THE IPTS TRANSPORT TECHNOLOGIES MODEL

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Abstract

The IPTS transport technologies model aims to describe the dynamics of the passenger car market and the introduction of new technologies in the sector. The model simulates the impact of changes in fuel and car prices, technological development, income, and user preferences on the supply and demand of different passenger car technologies. It was originally planned as an extension of the POLES energy market model, but it may be used as a standalone model as well. The model is a scenario analysis tool, rather than a prediction tool. It can provide a general outlook for the future developments in the sector, but this corresponds mainly to the expectations of industry experts as regards the development of the various technological options, and thus strongly depend on whether those expectations are materialised in the future.

Keywords: Modelling; Vehicle technology; Innovation
Topic Area: A1 Road and Railway Technology Development

1. Introduction

The main driver for the development of the IPTS transport technologies model was the need for a tool that would help the analysis of policy measures that could lead to the reduction of fuel consumption and emissions through the acceleration of the introduction of alternative technologies. The main objective of the initial phase of development was therefore to construct a model that could explain past trends and provide a plausible outlook for the future, rather than predict the exact future values of the model variables. Although the model is considered as sufficiently accurate in its predictive capacity, its main function is the analysis of "what if?" scenarios describing alternative paths as regards future policy measures, technological development, socio-economic trends and other external factors that may –directly or indirectly- influence the dynamics of adoption of new transport technologies and, eventually, the impacts of transport on fuel consumption and emissions.

2. Car ownership and new registrations

The decision to buy, substitute or scrap a passenger car is a choice made by each individual on the basis of various financial, socio-economic and technological parameters. Car ownership is an important element of modern society and its level often reflects a country's average income and underlying consumption patterns. Although the degree may vary depending on local conditions, there is an evident correlation between car ownership and per capita income that has been consistent in the past and is expected to remain so in the future. The relevant literature generally suggests that aggregate car ownership levels increase with income until they reach a saturation level, when the income elasticity of car ownership falls to zero [Dargay and Gately (1999), Greenspan and Cohen (1996), Medlock

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and Soligo (2002), Schafer and Victor (2000)]. Saturation levels for Western Europe and North America are estimated to range between 600 and 700 passenger cars per 1000 inhabitants. Such levels would mean that the majority of holders of a driving license who can afford owning a car actually owns one (or more).

At the level of the individual, the decision to buy a car depends on household income and utility, and can be compared to the purchasing behaviour demonstrated for typical durable goods. In general terms, the majority of households buy at least one passenger car if their finances permit it, and replace older cars for newer ones -if they can afford it- in order to increase performance, reduce maintenance costs, or just enjoy the feeling of buying a new car. The household's income is the main determinant for the purchasing decision and the chances of buying a car increase when income increases. On the other hand, the price of the car, as well as the cost of using and maintaining it, act as inhibiting factors. Country specific parameters also affect the extent of the impact of each variable. Differences in urbanisation or the quality of public transport may explain a different behaviour in different countries. People living in metropolitan areas with good public transport services do not need a car as much as people living in rural areas.

Demographics and lifestyles also play an important role. A household owning a second or third car is becoming a frequent case. The increased participation of women in the workforce in the last 30 years (and the additional income they bring to the household) has largely contributed to the increase in car ownership. In addition, the fact that a larger proportion of the younger generations holds driving licences, a phenomenon even more evident for women, suggests that a larger number of potential car buyers exists today compared to ten or twenty years ago. As surveys from France and the UK show, the gaps between generations, which have been important in the past, have been smoothened out for households whose head is born after the 40's, implying that the diffusion of car ownership over generations is nearing completion [Dargay, Madre, et al. (2000)].

The new car purchases at an aggregate level correspond to the sum of the effect of the change in car ownership levels plus the substitution of cars that are removed from the car park (scrapped or exported as used cars). This implies that the overall car ownership level of a country is determined by the average income, the extent to which car ownership levels are saturated, and the country-specific parameters related to urbanisation and transport patterns. A number of cars are also removed each year, being too old or too expensive to maintain. New car registrations represent the cars bought by individuals that did not own a car before (because they didn't need or want one, or because they couldn't afford one, or because they were too young to have a driving licence), and the cars bought in order to replace a car that was scrapped.

The type of car purchased depends on numerous variables, not all of them quantifiable. Purchase and use costs are certainly important parameters, and probably provide a reliable indicator of market segmentation: high-price cars are bought by high-income households, low-income households are more sensitive to price differences, etc. There are, however, numerous non-economic factors that influence the type of car the individual consumer buys. Such factors may include the prestige associated with a certain brand or car size, fashion or lifestyle trends, advertising and marketing, and technological progress itself. The combination of the above factors in the last decade has resulted in a highly fragmented car market with strongly connected segments.

The share of the small and lower-medium segments has increased, probably as a result of the gradual fall of car prices compared to the lower and medium income levels. The fact that more young drivers and women buy cars, combined with the increasing number of second and third cars in one household, is probably the main reason. But issues such as congestion, the lack of parking space in urban areas, or the increasing environmental concerns of consumers could also be drivers for the trend toward smaller cars. The introduction of modern small cars such as Smart or Mercedes A1 can be seen as either a trend-setter or, from the opposite point of view, as the reaction of auto manufacturers to the trends in society. Consumer tastes have also changed concerning body type. Saloons dominated the market in 1995, but newer car designs are rapidly increasing their share in consumer preferences. The trend towards more Sport-Utility Vehicles (SUVs) that was impressive in the U.S.A. during the last decade seems to be taking off in Europe too. The share of another special category, 4x4 passenger cars, has doubled in the last 10 years, reaching 5% of sales in 2001 [ACEA (2002)]. Consumers demonstrate a strong tendency towards cars of higher performance. Aided by the relative drop in car and fuel prices compared to average income which is accompanied by (and, to a large extent, driven by) improvements in car technology and fuel efficiency, the average power of new cars has risen dramatically during the last decade. Another important factor for this trend is the fact that a large share of new car sales is in fact a replacement of the car that the individual owned before. Consumers tend to upgrade cars; they often sell or scrap their old car in order to buy a larger, faster or more expensive one. This results in an increased cost for the consumer that cannot be explained in strict economic terms. The utility of a car with improved performance, probably better than that actually needed, cannot be measured, since it depends on each consumer's perceived needs and choices.

The type of engine and/or fuel used seems to be a secondary decision. Since only two real alternatives exist today, i.e. gasoline and diesel fuelled internal combustion engines, the individual's choice depends largely on price, performance and use costs. Since diesel technology has made great improvements in the last 10 years in terms of performance, fuel efficiency and environmental impacts, the share of diesel fuelled sales has risen from under 14% in 1990 to over 35% in 2001. Except some limitations for diesel cars in urban areas (e.g. in Greece), and the still limited supply of a full range of diesel models (e.g. Japanese cars or smaller models), there doesn't seem to be any other differentiating factor between gasoline and diesel cars of comparable performance, apart from cost. However, the same cannot be easily said about emerging technologies such as electric cars, fuel cells or car fuelled by natural gas or bio-fuels. Whereas gasoline and diesel are established fuels, and the internal combustion engine is a proven technology, the emerging alternatives still lag in terms of maturity, infrastructure and fuel availability, safety and public perception, and are not yet considered as alternatives by consumers. Whether they will eventually become such, when their cost falls to competitive levels, remains an open question.

3. Overview of methodology

The model simulates the way that consumer choices concerning passenger cars are influenced by changes in car and fuel prices, technological development and general socio-economic trends. Data from 1965 to 2000 have been used for the calibration of the model parameters that describe the dynamics of the car market and define the weight of each variable in the model equations. Using exogenous projections for fuel prices, GDP and population growth, and the future technical and economic characteristics of each technological option, the model provides an outlook for the potential of each option and the subsequent implications for energy consumption and environmental impacts.

The first step of the simulation is the estimation of the expected changes in car ownership levels for each EU member state. As in most comparable models, car ownership levels are modelled with a Gompertz function that uses the changes of GDP per capita as input. The calibration of the model on the basis of past data allows the definition of the country specific parameters that affect factors such as the saturation level of demand, the changing elasticities as income grows and the differences in the speed of the effects. The exogenous projections needed, i.e. GDP and population growth, are obtained from EUROSTAT and UN projections.

The number of new registrations corresponds to the changes in the car park. These are a result of either the change in the overall car ownership level, or of the replacement of cars that are scrapped or removed from the car park (i.e. in the case of used car exports). The number of the cars removed each year from the park is modelled through country-specific survival rate curves for each cohort of cars that has entered the market since 1965. The survival curve rate can itself change over time, either as a result of technological progress or because of higher or lower incomes that accelerate or delay car scrapping.

The model distinguishes between 3 types of users for each country, each corresponding to different preferences as regards car use and -as a result- different responsiveness to costs and technological characteristics. The classification of user types for each country was based on urbanisation statistics and projections, while the model parameters that define user choices are endogenous, a result of the model calibration for the years 1980-2000. The model currently includes 7 technological options, conventional (internal combustion engines using gasoline or diesel, light or large) or emerging (electric, gasoline-electric hybrid, fuel cells). The technical and economic characteristics of each technological option have been defined through a number of sectoral techno-economic characterisation studies. These studies have provided a database of historic data for the conventional technologies and of projections by industry experts as regards the outlook for both conventional and emerging technologies. In addition, the model uses the projected future fuel prices of the POLES model in order to estimate the future usage cost for each option.

The share of the new registrations that each option can have in the future depends therefore on the combination of the number of users of each type in each country, their responsiveness to the technical and economic characteristics of each technology, the technological progress of each option, and the development of fuel prices in the future. The model also allows the introduction of infrastructure capacity limits.

Transport demand in the model is also affected by the fluctuations of fuel prices, GDP growth, the general trends of increased transport intensity, and the changes in the costs for each market segment. Combining the projected demand, the breakdown of the car park in technologies, and the expected efficiency for each technology in each generation, the model provides an outlook for fuel consumption and CO_2 emissions for each country, as well as for each of the market segments covered.

3.1. Modelling of car fleet and new registrations

The number of cars per capita is closely related to the per capita income level. The relationship has the form of an S-shaped curve; car ownership increases slowly at the lowest income levels, and then more rapidly as income rises, finally to slow down as saturation is approached. The theoretical basis for the estimation of the overall car ownership level comes from Dargay and Gately(1999). They use the Gompertz model, where the long run level of the vehicle-population ratio can be written as:

$$C_t^*\left(G_t\right) = \gamma \cdot e^{\alpha \cdot e^{\beta \cdot G_t}}$$

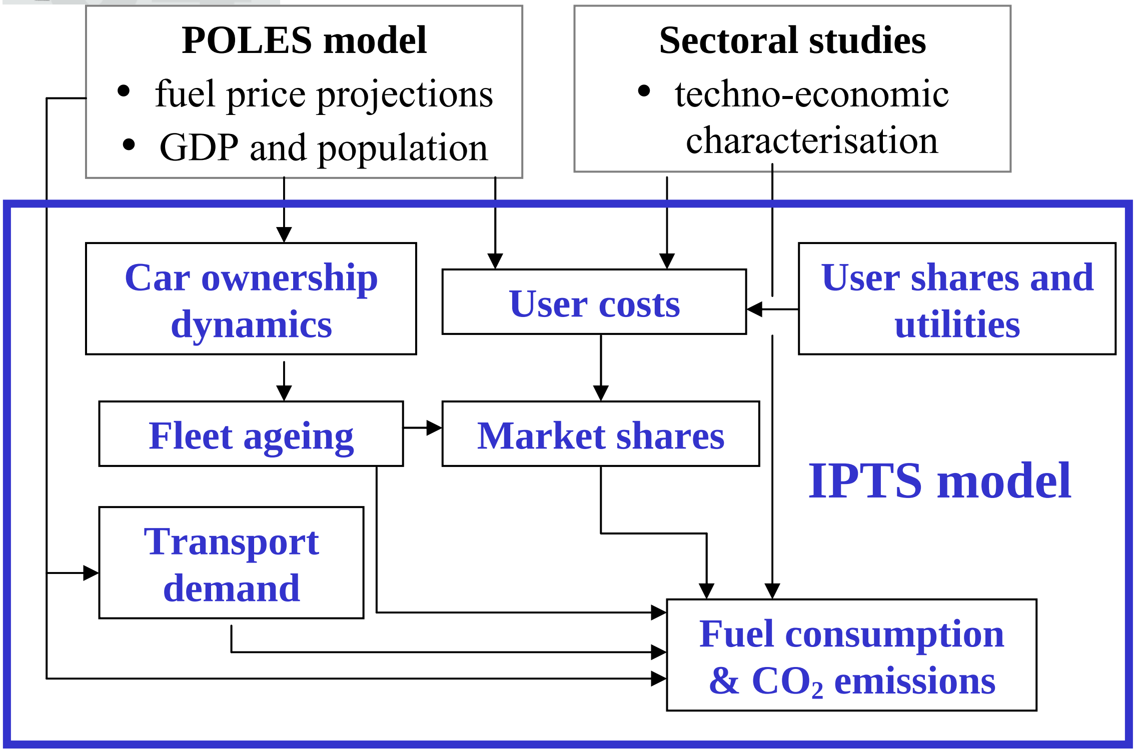

Figure 1 Overview of model links

In this equation α and β are negative parameters defining the shape, or curvature, of the function and γ is the saturation level, since for β<0. The parameter α determines the value for Gt =0, i.e.:

$$G_t \to \infty \Rightarrow C_t^* \to \gamma$$
$$G_t = 0 \ \to \ C_t^*(0) = \gamma \cdot e^{\alpha}$$

The long run income elasticity is calculated by appropriate differentiation as:

$$\eta_{LR} = \frac{d \ln C_t^*}{d \ln G_t} = \alpha \cdot \beta \cdot G_t \cdot e^{\beta \cdot G_t}$$

The cars per capita have are modelled by using a modified Gompertz function. The Gompertz function describes the long run relationship between vehicle ownership and per capita income. In order to account for lags in the adjustment of vehicle ownership to per capita income, a simple partial adjustment mechanism is implemented:

$$C_t = C_{t-1} + \theta \cdot (C_t^* - C_{t-1})$$

where θ is the speed of the adjustment (0<θ<1). The lags represent the slow adjustment of car and vehicle ownership to increased income due to the necessary build-up of savings to afford ownership, the gradual changes in housing patterns and so on. Substituting Ct* in the last equation, the result is the equation used in the model:

$$C_t = \gamma \cdot \theta \cdot e^{\alpha \cdot e^{\beta \cdot G_t}} + (1-\theta) \cdot C_{t-1}$$

where γ is the saturation level, θ is the speed adjustment factor of the curve, α and β are negative parameters defining the shape of the Gompertz function and G_t is the GDP per capita (in thousands of € ppp per capita).

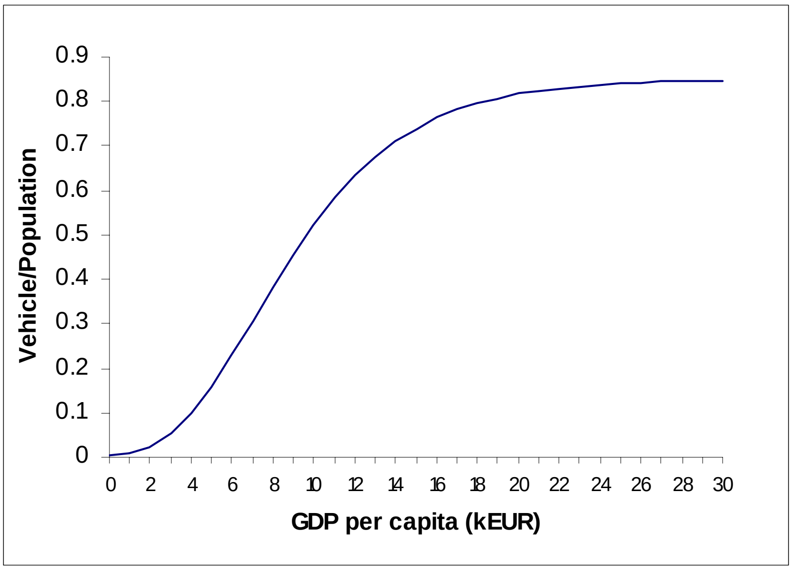

Figure 2 Car ownership function based on the Gompertz model

The total number of car registered is estimated regardless the car category, technology or customer profile. This total number of car registered is distributed among customer categories and technology types according to the rules described in the following sections.

The model uses the value calculated for speed adjustment given in Dargay and Gately (1999) and the adapted saturation levels calculated by Medlock and Soligo (2002). The curve parameters were re-calibrated in order to allow for the change in GDP per capita reference year.

The number of new registrations corresponds to the changes in the car park. These are a result of either the change in the overall car ownership level, or the replacement of cars that are scrapped or removed from the car park (i.e. in the case of used car exports). The number of new cars registered per country (or the car sales) is a function of the variation of the number of cars per capita, the population and the total amount of scrapped vehicles:

$$NCR_t = (C_t - C_{t-1}) \cdot POP_t + TOTSCR_t$$

where:

NCR_t is the number of new car registrations at time t

C_t the per capita car ownership

$TOTSCR_t$ the number of cars removed from the car park during the period

3.2. Dynamics of car scrapping and fleet ageing

In the model, car scrapping refers to the case of a car being removed from circulation. This can be the consequence of one or more of the following:

- the car is not usable any more (e.g. because of mechanical problems or as a result of an accident)
- the car is too expensive to use or maintain: other options such as buying another car or owning no car at all are more attractive for the owner, and no other buyer can be found

- the car is sold in another country as a used car: this case has more to do with statistics rather than with actual scrapping, but it also implies that the perceived value of the used car in the country of origin is lower than in the destination
- specific regulations or measures prohibit the use of a specific type or age group of cars, or stimulate the early retirement of older vehicles

In all of the above cases, the underlying variables are the cost of use and the remaining value of the car. A micro-economic approach modelling the decision to buy or scrap a car was used in Adda and Cooper (1997) in order to estimate the impacts of car scrapping subsidies in France. Individuals are assumed to have a certain utility from buying or scrapping a car, and a change of the relative costs through government intervention greatly affects the overall car market, accelerating the speed of replacement when scrapping subsidies are given. The models used by Alberini, Harrington, et al. (1998) simulate the owner's decision to keep, repair or scrap their old vehicles. This decision depends critically on the owner's perceived value of the vehicle that, in turn, depends on the mileage and condition of the car, and declines systematically with its age. Greenspan and Cohen (1996) divide scrapping into two types, engineering scrapping and cyclical scrapping. Engineering scrapping results mainly from age-dependent physical wear and tear, while cyclical scrapping is a result of business cycles. The non-engineering component of scrapping also depends on the price of gasoline, the price of new vehicles, and on the cost of repairs. An increase in their price delays the purchase of new vehicles and the scrapping decision, while a reduction in the cost of repairs encourages increased repair of vehicles and less scrapping. The price of new vehicles relative to repair costs is considered as significant in explaining total scrapping.

The dynamics of the car park and, subsequently, the scrapping behaviour in each country were modelled on the basis of the historical data on new car registrations and car park figures, since only limited data were available concerning car scrapping. In the general form, the dynamics of fleet ageing are described by a set of 3 equations:

$$CARFLEET_t = \sum_{car} \sum_{i=0}^{\infty} SURPC_{car,i}$$

$$SURPC_{car,i} = NCR_{t-i} \cdot SR_i$$

$$SR_i = 1 - e^{\left(a \cdot e^{(-b \cdot i)}\right)}$$

Where $CARFLEET_t$ the number of cars in circulation at time t

$SURPC_{car,i}$ the number of car survivors of category car per period (cohort), i.e. from those that belongs to category car and are i years old at time t.

i the age of the cohort

SR_i the survival rate of the cohort i years old, which is computed also following a Gompertz survival model.

The parameters a and b define the survival rate curve for the specific country and technology. Their values where calibrated through the process of multi-variate optimisation that determined the values that provide the best match between the car park numbers this set of equations calculates and the data from statistics between 1970 and 1998.

The survival curve rate can itself change over time, either as a result of technological progress or because of higher or lower incomes leading to scrapping cars earlier or later. The model allows the incorporation of the technological progress in the determination of parameters a and b and therefore endogenise it. However, the short-term economic parameters that affect scrapping are not included, since they are outside the scope of the model.

3.3. Market segmentation

The model allows the segmentation of the market into both technologies and user type and allocates new car registrations per technology for each user group. The underlying assumption is that each type of user has different preferences that can expressed in terms of utility. The utility for each category of use or customer is expressed as follows:

$$U_{cust,t} = U_{cust,t-1} \cdot e^{\left(\alpha_{cust} \cdot \left(\frac{G_t - G_{t-1}}{G_t}\right) + \beta_{cust} \cdot \left(\frac{P_t - P_{t-1}}{P_t}\right) + \gamma_{cust} \cdot \left(\frac{C_{t-1} - C_{t-2}}{C_{t-2}}\right)\right)}$$

where:

α_{cust} is the adjustment parameter for the income per capita.
G_t is the GDP per capita.
β_{cust} is the adjustment parameter for urban population
P_t is the percentage of urban population.
γ_{cust} is the adjustment parameter for the number of cars per capita
and C_t is the variable the number of cars per 1000 inhabitants.

These utilities are used to compute the share of each customer in the total number of new car registrations per country:

$$CUSTSH_{cust,t} = \frac{U_{cust,t}}{\sum_{cust} U_{cust,t}}$$

Having split the total new registrations per customer category, the decision to select some particular car technology depends on the utilization costs associated with each car category. Such costs depend on the fuel costs, the fixed costs (discounted during the lifetime of the vehicle) of each type of car, the expected mileage, and the stack/battery replacement costs in the case of electric, hybrid and fuel cells.

4. Scenario analysis capabilities

The model currently allows four general types of scenarios to be analysed:

4.1. Technological scenarios

Technological scenarios can provide the outlook for the penetration of new technologies and their impacts on the indicators measured under different assumptions than the ones currently used. Technology development is expressed in the model in terms of fuel economy and car prices for a given level of performance. The values used in the baseline scenario are derived from specific studies on the potential of the various alternative technologies. Alternative scenarios can be constructed by using more optimistic or pessimistic development paths that would change the competitive position of each alternative and influence the speed of its adoption. Technology scenarios in the model are mainly constructed through changing the exogenous variables (input) of the model.

4.2. Policy measures

Policy measures are perhaps the most interesting type of scenario analysis, and the one that provides more flexibility. The policy measures that scenarios can cover include the following:

- fuel taxes: changing the level of taxation of some or all fuels influences the total demand for transport and the share of each car technology
- carbon taxes: imposing a tax that is based on the carbon content of the fuel used can favour technologies that produce less CO_2 and accelerate the introduction of alternatives such as hybrids and fuel cells.
- subsidies: subsidising a specific technology changes its competitive position and increases its sales
- emission limits: imposing an emission limit (e.g. gCO_2/km) favours alternative technologies and/or leads to smaller cars being used
- accelerated scrapping schemes: providing a financial stimulus to scrap cars can accelerate the renewal of the car stock and reduce total fuel consumption and emissions
- zero emission zones: imposing a zero emission limit in urban areas leads to the acceleration of the introduction of electric, hybrid and fuel cell vehicles
- combination of policies: e.g. using the carbon tax revenue to subsidise alternative technologies can significantly speed up their introduction

Policy measures in the model can be introduced by changing a number of parameters in the model that, in turn, affect the costs and prices calculated by the model.

4.3. Socio-economic trends

User choices are influenced by the socio-economic profile and other country-specific issues. They can significantly affect the dynamics of the transport sector, transport demand and the potential of alternative technologies. User choices are modelled in the context of specific socio-economic trends, covering market segments, user types, the degree of urbanisation, the environmental awareness of users, etc. that are endogenous to the model.

For example, possible scenarios of socio-economic trends can include different degrees of responsiveness to environmental pressure (user awareness), urban sprawl (urbanisation), changing household structures and demographics. Normally, such scenarios involve modifications of the equations describing the dynamics of the model and, as far as user choices are concerned, price elasticities for each specific user group.

4.4. External factors

The main external factors that the model can analyse in terms of scenarios are fuel prices and GDP growth. In its current form, the model uses as input the projections of fuel prices from the POLES model, and the same assumptions for GDP growth that the POLES model uses. Scenarios that can be carried out include the investigation of the impact that a higher or lower price of, and/or a faster or slower economic growth would have on the dynamics of the car market, total demand, fuel consumption and CO_2 emissions.

5. Indicative results

According to the model's baseline projections, car ownership levels in the EU-15 are expected to continue to increase but, especially after 2015, will probably reach saturation at values between 600 and 650 cars per 1000 inhabitants (Figure 3). As a result, and in combination with the demographic and technological trends, annual new car registrations are expected to stabilise around 15 million for EU-15. The number of cars removed from the stock (scrapped or exported as used cars outside the EU-15) is expected to rise to almost 14 million per year, as a result of the 10-15 year lag compared with the increase of car ownership in the 1990's. The total number of passenger cars in circulation in EU-15 will rise to almost 220 millions by year 2020, an increase of 23% compared to year 2000.

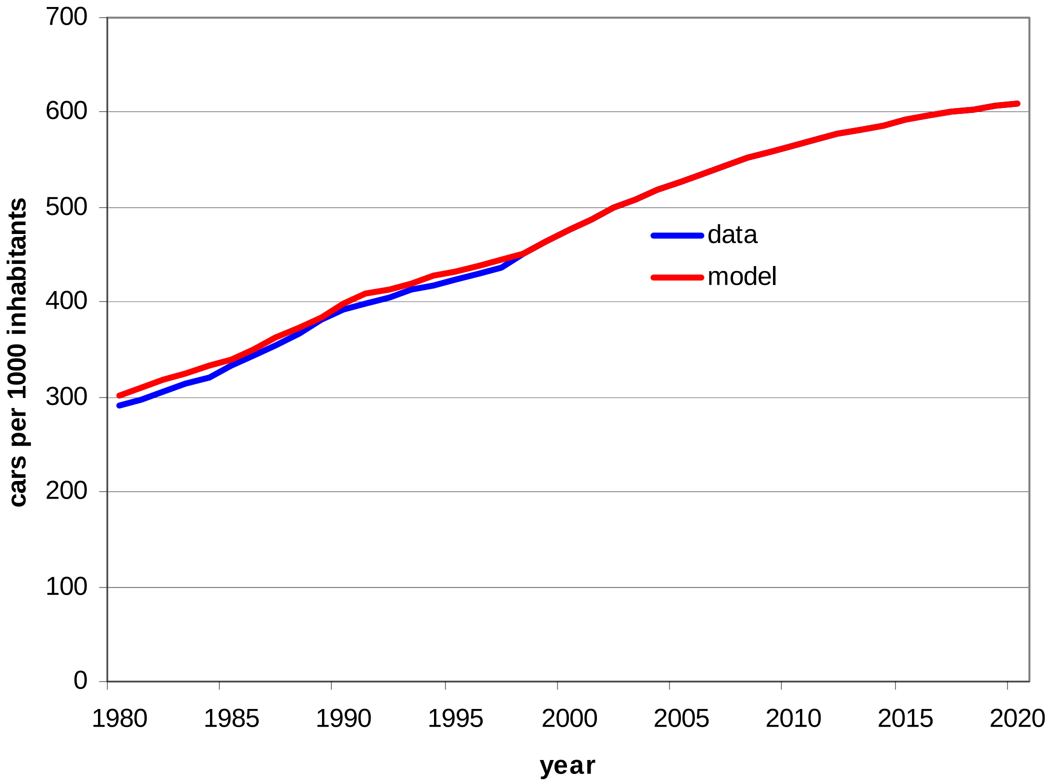

Figure 3 Car ownership levels in EU-15, data and model projections

As regards the penetration of new vehicle technologies, the model results suggest that only hybrid vehicles have the potential for a wide scale introduction by 2010 (figure 5). Electric vehicles show a limited potential, concentrated mainly in some niche markets (urban areas in countries with cheap electricity), while fuel cells may capture a significant part of the market only by the end of the 2010's. Another trend that can be identified is that of the shift from gasoline to diesel. The expected improvements in diesel technology could provide significant cost savings and comparable performance with gasoline technology. A gradual replacement of gasoline cars with either diesel or hybrid (mainly gasoline-electric hybrids) is therefore expected in the medium term (2010-2015). In the longer term, conventional ICEs and hybrids may gradually lose their share to fuel cells (probably using hydrogen from reformed gasoline, natural gas or methanol), depending on the progress made in the development of fuel cell technologies.

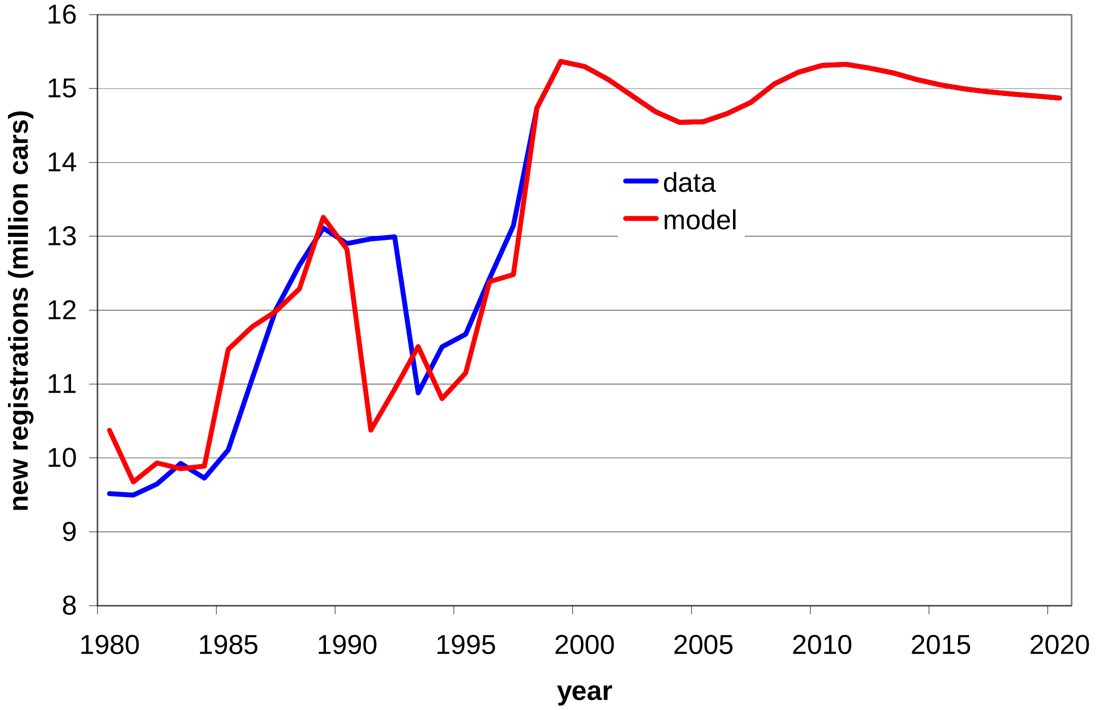

Figure 4 New car registrations in EU-15, data and model projections

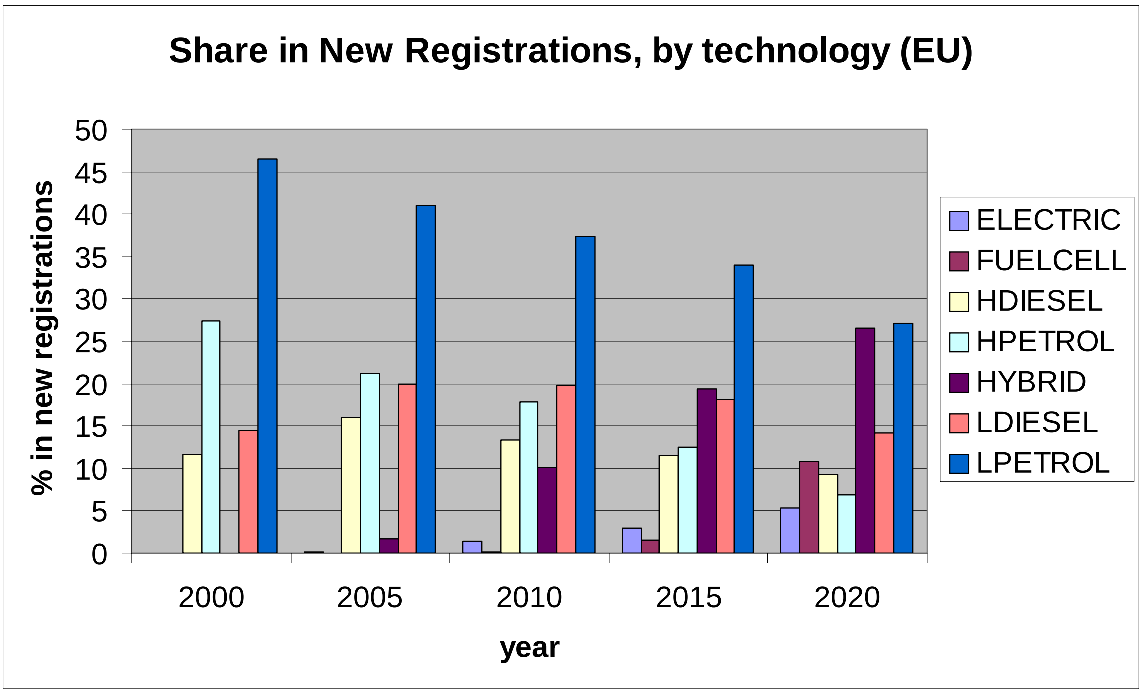

Figure 5 Potential share of each technology in new registrations

Concerning the total number of kms driven in each country, both the number of cars and the average distance are expected to rise and, as a result, total car use may increase by about 33% between 2000 and 2020. Average car use is expected to stabilise around 14,000 kms per car per year by 2020. However, notable differences among member states can be seen, due to the different lifestyles, geography, urbanisation and urban sprawl levels, and differences in statistics. Most of the expected changes in the driving factors can lead to increases in the average distance driven, but a certain saturation level for each country is expected to be reached in the next 15-20 years. This projection implies that the overall increase in passenger transport demand that is expected in the next 20 years is most probably going to be covered by other modes (notably air transport for long distances), since car passenger transport will have reached saturation levels. This is highlighted in the projections for transport intensity that corresponds to passenger car transport. The ratio of kms driven to GDP is expected to continue rising until around 2005, but will tend to fall afterwards, since the growth in GDP will not be accompanied by a comparable growth in car passenger transport.

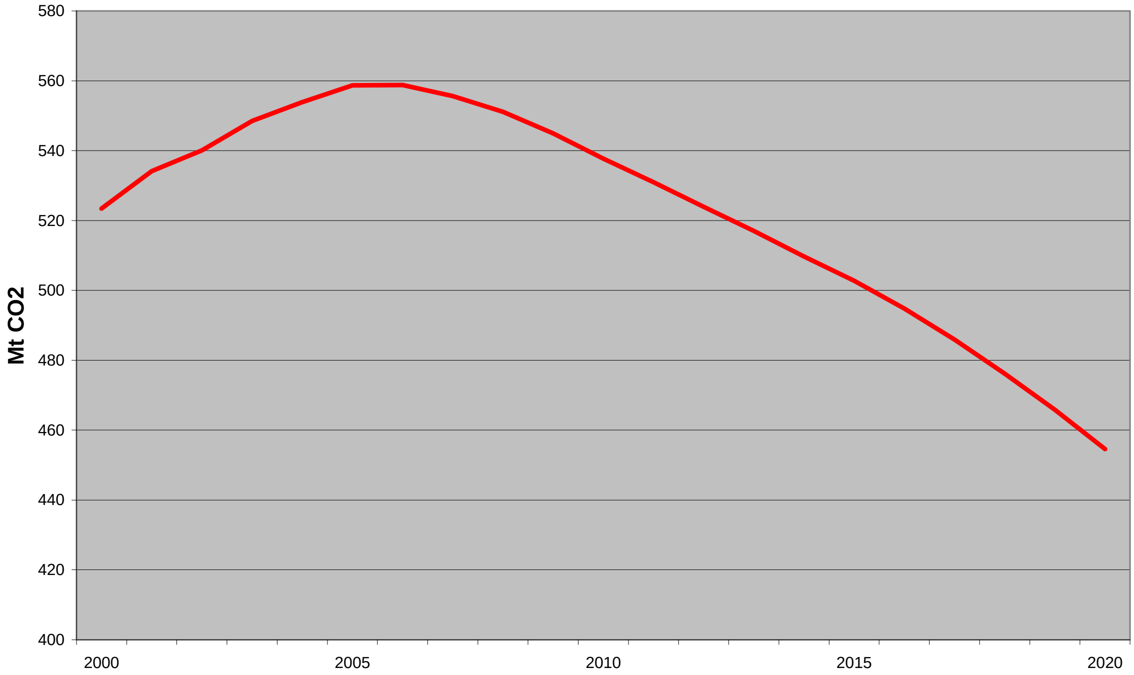

Figure 6 CO_2 emissions from passenger road transport, EU-15

Total fuel consumption and CO_2 emissions are expected to follow a similar trend, reaching a maximum around year 2005 and starting to fall soon afterwards. This is the result of the expected fuel economy of passenger cars improving faster than the rate of growth of total car use. An important part of the improvement of fuel economy is expected to come from the introduction of hybrids and, later on, fuel cells but -even without these alternatives- the evolution of gasoline and diesel ICEs according to the EURO standards and the ACEA agreement should be enough to prevent CO2 emissions from rising further. Fuel economy in Europe is expected to improve, but differences will still exist between member states due to the differences in user choices. The improvement of the average fuel economy for the whole car stock is expected to be even larger, since the majority of the cars that entered into circulation in the 1980's and 1990's will have been replaced in the next 10 years by much more fuel efficient cars.

The average age of cars in circulation is expected to rise slightly in the next 20 years, from 7.4 to 8.3 years. This is mainly the result of demographics in Europe (age distribution of car owners) and the saturation in car ownership levels (total demand). The effects of improved car technology on the length of a car's life (either technical or economic) seem to become marginal, and the average age of car scrapping (or removal from circulation in general) is stable. However, in both average age indicators, significant differences exist among member states. These differences are mainly the result of the different socio-economic conditions, car costs, disposable income and (new and used) car market operation in each country.

6. Conclusions

The model is a scenario analysis tool, rather than a prediction tool. It can provide a general outlook for the future developments in the sector, but this corresponds mainly to the expectations of industry experts as regards the development of the various technological options, and thus strongly depend on whether those expectations are materialised in the future.

The main results of the IPTS transport technologies model presented here correspond to the business-as-usual case, i.e. the baseline projections for the input variables used by the model (GDP growth, fuel prices, car prices, trends in fuel economy, etc.). Although the model is considered sufficiently reliable, it should be noted that, since its objective is mainly the comparison of alternative policy measures, these projections should be used as the basis for comparisons or trend analysis, and not as a means for prediction of the future value of the variables.

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