Evaluating CO$_2$ emissions in inland transport and climate change mitigation

ForFITS
A monitoring and assessment tool "For Future Inland Transport Systems"
General overview

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Key requirements

Allow the estimation/assessment of emissions in transport
Allow the evaluation of transport policies for CO₂ emission mitigation

Be developed as a software tool
Be freely available for users (e.g. national and local governments, general public)
Be developed between 2011 and 2013

Convert information on transport activity into fuel consumption and CO₂ emission estimates considering the influence of the demographic and socio-economic context, including policy inputs

Sectoral model (focused on inland transport only): we do not expect it to target the evaluation of overall effects on the economic growth
ForFITS model: coverage

- Passenger and freight transport services
- Two different areas (e.g. to define the transport systems: urban, non-urban, non-spec.)
- Nine transport modes: non-motorized transport, two wheelers, three wheelers, light road vehicles, medium and heavy road vehicles, rail, navigation (inland, short-sea and deep-sea/martime), air and pipelines
- Different vehicle subsets within each mode (organized in six vehicle classes – A to F) (figures)
- 31 powertrain technologies (e.g. internal combustion engines, hydraulic hybrids, electric hybrids, plug-ins, fuel cell, electric)
- 10 fuel blends, some of which are associated with specific modes and/or powertrains
Passenger transport demand (pkm, vkm) and vehicle stock largely determined by relationships linking GDP per capita with vehicle ownership and pkm

Motorized personal vehicles

- Vehicle stock primarily a function of GDP per capita (figure)
- Annual vehicle travel (km/year) affected by changes in the cost of driving (through direct and cross elasticities)
- Vehicle load affected by changes of vehicle ownership (lower ownership associated with higher average loads)

Shifts to/from personal from/to public transport are considered as structural changes having an effect on:
- the vehicle stock (vehicle ownership is lower in areas with high shares of public transport)
- the average travel per vehicle (the average travel of personal vehicles is lower in areas with high shares of public transport)

Vehicle ownership is also assumed to be influenced by environmental culture (behavioural aspect)
Public transport (except air)

- Pkm share on public transport modes (in total personal and public transport, excluding air) primarily a function of GDP per capita (figure), also assumed to be influenced by environmental culture (behavioural aspect)
- Pkm affected by changes in the cost of driving (direct & cross elasticities)
- Pkm influenced by modal shifts to/from personal from/to public transport
- Vkm from pkm and annual travel
- Vehicle stock from vkm and loads

Source: elaboration of UITP, quoted by IEA, 2008
ForFITS model: demand generation
Passenger transport (3/3)

Air transport

- Pkm share of air transport (in total pkm) primarily a function of GDP per capita (figure), also assumed to be influenced by environmental culture (behavioural aspect)
- Pkm affected by changes in the cost of driving (direct & cross elasticities)
- Vkm from pkm and annual travel
- Vehicle stock from vkm and loads

Modal share of air transport in total transport

Source: elaboration of Schäfer, 2005
Large-freight

- Transport activity (tkm) proportional to GDP (figure)
- Tkm is the product of tonnes lifted (also proportional to GDP) and haul length (constant by distance class)

Tonnes lifted by mode are subject to structural changes, driven by:
- the trade-related nature of the economy (e.g. free trade vs. low imports and exports)
- the origin/destination of goods (e.g. changes in sourcing and/or destination of exports)
- the type of goods transported (e.g. change of importance of the manufacturing industry with vs. primary material extraction and trade)
- the modal competitiveness (e.g. changes due to the construction of new network links)

Tkm and loads are also subject to the influence of the cost of moving goods (through elasticities)

Vkm from tkm and annual travel
Vehicle stock from vkm and loads
Light road freight

- Light commercial vehicles (<3.5 t)
- Typically out of freight transport statistics
- Transport activity (tkm) built bottom-up from vehicle stock, travel and loads

Vehicle stock deduced from:
- vehicle stock of large road freight
- historical share of light road freight vehicles in total road freight, function of GDP per capita (figure)

Annual vehicle travel (km/year) affected by changes in the cost of driving (through direct and cross elasticities)

Vehicle load affected by changes of vehicle ownership (lower ownership associated with higher average loads)

Source: Eurostat
The **fuel consumption** is calculated from:

- **vehicle activity**
- **the structure** of the organization of vehicle across services, modes, vehicle classes and powertrain groups
- **the energy intensity** of each of the vehicles in this structure

**ASIF: Activity, Structure, Intensity → Fuel consumption**

The calculation is based on Laspeyres identities (frequently used for the development and the analysis of energy efficiency indicators)

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

- **F** total Fuel use
- **A** vehicle activity (expressed in vkm)
- **F_i** fuel used by vehicles with a given set of characteristics (by service, modes, vehicle class and powertrain)
- **A_i/A = S_i** sectoral structure (expressed as shares of vkm by service, modes, vehicle class and powertrain)
- **F_i/A_i = I_i** energy intensity, i.e. the average fuel consumption per vkm by service, modes, vehicle class and powertrain)
ForFITS model: CO\textsubscript{2} emissions

Extended ASIF

The same methodological approach used for the calculation of fuel consumption (ASIF) can be extended to evaluate CO\textsubscript{2} emissions

This extension is suitable to the case of where several energy carriers need to be considered

\[
E = \sum_{i} E_i = A \sum_{i} \left( \frac{A_i}{A} \right) \left( \frac{F_i}{F} \right) \left( \frac{F_{ij}}{F_i} \right) \left( \frac{E_{ij}}{EF_{ij}} \right) = A \sum_{i} S_i I_i EF_{ij} = E
\]

\( E \) emissions

\( E_i \) emissions due to the the vehicle \( i \)

\( F_{ij} \) fuel (energy carrier) \( j \) used in the vehicle \( i \)

\( EF_{ij} \) emission factor for the fuel (energy carrier) \( j \) used in the vehicle \( i \)
ForFITS model: simplified structure

Passenger transport system characteristics
- Base year: vehicles, travel and loads
- Projections: structural information

Gross Domestic Product
- Population (base year and projections)

Freight transport system characteristics
- Base year: vehicles, travel and loads
- Projections: structural information

Passenger transport demand generation module

Freight transport demand generation module

Transport activity (pkm, tkm, vkm) and vehicle stock

Vehicles by age and powertrain

Energy consumption

Vehicle characteristics (cost), performance by powertrain

Fuel characteristics (cost)

Policy inputs

Vehicle characteristics (cost), performance by powertrain

Fuel characteristics (emission factors)

Fuel characteristics (cost)

CO₂ emissions

GDP

Population

Base year: vehicles, travel and loads

Projections: structural information

Extended ASIF

ASIF
ForFITS model: powertrain selection

Multinomial logit: used when the "endogenous powertrain selection" is activated

Choice based on the maximization of consumer utility
• corresponds to the maximization of savings from the powertrain selection

Requires the characterization of the utility of all options (powertrains of each vehicle class)
• Vehicle and fuel prices - including costs, margins and tax rates
• Vehicle fuel consumption
• Discount rates

Information on average vehicle travel (km/year) is needed to characterize fuel costs
• average vehicle travel assumed to decrease with vehicle age
• alternative technologies to gasoline-powered positive-ignition powertrains assumed to travel more if their market share is close to zero (figure)

Users are assumed to consider constant fuel prices when taking into account future expenditures (this is justified by the volatility of fuel prices)

Average travel and share of diesel powertrains in selected countries

Sources: various datasets and publications, including Bodek and Heywood (2008), Eurostat, Howley et al. (2007), Caputo et al. (2008)
Even if ForFITS has the capacity to adapt to different levels of data availability, **the model does require a substantial amount of data**, for:

- 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)

Information on the initial and final times, the characterization of the areas, and the selection of the modelling approach for the powertrain choice (exogenous or endogenous), are also firm needs

**Minimum data requirements** (other inputs are defined by default data and can be modified)

### Historical inputs

- GDP, population
- Vehicle stock: number of vehicles by powertrain, average travel and loads, average fuel consumption
- New vehicle registrations: same detail used for stocks needed for the base year, 5 and 10 years earlier (data in between are taken into account with linear interpolations)

### Projections

- GDP and population
- Fuel prices (cost and taxation)
- Vehicle shares between two and three wheelers
- Pkm shares for different public transport modes (e.g. due to the construction of urban rail)
- Modal shares of light road freight vehicles
- Evolution of the network extension for pipelines
- With endogenous powertrain selection (optional), discount rate and powertrain shares

**Need for coherence for inputs on each AREA, SERVICE, MODE, VEHICLE CLASS and POWERTRAIN**
A wide set of default data are included in the ForFITS Excel file

These default data are used to characterizing several parameters of the ForFITS model

They concern the following input categories:

M Data absolutely required
  Corresponding to the minimum data requirements

A Inputs expected to be introduced by the user
  The default value in ForFITS is for guidance only
  This category includes policy inputs that allow exploring different scenarios

B Input containing technical information (e.g. technological potential and costs by powertrain)
  These data may be maintained unchanged
  The defaults are set on the basis of research activities involving literature reviews and statistical analyses (further information on this is provided in the relevant section of the ForFITS manual)

C Inputs on structural characteristics of the model
  Unless the users acquired significant experience with the model, these inputs shall not be modified: changes to these inputs will result in significant modifications to the model behaviour
# ForFITS model: data requirements

## Time period analyzed

Initial and final projection times
- Base year and final year

## Initial conditions

**Initial transport system**
- Vehicle stock
  - Vehicles
    - Number of active vehicles
    - Powertrain group shares in each vehicle class
  - Travel
    - Annual travel per vehicle
  - Load
    - Vehicle load
  - Fuel consumption
    - Vehicle fuel consumption
    - Fuel consumption gap by powertrain group
  - New vehicle registrations
- Base year
  - Vehicles
    - Newly registered vehicles
    - Powertrain group shares in each vehicle class
  - Fuel consumption
    - Vehicle fuel consumption
    - Fuel consumption gap by powertrain group
  - Base year-5
  - Vehicles
    - Newly registered vehicles
    - Powertrain group shares in each vehicle class
  - Fuel consumption
    - Vehicle fuel consumption
    - Fuel consumption gap by powertrain group

## Economic & demographic data

**Base year**
- Population
- GDP
- GDP deflator

**Base year-10**
- Population
- GDP

**Crew costs**
- Crew cost per day (base year)

## Fuel consumption (projections)

### Modal shares

| Mode of transport | Share
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Air</td>
<td>M</td>
</tr>
<tr>
<td>Rail</td>
<td>A</td>
</tr>
<tr>
<td>Road</td>
<td>M</td>
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</tbody>
</table>

## Fuel consumption by powertrain

<table>
<thead>
<tr>
<th>Powertrain group</th>
<th>M</th>
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<tbody>
<tr>
<td>ICE</td>
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</tbody>
</table>

## Demand generation parameters

- **Passenger**
  - Drivers as functions of GDP per capita
  - Personal passenger vehicles (PPV) per capita
  - Personal passenger LDVs
  - Personal passenger large road modes

## Fuel consumption characteristics

<table>
<thead>
<tr>
<th>Powertrain group</th>
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<tbody>
<tr>
<td>ICE fuel</td>
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</tbody>
</table>

## Fuel prices and taxes

- **Fuel prices and taxes**
  - Fuel price per litre
  - Fuel excise tax
  - Fuel duty
  - Fuel consumption gap by powertrain group

## Modal shares

| Mode of transport | Modal shares
<table>
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<td>Rail</td>
<td>M</td>
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<td>Road</td>
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</table>

## Private passenger vehicles (PPV) per capita

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## Public passenger LDVs

| Mode of transport | Share
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<tbody>
<tr>
<td>Rail</td>
<td>A</td>
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## Public passenger vessels

| Mode of transport | Share
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<tbody>
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<td>Rail</td>
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## Public transport

- **Cost of vehicle-km**
  - Cost of travel per vehicle
  - Cost of travel per vehicle per capita

## Technology choice (projections)

- **Powertrain technology choice switch**
  - Choice switch (endogenous / exogenous)
  - Discount rate

## Other inputs (projections)

- **Distance travelled/network extension**
  - Distance travelled per vehicle
  - Transport system over time

## Other inputs (projections)

| Mode of transport | Share
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## Modal shares

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ForFITS users

Who may be interested in using ForFITS?

• Someone willing to understand the transport system he is concerned about (typically a geographical region), its impacts in terms of energy consumption and CO₂ emissions
• Someone having access to a sufficient amount of statistical information
• Someone having some degree of specific competence (transport, transport policies, energy policies, environmental policies)
• Someone having sufficient financial means to support his/her ambitions
• Someone from...
  • a national administration and/or a local government
  • an Inter-Governmental Organization
  • a Non-Governmental Organization
  • an Academic institution and/or a consulting company
  • the industry sector (company/corporation, industry association)
Links

Model download/UNDA project page
http://www.unece.org/trans/theme_forfits.html

User manual, including methodological information
http://www.unece.org/trans/forfits_user_manual.html

Contact information
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Workshop survey
http://www.surveymonkey.com/s/39KGGW5