Monitoring and assessment of CO₂ emissions in inland transport to facilitate climate change mitigation
The UNECE ForFITS model - Capacity Building Workshop in Montenegro
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ForFITS
Explanation of the Vensim model

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ForFITS structure and model "views"
Levels

- Area
- Service
- Mode
- Vehicle class
- Powertrain
- Age
Economic parameters

Target
Socio-economic data from the inputs excel file

Inputs
- GDP
- Population
- Time span

Outputs
- GDP per capita
  main driver to determine passenger transport demand
Target
S-Curves link the passenger demand with the GDP per capita taking into account several factors, such as the passenger transport characteristic index, the cost of driving and the environmental culture.

Inputs for the calibration of the initial S-Curve
Parameters characterizing the passenger transport demand as function of the GDP/capita

- Ownership of personal passenger road vehicles
- Ownership of personal passenger LDVS
- Share of pkm on personal vehicles in total pkm of public transport and personal passenger vehicles
- Share of air transport in total pkm (personal passenger vehicles, air and public transport)
- People per active bike
- Ownership of personal passenger vessels

Reference value → Base year
Demand passenger (main drivers)

Factors affecting the shape of the initial S-Curve

• Passenger transport characteristic index
  0  Focus on personal vehicles, low density of population, significant presence of urban sprawl, horizontal urban development
  1  Very high density of population, very strong focus on public transport, geographical and other constraints leading to the vertical development of the urban area

• Environmental culture
  Takes into account behavioural aspect
  0  Little relevance of environmentally conscious behaviour
  1  Higher relevance of environmentally friendly transport options

• Cost of driving (and moving goods)
Demand passenger (NMT)

**Target**
Projecting transport demand for NON-MOTORISED TRANSPORT (NMT)

**Inputs**
- S-Curve on people per active bike
- GDP per capita
- Population
- Share of people walking
- Annual travel per vehicle
- Load per vehicle

**Outputs**
- Target number of bikes
- Target number of walkers
- Target vkm
- Target pkm
Demand (pass. personal motor road)

**Target**
Projecting vehicle stock, vkm and pkm for passenger personal motorized road transport (cars, two and three wheelers)

**Inputs**
- S-Curve on ownership of personal passenger road vehicles
- S-Curve on ownership of personal passenger LDVS
- GDP per capita
- Population
- Exogenous vehicle shares
- Annual travel per vehicle
- Load per vehicle

**Outputs**
- Target vehicle stock for LDVS (cars)
- Target vehicle stock for total personal passenger road vehicles
- Target vehicle stock by vehicle class for TWO WHEELERS, THREE WHEELERS and LDVS
- Target vkm
- Target pkm
**Inputs**

- S-Curve on ownership of personal passenger vessels
- GDP per capita
- Population
- Exogenous vehicle shares
- Annual travel per vehicle
- Load per vehicle

**Outputs**

- Target number of boats
- Target vehicle stock by vehicle class
- Target vkm
- Target pkm

**Target**

Projecting vehicle stock, vkm and pkm for transport taking place on boats
Demand (passenger, public)

**Target**

Projecting pkm, vkm and vehicle stock for public passenger transport

**Inputs**

- Share of pkm on personal vehicles in total pkm of public transport and personal passenger vehicles
- GDP per capita
- Target pkm on personal passenger vehicles
- Exogenous pkm shares
- Cost elasticities
- Load per vehicle
- Annual travel per vehicle

**Outputs**

GDP/capita-driven pkm on public passenger transport vehicles

GDP/capita-driven pkm on public transport vehicles by class

Target pkm

Target vkm

Target vehicle stock
**Demand (passenger, air)**

**Target**

Projecting pkm, vkm and vehicle stock for passenger air transport

**Inputs**

- Share of air transport in total pkm (personal passenger vehicles, air and public transport)
- GDP per capita
- Target pkm on personal passenger vehicles
- Target pkm on public transport vehicles
- Exogenous pkm shares
- Cost elasticities
- Load per vehicle
- Annual travel per vehicle

**Outputs**

- GDP/capita-driven pkm on passenger air transport vehicles
- GDP/capita-driven pkm on passenger air transport vehicles by class
- Target pkm
- Target vkm
- Target vehicle stock
Demand (large-freight, GDP & structure)

**Target**
Projecting freight activity in large-freight modes as function of the GDP and the structure of the freight transport system

**Inputs**
- Freight activity at the base year
- GDP
- Shares of tonnes lifted by good type
- Shares of tonnes lifted by haul distance
- Shares of tonnes lifted by transport zone
- Haul length by haul distance
- Hauls per vehicle ratios
- Load factor ratios
- Vehicle capacity ratios
- Target vehicle shares

**Outputs**
- Evolution of the tonnes lifted over time
- Disaggregation depending on the structural characteristics of the freight transport system
- Freight activity (tkm) over time
- GDP & structure-driven tkm by vehicle class
**Target**

Projecting freight activity in large-freight modes taking into account the effects of costs

**Inputs**
- GDP & structure–driven tkm by vehicle class
- Cost elasticities

**Outputs**
- Target tkm
Demand (light road freight veh shares)

**Target**

Projecting the share of light vehicles in total road freight

**Inputs**

- S-curves family of light vehicles share in total road freight expressed as a function of the GDP per capita
- Reference value (base year)
- GDP per capita

**Outputs**

- Target light vehicles share
**Demand (freight)**

**Target**
Projecting tkm, vkm and vehicle stock by vehicle class for all freight modes

**Inputs**
- Target tkm for large-freight
- Annual travel per vehicle
- Load per vehicle
- Number of road vehicles belonging to large-freight modes
- Light vehicles share in total road freight
- Annual travel per vehicle
- Load per vehicle

**Outputs**
- Target tkm, target vkm and target vehicle stock for large-freight modes by vehicle class
- Target vehicle stock for light-freight by vehicle class
- Target vkm for light-freight by vehicle class
- Target tkm for light-freight by vehicle class
Vehicles, new registrations (hist., input)

**Target**

Vehicles by powertrain registered within the ten years prior to the base year

**Inputs**

- User inputs on vehicle registrations at the base year as well as in the past (5 and 10 years before the base year)

**Outputs**

New vehicle registrations by powertrain and by age at the base year
Vehicles, new registrations (historical)

Target
Calibration of the vehicle survival curves

Inputs
- Vehicles sold within the ten years prior to the base year
- New registrations assumed to be constant before the ten years period prior to the base year
- Vehicle stock at the base year

Outputs
- Survival curve
- Maximum scrappage age by vehicle class
- Average vehicle life by vehicle class
**Vehicles by age**

**Target**

Projection of the new vehicle registrations and the vehicle stock by age

**Inputs**

- Target vehicle stock from the transport demand generation module
- Number of vehicles in the stock
- Vehicle scrappage curves
- Aging system

**Outputs**

- New vehicle registrations over time
- Vehicle stock by age over time
Vehicles, powertrain shares (input)

**Target**
Powertrain shares or powertrain availability to distribute the new vehicle registrations across the different technologies

**Inputs**
- If the powertrain choice is treated exogenously, user inputs on technology shares
- If the powertrain choice is treated endogenously, user inputs on technology availability

**Outputs**
- Powertrain shares to allocate the new vehicle registrations over time across the different technologies
- Powertrain availability affecting the endogenous calculations that lead to the technology shares (logit model)
Vehicle cost (input)

Target
Information on the vehicle cost over time depending on the technology

Inputs
- User inputs on technologies cost at the short and long term

Outputs
Cost per vehicle by powertrain with respect to the new vehicle registrations over time
Vehicles, powertrain choice (logit)

**Target**
Calculation of the technology shares in the new vehicle registrations in the case that powertrain selection is treated endogenously

**Inputs**
- Vehicle cost
- Estimated cost due to fuel consumption within the vehicle life
- Annual travel per vehicle by age
- Discount rate effect by age
- Logit function taking into account the savings of purchasing one technology compared to the another

**Outputs**
- Total cost by powertrain
- Total cost per km by powertrain
- Total discounted cost per km by powertrain
- Powertrain shares
Travel per vehicle (passenger)

**Target**
Travel per vehicle by vehicle class over time for passenger vehicles

**Inputs**
- User inputs on travel per vehicle at the base year
- Cost elasticities
- GDP per capita elasticity (very small)
- Passenger transport characteristic index elasticity
- User inputs on travel per vehicle at the base year
- Vkm variations
- Minimum and maximum factors that limit the fraction of the vkm variations absorbed by the travel component

**Outputs**
- Travel per vehicle by vehicle class for personal passenger vehicles
- Travel per vehicle by vehicle class for public and air passenger transport. Currently the factors are set in a way that the annual travel per vehicle remains always constant at the base year value
Travel per vehicle (freight)

**Target**
Travel per vehicle by vehicle class over time for freight vehicles

**Inputs**
- User inputs on travel per vehicle at the base year
- Cost elasticities
- GDP elasticity
- User inputs on travel per vehicle at the base year
- Vkm variations
- Minimum and maximum factors that limit the fraction of the vkm variations absorbed by the travel component

**Outputs**
- Travel per vehicle by vehicle class for light freight vehicles
- Travel per vehicle by vehicle class for large freight vehicles. Currently the factors are set in a way that the annual travel per vehicle remains always constant at the base year value
Travel per vehicle

**Target**

Travel per vehicle by powertrain over time

**Inputs**

- Travel per vehicle by vehicle class
- Travel gap law for LDVS
- Powertrain shares in the vehicle fleet
- Factors correcting the travel gap law taking into account the different travel order of magnitude between the modes

**Outputs**

- Travel per vehicle by powertrain for LDVS
- Travel per vehicle by powertrain for all the modes
Travel per vehicle by age

**Target**
Travel per vehicle by age over time

**Inputs**
- Travel per vehicle by powertrain
- Vehicle shares by age in the fleet
- Annual travel per vehicle assumed as a linear function of the vehicle age

The annual travel per vehicle at the maximum scrappage age is estimated to be half of the travel taking place in the first year of life of the vehicle

**Outputs**
Travel per vehicle by age
## Cost of fuel

### Target
Cost of fuel per vkm at different levels of detail

### Inputs
- User inputs on cost of fuel per unit energy by fuel blend
- Fuel blend and powertrain matching matrix
- Energy consumption per km by powertrain
- Vkm at different levels of detail

### Outputs
- Cost of fuel per vkm by powertrain
- Aggregates on cost of fuel per vkm for the different modes and sub-modes
**Target**

Cost of vehicles per vkm at different levels of detail

**Inputs**

- Cost of the vehicles in the stock by age (for simplicity and to limit input requirements, this assumes that all the vehicles, independently of the age, cost the same as those registered at the base year)
- Vehicle shares in the fleet
- Average vehicle life
- Annual travel per vehicle

**Outputs**

- Aggregates on cost per vehicle
- Aggregates on annual cost per vehicle
- Aggregates on cost per vkm for the different modes and sub-modes
Cost of crew

Target
Cost of crew per vkm at different levels of detail

Inputs
- User inputs on annual crew cost per vehicle
- Aggregates on annual travel per vehicle

Outputs
Aggregates on cost of crew per vkm for the different modes and sub-modes
Cost of driving

**Target**
Total cost of driving per vkm at different levels of detail

**Inputs**
- Cost of fuel per vkm
- Cost of vehicles per vkm
- Cost of crew per vkm
- User inputs on road pricing per vkm
- Aggregates on load per vehicle

**Outputs**
- Total cost of driving per vkm for the different modes and sub-modes
- Total cost of driving per pkm/tkm for the different modes and sub-modes
**Target**

Load per vehicle by vehicle class over time for passenger vehicles

**Inputs**

- User inputs on load per vehicle at the base year
- Load per vehicle as linear function of the personal vehicle ownership
- User inputs on load per vehicle at the base year
- Pkm variations
- Minimum and maximum factors that limit the fraction of the pkm variations absorbed by the load component

**Outputs**

Load per vehicle by vehicle class for personal passenger vehicles

Load per vehicle by vehicle class for public and air passenger transport. Currently the factors are set in a way that the load per vehicle remains always constant at the base year value.
Load (freight)

**Target**
Load per vehicle by vehicle class over time for freight vehicles

**Inputs**
- User inputs on load per vehicle at the base year
- Load per vehicle as linear function of the vehicle shares in total road freight
- User inputs on load per vehicle at the base year
- Change of tkm cost
- Elasticities of load per vehicle with respect to the cost of tkm

**Outputs**
- Load per vehicle by vehicle class for light freight vehicles
- Load per vehicle by vehicle class for large freight vehicles
Activity, loads and stock aggregates

**Target**
Calculating aggregates on activity, load and annual travel per vehicle

**Inputs**
- Vehicle stock by powertrain
- Annual travel per vehicle by powertrain
- Load per vehicle by powertrain (assumed to be the same as by vehicle class)
- Aggregates on vehicle stock

**Outputs**
- Tkm, pkm and vkm by powertrain
- Aggregates on tkm, pkm and vkm
- Aggregates on annual travel per vehicle
- Aggregates on load per vehicle
Activity, loads and stock by age

**Target**
Calculating activity (tkm, pkm, vkm) by age

**Inputs**
- Vehicle stock by age
- Annual travel per vehicle by age
- Load per vehicle by age (assumed to be the same as by vehicle powertrain)
- Share of electric driving of plug-in electric or dual fuel electric powertrains
- Fuel blend and powertrain matching matrix

**Outputs**
- vkm by age
- Tkm/pkm by age
- Vkm by powertrain, fuel blend and age
**Target**

Energy consumption of those vehicles registered within the ten years prior to the base year

**Inputs**

- User inputs on registrations-weighted energy consumption per km of vehicles registered at the base year as well as in the past (5 and 10 years before the base year)
- Technology ratios with respect to GASOLINE PI ICE

**Outputs**

- Registrations-weighted energy consumption per km by vehicle class and by age of those vehicles registered within the ten years prior to the base year
- Registrations-weighted energy consumption per km by powertrain and by age of those vehicles registered within the ten years prior to the base year

Energy consumption per km by powertrain (new registrations within the last ten year)
**Target**

Energy consumption per km of those vehicles in the stock at the base year

**Inputs**

- Energy consumption per km by powertrain of vehicles registered within the last ten years prior to the base year
- Energy consumption per km oh those vehicles registered before the period of ten years prior to the base year assumed to be linear
- User inputs on energy consumption per km by powertrain in the vehicle stock at the base year

**Outputs**

Energy consumption per km by age of those vehicles that constitute the fleet at the base year

Energy consumption per km by powertrain (historical new registrations)
Energy cons (new reg) (region)

**Target**
Energy consumption per km of new vehicles registered over time

**Inputs**
- User inputs on the evolution of GASOLINE PI ICE fuel consumption
- Powertrain ratios with respect to GASOLINE PI ICE
- Index of performance

**Outputs**
- Reference value for the energy consumption per km of new registrations by powertrain
- Energy consumption per km of new registrations by powertrain
Energy cons by age

**Target**
Energy consumption by age and aggregated at different levels

**Inputs**
- Energy consumption per km by age of those vehicles that constitute the stock at the base year
- Energy consumption per km of new vehicles registered over time
- Aging system
- Vkm by age
- Aggregates on vkm

**Outputs**
- Energy consumption per km by age
- Energy consumption by age
- Aggregates on energy consumption
- Aggregates on energy consumption per km in the vehicle stock
CO₂ emissions

**Target**

CO₂ emissions by age and aggregated at different levels

**Inputs**

- Energy consumption of vehicles by age
- User inputs on WTT/TTW/WTW CO₂ emission factors
- Aggregates on vkm

**Outputs**

- WTT/TTW/WTW CO₂ emissions by age
- Aggregates on WTT/TTW/WTW CO₂ emissions
- Aggregates on WTT/TTW/WTW CO₂ emissions per km in the vehicle stock
**Target**
Total cost associated to the new vehicle registrations and the fuel consumption of the vehicle fleet

**Inputs**
- New vehicle registrations
- Cost of the new vehicle registrations
- Energy consumption by fuel blend
- Cost by fuel blend

**Outputs**
- Total cost
**Target**

Showing the results disaggregated and stacked in different ways

**Outputs views**

- Vehicle stock (vehicles)
- Transport activity (tkm, pkm) and vehicle activity (vkm)
- Energy use (toe)
- Costs (USD)
- WTT CO₂ emissions (kg CO₂)
- TTW CO₂ emissions (kg CO₂)
- WTW CO₂ emissions (kg CO₂)
- New registrations (vehicles)