A META-MODEL FOR PASSENGER TRANSPORT IN EUROPE INTEGRATING EXISTING MODELS

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1. INTRODUCTION

In the recent White Paper on **European Transport Policy in 2010 'Time to Decide'**, the European Commission accepts that at the European level, as at local and national levels, the answer to traffic emissions, accidents and chronic delays cannot just be to build new infrastructure . A large number of pricing and regulatory policy measures is proposed to shift the balance between modes of transport, notably to reduce the growth of road and air traffic. Little is known about the effectiveness of these measures at the European scale or about the groups of society that will be affected most.

In Europe, many transport models are available for forecasting and policy simulation at the national and regional level. Furthermore, there are models at the European scale (either for the current 15 member states of the European Union or also covering countries that will join the Union in 2004). However, these are usually network-based models with considerable run times. Moreover, these large European models can only provide a limited number of segmentations of the population and a limited number of policy sensitivities, especially for short distance transport (more than 90% of all passenger travel in European countries is on trips below 30 km).

Therefore, there is a need for a model with the following characteristics:

- The model is fast and easy to use, so that it can be run for many policies and bundles of policies;
- The model distinguishes between many different segments of the population, so that differences in behaviour can be incorporated, as well as differences in how policy measures affect the population segments;
- The model focuses on representing transport over everyday distances, up to 160 kilometres, to complement the long-distance models developed for trans-European travel.

In the EXPEDITE project, carried out for the European Commission, such a model was developed and applied in forecasting and policy simulation. This model, called the 'EXPEDITE meta-model', integrates outcomes of five national passenger transport models and four national freight models and results of the European models. The meta-model is not intended to replace detailed network-

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based models, but to offer the possibility of a quick scan for the effects of a large number of policy measures. More detailed studies for promising measures and for the assessment of specific infrastructure projects should then be done using the network models. The paper will discuss the EXPEDITE meta-model for passenger transport. Freight transport is dealt with in another paper. The methodology will be discussed in section 2, results for the Reference Forecast for 2020 in section 3 and outcomes for a large number of policy measures in section 4). Section 5 will provide the conclusions.

2. THE METHODOLOGY

Meta-models

Meta-analysis (see for example Button el al., 1999; Nijkamp and Pepping, 1998) can be described as the statistical analysis of analyses. It is a research method for systematically describing and analysing existing findings on some quantitative relationship. These definitions also apply to the EXPEDITE meta-model, but this meta-model differs in two ways from the usual approach in meta-analysis. This is described below.

First, most meta-models are based on results from the literature, whereas the EXPEDITE meta-model integrates results from runs with 'underlying' models that have been carried out within the EXPEDITE project itself.

Second, most meta-analyses estimate a regression equation with parameter values or elasticities as dependent variable and attributes of the underlying studies (e.g. type of data used, sample size, year of observation, country, functional specification, estimation technique) and background variables (e.g. income) as explanatory variables. This meta-regression can later on be used to produce values or elasticities for other study areas, for which there is no information on the quantitative relationship ('value-transfer').

Crucial to this approach is the idea that the focus is on the *input* to the models and the *output* from the models; the complex process in between is then approximated in a simple way. For EXPEDITE, the input variables to the comprehensive travel demand models were categorised into context/traveller/network/land-use types, and the output was taken as a series of small matrices in which demand (in terms of numbers of trips or kilometres) were recorded, broken down by mode chosen and distance band to destination.

In our meta-model we derive 'levels' matrices of this type from the runs with the underlying models for the number of tours and kilometres in many segments, and 'switching matrices' (measures of how the matrices change) for various changes in policy variables (e.g. running cost of the car +10%, +25%). This gives a highly flexible relationship between travel demand and policy variables: simple interpolation would lead to piecewise linear functions and the specific method used (see below) leads to a piecewise non-linear (logistic) functions. In the EXPEDITE meta-model a large number of background variables (segmentation variables) is used, much larger than would be possible in a (dummy) regression model. The models used in EXPEDITE were selected to be methodologically

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comparable; all were based on the disaggregate, utility-maximising framework developed for the Dutch National Model in the 1980s. This reduces the need for correcting for different national study methodologies. The value-transfer method is also used in EXPEDITE, but with correction to zonal data.

The EXPEDITE meta-model

The EXPEDITE meta-model has been developed because there is a need to explore a large number of policy options and the impacts on many segments of the transport markets in the European context. The requirements for the EXPEDITE meta-model therefore are that it will run fast and extend the available national models to cover the whole (future) EU. In this extension, it is not of vital importance that models for all countries in the EU are included, but that the most relevant segments of the travelling population in the EU are included in the models used and expanded properly, and that the outcomes are calibrated to observed base-year distributions for transport in the respective zones. This methods builds on a similar methodology developed for estimating the demand impacts of car cost and car time changes in Europe (TRACE consortium, 1999, de Jong and Gunn, 2001)

The national models

Since the mid-1980's, a number of model systems have been developed in Europe, predicting future passenger transport at the national scale, using disaggregate, behavioural (based on the concept of random utility) model structures. Within the EXPEDITE consortium, five of these models are available. These are all the existing national models based on this methodology, as far as we are aware. National models based on different methodologies exist in for instance France, Germany, Hungary and Switzerland. Disaggregate, behavioural models have been developed for large regions within a country (e.g. Paris, Portland, Sydney) and have also been used for international corridors (e.g. Great Belt, Fehmarn Belt). The five models are (in the order in which they were originally developed):

- the Dutch National Model System (NMS or LMS);
- the Norwegian National Model (NTM-4);
- the Italian National Model (SISD);
- the Danish National Model;
- the Swedish National Model (SAMPERS).

Within the EXPEDITE Consortium, there are four national models for freight transport:

- the Swedish model (SAMGODS);
- the Norwegian model (NEMO);
- the Belgian model (WFTM);
- the Italian model (SISD).

The first three models are all built up around a so-called network model (this is a model that searches for the modes and routes that minimize transport cost on the network) while the latter is based on discrete choice theory (explaining

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choices between alternatives such as modes on the basis of utility maximization), as the national models for passenger transport. The Italian model contains components for both passenger and freight transport.

Integrating the outcomes of the underlying models for passenger transport

A large number of runs have been carried out (up to 80 runs per model) with each of the above national models and with the SCENES model for passenger and freight transport. In the explanation below, we describe the meta-model for passenger transport first, and then we explain where the freight model differs. To the maximum possible extent, the same runs were done with each of the models. For the base-year (1995), outcomes were generated in the form of 'levels matrices'. The levels matrices for tours give the number of tours per person per year by mode and distance band. A 'tour' is defined as a round trip, starting and ending at home. The levels matrices for passenger kilometres give the number of kilometres travelled per person per year, by mode and distance band.

The modes are:
- car-driver;
- car-passenger;
- train;
- bus/tram/metro;
- non-motorised.

Distance band is the other dimension of the levels matrices. As in the SCENES project, the following classification is used:
- 0-1.5 km;
- 1.6-3.1 km;
- 3.2-7.9 km;
- 8.0-15.9 km;
- 16-39.9 km;
- 40-79.9 km;
- 80-160 km.

There are different levels matrices (tours and kilometres) for five travel purposes and for many population segments. The travel purposes in the meta-model for passenger transport are:
- commuting;
- business;
- education;
- shopping;
- social, recreational and other.

The socio-economic and demographic population segmentation used in the meta-model is as follows:
- age distribution (<18, 18-<65, >=65);
- gender (male, female);
- occupation of persons (employed; not employed);

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- household size (1, 2, 3, 4+);
- household net income class (0-11300, 11300-18200, 18200-29500, 29500-38600, 38600 Euro per year);
- car ownership (person in a household without a car, person without a driving licence in a car-owning household, person with a licence in a household that has more driving licences than cars, person with a licence in a household that has at least as many cars as licences).

Besides levels matrices for 1995, the outcomes of the national model runs also consist of switching matrices: changes in tours or in passenger kilometres (same units as the levels matrices), as a result of a change in a policy-related model input variable. There are switching matrices for changes in the running cost of the car, travel times by car, and for cost, in-vehicle time, wait and transfer time and access/egress time of train and bus/tram/metro. Runs for different percentage changes (e.g. +10%, + 25%, +40%, -10%, -30%) were carried out, because the travel demand response to cost and time changes may very well not be linear.

For each segment, the levels and switching matrices in tours and kilometres from all five national models were averaged (unweighted) to get the "prototypical" matrices that are used in the meta-model to forecast for Europe.

The zoning system in the meta-model, as in the SCENES model, is the NUTS2 level. At this levels there are around 250 zones in the following study area:

- the EU15;
- Norway;
- Switzerland;
- Estonia;
- Latvia;
- Lithuania;
- Poland;
- Hungary;
- The Czech Republic;
- Slovakia;
- Slovenia.

For each zone, expansion factors were calculated depending on the importance of the population segments in the zone (many of these weights could be zero for a specific zone). By multiplying the tours and passenger kilometres from the prototypical matrices with the expansion factors, initial predictions for each of the zones are derived. These are forecasts for all travel demand generated in the zone, with one-way distances up to 160 km, by mode, distance class, travel purpose and population segment.

These initial forecasts are first corrected for differences in travel behaviour by area type and by road and rail network type, based on runs with the Dutch national model, the ANTONIN model for the Paris region and the SCENES model. These factors were not taken into account in the population

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segmentation, and therefore they are included in a subsequent step. The area types used in EXPEDITE are:

- metropolitan;
- other big cities;
- areas around the metropolitan areas;
- areas around the other big cities;
- medium density areas;
- low density areas;
- very low density areas.

For road and rail network type, there are five categories, depending on the density of the network. In this correction the use of public transport and non-motorised modes in metropolitan areas is increased, as is car use in the areas with lower density, at the expense of the other modes.

The model forecasts for 1995 that result after applying the area and network type correction factors have been validated against observed data on the use of each mode (if available by distance class), by country. This has resulted in a set of mode-specific, distance-class-specific and country-specific correction factors, which are also kept in forecasting. In this way, the meta-model accounts for 'residual' factors affecting travel demand, such as climate, hilliness and historical developments.

This meta-model for passenger transport also includes area-wide speed-flow curves to take account of the feedback effect of changes in congestion due to policies that change the amount of car use.

To obtain forecasts for all distance bands (the meta-model for passenger transport, based on the national models is for travel up 160 km), results from the SCENES model for travel above 160 km can be added to those of the meta-model. In an ongoing project, these outcomes of runs with SCENES for transport above 160 km are being built into the meta-model itself, in the same way as the national model results were included.

Calculating the impact of policy bundles

For a change in travel time or cost for which the national models have not been run (e.g. +20%), we could have derived the switching matrices by linear interpolation between the matrices of a 10% change and a 25% change. This would amount to assuming a piece-wise linear response to cost changes. However, in the meta-model we try to account for the non-linearities in the response to policy changes by going back to the original logit formulation, as used in the national models. This method is also used to calculate the impact of a policy bundle

A policy bundle is a combination of individual policy measures (e.g. increase in car cost and decrease in public transport cost). A limited number of policy bundles have been tested in the national models, and change matrices for these bundles are directly available for use in the meta-model. For all other policy

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bundles, the meta-model calculates the effects of the combination of policy measures from the results of individual policy measures, taking account of non-linear effects in the following way.

- sub-additivity: the combined effect is less than the sum of the separate effects
- super-additivity: the combined effect is more than the sum of the separate effects.

The method used can lead to both types of effects, depending on the location on the logit curve. As an example we study the combined effect of an increase in the car running cost of 25% and a decrease in the train and bus/tram/metro cost by 25%.

The switching matrices for both of these measures in isolation are available from the national model runs.

We now calculate probability matrices P_{mdp} (m indicates mode, d distance class and p population segment) by dividing all numbers in the levels matrix of a segment by the total in the bottom-right cell for:

- the levels matrices T_{mdp};
- the levels matrices with policy 1: $T_{mdp} + D^1_{mdp}$;
- the levels matrices with policy 2: $T_{mdp} + D^2_{mdp}$.

We further assume that:

- the non-linearities in the responses of the meta-model to policy measures are due to the logit nature of the underlying utility-based models;
- the average utility of the shortest distance band for the non-motorised modes will remain unchanged in any forecast scenario (for standardisation).

Now the average utilities (standardised by the utility of the shortest distance band for the non-motorised modes) can be calculated from the probability matrices as follows.

The general formula for the multinomial logit model is:

$$P_{mdp} = \frac{e^{U_{mdp}}}{\sum e^{U_{mdp}}}$$

Therefore:

$$\ln(P_{mdp}) = U_{mdp} - \ln(\sum e^{U_{mdp}})$$

and:

$$U_{mdp} = \ln(P_{mdp}) + \ln(\sum e^{U_{mdp}})$$

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The same can be done for the average utility of the shortest distance band for the non-motorised mode. The standardised utility for mode m, distance class d and primitive p then becomes:

Standardised $U_{mdp} = \ln(P_{mdp}) - \ln(P_{m=non\text{-}motorised,d=shortest,p})$

We calculate these average utility matrices for each of the three situations (base, base with policy 1, base with policy 2). Then to obtain the utility matrix of the policy bundle 1&2, we add the utility of the base, the utility change of policy 1 and the utility change of policy 2. After that we standardise the outcome by using the utility of the shortest distance band for non-motorised as the base. The results are transformed to probabilities (by exponentiation). The resulting probability matrices for the base with the policy bundle 1&2 are below.

Measure of welfare change

These underlying utility functions are also used to calculate the change in the logsum, that is caused by a policy measure or bundle.

Logsum = $\ln(\sum e^{U_{mdp}})$

This gives an approximation to the change in consumer surplus, and can be segmented by population segment to analyse how different population segments are affected by a policy.

3. RESULTS FOR THE 2020 REFERENCE SCENARIO

EXPEDITE has chosen the SCENES Reference Scenario for 2020 as the basis for its own Reference Scenario. For the intermediate years for which EXPEDITE needs to produce forecasts (2005, 2010, 2015), the SCENES project could only provide some aggregate information. For these years, EXPEDITE developed its own Reference Scenario, using information from SCENES and other European projects.

In SCENES the scenarios for 2020 consist of two elements (SCENES consortium, 2001). The first is called the ‘External’ scenario, to emphasise that this reference scenario includes autonomous changes, not policy changes. The second component is a transport scenario.

The EXPEDITE Reference Scenario includes for 2020:

- Population will grow in most EU15 countries, but will decline in some (e.g. Italy); Net migration is included in these forecasts. In the Central and Eastern European countries (CEEC), population will decline somewhat, except in Poland and the Slovak Republic; By the year 2020 the total EU15 population will have grown by almost 4% compared to 1995.

- The share of persons of 65 year and older will increase.

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- Employment will increase in most EU15 countries, but will declines in some (e.g. Greece); the same applies to the CEEC.

- Car ownership rates per 1000 persons will increase in all countries, especially in Eastern Europe; for the EU15 by about 25% in total, for some CEEC countries the motorisation rate will almost double. For the EU15, EXPEDITE adopted the ASTRA forecasts on the future number of passenger cars per 1000 persons. The SCENES consortium adopted growth rates from the PRIMES project, which give a total growth in motorisation in the EU15 of 50% in the period 1995-2020. It has been argued that these growth rates are too high (notably for the EU15), and we agree with this. Therefore we have chosen the –lower- ASTRA forecasts for the EU15. For the CEEC, the predictions on motorisation from the SCENES Internet Database are used.

- For most EU15 countries the gross domestic product (GDP) will in the period 1995-2020 grow by between 2 and 3 % per year; in the CEEC the growth rates are 4-5.5%. We also tested a scenario with a lower income growth.

- The transport networks will be expanded according to planned national and international infrastructure developments (especially the European Commission's 'TEN Implementation Report'); the networks are the same in all scenarios tested using the SCENES model, unless otherwise specified. In the runs with the EXPEDITE meta-models (which are not network models), we use the assumption that in the Reference Scenario in the EU15 the travel times will stay the same. Where travel demands grow over time, at some links the new demand may exceed the old capacity. Here our assumption implies that capacity will be expanded to keep the network performance at the 1995 level. For the CEEC we assume that the network performance of the road and rail networks will become better between 1995 and 2020, moving towards West-European standards.

In SCENES there are four different transport scenarios, both for passenger and freight transport. The only differences are in the future levels of transport cost by mode, the networks and travel times are the same in all scenarios tested. For both passenger and freight transport we used one of the four, the constant cost transport scenario: all modes have constant cost in real terms.

For the CEE countries (both for passenger and for freight transport) there is only one scenario in SCENES with decreasing car cost (following past Western European developments) and increasing public transport cost (less subsidies, privatisation).

In EXPEDITE we use the combination of the SCENES external scenario (but modified for motorisation in the EU15) with the SCENES constant cost scenarios for passengers and freight as the Reference Scenario for 2020. In the following, this scenario is called the 'EXPEDITE Reference Scenario'.

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Forecasts for passenger transport with one-way distances up to 160 km

The overall growth in the number of tours for the distances up to 160 km in the period 1995-2020 in the Reference Scenario is limited: +5%. Please note that travel for longer distances is predicted to grow much faster than this (see below). The mode that grows fastest is car driver (+22%).

As can be seen in Figure 1, for car passenger and train as main mode, there is also a growth in the number of short distance tours per year (+4% and +10% respectively). Bus/tram/metro tours and non-motorised (walking, cycling) tours will between 1995 and 2020 decrease by 12% and 5% respectively, according to the meta-model.

The total number of passenger kilometres (in trip distances up to 160 km) grows faster than the total number of tours: +10% versus +5% for the period 1995-2020. There is thus not only an increase in the number of tours, but also in the average tour distance. As for tours, car driver is the mode with the highest growth (24% more passenger kilometres in the study area). The growth rates for vehicle kilometres (=car driver kilometres) in the EU15 countries are between 10 and 40%, but can go as high up as 150% in the CEEC. These high growth rates of car use are mainly caused by the predicted increases in car ownership and income in the CEEC (to a lesser extent also by the increased performance of the road networks). Car passenger grows by 4% and train traveller kilometrage by 5%. The kilometrage travelled by bus/tram/metro and by the non-motorised modes will between 1995 and 2020 decline by 6% and 9% respectively.

Figure 1. Changes (in %) between 1995 and the 2020 Reference Scenario in the number of tours and the number of passenger-kilometres, by mode, in the study area

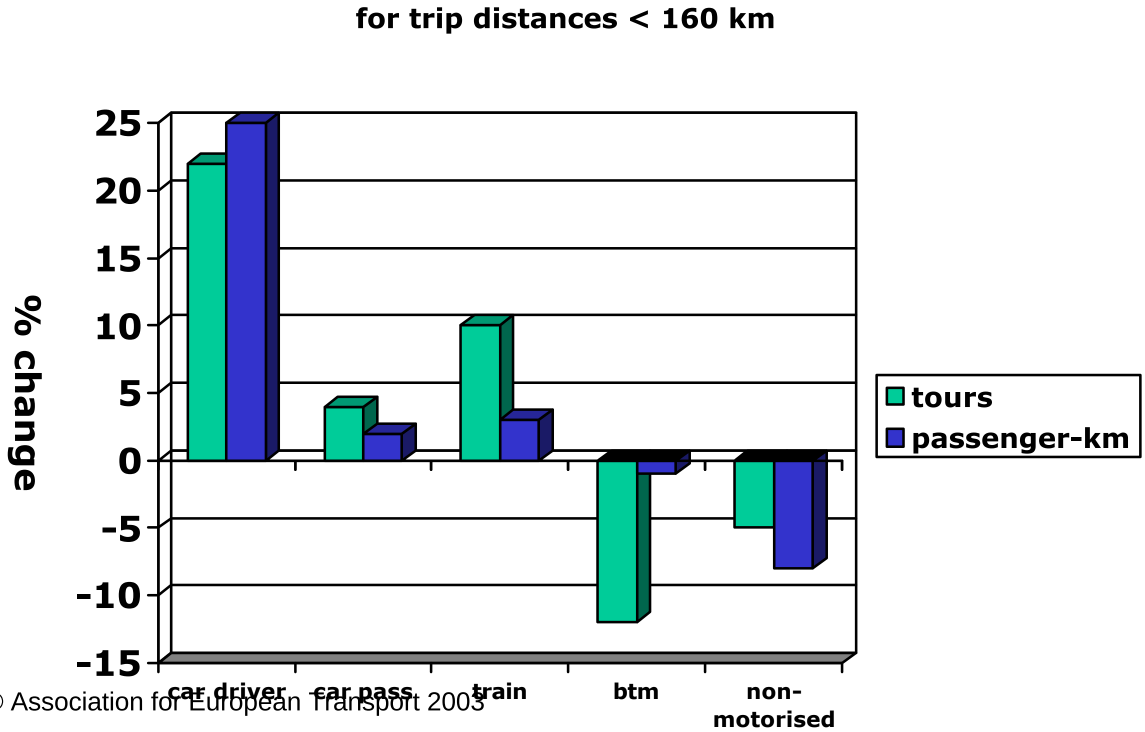

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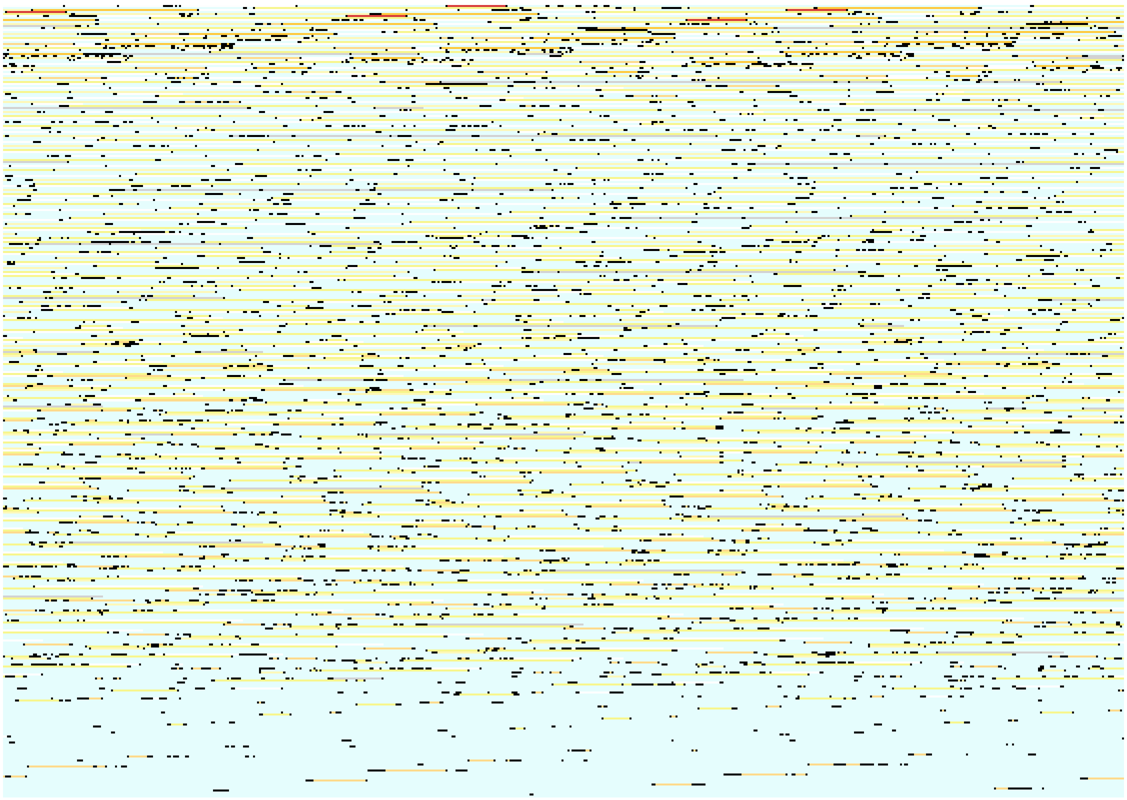
Figure 2. Percentage growth of car kilometres in trips up to 160 km in Europe 1995-2020 under the Reference Scenario



The variation between countries is considerable, as can be seen from Figure 2.

The increase in the number of kilometres as car driver is lowest in countries which already have the highest car ownership levels, such as Italy and Germany. It is highest in the CEEC, where the number of car-driver kilometres sometimes goes up by more than 100%.

Forecasts for passenger transport at all distance bands

To get forecasts for passenger transport for all distance bands, the meta-model results for trip distances up to 160 km need to be combined with results for the longer distances from the SCENES model. In Figure 3 forecasts from both models are combined.

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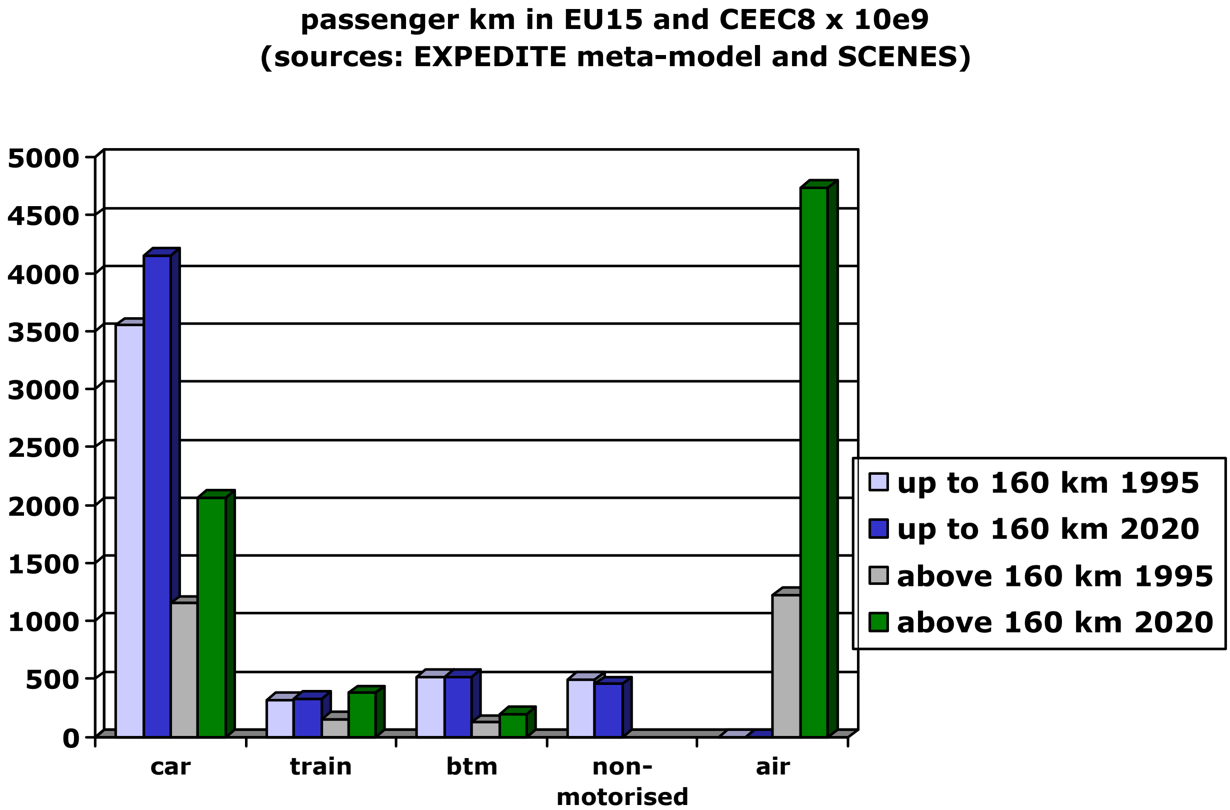
Figure 3. Passenger kilometrage in 1995 and the 2020 Reference Scenario, from SCENES for trips >160 km and from the meta-model for distances up to 160 km.



In the SCENES model, there is no distinction between car driver and car passenger; the 'car' mode includes both. For this mode we see both for work-related travel (commuting, business trips) and leisure trips a large increase (much larger than for the shorter distances) in passenger kilometrage between 1995 and 2020 for the longer distances. Also for long distance train transport, a big growth is predicted. For bus transport, there is no significant work-related long-distance travel, but there is for leisure travel. The latter is also predicted to grow considerably. But the largest growth by far (+5.6% per year) is for long distance air travel, both for leisure and work-related travel.

4. OUTCOMES OF POLICY SIMULATIONS

The policy measures simulated

The policy measures simulated with the meta-model were mainly taken from documents of the European Commission on the Common Transport Policy (CTP), including the recent 'Time to Decide' White Paper (European Commission, 2001). The selection of policy measures was also discussed with experts at a number of THINK-UP workshops and seminars. The focus in the simulations is on policies that might lead to a substitution in passenger transport from car to public transport and non-motorised modes and in freight transport from lorry to rail and sea and inland waterways-based modes. The policy

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measures and the way these were translated into input variables for the meta-model are given in Table 1. Some policies were also simulated with the SCENES model (not reported in this paper).

Table 1. Policy measures for passenger transport and translation of policy measures for simulation in EXPEDITE.

Policy	**Simulation (for 2020)**
Intermodality	Rail and BTM access/egress time –5%, -10% and Rail and BTM wait and transfer time –5%, -10%
Interconnectivity	Rail and BTM access/egress time –5%, -10% and Rail and BTM wait and transfer time –5%, -10%
Fuel price increase	Variable car cost +10%, +25%, +40%
Congestion and road pricing	Variable car cost +25%, +40% in area types 1, 2, 3 and 4
Parking policies	Car cost +25% in/from area type 1, 2, 3 and 4
Public transport pricing	Rail and BTM cost –10%, -30%
New urban public transport	BTM travel times in area types 1, 2, 3 and 4 –10%, -25%
Rail and fluvial interoperability	Rail times -5% and cost -5%
Market liberalization (rail)	Rail cost –5%, -10%
Cost internalisation	Car cost +25 +40%, and Bus cost +10%, +25%
Maximum speed limits	Car time +10%, +20%
Promoting housing densification	Shift of population from area types 5-7 to 1-4
Promoting employment densification	Shift of employed population from area types 5-7 to 1-4
Harmonisation of rules on speeding	Car time +5%, +10%

Note:
The EXPEDITE meta-models for passengers and freight can also be used for simulations of car ownership changes and simulations for qualitative ('soft') factors (e.g. reliability). In the latter case the change in the soft factor needs to be translated into a change in model inputs, such as time and cost by mode, but results from stated preference valuation studies for a number of qualitative factors are available to do this.

Outcomes of policy runs for passenger transport

The meta-model for passenger transport was used to simulate the amount of tours and passenger kilometres in 2020 for each of the policy measures in Table 1. The outcomes (in passenger-kilometres by mode and country) were used in an evaluation module. In Table 2 the outcomes for the policies are given in terms of the change in the sum of the internal and external cost of transport (in billions of Euros of 1995, or rather ECU's the predecessor of the Euro). The change in internal costs is measured here as the change in the logsum variable (compared to the 2020 Reference Scenario). A reduction means that the cost to society are reduced. The cost of investment, operation and maintenance of the infrastructure (except road damage) are not included in this table. For these effects of the policies, only a qualitative categorisation of policies could be given.

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Table 2. Main outcomes of the evaluation results of the policy measures for passenger transport (change w.r.t. the 2020 Reference Scenario in internal and external cost of transport in billions of Euros)

Policy	Total change	Internal cost change	External cost change			
			total	emissions	noise	accidents
Intermodality/ Interconnectivity, low	-42.47	-41.23	-1.24	-0.31	0.06	-1.00
Intermodality/ Interconnectivity, high	-101.45	-97.50	-3.94	-0.89	-0.17	-2.89
Rail and fluvial interoperability	-13.55	-13.14	-0.40	-0.12	0.10	-0.39
Cost internalisation, low	109.74	113.97	-4.24	-0.77	-0.95	-2.51
Fuel price increase 10%	38.28	41.27	-3.00	-0.55	-0.64	-1.81
Fuel price increase 25%	76.45	83.40	-6.94	-1.28	-1.48	-4.18
Fuel price increase 40%	111.35	121.60	-10.25	-1.89	-2.18	-6.18
Public transport pricing, low	-18.68	-17.37	-1.31	-0.30	-0.03	-0.98
Public transport pricing, high	-130.98	-126.42	-4.56	-1.05	-0.09	-3.42
Cost internalisation, high	173.86	179.84	-5.98	-1.07	-1.43	-3.49
Market liberalization (rail), low	-2.18	-2.12	-0.06	-0.03	0.07	-0.09
Market liberalization (rail), high	-4.60	-4.48	-0.12	-0.06	0.13	-0.20
New urban public transport, low	-12.67	-12.54	-0.13	-0.04	0.04	-0.13
New urban public transport, high	-38.79	-38.37	-0.42	-0.13	0.10	-0.39
Harmonisation of rules on speeding, low	65.36	72.62	-7.27	-1.34	-1.54	-4.38
Harmonisation of rules on speeding, high; Maximum speed limits, low	128.16	142.60	-14.44	-2.67	-3.06	-8.71
Maximum speed limits, high	217.21	243.25	-26.04	-4.82	-5.50	-15.71
Congestion and road pricing, or parking, low	28.78	30.52	-1.74	-0.34	-0.35	-1.04
Congestion and road pricing, high	42.19	44.75	-2.56	-0.50	-0.51	-1.54
Promoting housing densification	71.47	73.51	-2.05	-0.23	-0.44	-1.38
Promoting employment densification	39.53	40.72	-1.19	-0.13	-0.26	-0.80

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The best policies (on this aggregates cost measure) are the ones that make public transport cheaper or faster, such as public transport pricing, intermodality, interconnectivity, new urban public transport, interoperability and rail market liberalisation. According to the meta-model, these policies are not effective (the cross elasticities are very close to zero) in reducing car use. But such policies increase the user benefits (measured through the logsum variable) from transport, because the public transport users have lower fares or lower time costs, and at the same time these policies (slightly) decrease the external effects. All these policies lead to a reduction in the total internal and external cost of transport. Not taken into account here is that the revenues of the public transport operator might decrease when the fares are reduced.

Cost internalisation, congestion pricing, road pricing, parking policies, harmonisation of rules on speeding, maximum speed limits and fuel price increases all make car more expensive or slower. This leads to a substantial increase in the user cost (measured by the change in the logsum, and converted into money units), which is not outweighted by the reduction in the external cost. Therefore all these policies lead to an increase in the total internal and external cost of transport. These policies have the highest impact on car use of all policies simulated, with implied overall long run price elasticities of car kilometrage between –0.05 and –0.35 (taking into account the congestion feedback effect that reduces the sensitivity), depending on the travel purpose. The transport time elasticities are bigger: around –0.5. However, this is not so much due to modal shift but to destination switching: if car use becomes more expensive, than in the long run there will be a shift to the shorter distance classes, especially for shopping and 'social, recreational and other' travel. Not taken into account here is that the policy measures that increase the cost for transport users also increases the government revenues (there is a shift of taxes or charges from the transport users to the government).

Promoting housing densification or employment densification leads to a decrease in the external costs, but the increase in internal cost for the travellers dominates the picture. The reduction in car use is small (about –1%).

Most policies that make public transport policy more attractive require substantial investment, operation and maintenance cost. Most policies that make car less attractive have lower costs for these items. In Table 3 is an overall assessment of the policies.

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Table 3. Overall assessment of the policies for passenger transport

	Effectiveness (modal shift from road to other modes)	**Change in internal and external transport cost**	**Required investment and operation and maintenance cost**	**Ranking** (1 is best)
Intermodality	Low	Big reduction	Medium	7
Interconnectivity	Low	Big reduction	Medium	7
Congestion and road pricing	High	Medium increase	Low and government revenues	1
Parking policies	High	Medium increase	Low and government revenues	1
Rail and fluvial interoperability	Low	Small reduction	Medium	11
Market liberalisation (rail)	Low	Small reduction	Medium	11
Cost internalisation	High	Big increase	Low and government revenues	3
Maximum speed limits	High	Big increase	Low	5
Harmonisation of rules on speeding	High	Big increase	Low	5
Public transport pricing	Low	Big reduction	Medium	7
New urban public transport	Low	Medium reduction	Medium	10
Fuel price increase	High	Big increase	Low and government revenues	3
Housing and employment densification	Low	Big increase	Medium	13

A simple categorization has been introduced for readability. Given that effectiveness is the main objective, and that in money terms internal+external costs over a project lifetime usually dominate investment costs (except maybe for new infrastructure), a simple ranking (see last column of Table 3) can be implied by ordering policies first on the effectiveness criterion, then on internal+external costs, then on investment costs. The result is clear; policies penalizing motorists through parking or road charging are best. Cost internalisation, fuel price increases and lower maximum speeds are next; in the same league for effectiveness, but hitting the users harder. Policies to affect land use by densification, or making public transport more attractive, come bottom of the league; they are simply ineffective. All of the policies investigated have been characterised by levels of change to the system which have been judged to be realistic, and if other levels were posited (e.g. free public transport or zero interchange costs for intermodal transport) other results would emerge.

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5. SUMMARY AND CONCLUSIONS

The EXPEDITE meta-model for passenger and freight transport was developed in a project for the European Commission, Directorate-General for Energy and Transport (DGTREN). This is a fast and relatively simple model that integrates results from a number of national and international models.

This meta-model was used to generate forecasts for both passenger and freight transport for Europe for a number of future years up to 2020. Furthermore we reported on the policy runs carried out with those models and the evaluation of these policies. On the basis of these policy runs we can also reach conclusions on the effectiveness of policy measures and on (in)sensitive market segments.

- In the period 1995-2020,the meta-model predicts for the Reference Scenario that for distances up to 160 km the number of tours will grow by 5% (car driver +22%) and passenger kilometrage will increase by 10% (car driver +24%). There will be a much higher growth in Central and Eastern Europe.
- Long distance travel (above 160 kilometres) increases much faster (car, train and especially air) than short distance transport.
- Policies that increase the car cost (fuel price increase, congestion and road pricing, parking policies, infrastructure tariff, cost internalisation), will only have limited mode shift effects. There will be non-marginal reductions of car use, but most of the impact on car kilometrage is due to destination shift. The biggest reduction in car kilometrage is found for 'other' purposes (social and recreational traffic)
- Policies that lead to an increase in car time (speed limits, speed controls) are relatively effective means of reducing car use (again mainly through destination shift, not mode shift). This does not automatically imply that these are the most desirable polices for passenger transport; this also depends on the other impacts (see the evaluation outcomes below) of the measures than just the impacts on the transport volumes.
- If the travel time goes up by x% then this will have a bigger impact than an increase in the travel cost up by x%. This goes for changes in cost and time for all modes.
- Policies that decrease the public transport cost or time (intermodality, interconnectivity, public transport pricing, rail and fluvial interoperability, rail market liberalisation), will have a large impact on kilometrage for the mode itself (or these modes themselves), but a very limited impact on car use.
- None of the policies simulated was really effective in shifting passengers from car driver to the non-car modes. Policies that increase the car cost or time are most effective in reducing car kilometres (mainly through destination shifts, not much modal shift). To be effective in reducing car use, a policy bundle should include elements of a car cost and/or car time increase. At the same time, such a policy could be complemented by policies that make public transport more attractive (also for equity purposes and to provide accessibility to lower income groups).
- Segments of the passenger transport market that might be targeted because of their higher than average sensitivity for policy measures are long distance travel and social/recreational travel (and by definition for policies that make

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car less attractive: car owning-households). We did not find clear differences between the responsiveness of different income groups, area types and countries.

- Policies that make public transport cheaper or faster, such as public transport pricing, intermodality, interconnectivity, new urban public transport, interoperability and rail market liberalisation lead to a reduction in the total internal and external cost of transport. Such policies increase the user benefits from transport, because the public transport users have lower fares or lower time costs, and at the same time (slightly) decrease the external effects. Not taken into account here is that the revenues of the public transport operator might decrease when the fares are reduced. Most policies that make public transport more attractive require substantial investment and/or operation costs.
- Promoting housing densification or employment densification leads to a decrease in the external costs, but the increase in internal cost for the travellers dominates the picture.
- Cost internalisation, congestion pricing, road pricing, parking policies, harmonisation of rules on speeding, maximum speed limits and fuel price increases all make car more expensive or slower. This leads to a substantial increase in the user cost (the travellers having to pay more or incurring higher time cost), which is not outweighted by the reduction in the external cost for society as a whole. Therefore all these policies lead to an increase in the total internal and external cost of transport. Not taken into account here is that the policy measures that increase the cost for transport users also increases the government revenues (there is a shift of taxes or charges from the transport users to the government). Moreover, policies that make car less attractive usually have lower investment cost than policies that make public transport more attractive.

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