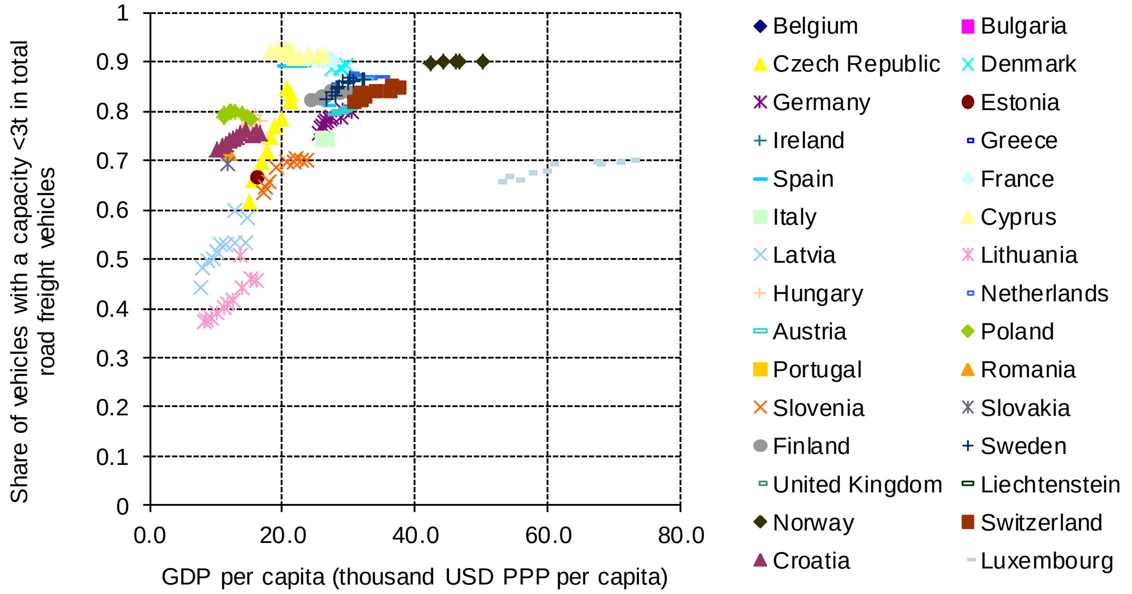
Vkm are calculated from tkm and loads. The latter are assumed to be affected by variations of the cost of tkm (higher costs are associated, via elasticities, to higher loads).

Beyond certain vehicle travel ranges (i.e. between a minimum and maximum variation of the average travel per vehicle), ForFITS is designed to transfer variations of vkm of large freight vehicles to the vehicle stock. Default data are such that all changes in vkm are entirely reflected in changes to the vehicle stock.

Within each large-freight submode, the share of vehicles belonging to different vehicle classes depends on exogenous inputs.

The share of light freight vehicles in the total freight vehicle stock is evaluated from the large freight vehicle stock and S-shaped curves linking GDP per capita to the shares of vehicles with a load capacity lower than 3 t in the total of all road freight vehicles (the definition of these curves is based on the statistics shown in Figure A.7). The average light freight vehicle travel is assumed to be affected by the cost of driving (as in case of passenger light vehicles, the coupling parameters are functions of income). Average vehicle loads of light freight vehicles are functions of ownership rates.

Figure A.7 Share of vehicles with a load capacity lower than 3 t in total road freight vehicles



Source: elaboration of Eurostat (2011)

New vehicle registrations

New vehicle registrations are to be estimated (for all modes and transport service types) on the basis of the data on the vehicle stock, the vehicle sales in the same class in previous years (either from historical data or projected estimates), and vehicle mortality, calculated using survival curves.

Powertrain selection

The shares of powertrain technologies of newly registered vehicles within each vehicle class, for each mode, transport service (passenger and freight) and each area are either estimated on the basis of a discrete choice approach using a multinomial logit model combined with inputs on the availability of the different powertrain technologies on the vehicle market (endogenous selection), either on the basis of direct user inputs (exogenous selection).

Table A.1 contains the full list of technologies taken into consideration.

This section focuses on the methodology applied for the endogenous selection.

Multinomial logit

In the multinomial logit model (Ben Akiva and Lerman, 1985), the probability that a decision maker *n* selects the element *i* in the total set of choices C_n, expressed as:

$$P_n(i) = \frac{e^{\mu V_{in}}}{\sum_{j \in C_n} e^{\mu V_{jn}}}$$

$P_n(i)$ is such that $0 \le P_n(i) \le 1$ and $\sum_{i \in C_n} P_n(i) = 1$

This formulation assumes that the utility of the choice i made by the decision maker n, U_{in}, results from a deterministic component, V_{in}, and an unknown disturbance, ε_{in}:

$$U_{in} = V_{in} + \varepsilon_{in}$$

This formulation also assumes that all the disturbances ε_{in} are independently and identically Gumbel-distributed[2], with a location parameter η (which is assumed to be zero in this case, indicating that in the absence of disturbances the utility corresponds to its deterministic component) and a scale parameter μ.

The multinomial logit approach requires the definition of the characteristics of all different options (the powertrains groups in each vehicle class, in this case) in order to characterise the utility of the individuals that need to select one of the choices.

The utility parameter to be maximised by the discrete choice approach is the expected amount of savings derived from the selection of one option with respect to the others. Such savings are determined on the basis of the actualized cost of travel. [3]

The estimation of the average cost of travel for each powertrain technology is based on:

- a personal discount rate for future expenditures (user input);
- the vehicle purchase price of vehicles, including taxes (user input);
- the expected purchase price of fuel (user input);
- the annual travel per vehicle at each age of the vehicle.

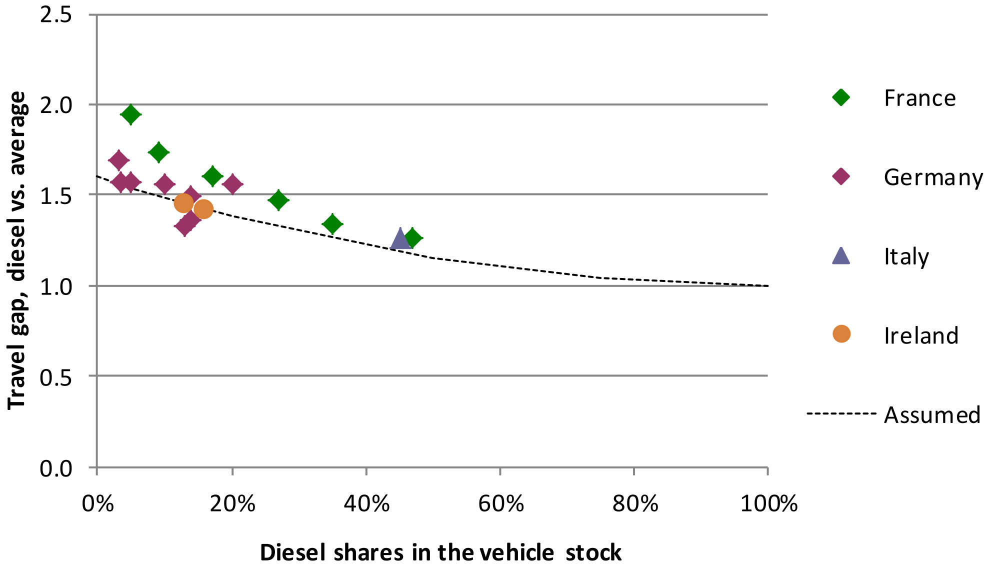
The average vehicle travel decreases with vehicle age, and technologies representing an alternative to the conventional spark-ignition powertrain fuelled with a gasoline-based blend are characterised by an average annual amount of travel that is higher if their market share is close to zero (Figure A.8).

In addition, users are assumed to consider constant fuel prices when taking into account future expenditures. This is justified by the volatility of fuel prices and the difficult assessment, for users, of the evolution of fuel prices beyond the time of vehicle purchase.

[2] The assumption of a Gumbel distribution is used for reasons of analytical convenience — mainly the availability of an explicit formulation of the probability $P_n(i)$ associated with it. The Gumbel distribution is not a major limitation of this approach and can be defended as an approximation of the normal distribution. On the other hand, the assumption of independently and identically distributed disturbances is a more important restriction, especially for innovative technologies.

[3] The restrictions imposed by this assumption are acceptable in this specific case (powertrain group selection), since it is conceivable that the disturbances characterising the utility resulting from the adoption of different powertrains do not change significantly for most powertrain options, especially if they are associated to similar performances. However, it must be noted that the limitations associated with the assumption of independently and identically distributed disturbances becomes more relevant for powertrains having performance characteristics that tend to differ more (e.g. because of important gaps in terms of range, refuelling time and availability of refuelling points) in comparison with conventional alternatives. This is the case, for instance, for electric motors and fuel cells. In the future, improvements to this approach may be needed. One possibility is to differentiate among different categories of individuals selecting the different options, e.g. in order to address the emergence of new types of ownership patterns. Another possibility is to include additional parameters in the deterministic component of the utility.

Figure A.8 Travel gaps diesel and gasoline vehicles (1990 – 2010)



Sources: various datasets and publications, including Bodek and Heywood (2008), Eurostat (2011), Howley et al. (2007), Caputo et al. (2008).

The scale parameter μ is proportional to the inverse of the mean deviation of the disturbances from the mean value of their Gumbel distribution (σ):

$$\mu = \frac{\pi}{\sigma\sqrt{6}} \text{, since } \sigma^2 = \frac{\pi^2}{6\mu^2}$$

The effect on the choice probabilities of the scale parameter is certainly not irrelevant (Adamowicz et al., 1998). The higher the mean deviation from the location parameter of the Gumbel distribution (i.e. the location of the maximum of the distribution), the lower the scale parameter, and the less extreme the choice coefficients. Vice-versa, the lower the mean deviation from the location parameter, the higher the scale parameter.

In the case considered here, the utility determines the selection of the available options, and it is given by the sum of a deterministic component and an unknown disturbance. The growth of the scale parameter μ means that the mean value of the unknown disturbances becomes increasingly negligible with respect to the value of its deterministic component. This leads to a choice that is increasingly characterised by the deterministic component of the utility.

On the other hand, a decreasing value of μ (towards zero) implies that the mean deviation of the distribution of the disturbances tends to grow, also increasing the mean magnitude of the disturbances with respect to the value of the deterministic component of the utility. This results in a decreasing relevance of the deterministic component of the utility for the choice of one option rather than another. In this case, all choices tend to have the same probability of being selected because they are increasingly influenced by the non-deterministic component.

In the ForFITS model, μ is calculated (when possible) on the basis of the technology shares in the base year. Alternatively, it is set in a way that corresponds to a mean deviation of the unknown disturbances of the utility of 10% of the total cost of travelling estimated for the cheapest powertrain technology option.

Availability of the different powertrain technologies on the vehicle market

ForFITS combines the choices resulting from the application of the choice model with exogenous inputs that represent the level of technology available on different models within the same vehicle class.

This reflects the fact that, in the case of new technologies like hybrid, fuel cell or electric powertrains (or in case of specific market characteristics, like for instance in the United States of America, where compression ignition powertrains are not commonly available on light duty vehicles), only a fraction of all models within a given vehicle class are offered with one or more motorisation options that are based on the advanced technologies.

The use of exogenous inputs described earlier is intended to provide a framework for the definition of the feasible alternatives to conventional spark-ignition powertrains powered by a gasoline fuel blend: helping the analyst to define the set of options available to the consumer for its choice (whose selection is then addressed with the multinomial logit approach).

Fuel mix

Each powertrain group can be powered by a number of different fuels.

Spark-ignition engines may use a blend of petroleum gasoline and ethanol, for instance. Ethanol may be obtained from several different primary feedstocks, like sugar cane, corn and wooden biomass.

Similarly, compression ignition powertrains may be fuelled by petroleum diesel fuel, as well as biodiesel obtained from different feedstocks (like vegetable oil, coal, natural gas or woody biomass) through different conversion processes.

The characterization of fuels in ForFITS requires user inputs on the well-to-tank and tank-to-wheel emission factors (per unit energy) for each of the fuel blends coupled with the relevant powertrain technologies (see Table A.1 for details).

Input data

Minimum requirements

The ForFITS model can easily adapt to different levels of data availability. Notwithstanding the possibility of relying on a significant amount of information entered by default in the model, ForFITS requires a minimum amount of data to function correctly.

Minimum input data requirements in ForFITS cover[4]:

- the characterization of the transport system in the base year (historical inputs);
- the definition of the context in which the transport system should evolve (projections).

[4] Section C on the ForFITS Excel interface gives a complete explanation of the minimum data requirements (as well as the complete set of inputs).

General information on the initial and final projection times, the characterization of the AREAs (as urban, non-urban or non-specified), and the selection of the modelling approach for powertrain selections (exogenous or endogenous) are also required inputs. [5]

Minimum data requirements for historical inputs concern socioeconomic variables (GDP, population), vehicles in the stock (including their average travel and loads, their average fuel consumption, the powertrain shares characterizing them), new vehicle registrations (same detail given for stocks, needed for the base year-5 and -10)[6] and, for freight transport, the shares of tonnes lifted by good type (if available).

Minimum input requirements for projections include information on the evolution of GDP and population, fuel prices (namely the fuel cost component), the evolution of the vehicle shares between two and three wheelers (especially in regions with high shares of three wheelers), the evolution of the pkm shares for different types of public transport modes (e.g. defining changes due to the construction of urban rail infrastructures and replacing buses), the modal shares of light road freight vehicles (i.e. two wheelers, three wheelers and light commercial vehicles), and the evolution of the network extension (average distance travelled) for pipelines.

Need for coherence

It is of fundamental importance that inputs for each AREA, SERVICE, MODE, VEHICLE CLASS and POWERTRAIN TECHNOLOGY are coherently entered into the ForFITS Excel file. [7]

If inputs on the PASSENGER vehicle stock are differentiated by AREA to treat differently urban and non-urban information, all other inputs (wherever they are requested by area) need to refer to the same transport and socioeconomic system. This is necessary both for base year inputs and for projections.

The coherence requirement does not force users to enter inputs that have the same degree of disaggregation for different services.

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[5] If the powertrain selection is endogenous, the discount rate is a required input. If the powertrain selection is exogenous, projections on the powertrain shares are also needed.

[6] Values for the years between the base year, base year -5 and base year -10 are obtained in Vensim by linear interpolations. For this reason, it is a good practice to enter information that does not represent a specific year, but rather an average of the three (or five) years around the input point.

[7] More details, including examples, are found in Section C on the Excel interface of ForFITS.

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