TREMOVE VERSION 2.3 SIMULATION MODEL FOR EUROPEAN ENVIRONMENTAL TRANSPORT POLICY ANALYSIS

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ABSTRACT

TREMOVE 2.3 is a transport and emissions simulation model developed for the European Commission Directorate-General Environment. The model has been developed by the Catholic University of Leuven and Transport & Mobility Leuven, in collaboration with their subcontractors[1].

The model estimates the transport demand, the modal shifts, the vehicle stock turnover, the emissions of air pollutants and the welfare level under different policy scenarios. TREMOVE 2.3 models both passenger and freight transport in the EU15 plus 6 extra countries, and covers the period 1995-2020.

This paper provides an overview of the TREMOVE 2.3 model structure and its applications.

Keywords: *Clean Air for Europe Programme, Transport Policy, Environmental Policy, Transport model, Emission model*

1 INTRODUCTION

TREMOVE is a policy assessment model to study the effects of different transport and environment policies on the emissions of the transport sector. It is an integrated simulation model developed for the strategic analysis of the costs and effects of a wide range of policy instruments and measures applicable to local, regional and European transport markets.

The first versions of the TREMOVE model were developed in 1997-1998 by the university of Leuven and Standard & Poor's DRI as an analytical underpinning for the European Auto-Oil II Programme (European Commission, Standard & Poors' DRI, K.U.Leuven, 1999). This paper discusses TREMOVE version 2.3 (De Ceuster, Franckx, 2005), which has been developed in the context of the European Clean Air for Europe Programme.

TREMOVE 2.3 covers 21 countries and 8 sea regions. All relevant transport modes are modeled, including air and long-distance maritime transport (the maritime model will not be discussed in this paper). The model covers the 1995-2020 period, with yearly intervals.

Figure 1 maps the modular structure of TREMOVE. The model performs a year-by-year loop over its modules. The same modules are used for both the construction of the baseline (business as usual) scenario as for the policy scenarios.

[1] Subcontractors included WSP, TRT, INFRAS, COWI, TRL, GAMS software and ADPC

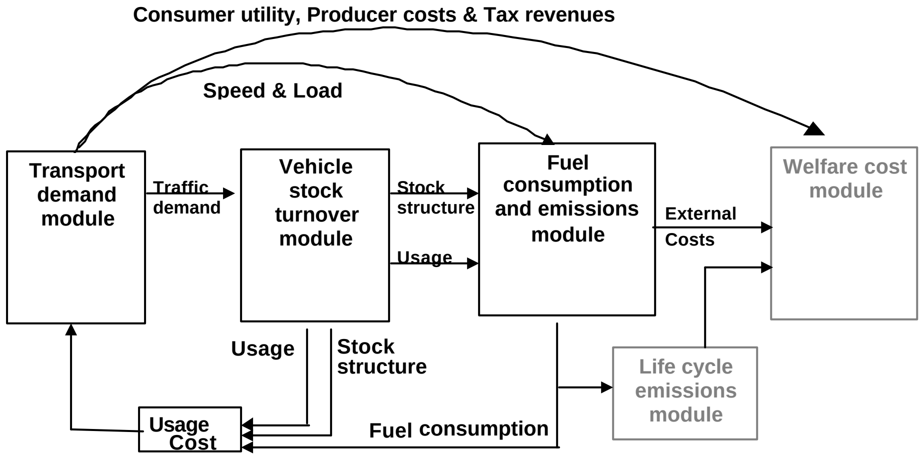

Figure 1 : Modular Structure of TREMOVE 2.3 model

This paper gives an overview of the TREMOVE modeling approach and first simulations, as well as perspectives for further model development.

2 TRANSPORT DEMAND AND WELFARE MODULES

2.1 Scope of the TREMOVE demand module

The TREMOVE model consists of separate country models that describe transport flows and emissions in three model regions: one metropolitan area, an aggregate of all other urban areas and an aggregate of all non-urban areas. Trips in the non-urban areas are further separated in short (-500 km) and long (+ 500 km) distance trips. The model explicitly takes into account that, depending on the area taken into consideration, the relevant modes and road types differ significantly. Thus, while the numeric values of the model differ from country to country, the structure is identical across countries.

The transport demand module represents, for a given year and transport mode, the number of passenger-kilometres (pkm) or ton-kilometres (tkm) that will be used in each "model region" of the country considered. In this representation, demand is broken down in peak and off-peak demand. With this demand module, the impact of policy measures on the transport quantity of all transport modes is calculated.

TREMOVE models the transport activities within these areas without explicit network disaggregation. This simplification allows us to calibrate a simple but complete policy simulation model on top of a baseline of transport flows. Note however, that the TREMOVE demand module is a reconstruction of the SCENES model (ME&P, 2000), which is a genuine network model.

2.2 Modeling transport decisions of households and firms

Private transport and business transport are modelled separately in the transport demand module.

The demand for private transport (non-work and commuting passenger trips) is the result of the decision processes of all households in a country. Therefore, private traffic demand has been determined assuming that, within the constraints of their available budget, households choose their preferred consumption bundle. The demand for goods and services follows then from this maximizing behaviour.

The decision processes of households are modelled using nested Constant Elasticity of Substitution (or CES) utility functions (Keller, 1976). Based on the consumed quantities and current prices of all different options, a utility value is estimated. This represents the preference relation of all households for the different transport options. Knowing the substitution between the different transport options, it is possible to model the change in consumed quantities in policy simulations.

The demand for business transport (freight transport and business passenger trips) is modelled as a result of the decision processes within firms. The business transport demand is determined by generalized prices, desired production quantities and substitution possibilities with other production factors.

It is assumed that, in any given year, the production level of all firms in a country is given and kept constant. For a given production level, profit maximization is equivalent with cost minimization. The cost-minimizing substitution processes is represented by a nested CES production function. At the highest level, there is the total production, which is a function of the components at the lower levels. At the lowest level, the arguments are the inputs in the production process.

Transportation modes for passenger trips comprise small car, large car, motorcycle, slow mode, bus, train and plane. Freight trips are using inland waterways, freight train, light duty vehicles or heavy duty vehicles. Furthermore four road types are distinguished and three freight categories (bulk, unitized and general cargo).

2.3 Transport prices

Transport users react on the generalized price of transport. Therefore, the price is considered as a sum of detailed cost components.

The resource price for transport services consists of the monetary producer price of all inputs necessary for these services (cars, fuels, maintenance, etc.). The resource costs are calculated in detail in the vehicle stock module or derived from the SCENES model (depending on the mode).

On top of the resource costs, the consumer usually pays taxes or receives a subsidy, both of which have been taken into account to calculate the market price. The distinction between user prices and costs is important for the welfare assessment module. In the demand module, transport users are assumed to make their decision on the basis of user prices.

Furthermore, time costs are added in the generalized price. Time costs depend on the ‘value of time’ of the considered travel mode and the travel speed. The speed is modelled explicitly and varies with transport demand, time period and road type. The speed values are also used in the calculation of emissions as discussed in chapter 3.

2.4 Simulations

The impact of several policy measures will affect the prices of transport in the demand module. The new prices can be affected by technological measures and new taxation and regulation policies as illustrated in chapter 4. Within the demand module, these new prices will change transport demand. Therefore, also congestion, travel speed and the time price of transport will be affected.

Within the simulation, a higher price for a certain mode will result in :

- Lower volumes (quantities) with that mode
- A possible increase in transport volumes with other modes (modal shift)

2.5 Welfare module

To evaluate policies in TREMOVE, a welfare assessment module has been made. Differences in welfare between the base case and the simulated policies are calculated.

Based on the utility functions for the private transport demand, the consumer surplus is quantified. The modelling of business decisions leads to the producer surplus. Additionally, welfare changes stemming from changes in tax revenues are incorporated by using the marginal cost of public funds. This approach accounts for the options of the government to beneficially use additional tax revenues from the transportation sector to lower taxes in other sectors. The external costs caused by emissions are calculated in detail as explained in the next section. The costs of these emissions are also incorporated in the welfare evaluation of policy measures.

3 VEHICLE STOCK AND EMISSIONS MODULES

3.1 Vehicle stock

The demand module produces aggregate transport quantities by mode. The *vehicle stock module* disaggregates these into detailed vehicle-kilometer figures by vehicle type, vehicle technology and vehicle age. This requires a detailed modeling and forecasting of the vehicle fleet structures for each mode.

Road and rail vehicle fleet evolution is modeled using a 'classic' scrap-and-sales approach. Each year scrap rates are applied to estimate the number of scrapped vehicles. Total vehicle sales by mode then can be derived by comparing remaining vehicle stock to the stock needed to fulfill transport demands. The following step then is to disaggregate total sales by mode into sales by vehicle type and technology.

For cars, motorcycles, light duty trucks and buses the disaggregation by vehicle type is performed using a discrete choice (multinomial) logit model. The logit models have been calibrated on (mainly) data from COWI (COWI, 2001) and EUROSTAT. The most extended logit model is used for car purchase modeling. The market shares of the 13 car types (including 6 hybrid types) in total sales are a function of following parameters:

- Engine displacement (< 1.4 litre, 1.4-2.0 litre, > 2.0 litre)
- Fuel type
- Acceleration performance
- Total (lifecycle) cost per vehicle-kilometer

The heavy duty trucks and trains disaggregation in the baseline is based upon exogenous inputs. The share of the four truck weight classes is derived from German and Italian road counts on different road types. The baseline sale shares for trains have been determined such that the 1995-2020 evolution of the train fleet is consistent with the long-term trends in the TRENDS dB (LAT, DTU, PSIAMTK, INFRAS, 2002). Both for trains and heavy duty trucks the exogenous assumptions can be changed in policy simulations.

For road vehicles, the vehicle types are further split up according to their technology. The technologies modeled in the baseline correspond with the EU emission standards. They are directly linked to the vintage of the vehicle.

TREMOVE does not include an explicit vessel scrap-and-sales model for inland waterway vessels. Instead, shares of different vessel types in total transport are exogenous and the model includes a module for the simulation of engine replacements/maintenance, retrofit of aftertreatment equipment and alternative fuel characteristics. The baseline fleet composition forecast for the 21 vessel types in TREMOVE, which are classified according to size and freight category, is based upon detailed Dutch statistics (CBS[2]) and predictions (AVV[3]) on domestic and international movements. Where needed extrapolations to other countries have been performed taking into account differences in inland waterway network characteristics between countries.

No vehicle fleet is modelled for aircrafts. The demand module disaggregates total air transport into 5 distance classes. Fuel consumption and emissions then are calculated using factors that implicitly account for differences in fleet composition for the 5 distance classes.

3.2 Fuel consumption and emissions

In the *fuel consumption and emissions module* fuel consumption and exhaust and evaporative emissions are calculated for all modes. Emission factors have been derived consistently from EU sources, thus might deviate from national estimates.

For road vehicles TREMOVE 2.3 emission factors are based upon the copert III emission calculation methodology (Ntziachristos, Samaras, 2000), to which following additions have been made :

- Disaggregation of COPERT diesel car fuel consumption factor into three factors according to engine displacement, based upon EU CO_2 monitoring data[4];
- Upward scaling of COPERT fuel consumption factors for 2002 cars, based upon EU test-cycle monitoring data and information on the difference between test-cycle and real-world fuel consumption (a.o. Van den Brink, Van Wee, 2001);
- Introduction of fuel efficiency improvement factors up to 2009. For cars these are based upon the voluntary agreements between EU and the car industry[5]. For other road vehicles predictions are taken from the Auto Oil II Programme;
- Update of moped and motorcycle emission factors based on recent information (Ntziachristos, Mamakos, Xanthopoulos, Iakovou, 2004);
- Emission factors for CNG buses (based on a.o. MEET : Hickman, 1999) and hybrid cars.

Fuel consumption and emission factors for diesel trains and aircrafts (by distance class) have been derived from the TRENDS dB. For electric trains, trams and metros only total energy consumption (kWh) is calculated in this module.

The fuel consumption and emission factors for inland waterway vessels have been calculated following the *first version* of the approach developed within the ARTEMIS project

[2] Dutch Central Bureau for Statistics
[3] Dutch Ministry of Transport, Public Works and Water Management.
[4] The monitoring decision can be found in the Official Journal of the European Communities L 2020, 10.8.2000, p.1
[5] Three agreements have been made. The full texts can be found in the Official Journal of the European Communities L 350, 28.12.1998 p. 58, L 100, 20.4.2000 p. 57 and L 100, 20.4.2000, p. 55.

(Georgakaki, 2003). Factors have been estimated using data on vessel characteristics for the 21 types included in TREMOVE and using estimates on waterway characteristics.

3.3 Lifecycle emissions

In TREMOVE, a restricted lifecycle assessment module is implemented, focusing on the fuel cycle only. To concentrate on fuel implies that not only operational emissions of vehicles, but also emissions due to production and distribution of the fuel (or electricity) are taken into account. Lifecycle emission factors for fossil fuels were derived by INFRAS from the Swiss ECOINVENT database (Ecoinvent Centre, 2004). Electricity production emission factors by country have been provided by the RAINS (IIASA, 2004) and PRIMES (Technical University of Athens) modellers, except for CH_4 and CO emission factors, which have been taken from MEET.

4 SIMULATIONS

At this stage, the TREMOVE 2.3 model has been used to evaluate following policy scenarios in the context of the EU Clean Air for Europe Programme :

- Reductions of car emissions beyond EURO IV standard levels. Scenario input is based on results and further analysis of a dedicated questionnaire sent by the EC to car industry representatives (Gense, Jackson, Samaras ,2005).
- Fuel efficiency improvements beyond the 2008/2009 voluntary agreements of the car industry. Scenarios are based upon preparatory research (ten Brink, Skinner, Fergusson, Haines, 2004).
- Heavy duty truck road charge schemes with charges covering external polluting costs
- Aftertreatment retrofit policies for most polluting heavy duty trucks
- Shore side electricity, aftertreatment technology and changes in fuel specifications for marine vessels. Scenario input data has been taken from de Jonge, Hugi and Cooper (2005).

In the remainder of 2005 and in 2006 further applications (and updates) of the TREMOVE model are scheduled within the Clean Air for Europe Programme and other programmes coordinated by EC DG Environment. The TREMOVE model will also be applied in the context of the mid-term review of the White Paper on the European Transport Policy for 2010. Furthermore the model has been and will further be applied in the context of the thematic network PREMTECH II[6] on improved road vehicle environmental technology.

5 CONCLUSIONS / OUTLOOK

With TREMOVE version 2.3, a transport model has become available that can be applied for environmental and economic analysis of different policies and measures to reduce atmospheric emissions from all modes of transport in the enlarged European Union. Both the baseline scenario and the results of policy simulations will be crucial inputs for the Clean Air for Europe (CAFE) programme for air quality, as well as for other environmental programmes at EU level.

Next to the further application of the current model for policy scenario analysis, further development of the model is envisaged. Future developments could include, amongst others :

[6] www.networkpremtech.org

- Extension to 27 countries (EU 25, Switzerland and Norway)
- Update for all modes to the emission calculation methodology developed in the EC DG Transport and Energy ARTEMIS project[7].
- Introduction of endogenous scrap rates in order to simulate policies focussed at increased renewal of the vehicle fleets.

It is worth to note that parallel to the "EU" TREMOVE 2.3 version, a TREMOVE version for Flanders has been developed by the University of Leuven (Proost, Meire, Knockaert, 2004) which is used for policy simulations for the Flemish government.

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