

Long-term outlook of energy use and CO₂ emissions from transport in Central and Eastern Europe

Theodoros Zachariadis*, Nikos Kouvaritakis

National Technical University of Athens, 9 Iroon Polytechniou Str., 15773 Zografou, Athens, Greece

Abstract

A forecast of transport activity, energy consumption and carbon dioxide emissions from transportation, carried out under ‘business as usual’ economic assumptions, is presented for the 10 countries of Central and Eastern Europe that have acquired the status of ‘accession countries’ to the European Union. Energy demand is projected under considerations of the dynamic evolution of transport modes and their use, the evolution of automotive fuel prices, which are assumed to gradually converge with Western European price levels within the current decade, and assumptions on efficiency improvements in all transport modes according to current technological trends and European regulations. The results, showing transportation energy demand to double and CO₂ emissions to be 70% higher in 2030 compared to 2000, are compared with other published forecasts and discussed with a view to potential future energy and environmental impacts in these countries, outlining major policy implications.

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1. Introduction

Transport is the fastest growing energy consuming sector worldwide. Specifically in Central and Eastern Europe (CEE), the transport sector had been characterised by limited private mobility, extensive use of subsidised public transportation, obsolete infrastructure, inefficient use of freight capacity and bad fuel quality. The economic reforms of the 1990s have given rise to a strong increase in private car ownership (although the utilisation of cars has not followed the same trend) and a decline in public transport. At the same time freight traffic experienced a significant restructuring process, with trucks overtaking rail in importance—although use of both modes decreased considerably in the first half of the decade due to overall negative economic growth.

Several national and international studies have attempted to analyse the current situation in the transport sector of CEE countries within the context of a country’s whole energy system, and identify priorities for efficiency improvements and advances in

environmental protection (see, e.g. [US DOE/EIA, 2002](#); [Martinot et al., 1995](#); [Meyers et al., 1994](#); [Midttun and Chander, 1998](#)). Moreover, the national communications to the United Nations Framework Convention on Climate Change (UNFCCC) provide a useful framework of analyses and medium-term forecasts¹ for these countries.

This paper deals with the 10 CEE countries that have attained the status of ‘accession country’ to the European Union (EU): Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the Slovak Republic and Slovenia. For each one of these countries, a forecast of passenger and freight transport activity is performed up to the year 2030 and the related energy consumption and carbon dioxide (CO₂) emissions are calculated, on the basis of projections of macroeconomic data and international energy prices, and taking into account that all countries will tend to converge with EU member states as far as market policies and environmental standards are concerned. Despite the long-term and international character of this analysis, a quite detailed approach is followed by constructing an analytical transport module within an

*Corresponding author. Tel.: +30-10-7723560; fax: +30-10-7723630.

E-mail address: zach@central.ntua.gr (T. Zachariadis).

¹All related documents can be found on the World Wide Web at the following address: <http://www.unfccc.de/resource/natcom/index.html>.

overall energy systems model, which allows for an explicit consideration of the particularities of energy markets and transport infrastructure in each country. In this way, separate analyses and detailed evaluation of policy options can be carried out for any one of these countries and for all of them as a group.

2. The model

The model that was developed and applied involves detailed analysis of important aspects for which data can be found for these countries, notably concerning road transport (both passenger and freight), while other transport modes (air, rail and water) are modelled in a more aggregate fashion. The basic model equations for passenger cars are presented in Appendix A, whereas the full algebraic specification of the model is provided elsewhere (Kouvaritakis and Zachariadis, 2001).

2.1. Road passenger transport

Eqs. (A.3)–(A.12) of the appendix outline the method for forecasting transport activity. For reasons of simplicity, gross domestic product (GDP) was selected to be the main income-related economic driver in the model. Both new registrations (Eqs. (A.6) and (A.10)) and scrapping rates (Eq. (A.8)) depend on national particularities and GDP evolution; generally, the higher the GDP growth rate the higher the scrapping rate because of accelerated replacement of old cars that are abundant in these countries. The equation for new registrations includes also a term that takes into account historical vehicle data of each country, contains a time-trend parameter (k_1 in Eq. (A.6)) and considers possible saturation effects by employing a S-shaped Gompertz function. This second term is of great importance for predicting the vehicle stock in CEE countries, which have experienced high car ownership growth at a time of economic crisis. This trend, which can be explained by market liberalisation that has given rise to a boom in consumer expenditure, albeit only for a fraction of the households, reveals that GDP alone cannot offer a satisfactory explanation of the car market evolution during the 1990s in these countries. The time-trend parameter mentioned above is similar to that applied by Button et al. (1993), whereas other approaches (e.g. the partial adjustment mechanism of Dargay and Gately, 1999) lead to a similar fine-tuning of the model to real-world data. As regards the Gompertz function, saturation levels of car ownership were estimated in each country; these were found to be in the order of 0.6–0.7 cars per capita, in line with saturation levels estimated in the related literature (Dargay and Gately, 1997, 1999).

The average distance driven by each car (Eq. (A.11)) is also determined recursively by using a GDP elasticity,

short-term price elasticities and a term that accounts for the fact that the growth rate of average annual mileage slows down when high car ownership levels have been reached. GDP and price elasticities fall generally within the range reported in major previous studies (Goodwin, 1992; IEA, 2000; Wohlgenuth, 1997) and may vary with time. Specific fuel consumption (Eq. (A.13)), expressed in grams (or litres) of fuel consumed per kilometre driven, is a function of long-term price elasticities and exogenous assumptions concerning regulatory measures and autonomous efficiency improvements.

Finally, the share of each technology in new registrations is computed with the aid of Eq. (A.18), which is effectively a cost-minimising function that also considers national particularities through parameter wsh . The various cost items (annualised capital cost, maintenance and fuel costs) are calculated for a distinct number of car mileage classes, in order to better represent real-world operating costs according to the use of each car: owners of vehicles that are driven intensively (e.g. more than 50 000 km per year) may opt for a different technology with potentially higher capital cost but lower fuel cost than owners of cars travelling only a few thousand kilometres annually. In order to realise this quasi-optimisation approach, discrete classes of car mileage are used; the number of these classes is quite high (greater than 10), thereby approaching a real-world distribution of mileage among cars. Technology shares are calculated in each individual class and total technology shares are then derived as the weighted sum of shares of all classes. This approach allows for a more appropriate economic description of the transport sector compared to other models of this type, which only take into account the costs of an average vehicle driven under average conditions.

Fig. 1 illustrates the effect of applying Eqs. (A.16)–(A.18) on the model's technology selection process. Let it be assumed that there are three competing technologies T_1 , T_2 and T_3 , with annualised capital costs CC_1 , CC_2 , CC_3 where $CC_1 < CC_2 < CC_3$ and total variable costs (operation, maintenance and fuel costs) VC_1 , VC_2 , VC_3 where $VC_1 > VC_2 > VC_3$. Cars are distributed into 11 classes according to their use (expressed in kilometers driven annually per car). The distribution of vehicles in the 11 classes is indicated with the thick solid line in the lower part of the graph. The upper part of the graph depicts the evolution of total cost for each technology and class: it is apparent that, for vehicles driven a few thousand kilometres per year, the technology with the lowest capital cost T_1 will be cheaper, whereas owners of vehicles driven more intensively may opt for T_3 , which has the lowest variable cost. If one does not consider the distribution of car mileage and uses the unit consumption of the average vehicle, then technology T_2 might be chosen by the model, thus misleading the analysis.

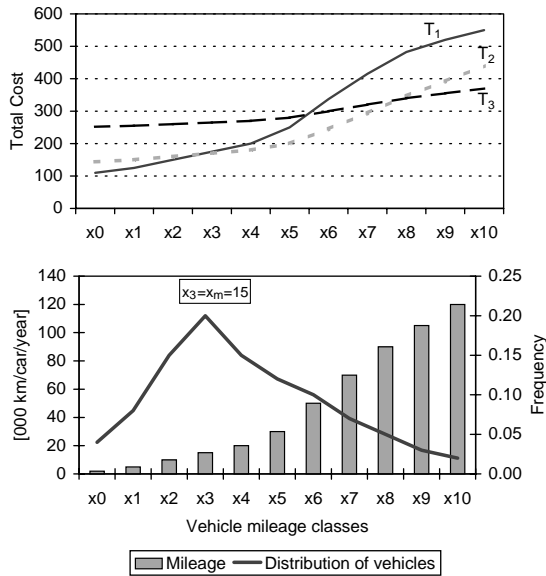


Fig. 1. Example of the approach employed by the model to compute technology shares.

2.2. Road freight transport

The main freight transport activity parameter is road tonne kilometres (tkm), whose forecast is a function of the evolution of GDP and fuel prices. Similarly to car transport, GDP is used here as the main economic driver instead of more appropriate parameters such as value added or production indices of industrial sectors, because of the lack of consistent time series across CEE countries. Income and price elasticities have been estimated or selected on the basis of national data and in line with those reported in the literature (see the corresponding references in Section 2.1). As regards technology substitution, the same approach as with cars was followed, i.e. cost minimisation with consideration of several classes of trucks, identifying different utilisation rates (expressed here as annual tonne kilometres driven).

2.3. Other transport modes

Passenger and freight transport activity for trains and waterways is forecast as a function of GDP and energy prices, while at the same time depending on the growth rates of road transport activity (e.g. a higher growth rate in road transport has a negative impact on the growth of rail); this feature provides an endogenous link between different transport modes. As far as air transport is concerned, only passenger transport is considered because of very limited information on airfreight transport (both in regular passenger flights and dedicated cargo flights), and activity data are adjusted in order to account for cargo flights as well. Fuel efficiency

and technology shares are calculated in a similar, though simpler, way with that of road modes.

3. Basic assumptions

Key exogenous variables in such a model are GDP, population and fuel prices. GDP forecasts for the short term (2001–2003) were taken from the official economic outlook of EU candidate countries published every 6 months by the [European Commission \(2001a\)](#); these were generally in line with the May 2001 World Economic Outlook of the International Monetary Fund ([IMF, 2001a](#)). For the period 2000–2010 the (usually high) GDP growth rates of 2001–2002 were assumed to persist, at least until the middle of this decade, fall slightly in the next decade 2010–2020 and finally reach more modest growth levels in the period 2020–2030. [Table 1](#) presents these growth rates for each country. As for population, the demographic projections of the United Nations were used; according to these, a significant decrease in population is expected in most CEE countries, with most notable examples those of Estonia (1.1 million in 2030 compared to 1.6 million in 1990) and Latvia (2.7 million in 1990–1.9 million in 2030).

With regard to fuel prices, which were pretty low before 1990 in most CEE countries because of very low taxation (and sometimes also because of subsidies), there is a general tendency towards tax harmonisation with the EU. However, one can still observe differences between countries with respect to their rate of convergence to EU standards. In Hungary, for example, price levels of transportation fuels were comparable to those of EU countries already in 1990, whereas in most other countries prices are still low, with the Baltic countries (Estonia, Latvia, Lithuania) being the most remarkable example. It was therefore assumed that price reforms will take place to a large extent within the current decade, in view of the fact that at least 8 countries (i.e. all except Bulgaria and Romania) are expected to join the EU by 2005. All countries will have their fuel prices converge to EU levels depending on their current levels: for most countries this will have been achieved largely by 2010, while for others this reform will have been completed somewhat later in order to avoid shocks within a short period of time.

After 2010–2015, it is assumed that transportation fuel prices will mainly be affected by the trend of the international price of oil. For the forecast of crude oil price, available energy reviews were taken into account ([Capros et al., 1999](#); [IEA, 2000](#); [US DOE/EIA, 2001a](#)). According to the forecast used in this study, it is assumed that the real price of crude oil will decrease from its 2000 levels of 28 US\$ per barrel to about 20 US\$ in 2005, will remain at about that level until 2010

Table 1
Gross domestic product of CEE countries and its projected evolution up to 2030

Country	GDP in year 2000 (millions of Euro ₂₀₀₀)	Real annual GDP growth rates (%)		
		2000–2010	2010–2020	2020–2030
Bulgaria	17 303	5.2	4.7	3.6
Czech Rep.	27 721	4.1	3.7	3.5
Estonia	5956	4.7	3.5	3.0
Hungary	39 648	4.6	4.0	3.0
Latvia	7714	4.5	4.0	3.8
Lithuania	9004	4.1	5.0	4.0
Poland	86 582	4.8	5.0	3.5
Romania	31 669	2.9	4.3	4.0
Slovak Rep.	16 788	3.7	3.5	3.3
Slovenia	28 902	4.3	3.0	2.5
Total	271 287	4.4	4.3	3.4

Table 1
Gross domestic product of CEE countries and its projected evolution up to 2030

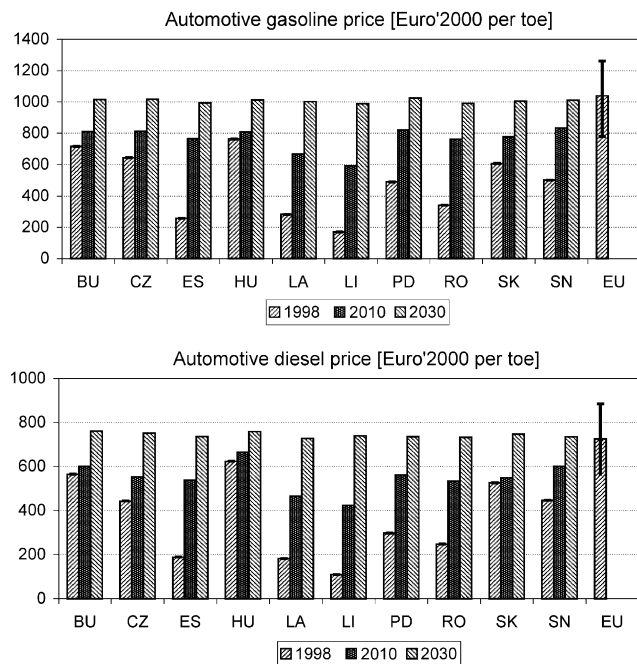


Fig. 2. Gasoline and diesel prices in CEE countries (in constant Euros per tonne of oil equivalent) in 1998 and assumed evolution in 2010 and 2030; the range of EU prices in 1998 is also indicated. Country acronyms: BU-Bulgaria; CZ-Czech Republic; ES-Estonia; HU-Hungary; LA-Latvia; LI-Lithuania; PD-Poland; RO-Romania; SK-Slovak Republic; SN-Slovenia.

and will then increase to 26 US\$ in 2020 and 28 US\$ in 2030 (all prices in 2000 US\$). Fig. 2 illustrates consumer prices of gasoline and transportation diesel in 1998 (year of latest consistent available data for all CEE countries) and the forecasts for 2010 and 2030, along with the corresponding average EU price in 1998. 1998 retail price data for CEE countries were taken from the International Energy Agency (IEA, 2001a), the EN-ERDATA (2001) database and information of the

German Agency for Technical Cooperation—GTZ (Metschies, 1999).

Fuel efficiency of existing and new transport technologies is a crucial issue, especially because CEE countries until recently were characterised by ageing vehicle fleets with poor fuel economy and a large share of imported second-hand vehicles in new registrations. This started to change recently in countries like Hungary, Romania and Slovenia, where newly registered passenger cars are obligatorily late-model vehicles that comply with emissions requirements similar to those in the EU, whereas legislation is still more lenient in other countries, e.g. in Poland (Meretei, 2001). Data on fuel economy of the existing fleets in each country were mainly derived by combining IEA energy statistics (IEA, 2001b, c) and transport statistics (European Commission, 2001b; European Conference of Ministers of Transport, 2001; Samaras et al., 1999).

As for the future development, in the case of passenger cars the agreements of the European Commission with the automobile manufacturer associations of Europe, Japan and Korea (ACEA,² JAMA and KAMA respectively—see European Commission, 2000) were assumed to take effect in CEE countries too. For the period after 2012, which is the time horizon of these agreements, only marginal efficiency improvements were considered for new vehicles. Here again, a differentiation among countries had to be made because of (i) their different rate of convergence to EU legislation and (ii) the diverse national regulations concerning indigenous production of new vehicles as well as imports of used vehicles, which directly affects the assumptions on average fuel economy of new registrations. The forecast is further complicated by the changing patterns in car purchases and use in these countries: while a part of the

²United States automobile manufacturers belong to ACEA too and have signed this commitment.

population can afford to buy more powerful, safe and comfortable cars, it seems that the majority opt for new cars of small engine size, which are cheaper and consume less fuel. In countries where imports of old used cars are allowed, cheaper solutions will be among older and less efficient vehicles. All these considerations lead to a contrasting picture with regard to fuel economy of new cars, and hence it was decided to follow different hypotheses for each country, depending on current national regulations and keeping in mind the overall trend of convergence with EU standards. Future shares of gasoline and diesel cars per country are computed with the aid of the cost minimisation function (Eqs. (A.16)–(A.18)) mentioned before.

As regards fuel efficiency of trucks, although there is no explicit regulation or voluntary commitment as in the case of cars, it was assumed that efficiency improvements of the order of 10–15% for new vehicles will have been achieved within the decade 2000–2010, with a much smaller improvement afterwards. Efficiency improvements up to 2020 have also been assumed for both diesel and electric trains as well as for aircraft, in line with findings of the relevant literature (Bek et al., 1999; Fitzgerald et al., 1999). It should be noted here that all these assumptions concern ‘autonomous’ enhancement in energy efficiency of transport modes, in addition to potential further improvements calculated endogenously as a long-term result of rising fuel prices.

Concerning the use of biofuels in transportation (i.e. organic substances that originate from biomass and are either blended with gasoline or diesel or are used as pure substitutes of conventional fuels), it was assumed that all countries will follow EU rules sooner or later. In line with the European Commission’s White Paper on Transport (European Commission, 2001c), in November 2001 a Directive was proposed implementing a compulsory biofuel consumption in EU countries, starting from 2% of total gasoline and diesel consumption of motor vehicles in 2005, reaching almost 6% in 2010 and extending beyond that in the following decades (European Commission, 2001d). Most of this share is expected to be achieved through blends of ethanol (derived mainly from cellulosic biomass) with conventional gasoline and diesel. For the purpose of this forecast, the above targets, which currently constitute only a proposal, were considered quite optimistic; still, in view of the countries’ convergence with the EU, the biofuel shares assumed here were 1%, 2% and 5% in years 2010, 2020 and 2030, respectively (expressed as a fraction of total transportation gasoline and diesel). The impact of blending gasoline and diesel with biofuels on final consumer prices was assumed to be negligible, since higher fuel production costs will probably be offset by tax exemptions scheduled to be implemented on these fuel blends.

In order to arrive at forecasts of passenger kilometres (pkm) of cars, an average car occupancy rate (i.e. passengers per vehicle) has to be applied. For this, available data from national and international sources (European Commission, 2001b; International Road Federation, 2000; Samaras et al., 1999) have been evaluated and extrapolated for the future in a way that trends in car ownership, demography (i.e. household size, which largely affects car occupancy) and convergence with West European standards are accounted for. It has to be noted that, according to the method employed by the model as described in the previous section, passenger kilometre forecasts are not necessary for calculating energy demand and emissions of cars; still, they provide useful insight for intermodal comparisons and transport efficiency assessment as will be outlined in the next section.

4. Results and discussion

Fig. 3 shows the forecasts of total passenger and freight transport activity (expressed in passenger kilometres and tonne kilometres respectively) according to the assumptions mentioned above. After the recession

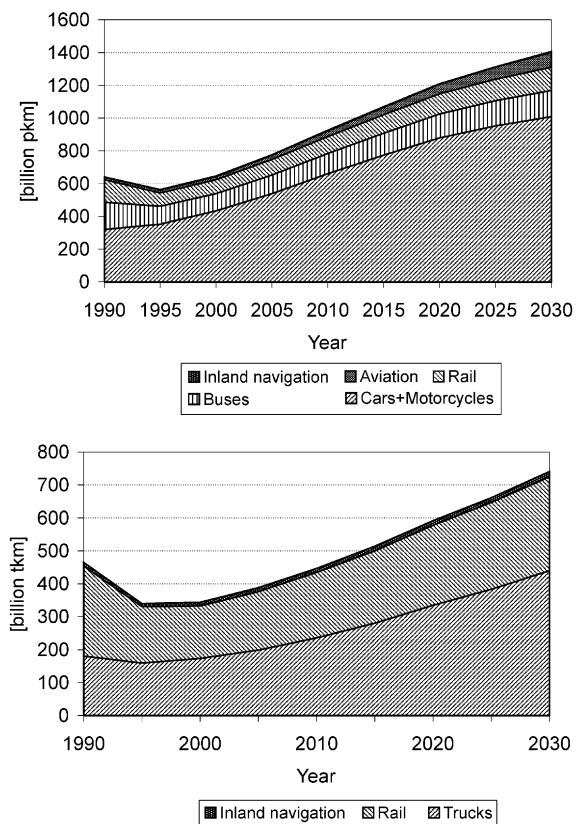


Fig. 3. Forecast of passenger and freight transport activity in the 10 CEE countries up to 2030. International ship transport is not included.

that almost all CEE countries experienced in the beginning of the 1990s, transport activity has recovered so that passenger transport has essentially reached the 1990 levels in 2000, while it may take another 5 years for freight transport to come back to the pre-recession levels. Both passenger and freight transport performance are expected to be about 2.5 times higher in 2030 compared to today. It is also evident that road passenger transport (particularly private cars) is expected to gain share over rail and water transport, particularly up to 2020, when the first signs of saturation may emerge, whereas air transport is foreseen to experience strong and continuous increase. As regards freight transport—where aviation is not included for the reasons mentioned previously—trucks will dominate in contrast to the pre-1990 situation, where trains were the leading mode for carriage of goods.

Since four out of the 10 countries studied here (Estonia, Latvia, Lithuania and Slovenia) did not exist as independent states in 1990, while two others (Czech and Slovak Republics) were united, it is not possible to compare future trends with those of past decades. This comparison is therefore demonstrated in Figs. 4 and 5 for those two countries among the remaining ones with the highest and lowest per capita GDP in 1998: Hungary and Romania respectively. The overall shift from low-speed to high-speed modes over the years is apparent

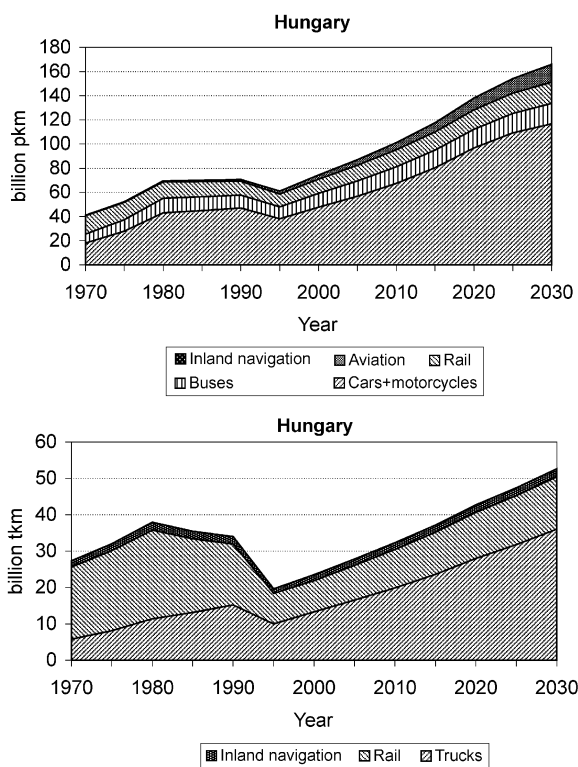


Fig. 4. Passenger and freight transport activity from 1970 to 2030 in Hungary.

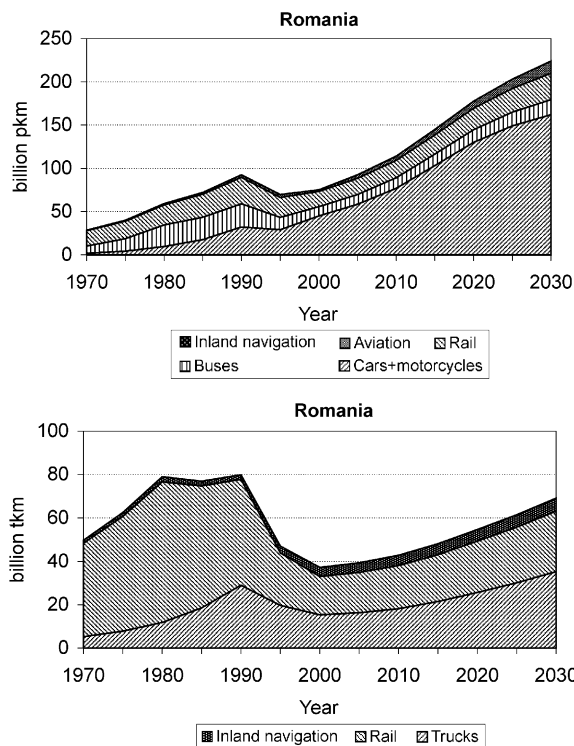


Fig. 5. Passenger and freight transport activity from 1970 to 2030 in Romania.

Table 2
Average annual distance travelled by passenger cars in CEE countries: data or best possible estimates for 1990 and 1998 and forecasts up to 2030

(km/car)	1990	1998	2010	2020	2030
Bulgaria	7800	6100	9065	12 556	15 810
Czech Rep.	8160	8500	10 571	13 315	16 803
Estonia	8450	6500	8327	10 282	12 444
Hungary	10 000	8500	11 821	14 953	18 121
Latvia	8500	6500	8529	10 475	13 173
Lithuania	8500	6500	8257	10 388	12 908
Poland	9000	9500	10 661	12 741	14 579
Romania	8500	7300	7876	10 451	13 251
Slovak Rep.	8300	8500	10 382	12 701	15 761
Slovenia	10 000	13 000	14 831	16 797	18 859

Table 2
Average annual distance travelled by passenger cars in CEE countries:

and consistent with global trends analysed in detail by Schafer and Victor (2000). In fact, passenger rail is projected to retain a substantial fraction of total passenger kilometres even in 2030 because it has been assumed within the model that high-speed trains will gradually penetrate in all countries.

Focusing further on motor vehicles, Table 2 displays average annual car mileage data and forecasts, and Fig. 6 provides car ownership vs. GDP per capita plots of the 10 CEE countries in 1990 and 2030, also showing corresponding data points of some EU countries as of 1990. One can remark that the steep growth of car ownership with GDP currently observed is expected to

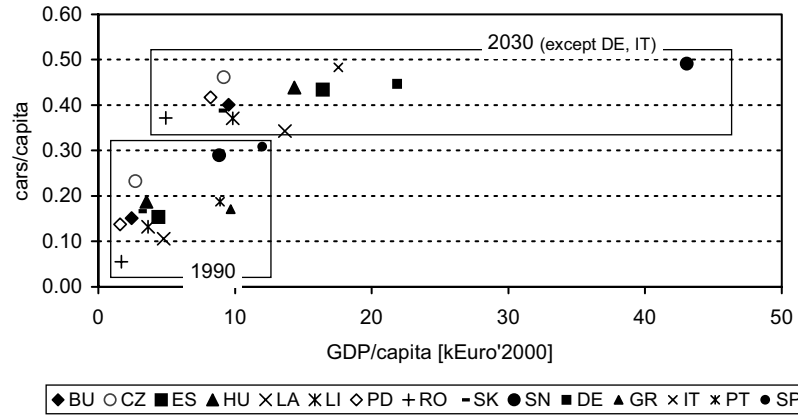


Fig. 6. Passenger car ownership plotted over GDP per capita for 1990 and 2030 for CEE countries; the corresponding figures for some EU countries in 1990 are also displayed. For CEE country acronyms, see Fig. 2. EU country acronyms: DE-Germany; GR-Greece; IT-Italy; PT-Portugal; SP-Spain.

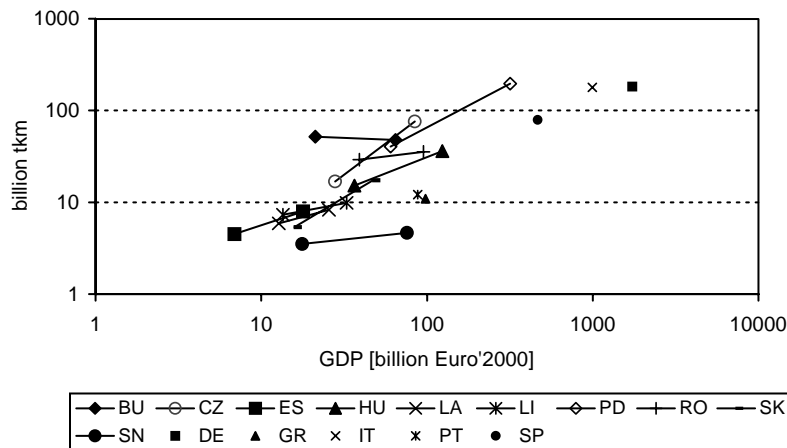


Fig. 7. Truck transport activity (expressed in tonne kilometres) plotted over total GDP for 1990 and 2030 for CEE countries; the corresponding figures for some EU countries in 1990 are also displayed. For country acronyms see Figs. 2 and 6.

slow down considerably in 2030, when all countries are assumed to have achieved per capita GDP levels comparable with today's Western European levels; this is primarily due to saturation effects. As regards car mileage, Table 2 shows that in the 1990s it decreased drastically in many countries, primarily as a consequence of economic crisis and secondarily because of the considerable increase in the stock of vehicles. Mileage is expected to reach Western European levels in about 2020. Furthermore, Fig. 7 presents data and forecasts on transport activity of trucks vs. total GDP. It is worth noting here that the virtually linear relationship between truck tonne kilometres and GDP persists for a long period, but after a point the implied GDP elasticity tends to decrease below unity.

With regard to energy use, Table 3 shows projections of energy consumption in each country and Fig. 8 displays shares of each fuel and transport mode. Evidently, the pattern follows that of transport activity,

whereas the relative contribution of those categories for which higher efficiency improvements are foreseen (notably passenger cars) slightly decreases over the years. A noteworthy development is also the rise of the use of biofuels from 2010 onwards.

Table 4 contains transport efficiency indicators and demonstrates the significant efficiency improvements foreseen for cars and trucks particularly up to 2020 (by which time virtually all old vehicles will have been replaced by the 'improved' vehicles to be gradually phased in during the decade 2000–2010). After 2020, marginal improvements in fuel economy of passenger cars, coupled with still declining car occupancy rates, may result in stagnating—or even somewhat deteriorating—car efficiency (expressed per passenger kilometre). This trend is comparable to that observed in the last decade in North America and Western Europe, where increasing safety and comfort standards in passenger cars, combined with purchases of bigger vehicles on

Table 3

Forecasts of energy consumption from transport in CEE countries; figures are expressed in thousand tonnes of oil equivalent (ktoe) per year

(ktoe/year)	1990	2000	2010	2020	2030	Average annual change (%)			
						1990–2000	2000–2010	2010–2020	2020–2030
Bulgaria	2633	1995	2529	3437	4139	–2.7	2.4	3.1	1.9
Czech Rep.	2588	3965	4947	5748	6965	4.4	2.2	1.5	1.9
Estonia	605	598	705	769	872	–0.1	1.6	0.9	1.3
Hungary	3153	3288	4207	5589	7121	0.4	2.5	2.9	2.5
Latvia	930	762	1001	1177	1356	–2.0	2.8	1.6	1.4
Lithuania	1778	1271	1444	1752	2178	–3.3	1.3	1.9	2.2
Poland	7578	10 288	13 472	16 500	19 501	3.1	2.7	2.0	1.7
Romania	4165	4069	5406	7161	8902	–0.2	2.9	2.9	2.2
Slovak Rep.	1080	1406	1958	2535	3285	2.7	3.4	2.6	2.6
Slovenia	947	1810	2216	2431	2677	6.7	2.0	0.9	1.0
Total	25 457	29 453	37 884	47 098	56 996	1.5	2.5	2.2	1.9

Table 3

Table 4

Transport efficiency indicators in the 10 CEE countries

	2000	2010	2020	2030	Average annual change (%)		
					2000–2010	2010–2020	2020–2030
Passenger transport (toe/Mpkm)	30.7	27.8	25.9	26.5	–1.0	–0.7	0.2
Road transport	33.0	29.2	26.8	27.3	–1.2	–0.8	0.2
Public road transport	21.7	20.9	19.9	19.3	–0.4	–0.5	–0.3
Cars and motorcycles	35.7	30.7	27.9	28.6	–1.5	–0.9	0.2
Train transport	10.2	9.3	8.4	7.9	–0.9	–1.0	–0.6
Aviation	54.5	50.4	46.0	43.9	–0.8	–0.9	–0.5
Inland navigation	59.0	56.5	54.3	52.9	–0.4	–0.4	–0.3
Freight transport (toe/Mtkm)	28.1	27.2	26.7	26.7	–0.3	–0.2	0.0
Trucks	49.8	46.8	43.5	41.9	–0.6	–0.7	–0.4
Train transport	5.4	4.9	4.5	4.2	–1.0	–0.9	–0.6
Inland navigation	11.9	11.4	11.2	11.2	–0.4	–0.2	0.0

Table 4

Transport efficiency indicators in the 10 CEE countries

Table 5

Forecasts of CO₂ emissions from transport in CEE countries; figures are expressed in million tonnes (Mt) per year

(Mt CO ₂ /year)	1990	2000	2010	2020	2030	Average annual change (%)			
						1990–2000	2000–2010	2010–2020	2020–2030
Bulgaria	7.4	5.8	7.0	9.0	10.7	–2.5	1.9	2.6	1.7
Czech Rep.	7.7	11.4	13.4	15.0	17.9	4.0	1.7	1.1	1.8
Estonia	1.7	1.8	1.9	2.0	2.2	0.1	1.0	0.4	1.0
Hungary	9.0	9.5	11.5	14.7	18.4	0.6	1.9	2.5	2.3
Latvia	2.8	2.2	2.8	3.1	3.5	–2.0	2.2	1.0	1.2
Lithuania	5.2	3.7	4.0	4.6	5.6	–3.2	0.7	1.4	2.0
Poland	21.2	29.0	35.9	42.0	48.7	3.2	2.2	1.6	1.5
Romania	12.4	11.8	14.8	18.5	22.5	–0.5	2.3	2.3	2.0
Slovak Rep.	2.9	3.9	5.2	6.5	8.3	3.1	2.9	2.2	2.5
Slovenia	2.7	5.3	6.2	6.5	7.0	6.9	1.5	0.5	0.8
Total	73.0	84.5	102.7	121.9	144.7	1.5	2.0	1.7	1.7

Table 5

Forecasts of CO₂ emissions from transport in CEE countries; figures are expressed in million tonnes (Mt) per year

average, have hindered further improvements in mean overall fuel economy (Greene and Plotkin, 2001; Schipper and Marie-Lilliu, 1999; van den Brink and van Wee, 2001). Furthermore, the efficiency of rail

transport (both passenger and freight) is expected to improve continuously in the forecast horizon, mainly because of the gradual electrification of trains (efficiency of electricity production as such is not accounted for).

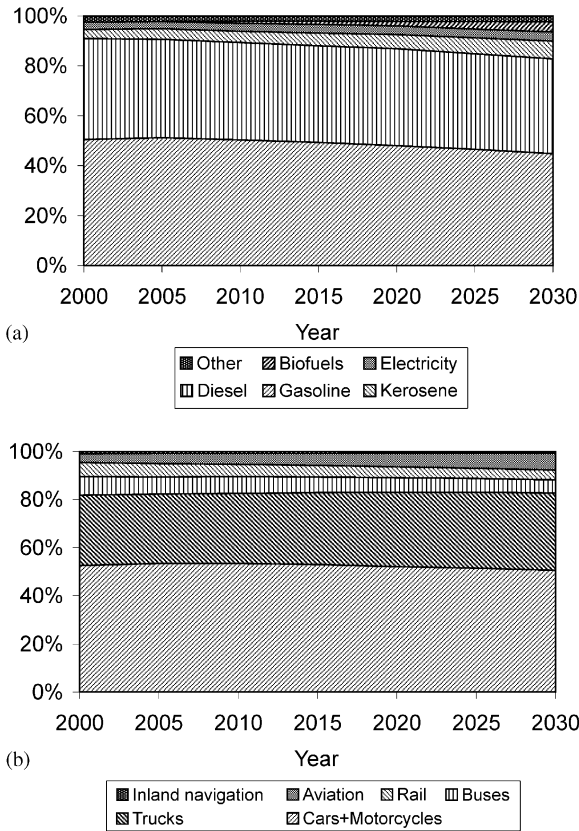


Fig. 8. Projected share of fuels (a) and various transport modes (b) in total energy consumption from transport in the 10 CEE countries.

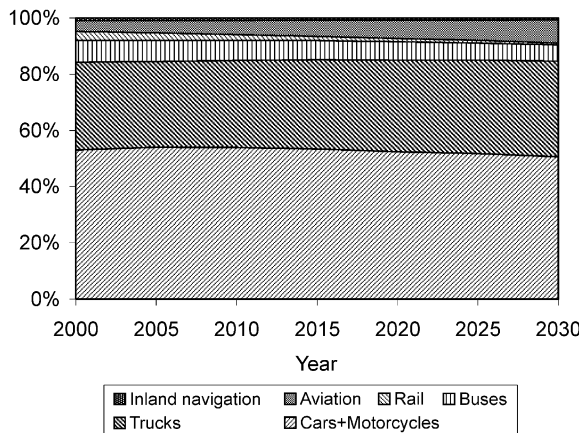


Fig. 9. Projected share of various transport modes in total transport CO₂ emissions in the 10 CEE countries.

CO₂ emission forecasts in each country are presented in Table 5, and the emissions share of different transport modes is illustrated in Fig. 9. Note that, similarly to energy use, indirect emissions from electricity generated to fuel electric trains and vehicles are not considered here, therefore the share of rail in total emissions diminishes after 2020. Overall, CO₂ emissions are expected to double in 2030 compared to 1990, with biofuels being considered as CO₂-neutral.

These projections are generally in line with trends recorded in North America and Western Europe over the last two decades (see, e.g. European Commission, 2001b), although some particularities are evident: for example, as one can note from Fig. 6, most CEE countries already in 1990 had similar or even higher car ownership levels than Western countries with higher per capita GDP. A second particularity is that, in view of the significant development of rail infrastructure before economic reforms, it is foreseeable that trains will continue to play a more important—though receding—role in both passenger and freight transport than in Western Europe.

When observing these forecasts, it might be argued that few remarkable developments seem to happen in the next 30 years, rendering this outlook quite conservative. In fact, several alternative fuel/technology options are currently explored, mainly for automobiles, trucks and aircraft such as compressed natural gas and hybrid vehicles, fuel cells, hydrogen vehicles and hydrogen-fuelled airplanes. Since, however, all these promising options are still at an early stage of development, additional assumptions would be required in order to obtain a more favourable picture for one or the other technology (e.g. assuming rapid technological progress, ample research funds or fiscal measures) and enable significant cost reductions in these technologies in the future. All this, however, is out of the scope of a ‘business as usual’ scenario, which is what this outlook is meant to be. It is noteworthy that established ‘business as usual’ projections lead to the conclusion that, even in North America and Western Europe, transportation energy use and greenhouse gas emissions will increase at rates similar to those of the last two decades unless strong policy intervention or unforeseen large and long-lasting fuel price increases alter this path (Greene and Plotkin, 2001; IEA, 2000; US DOE/EIA, 2001a,b, 2002). As for alternative fuels/technologies, it is worth mentioning as an example that only in the ‘advanced’ scenarios of Greene and Plotkin (2001) do fuel cell-powered vehicles penetrate the market before 2020, in contrast to their ‘business as usual’ and ‘moderate’ scenarios, where their share remains negligible.

To illustrate the numerous factors affecting the forecast, Table 6 displays the overall change in nine important parameters between 1990 and 2030 and the resulting change in passenger kilometers, energy use and CO₂ emissions of cars in the same period. The table focuses on passenger cars because it is the category analysed in most detail in the model. One can observe the evolution of the different parameters: some of them (like increasing car ownership and mileage and falling occupancy rates) tend to increase energy use and emissions, while others (rising fuel prices, improving fuel economy of new cars and increasing renewal rates) tend to reduce them. The outcome of this ‘business as

Table 6
Main parameters affecting the forecast of energy consumption and CO₂ emissions of passenger cars

% change 1990–2030	Real GDP per capita (%)	Population (%)	Real price of gasoline (%)	Car ownership (%)	km/car (%)	Occupancy rate (%)	New car fuel consumption (%)	Car renewal rate (%)	Carbon intensity ^a (%)	Passenger kilometres (%)	Energy demand (%)	CO ₂ emissions (%)
(1)	(2)	(3)	(4)=f (1)	(5)=f (1,3)	(6)	(7)	(8)	(9)	(10)=f (2, 4, 5,6)	(11)=f (3,7, 8, 10)	(12)=f (9,11)	
Bulgaria	293	-22	275	165	103	-32	-30	102	-17	183	69	52
Czech Rep. ^b	239	-11	16	98	106	-36	-24	67	-35	133	137	101
Estonia ^b	273	-30	133	183	47	-39	-26	84	-14	76	38	25
Hungary	307	-17	4	135	81	-31	-30	81	-24	143	117	94
Latvia ^b	186	-30	114	223	55	-37	-33	94	-18	88	43	25
Lithuania ^b	170	-11	305	180	52	-32	-33	79	-13	120	18	4
Poland	420	1	104	202	62	-23	-29	79	-28	284	141	113
Romania	194	-17	159	569	56	-23	-27	66	-37	402	157	120
Slovak Rep. ^b	196	1	30	133	90	-36	-27	52	-24	186	162	139
Slovenia ^b	386	-12	22	70	89	-19	-24	60	-22	118	116	94

^a Accounts for change in fuel mix and its effect on CO₂ emissions.

^b Became independent after 1990. Best possible estimates for 1990 on the basis of national and international data.

Overall change in the value of these parameters between 1990 and 2030 is shown in percent. *f* denotes a functional relationship between the given parameters and other ones as indicated by their numbers. Table 6

Table 7

Comparison of forecasts presented in this paper with the latest ones of the US DOE's International Energy Outlook (IEO) and the IEA's World Energy Outlook (WEO)

Oil price in 2020 in US\$(2000)/barrel	IEO ^a	WEO ^b	This paper
	24.7	27.7	26.0
<i>Average growth rates, 2000–2020</i>			
Gross domestic product (%)	4.1	2.1	4.3
Transportation energy demand—total (%)	2.6	1.5	2.4
Transportation energy demand—road (%)	2.3	—	2.3
Transportation energy demand—air (%)	7.6	—	4.7

^a Figures refer to IEOs 'Eastern Europe' group of countries, but Baltic States are included in 'Former Soviet Union' group, with slightly higher GDP growth and lower aviation growth than 'Eastern Europe'.

^b Outlook for OECD Europe; GDP and energy demand in CEE countries of this group will be considerably higher than these average numbers.

Sources: US DOE/EIA (2002); IEA (2000). Table 7

Comparison of forecasts presented in this paper with the latest ones of the US DOE's International Energy Outlook (IEO) and the IEA's

usual' forecast is the combination of all these contrasting effects. It is important to keep in mind that, since the starting year in this table is 1990, those countries that experienced the most serious crisis in the 1990s show a less dramatic increase in energy consumption and emissions. This has to be attributed to the significant decrease in transport activity between 1990 and 1995 (as shown, e.g. in Fig. 5 for Romania), whereas after that period the growth rates of energy use are similar to those of the other countries.

Table 7 compares the outlook presented in this paper with the latest corresponding projections of the Energy Information Administration of the US Department of Energy (DOE/EIA) and the International Energy Agency (IEA). In view of small (and to a large extent counterbalancing) differences in GDP growth and oil prices up to 2020, projections of this paper are similar to those of the DOE/EIA as regards road transport. The main difference with DOE/EIA lies in the forecasts of aviation fuel use, the DOE/EIA projections averaging 7.6% growth per year over the 1999–2020 period, as opposed to 4.7% of calculations in this paper, which therefore leads to higher growth in total transportation energy demand in the former study. On the other hand, the IEAs projections shown in Table 7 refer to 'OECD Europe' countries. Three major CEE countries are included in this group (the Czech Republic, Hungary and Poland), and it was considered more appropriate to compare with this outlook than with that of IEA for 'transition economies' because of the overall trend of convergence of all CEE countries with Western European trends. As the IEA outlook assumes lower GDP growth rates and higher oil prices than this paper, it reaches lower energy forecasts. This has to be attributed, however, to both the lower GDP growth (affected by assumptions for Western Europe) and the fact that

developed European economies are expected to experience saturation effects in transport sooner than Central and Eastern European ones.

5. Policy implications

Although the projected high GDP growth in CEE countries will cause a considerable upsurge in economic activity, the restructuring and modernisation of industrial and service sectors is expected to result in significant reductions in energy intensity, and therefore will most probably lead to a moderate increase in final energy demand. Similarly, energy consumption in households is not expected to rise drastically despite the gradual improvement of comfort, since at least a part of the significant energy saving potential will most likely be realised in coming years. These comments, based on quantitative information provided, e.g. by [Midttun and Chander \(1998\)](#) and various international organisations, underline the growing importance that the transport sector will have in total energy use. Furthermore, since none of the CEE countries (with the partial exception of Romania) is a major oil or gas producer, the expected increase in transportation energy use in the coming decades will lead to an analogous rise in their dependency on imported energy.

It is inherently difficult to restrict the spread of mobility in open and fast developing economies such as those of CEE countries. Therefore, options for reducing the growth rate of transportation energy use and thereby preventing large increases in import dependency and CO₂ emissions will mainly lie with measures oriented at accelerating the penetration of new technologies in all transport modes. Incentives for scrapping old cars, implemented in many Western countries in the 1990s, seem to be effective policy instruments, provided that they are included in a carefully designed scrappage scheme. Hungary has already applied such measures in the period 1993–1999, but without much success. Based on the Hungarian experience, [Fontana \(1999\)](#) has outlined the difficulties encountered in CEE and other Eastern countries with scrapping incentives and has provided recommendations (addressing scrappage schemes for buses and trucks too) that can lead to significant improvements in both fleet-average energy efficiency and air pollutant emissions.

Another option that is particularly relevant for CEE countries is the improvement in rail transport. Modernisation of existing rail infrastructure, investments in new train engines and high-speed trains in order to keep rail an attractive option for passengers, and progress in electrification of railways can somewhat restrain the growth of road traffic and reduce dependency on oil imports.

6. Conclusions

The paper has presented a long-term ‘business as usual’ outlook of energy use and CO₂ emissions from transport in the 10 states of Central and Eastern Europe that have acquired the status of ‘accession countries’ to the European Union. This was done with the aid of macroeconomic and demographic forecasts taken from international organisations and adjusted in order to account for recent developments, and moderate projections of fuel prices that consider both the path of convergence of CEE economies towards EU standards and the potential future development of crude oil prices. The main results can be summarised as follows:

- Public transport modes (buses and trains), which are expected to experience little or moderate growth after their collapse in the beginning of the 1990s, will lose much of their share in both passenger and freight transportation mainly to cars and trucks, while after 2015 aviation is expected to be the most booming mode. Car ownership, which is still at low to medium levels in most CEE countries, will grow rapidly up to 2015–2020 and then will gradually approach saturation.
- Despite considerable improvements in energy efficiency in all modes and especially in cars, transportation energy use is expected to almost double in 2030 compared to 2000, with private road transport (cars and trucks) being constantly responsible for about 80% of the total, while accounting for almost 60% of total passenger kilometres and tonne kilometres respectively. As a result of potential future EU legislation, a rising fraction of automotive gasoline and diesel blends will be produced from biomass, so that biofuels are foreseen to account for approximately 5% of total transportation fuel use by 2030.
- CO₂ emissions from transport are expected to be 70% higher in 2030 in comparison to 2000, even when treating biofuels as CO₂-neutral and not considering indirect CO₂ emissions of electric vehicles and trains.

The model that was developed and employed for this outlook considers each CEE country in a quite detailed manner, without overlooking the limitations of data availability. National particularities can be largely taken on board because of the explicit representation of the transport sector in each country, and competition between different technologies is simulated with the aid of vehicle mileage distributions that enable a more appropriate representation of costs compared to most transport-energy models. Thus the model is a useful tool for the evaluation of alternative policy options in CEE countries.

It can be envisaged that within the next few years, access to transport-related information will improve, and data availability and harmonisation will have

progressed in all countries. This will enable further work that is necessary for a more in-depth analysis (which is still missing from this study as well as from the previously cited studies conducted for these countries), addressing, e.g. the split between urban and non-urban travel, the differentiation among big and small cars as well as intermodal substitution issues.

Regarding GDP and oil price forecasts, their large uncertainties should always be born in mind. Recent developments after September 2001, both in overall economic activity and specifically in air transport (IMF, 2001b; Association of European Airlines, 2001), make the short-term GDP growth rates assumed earlier by international organisations and adopted in this paper questionable. It is too early, however, to draw conclusions on whether these events will affect the evolution of world economy and transport patterns in the long run.

Regarding GDP and oil price forecasts, it has to be pointed out that, although both are obviously governed by many uncertainties, it is nevertheless most probable that their evolution will be correlated. One could consider performing the analysis with two ‘extreme’ scenarios: a ‘high energy use’ one with high GDP growth and low oil prices, and a ‘low energy use’ one with very small growth (or even stagnation for some years) and high oil prices. Both scenarios, however, would run the risk of being quite unrealistic in view of fundamental economic principles. It was therefore decided to proceed with the one ‘moderate’ scenario as described in the previous paragraphs, still bearing in mind the large uncertainties of such an approach. Recent developments after September 2001, both in overall economic activity and specifically in air transport (Association of European Airlines, 2001; IMF, 2001), make the high GDP growth rates assumed earlier by international organisations and adopted in this paper questionable. It is too early, however, to draw conclusions on whether these events will affect the evolution of world economy and transport patterns in the long run.

Appendix A. Basic equations of the transport model for passenger cars

A.1. Nomenclature

p_j	price of fuel j (Euro90/toe)
rp_j	exogenous adjustment (to account, e.g. for changes in taxation or subsidies)
$pint_l$	international price of primary fuel l that affects the price of the particular fuel (e.g. crude oil price if j is a petroleum product, gas import price if j is natural gas)

αp_j	parameter that links international fuel price variation with the price of the particular fuel
AP_{kl}	average energy price of sector k and subsector l (Euro/toe)
wap_{ij}	weights of each fuel j to determine AP_{kl}
C_{klm}	final energy demand of vehicles of sector k , subsector l , technology m (toe)
\overline{C}_{klm}	final energy demand vehicles of sector k , subsector l , technology m remaining in the market (toe)
VEH_{kl}	stock of vehicles of sector k and subsector l
$NEWREG_{kl}$	newly registered vehicles of sector k and subsector l
$SCRAP_{kl}$	scrapped vehicles of sector k and subsector l
$MEXT_{kl}$	market extension (net new registrations) for vehicles of sector k and subsector l
k_1	exogenous time-trend parameter
k_2	car scrapping rate
α	GDP elasticity
s_1, s_2, s_3	parameters of a Gompertz function
$OWN_{kl,t}$	car ownership (=cars per capita) in year t
$OWN_{kl,saturation}$	exogenous parameter, can be set to, e.g. 0.7 cars/capita
KMV_{kl}	average annual mileage of vehicles of sector k and subsector l (km/vehicle)
A_{kl}	activity of sector k and subsector l (vehicle kilometres or passenger kilometres for $k = 1$, tonne kilometres for $k = 2$)
SFC_{klm}	specific fuel consumption from transport mode of sector k , subsector l and energy use m (toe/vehicle-km, toe/pkm, toe/tkm depending on transport mode)
GAP_{kl}	‘gap’ in transport activity that has to be filled by new registrations
$n + 1$	number of vehicle mileage classes to be considered (0 the smallest, n the largest)
x_0	annual mileage of the class with lowest mileage (km/year)
x_n	annual consumption of the class with highest mileage (km/year)
x_m	annual consumption of the class with modal mileage (km/year)
$wsh_{ij,t}$	exogenous ‘maturity factor’ that accounts for national particularities in the technology substitution process
d_i	discount rate for sector i

CC_{ij}	capital cost of vehicle of technology/ fuel j (Euro/vehicle)
FC_{ij}	fixed operation and maintenance cost of vehicle of technology/fuel j (Euro/ vehicle)
VC_{ij}	variable operation and maintenance cost of vehicle of technology/fuel j (Euro/km)
α, β, γ	various elasticities
Indices	
i	sector
j	fuels (conventional and alternative transportation fuels)
k	transport 'sectors' ($k = 1$ for passenger transport, $k = 2$ for freight transport)
l	subsectors
m	technologies
t	time index

A.2. Price formation

Fuel prices are forecast with the aid of the following equation:

$$p_{j,t} = rp_{j,t} + ap_j \cdot (pint_{l,t} - pint_{l,t-1}) + p_{j,t-1}. \quad (A.1)$$

Average energy price is then calculated:

$$AP_{i,t} = \sum_j w_{ap_{ij}} \cdot p_{j,t}. \quad (A.2)$$

A.3. Transport activity

$$VEH_{kl,t} = VEH_{kl,t-1} + NEWREG_{kl,t} - SCRAP_{kl,t} \quad (A.3)$$

or

$$VEH_{kl,t} = VEH_{kl,t-1} + MEXT_{kl,t}, \quad (A.4)$$

$$MEXT_{kl,t} = MEXT_{1kl,t} + MEXT_{2kl,t}, \quad (A.5)$$

$$MEXT_{1kl,t} = k_{1,t} s_1 \exp[s_2 \cdot \exp(s_3 \cdot \lambda_{kl,t})] \times VEH_{kl,t-1} - SCRAP_{kl,t} \quad (A.6)$$

with

$$\lambda_{kl,t} = \frac{OWN_{kl,t-1}}{OWN_{kl,saturation}}, \quad (A.7)$$

$$SCRAP_{kl,t} = k_{2,t} VEH_{kl,t-1} \quad (A.8)$$

with

$$k_{2,t} = k_{2,t-1} \cdot \left(\frac{GDP_t}{GDP_{t-1}} \right)^\rho, \quad 0 < \rho < 1, \quad (A.9)$$

$$MEXT_{2kl,t} = MEXT_{2kl,t-1} \left(\frac{GDP_t}{GDP_{t-1}} \right)^{\alpha_t}, \quad (A.10)$$

$$KMV_{kl,t} = KMV_{kl,t-1} (1 + r_v) \left(\frac{AP_{kl,t}}{AP_{kl,t-1}} \right)^{\beta_1} \times \left(\frac{AP_{kl,t-1}}{AP_{kl,t-2}} \right)^{\beta_2} \left(\frac{VEH_{kl,t}}{VEH_{kl,t-1}} \right)^{\gamma_1} \left(\frac{GDP_t}{GDP_{t-1}} \right)^{\gamma_2} \quad (A.11)$$

with β_1, β_2 being the short-term price elasticities, γ_1 the vehicle stock elasticity ($\gamma_1 < 0$), and γ_2 the GDP elasticity.

Based on the above, total activity will be

$$A_{kl,t} = VEH_{kl,t} KMV_{kl,t} \text{ (vehicle-km/a)}. \quad (A.12)$$

Specific fuel consumption will be equal to

$$SFC_{klm,t} = SFC_{klm,t-1} (1 + r_f) \prod_{r=1}^n \left(\frac{p_{j,t-r}}{p_{j,t-r-1}} \right)^{\phi(r/n)\gamma_j} \quad (A.13)$$

for those m that correspond to fuel j , with r_f exogenous residual adjustment, to account for autonomous efficiency improvements or other regulations (e.g. ACEA agreement), γ_j the long-term price elasticities

$$\phi(k|n) = \frac{6(n+1-k)k}{n(n+1)(n+2)}$$

where $\phi(k)$ are the weights of a second degree polynomial distributed lag such that $\phi(0) = 0 = \phi(n+1)$ and $\sum_{k=1}^n \phi(k) = 1$; n is the maximum lag.

A.4. Fuelltechnology substitution

The consumption of vehicles of technology m remaining in the market will be

$$\overline{C}_{klm,t} = A_{klm,t} SFC_{klm,t-1} (1 - k_2) \quad (A.14)$$

for those m that correspond to fuel j .

The 'gap' in the car market that has to be filled by new registrations is

$$GAP_{kl,t} = NEWREG_{kl,t}$$

and is non-negative.

This 'gap' has to be filled by new equipment, and several technologies (fuels) may compete for this purpose. In order to compute the shares of the different technologies in new equipment, the size of different 'consumers' is taken into account. Let it be assumed that there are $n+1$ vehicle classes, each one of which is characterised by different annual mileage. For these classes, the shares sh_{ij} are calculated.

Let

$$V_r = \frac{n! [\ln(x_m/x_0)]^r [\ln(x_n/x_m)]^{n-r}}{(n-r)! r! [\ln(x_n/x_0)]^n} \times x_0 \left(\frac{x_n}{x_0} \right)^{r/n} \quad r = 0, \dots, n. \quad (A.15)$$

where x_0, x_n and x_m are expressed in kilometres driven per car per year.

Let also

$$SU_{i,r,t} = \sum_j wsh_{i,j,t} \left[\frac{d_i e^{d_i L F_{i,j}}}{e^{d_i L F_{i,j}} - 1} CC_{i,j,t}^r + FC_{i,j,t} + (VC_{i,j,t} p_{j,t} SFC_{klm,t}) x_0 \left(\frac{x_n}{x_0} \right)^{r/n} \right]^{-\gamma_i} \quad (\text{A.16})$$

and

$$STT_i = \sum_{r=0}^n V_r. \quad (\text{A.17})$$

Then the technology shares in new equipment are calculated as follows:

$$SH_{i,j,t} = wsh_{i,j,t} \frac{\sum_{r=0}^n \left[(d_i e^{d_i L F_{i,j}} / e^{d_i L F_{i,j}} - 1) CC_{i,j,t}^r + FC_{i,j,t} + (VC_{i,j,t} p_{j,t} SFC_{klm,t}) x_0 (x_n / x_0)^{r/n} \right]^{-\gamma_i} V_r / SU_{i,r,t}}{STT_i}, \quad (\text{A.18})$$

where γ_i is the elasticity of substitution in this sector.

A.5. Calculation of transportation energy demand

Total demand of fuel j in sector i will be

$$C_{klm,t} = \overline{C_{klm,t}} + SH_{i,j,t} GAP_{kl,t} \quad (\text{A.19})$$

for those m that correspond to fuel j .

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