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Projection of end-of-life vehicles

Development of a projection model and estimates of ELVs for 2005-2030

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Context

The Topic Centre has prepared this working paper for the European Environment Agency (EEA) under its 2007 work programme as a contribution to the EEA's work on waste outlooks.

Part of this working paper has been accepted for publication in the *International Journal of Automotive Technology and Management Vol. 7, No. 4, 2007, 343-355* (in particular the sections: 2. The ELV projection model and 3. Data and estimations, and parts of section 1. Introduction, 5. Projections and sensitivity analysis, and 7. Final remarks).

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Executive summary

When the European Union adopted the Directive on End-of-Life Vehicles (ELVs) in 2000, it was estimated that 8 to 9 million tonnes of waste from used cars was generated every year. However, it is likely that this amount will increase to somewhere between 14 and 17 million tonnes in 2015.

The directive aims at limiting the use of hazardous substances in vehicles and sets specific targets on the reuse, recycling and recovery of waste from vehicles for the years 2006 and 2015.

In this paper we focus on passenger cars. Hence, light commercial vehicles, busses and trucks are not included.

An ELV projection model

The paper presents a model for the projection of the number of end-of-life vehicles (ELVs) and presents a baseline projection and sensitivity analyses for selected parameters. The model describes long-term developments for individual EU Member States. However, only aggregated projections are presented. The geographical coverage of the model is the EU Member States, excluding Romania and Bulgaria.

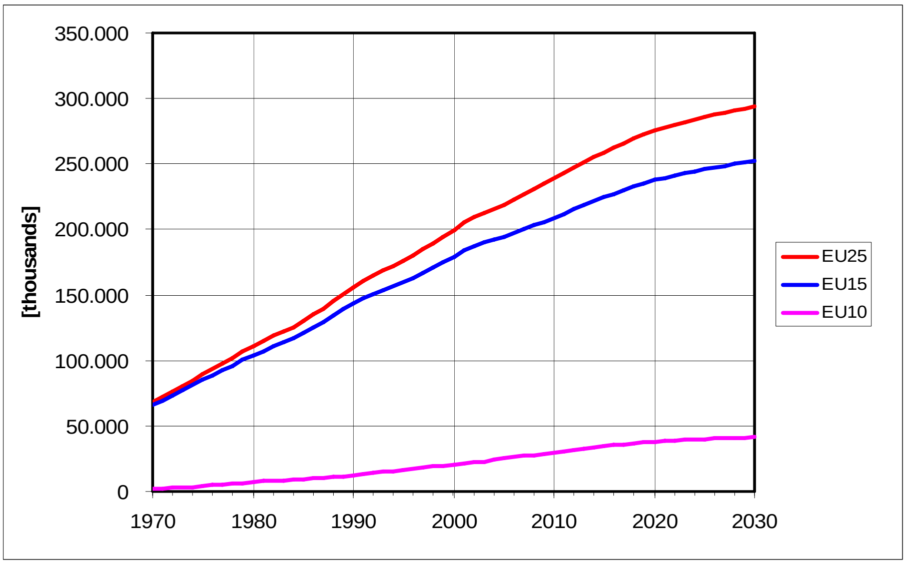
To model the generation of end-of-life vehicles, historical data on population, the number of cars per capita (car density), GDP per capita and the vintage distribution of cars are combined. To estimate the number of ELVs, an EU energy and transport scenario, that includes projections of the population and economic development, is used.

The lifetime of car vintages is described by a Weibull distribution. The development in car density is modelled by a Gompertz function which is an S-curve that increases towards a saturation level. Parameters of the Weibull distribution and Gompertz function are calibrated using historical data, mainly from Eurostat.

Projected stock of passenger cars

Between 2005 and 2015, the projected growth rate of the stock of cars is 1.7% p.a. for the EU-25. For the EU-15 the annual growth rate is 1.5% whereas it is more than twice as high for the 10 new Member States with 3.3%.

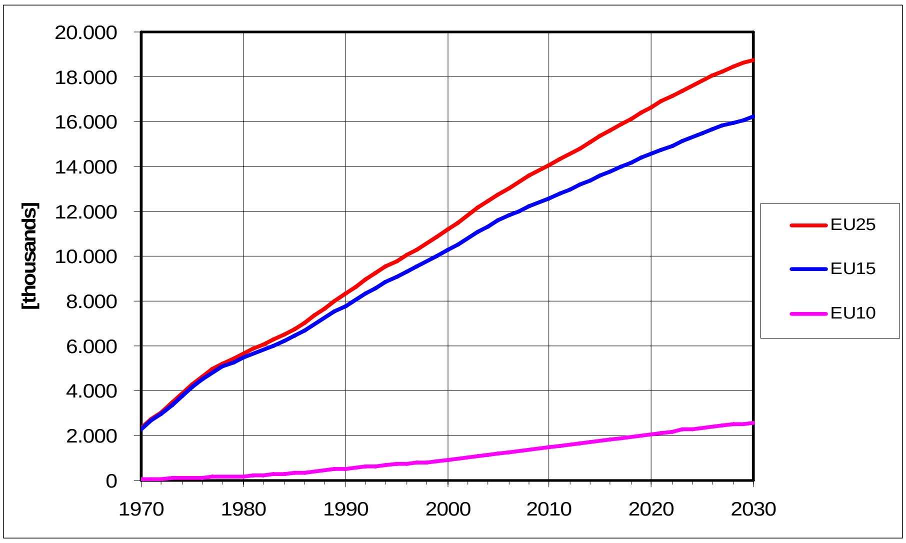
Projected development in the stock of passenger cars, 1970 - 2030



Projected number of ELVs

The baseline projection shows that the number of ELVs for the 25 EU Member States is likely to increase by 20-25% between 2005 and 2015. This corresponds to an increase of 2.5 million ELVs. Looking further ahead, around 45% more ELVs may arise in 2030 compared to 2005 which corresponds to an increase of 6 million ELVs. There is a time lag between the stock of cars and the number of ELVs: from 2020 the growth in the stock of cars seems to level whereas a slower growth in the number of ELVs seems apparent after 2025.

Projected development in the number of ELVs, 1970 - 2030



However, the current ELV projection model does not take export and import of used cars into account. Export (intra EU25 and extra EU25) amounts to around 2 million used cars which should be deducted from the projected figures. In the table this has been done in line 'EU-25 (incl. export)'.

Projected number of ELVs, 2005 – 2030

Thousand	2005	2010	2015	2020	2030
EU-25 (excl. export)	12 770	14 077	15 347	16 642	18 756
EU-25 (incl. export)	~10 800	~12 000	~13 300	~14 600	~16 800
EU-15	11 583	12 595	13 579	14 565	16 206
EU-10	1 187	1 482	1 767	2 077	2 550

The average weight of cars is increasing which will generate more waste when they are scrapped. If the average weight of an ELV increases to 1 025 kg in 2015, about 14 million tonnes of waste will be generated. However, the European Commission seems to expect that the average weight will increase to 1 280 kg, and then the waste generation will be about 17 million tonnes.

Based on the projection of ELVs, a model may be developed to estimate the environmental effects of managing waste from used cars. Cars comprise a host of materials such as ferrous metals, plastics, glass, tyres, batteries etc. and the environmental effects will depend on how each of these materials are reused, recycled and recovered. Unfortunately, detailed data on the composition of cars and the management of the (waste) materials are not available on a Member State level, and therefore a series of assumptions would have to be made.

Recently, the European Commission has published its report on the implementation of the ELV Directive. In addition to the number of collected ELVs for 2002-2004, the report includes the total reuse, recycling and recovery of waste from vehicles in 2004. The latter allows for a preliminary assessment of whether the 2006-targets of the directive are likely to be met.

1. Introduction

Around 8 to 9 million tonnes of waste from End-of-Life Vehicles (ELVs) was generated every year in the 15 old Member States, (Tuddenham et al., 1996). In order to improve the management of this waste, the European Union adopted the Directive on ELVs (Directive 2000/53/EC) in 2000. Among other things, the directive aims at limiting the use of hazardous substances in vehicles and at it sets specific targets on the reuse, recycling and recovery of waste from vehicles for the years 2006 and 2015.

However, since the mid-1990s the European Union has been expanded with 12 new Member States. The economic growth has also started to rise again after some years in recession: the economies in the 15 old Member States seem to be improving and the 12 new Member States continue their high growth rates. And finally, from the waste perspective, the average weight per car is on the increase which of course will contribute to more waste generation.

Based on an analysis of past developments, we present in this paper a model for projecting the number of ELVs in 25 EU Member States[1] and the results of the model, i.e. the likely development in ELVs from 2005 to 2030. The model combines projections of the number of vehicles per capita with data on the age distribution of the car fleet and the statistical lifetime of vehicles in individual countries to perform country specific projections of numbers of ELVs.

Numerous analyses of the density of vehicle ownership are reported in the literature, mainly focussing on effects related to congestion of traffic or energy consumption. In these analyses, the development in the density of vehicle ownership is modelled by an S-curve approaching some maximum density. In Holtmann et al. (1995), a simple time-dependent Gompertz function is used. In Dargey and Gately (1997), a GDP-dependent Gompertz function is used such that vehicle density depends on the GDP per capita (as a measure of the consumer wealth in the country). Dargey and Gately (1997) assumes that the saturation level is equal for all countries and they have estimated that 62% of the population has a passenger car.

Medlock and Soligo (2002) develop a model relating vehicle density to wealth (measured by income per capita) and user costs of vehicles while assuming optimal consumer behaviour[2]. They estimate vehicle density relations for 28 countries by applying a log-quadratic approximation and country specific saturation levels. Two major findings in Medlock and Soligo (2002) are that saturation levels vary considerably between countries and that user costs have a significant influence on the development in the stock of passenger cars. From a theoretical point of view, user costs determine the level of GDP required for saturation, that is the GDP-elasticity. Saturation levels should depend on transport infrastructure characteristics.

As time-series for user costs of vehicles is not available in the current study, the model presented here relies on the approach adopted by Dargey and Gately (1997), whereby the number of vehicles per capita is assumed to vary according to a GDP-dependent Gompertz function. However, contrary to Dargey and Gately (1997) the present study allows for country specific saturation levels. Further, differences in estimated saturation levels and GDP-elasticities are compared to national differences in user costs approximated by fiscal income from vehicles and differences in infrastructure approximated by population density.

To approximate the relationship between car density (or the total stock of passenger cars) and the number of ELVs, the attrition rate of the car fleet is calculated via a Weibull distribu-

[1] Bulgaria and Romania are not yet included in the projection.

[2] Optimal consumer behaviour refers to a rational consumer behaviour as assumed in economic theory.

tion. The Weibull distribution is calibrated by data that describes the age-distribution of the car fleet. Moreover, the Weibull distribution is country specific, mirroring the variations in the average lifetimes of cars in different countries. However, because the Weibull parameters are assumed to be the same for all vintages, the Weibull distribution does not account for variations in the attrition rates of different car vintages.

The model presented in this paper is a simple approach to quantifying long-term average developments in the number of ELVs. It is a further development of a method described in Kilde and Larsen (2001a) and Kilde and Larsen (2001b).

The next section of this paper presents the model. In section 3, we present the data used in the model and the estimations (or calibrations) . In section 4 we compare the estimated GDP-elasticities and saturation levels to user costs of cars and selected indicators for infrastructure. Section 5 presents a projection and a few sensitivity analyses. Section 6 presents the Directive on ELVs and compares the national data for the number of ELV´s to the estimates from the ELV projection model. Finally, in section 7 we draw conclusions on the model and the estimates of ELVs.

2. The ELV projection model

To describe the relationship between car ownership per capita and per capita income, the Gompertz function (that describes an S-curve) is chosen. At low income levels the car density increases moderately with increasing income. At medium income levels the density increases considerably and at some high income level a saturation is reached. The Gompertz equation relating car ownership per capita (C_t) to the income per capita (GDP_t) (approximated by the gross domestic product per capita) can be expressed as follows:

$$C_t = \gamma \cdot e^{\alpha \cdot e^{\beta \cdot GDP_t}} \qquad \text{Eq. (1)}$$

where α and β are negative values and γ defines the saturation level. The position of Gompertz function is determined by $\ln(\alpha)/\beta$, and the steepness of the function is determined by β. The long-run GDP-elasticity is calculated as:

$$\eta = \alpha \cdot \beta \cdot GDP \cdot e^{\beta \cdot GDP} \qquad \text{Eq. (2)}$$

that is, the elasticity varies with the level of GDP and the maximum is determined as:

$$\eta^{\max} = -\alpha \cdot e^{-1} \qquad \text{Eq. (3)}$$

(Dargey and Gately (1997), p. 27)

For some countries it is difficult to estimate the GDP-dependent Gompertz function in Eq. (1), as the estimated saturation levels are not realistic. Alternatively, a time-dependent Gompertz function can be estimated:

$$C_t = \gamma \cdot e^{\alpha \cdot e^{\beta \cdot (t - t_o)}} \qquad \text{Eq. (4)}$$

where t is the year and t_o = 2000[3].

Multiplying the car density by the population yields the stock of cars:

[3] The model requires a base year and we have chosen it to be 2000.

$$S_t = C_t \cdot P_t \quad \text{Eq. (5)}$$

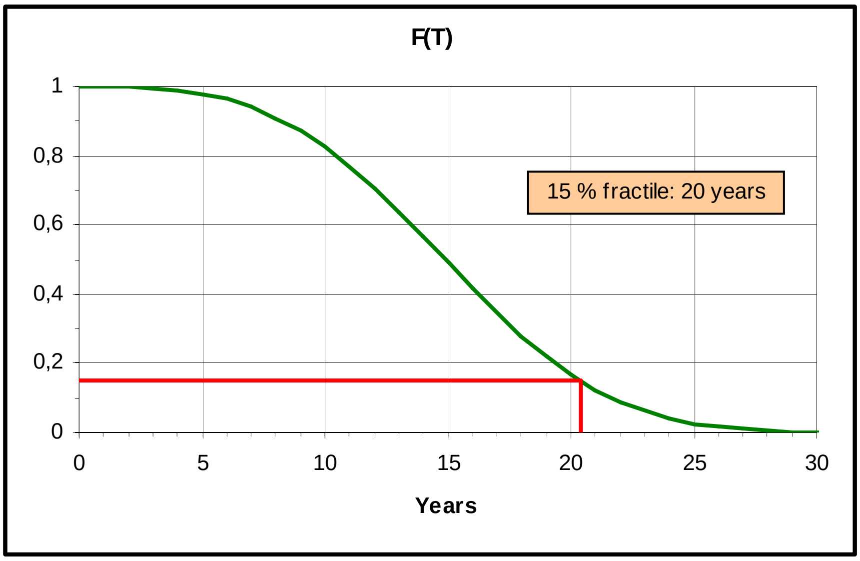
where P_t is the population.

For a specific vintage of cars, the lifetime of these cars is described by a Weibull distribution given by:

$$F(T) = e^{-\left(\left(T-\theta\right)/\lambda\right)^k} \quad \text{and} \quad F(T) = 1 \quad for \; T \leq \theta \quad \text{Eq. (6)}$$

where T is the age of the cars, $F(T)$ is the lifetime function giving the fraction of cars of vintage v still in operation in year t, ($T = t - v$). $\lambda > 0$ (scale along the y-axis), k > 0 (shape) and θ (location along the x-axis) are parameters describing the Weibull distribution. In the calib ration and the model we assume that $\theta = 0$. That is, the model allows for some cars being scrapped in the first year, e.g. due to car accidents.

Figure 2.1 The Weibull function



If we assume that the lifetime function is identical for all vintages, then in year t the remaining stock of a given vintage of cars is given by:

$$S_{v,t} = S_{v,v} \cdot F(t - v) \quad \text{Eq. (7)}$$

where $S_{v,v}$ is the initial stock of vintage v cars. In year t scrapping or end-of-life vehicles of vintage v cars is

$$ELV_{v,t} = S_{v,t-1} - S_{v,t} \quad \text{Eq. (8)}$$

and summing over vintages the total number of ELVs in year t is

$$ELV_t = \sum_v ELV_{v,t} \quad \text{Eq. (9)}$$

Finally, the model is closed by calculating the number of new cars in year t as:

$$S_{t,t} = S_t - S_{t-1} + ELV_t \quad \text{Eq. (10)}$$

That is, the number of new cars in year t is equal to the change in stock of cars from year $t-1$ to year t calculated from Eq. (5) plus replacement of scrapped cars in year t. The above implies the simplifying assumption of zero import and export of old cars. All cars introduced into the stock are new cars and all cars leaving the stock are ELVs. Another characteristic of the model is that the equations intend to describe long-term equilibrium situations. Where annual changes are considered, the observed number of ELVs may differ considerably from that which the model predicts. If e.g. income grows slowly or decreases, the scrapping of old cars may be postponed, thereby maintaining the stock of older cars and changing the age distribution of the stock. At present such effects are not included in the model.

3. Data and estimations

The coefficients of Eq. (1) were estimated using data for the car stock, population and GDP, mainly from Eurostat. The Eurostat data was supplemented by data on the age of cars are from the European Automobile Manufacturers Association (2006). Data on the projected GDP and population from 2005 to 2030 are from the CEC (2005).

The number of passenger cars per 100 inhabitants in EU-15 and EU-10 Member States is shown over time in Figures 3.1 and 3.2 and as a function of GDP per capita in Figures 3.3 and 3.4. Country codes are shown in appendix I.

Figures 3.1 to 3.4 show that there are considerable variations in the car density from one country to another, both in terms of the development over time and the development in GDP per capita. For some countries, there is a slight indication of a saturation level. However, a common saturation level for all countries is difficult to identify.

The Figures 3.1 and 3.2 show that the amount of cars have been steadily increasing since 1970. The figures also show a lower vehicle density in EU-10 Member States than in EU-15 Member States and also differences within the two groupings of Member States. In 2004, Luxembourg had the highest vehicle density with 69 vehicles per 100 capita, followed by Italy with 59 vehicles per 100 capita. Denmark and Greece on the other hand had a vehicle density of 35 and 36 vehicles per 100 capita. Among the 10 new Member States, Malta and Cyprus had the highest density of 53 and 46 vehicles per 100 capita, while Hungary, Latvia and Poland had 28-30 vehicles per 100 capita.

Figure 3.1 Number of passenger cars per 100 inhabitants in EU-15 against time

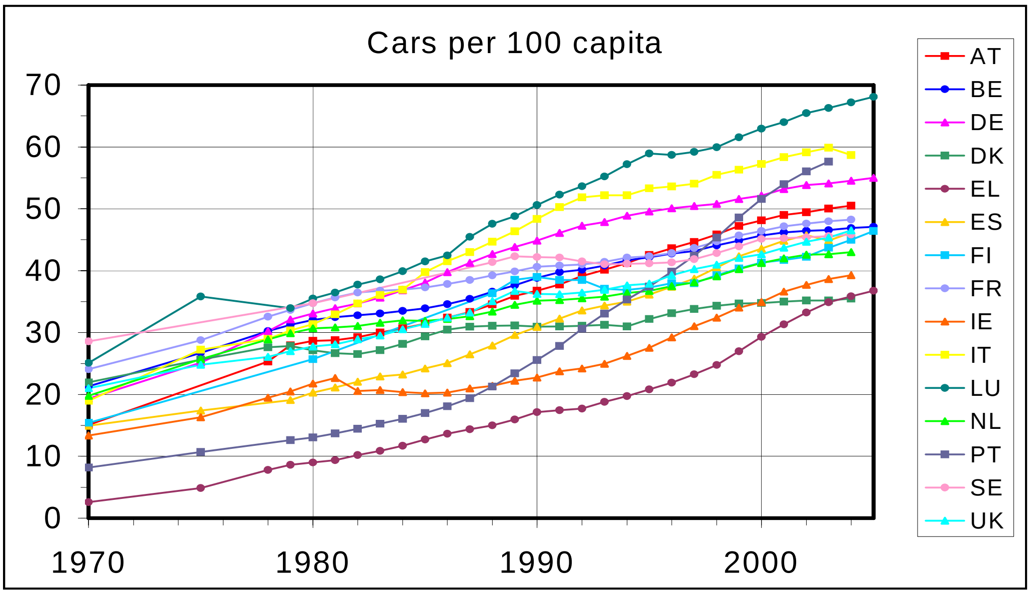
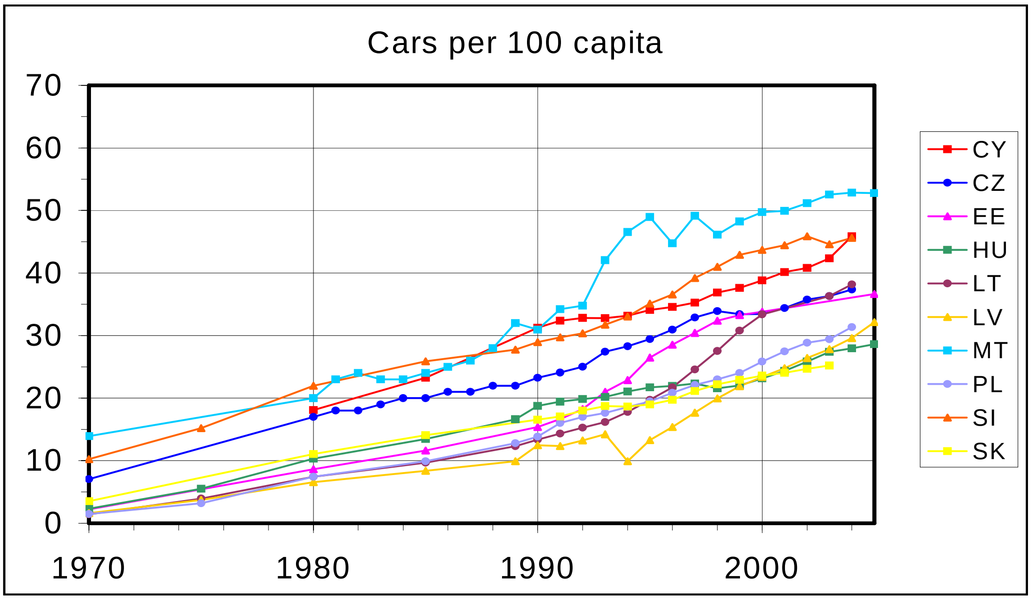


Figure 3.2 Number of passenger cars per 100 inhabitants in EU-10 against time



The relation between car density and GDP per capita is not very clear for the 10 new Member States. For some of these countries, the GDP per capita decreased in the beginning of the sample period without the stock of cars decreasing. This contradicts the assumed relationship and is indicative of the uncertainty characterising short-term model predictions. As discussed previously, the equations in the model are intended to describe long-term equilibrium situations and short term phenomena such as the decrease in per capita GDP mentioned above are not modelled adequately by the long-term specification in Eq. (1).

Figure 3.3 **Number of passenger cars per 100 inhabitants in EU-15 against GDP per capita**

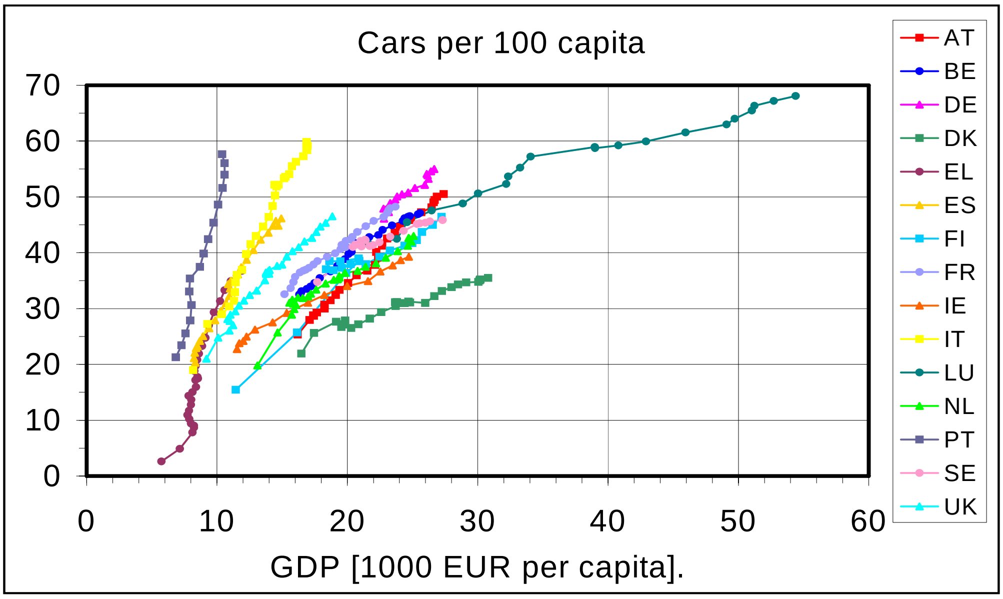
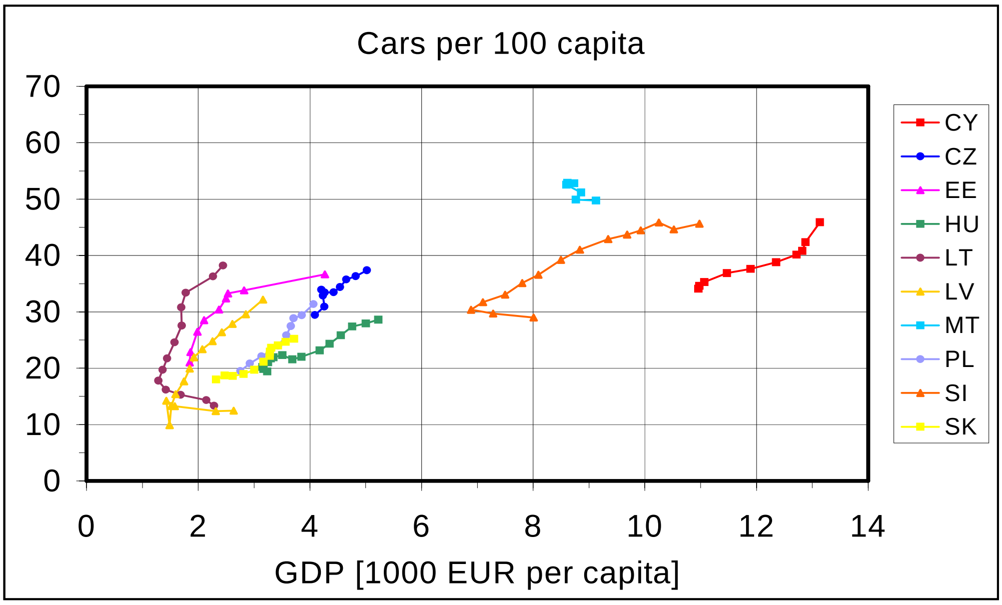


Figure 3.4 **Number of passenger cars per 100 inhabitants in EU-10 against GDP per capita**



Using the data in Figures 3.1 to 3.4, the estimated Gompertz functions in Eq. (1) and (4) are summarised in Table 3.1. In the model, the GDP-dependent Gompertz function in Eq. (1) is used (except for Malta). However, for some countries determining the saturation level is problematic. The estimation strategy used is:

- free estimation of all parameters of Eq. (1)
- γ found by free estimation of the time-dependent Eq. (4) is used in the GDP-dependent Eq. (1) where α and β are then estimated
- γ is fixed to 0.62 - the average estimated by Dargay, J. and Gately, D. (1997), and α and β are estimated conditioned on this γ
- γ is fixed from evaluation of a similar country, and α and β in Eq. (1) are estimated conditioned on this γ

In Table 3.1 the cells marked in yellow are fixed in the estimation (for Portugal the saturation level is taken from the estimation for Italy). As can be seen in the table, for most of the EU-10 Member States the saturation level of the GDP-dependent Gompertz function has been fixed from the time-dependent Gompertz function due to considerable problems. For most EU-15 Member States, free estimation of all parameters in Eq (1) is accepted.

However, in the estimation results for the time-dependent Gompertz function in Eq (4), the saturation level is fixed for six of the EU-15 Member States, and for EU-10 Member States saturation levels are fixed for four countries. Further it is noticed that for Malta, the estimation of the GDP-dependent Gompertz function implies an infeasible positive estimate of β. Very few GDP observations are available for Malta and the time-dependent Gompertz function is therefore chosen for the model.

The average saturation level of the free estimations in the GDP-dependent Gompertz function is 0.64, close to the average of 0.62 estimated by Dargay and Gately (1997). However, for individual countries, saturation levels differ considerably. For EU-15 quite high saturation levels are estimated for the southern part of Europe while the estimated saturation levels are more moderate for the northern part of Europe. For the high saturation levels, e.g. France, the long-term implication is a large share of two-car families. However, given reasonable GDP growth rates, high saturation levels are not met in the near future.

Table 3.1 Estimation results for the Gompertz curves

	GDP-dependent Eq. (1)				Time-dependent Eq. (4)			
	γ	α	β	R^2	γ	α	β	R^2
AT	87.1	-3.989	-0.073	1.00	89.3	-0.633	-0.032	0.99
BE	55.6	-4.654	-0.131	1.00	62.8	-0.331	-0.038	0.99
DE	67.5	-7.343	-0.133	1.00	64.0	-0.197	-0.061	1.00
DK	43.6	-2.171	-0.076	0.97	50.1	-0.375	-0.025	0.95
EL	86.1	-12.729	-0.241	0.87	62.0 1	-0.765	-0.050	0.97
ES	59.3	-5.865	-0.212	0.99	62.0 1	-0.401	-0.051	0.97
FI	46.4	-10.593	-0.196	0.94	48.1	-0.141	-0.069	0.93
FR	94.6	-2.228	-0.051	0.99	58.1	-0.235	-0.042	0.98
IE	51.3	-1.894	-0.077	1.00	62.0 1	-0.629	-0.033	0.87
IT	86.1	-5.799	-0.163	0.99	74.5	-0.259	-0.058	0.99
LU	74.0	-1.835	-0.053	0.99	62.0 1	-0.069	-0.098	0.85
NL	44.2	-9.318	-0.199	0.96	63.5	-0.448	-0.028	0.97
PT	86.1	-11.706	-0.306	0.99	62.0 1	-0.281	-0.098	0.93
SE	50.0	-4.645	-0.150	0.97	50.0	-0.123	-0.050	0.92
UK	54.8	-4.408	-0.170	0.99	62.0 1	-0.379	-0.037	0.98
CY	72.2	-4.791	-0.170	0.98	72.2	-0.602	-0.040	0.97
CZ	79.8	-2.540	-0.243	0.99	79.8	-0.855	-0.032	0.98
EE	70.3	-1.560	-0.238	0.95	70.3	-0.762	-0.059	0.96
HU	62.0 1	-1.968	-0.177	0.99	62.0 1	-0.920	-0.034	0.97
LT	62.0 1	-3.447	-0.852	0.90	62.0 1	-0.679	-0.099	0.98
LV	67.2	-3.192	-0.492	0.92	67.2	-1.076	-0.073	0.96
MT	62.0 1	-0.001	0.571	1.00	62.0 1	-0.250	-0.080	0.92
PL	62.0 1	-3.779	-0.418	1.00	62.0 1	-0.876	-0.050	0.99
SI	50.1	-12.527	-0.462	0.99	50.8	-0.166	-0.149	0.98
SK	44.6	-2.201	-0.358	0.99	44.6	-0.654	-0.042	0.99

Note 1: Average saturation level estimated by Dargay and Gately (1997).

Concerning the lifetime of cars, the Weibull distribution Eq. (6) with $\theta = 0$ is calibrated on data for the age-distribution of cars in 2004 (European Automobile Manufacturers Association 2006), accounting for changes in the car stock and assuming that the lifetime of individual vintages of cars follows the same Weibull distribution. Results of the calibration are summarised in Table 3.2, giving the parameters of the Weibull distribution, the mean lifetime of cars and the implied average age of the car stock in year 2004. The average age is approximately half the mean lifetime of cars, however the average age also depends on the growth of the stock.

Table 3.2 Calibrated parameters of the Weibull distribution

	λ	k	Mean life-time of cars	Average age of car stock in 2004
AT	16.20	3.99	14.7	7.8
BE	13.19	1.92	11.7	7.3
DE	15.12	4.01	13.7	7.4
DK	18.92	3.18	16.9	9.2
EL	20.13	3.00	18.0	7.8
ES	20.13	3.00	18.0	8.9
FI	24.77	2.50	22.0	11.6
FR	16.69	3.21	14.9	8.0
IE	12.01	3.00	10.7	5.5
IT	15.63	2.02	13.9	8.5
LU	13.19	1.92	11.7	6.8
NL	16.06	3.19	14.4	7.7
PT	20.13	3.00	18.0	9.1
SE	19.86	4.80	18.2	9.3
UK	14.40	2.76	12.8	6.9
CY	16.70	3.30	15.0	6.9
CZ	16.70	3.30	15.0	7.9
EE	16.70	3.30	15.0	8.2
HU	16.70	3.30	15.0	7.5
LT	16.70	3.30	15.0	7.1
LV	16.70	3.30	15.0	6.7
MT	16.70	3.30	15.0	8.0
PL	16.70	3.30	15.0	7.1
SI	16.70	3.30	15.0	7.9
SK	16.70	3.30	15.0	7.6

In Table 3.2 the Weibull distribution is calibrated for EU-15 Member States only. Data on the age distribution is not available for the new Member States, and parameters resulting in a mean lifetime of 15 years are assumed to be reasonable. However, as a sensitivity analysis an alternative projection for EU-10 with an assumed mean lifetime of 20 years is included in section 5.

Among the EU-15 Member States, the average age and mean lifetime varies considerably between countries, with a fairly old car stock in Finland and a rather new one in Ireland and Luxembourg.

4. Transport infrastructure and user costs of vehicles

In this paper we have assumed that the car stock per capita depends on the GDP per capita (as a measure for the consumer wealth in the country). However, in reality the consumer's decision whether or not to purchase a passenger car depends on a number of factors, such as the transport infrastructure and available income. Thus, the national saturation levels should relate to national infrastructure characteristics and the steepness (the GDP-elasticity) of the function should relate to user costs of vehicles.

This study, however, does not include a detailed analysis of these factors for the purchase of cars. Instead, we discuss the possible correlation of selected factors on the saturation level and the GDP-elasticity.

As a simple indicator for differences in national infrastructures we have chosen the population density in countries. From a theoretical point of view a good infrastructure and alternative transport means give the possibility to reach saturation at a relatively low stock of vehicles. If population density is high and a relatively large share of the population is concentrated in cities, the possibility for collective transportation and good infrastructure is present. However, population density is an indicator for the possibility – it is not the actual infrastructure characteristics.

As an indicator for user costs we have chosen the fiscal income per vehicle estimated as the fiscal income from motor vehicles divided by the stock of passenger cars.

Table 4.1 shows the saturation levels, and GDP-elasticises fiscal income per vehicle, excise duties on unleaded petrol, and the motor vehicle taxation when buying a new car.

Table 4.1 Saturation levels, GDP-elasticises and indicators

	Saturation level *g*	Population density	*a*	GDP-elasticity h^{max}	Fiscal income from vehicles per vehicle EUR	Excise duties EUR/1000 litres	Motor vehicle taxation % of net price of car
AT	87,1	98	-3,989	1,47	2440	417	30
BE	55,6	34	-4,654	1,71	2460	592	25
DE	67,5	231	-7,343	2,70	1739	655	16
DK	43,6	126	-2,171	0,80	3248	508	155
EL	86,1	84	-12,729	4,68	982	313	59
ES	59,3	85	-5,865	2,16	1350	396	28
FI	46,4	16	-10,593	3,90	3127	588	53
FR	94,6	114	-2,228	0,82	1995	589	20
IE	51,3	58	-1,894	0,70	3142	443	57
IT	86,1	194	-5,799	2,13	1880	564	21
LU	74,0	176	-1,835	0,67	n.a.	442	15
NL	44,2	393	-9,318	3,43	1915	668	57
PT	86,1	114	-11,706	4,31	1055	558	77
SE	50,0	20	-4,645	1,71	2330	366	25
UK	54,8	244	-4,408	1,62	2372	682	18
CY	72,2	81	-4,791	1,76		305	35
CZ	79,8	130	-2,540	0,93		400	19
EE	70,3	30	-1,560	0,57		288	18
HU	62,0	109	-1,968	0,72		413	44
LT	62,0	53	-3,447	1,27		287	18
LV	67,2	36	-3,192	1,17		276	20
MT	62,0	1275	-0,001	0,00		474	93
PL	62,0	122	-3,779	1,39		356	25
SI	50,1	99	-12,527	4,61		360	29
SK	44,6	110	-2,201	0,81		398	19

Source: Total fiscal income from motor vehicles and motor vehicle taxation: ACEA (2007), excise duties on unleaded petrol: ACEA (2006)

For some EU-15 Member States, a negative correlation may be observed when comparing population density and the estimated saturation level. For example, the Netherlands has a

high population density and a low saturation level and France has a low population density and a relatively high saturation level. However, other countries such as Austria has a high saturation level and a relatively low population density. This is shown in Figure 4.1.
For the EU-10 Member States a negative correlation is difficult to find in Figure 4.2. That is, in some cases a negative correlation may be observed, however, the population density is a poor indicator for infrastructure characteristics, indicating the possibility for a good public transportation system, but not whether the actual transport system is developed or not.

Figure 4.1 Saturation level and population density in EU-15

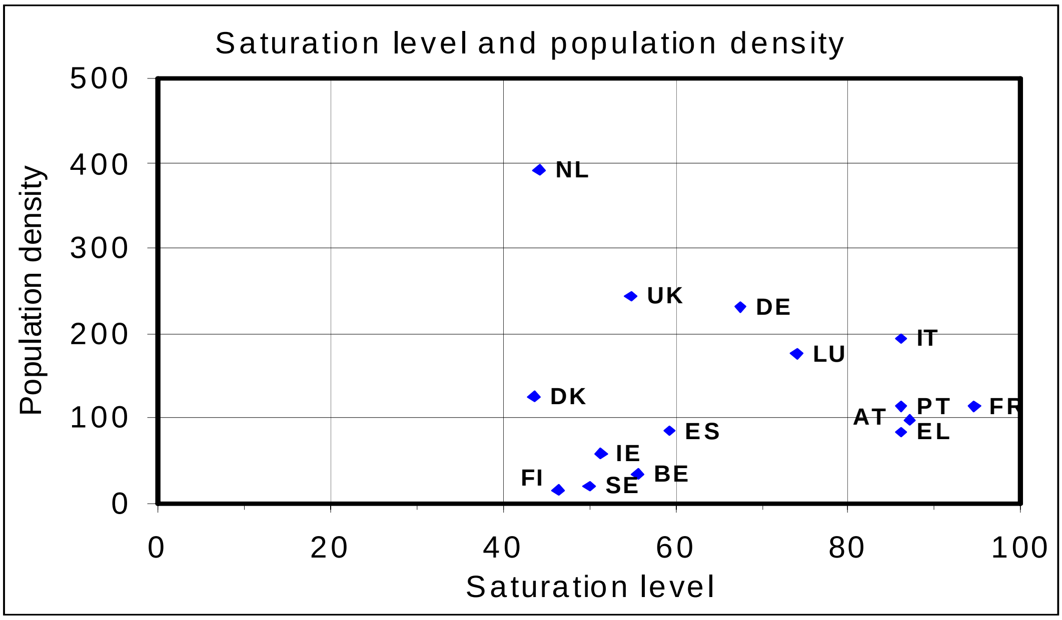
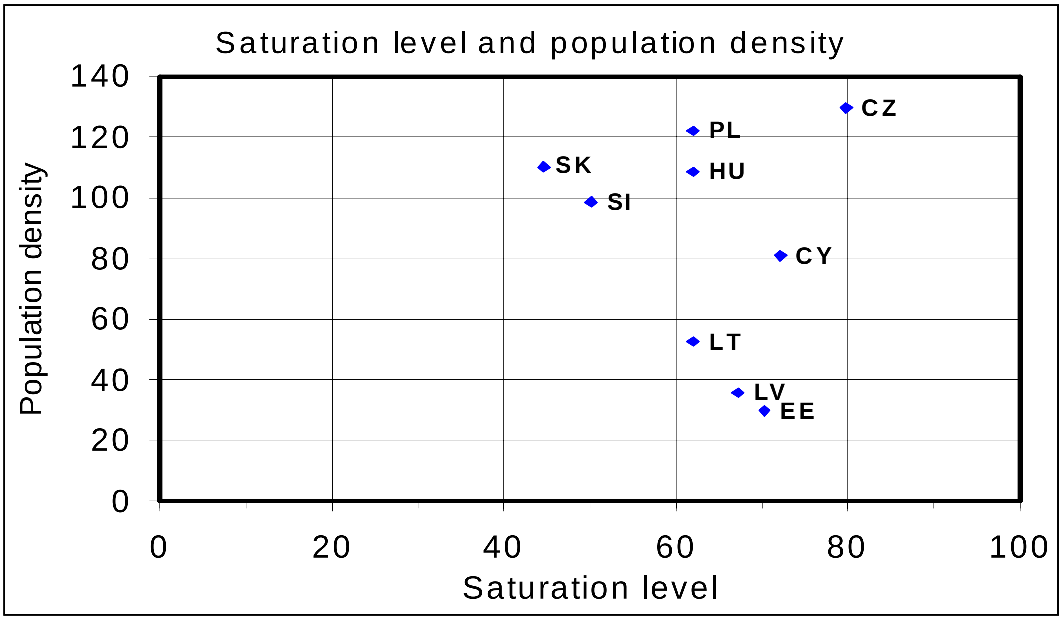


Figure 4.2 Saturation level and population density in EU-10

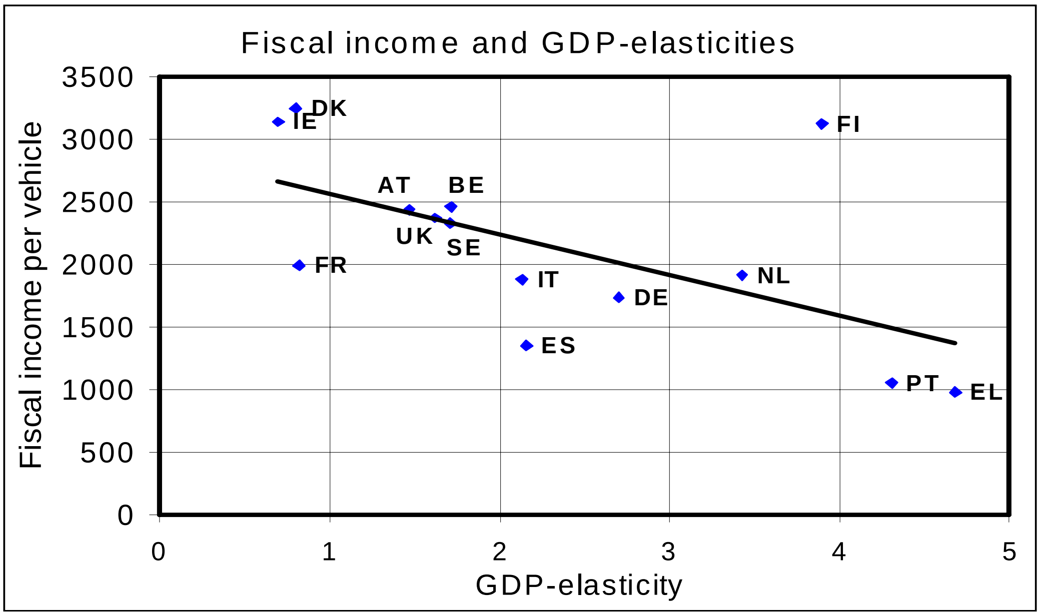


The user costs and GDP-elasticises in Figure 4.3 show the relation between fiscal income and the estimated GDP-elasticity for the EU-15 Member States. If user costs are high, the GDP-elasticity is expected to be low. That is, to obtain the same change in the stock of vehicles high user costs are expected to require a larger increase in GDP than if user costs are low (here high fiscal income from vehicles is used as an indicator for high user costs, assuming that user costs net of taxes are almost equal in all the countries).

Except for Finland, the expected negative correlation between user costs (fiscal income) and the GDP-elasticity is observed for the EU-15 Member States. For EU-10 countries data on the fiscal income from vehicles is not available; only taxes on fuels and the % tax-rate on purchase of vehicles are available, and none of these indicators give a reasonable relation to the estimated GDP-elasticises.

Concluding, for EU-15 a negative correlation between user costs and the estimated GDP-elasticity is in general observed. For EU-10 countries data to confirm this relation is not available.

Figure 4.3 Fiscal income from vehicles and GDP-elasticities in EU-15



5. Projections and sensitivity analyses

To generate projections, the model requires data for the development of the population and the GDP for the projection period, 2005-2030. The data applied in the present ELV projection model is an EU energy and transport baseline scenario to 2030 developed for the DG TREN (EC 2006). This baseline scenario represents current trends and policies as implemented in the Member States up to the end of 2004, and is summarised in Table 5.1.

Table 5.1. Key demographic and economic assumptions

	2005	2010	2020	2030
EU-25				
Population (Million)	461.2	466.9	472.2	472.4
GDP [1]	8 658.8	9 555.1	11 867.3	13 897.7
EU-15				
Population (Million)	387.1	393.6	400.4	401.8
GDP [1]	8 310.3	9 131.7	11 245.0	13 065.0
EU-10				
Population (Million)	74.1	73.4	71.8	70.6
GDP [1]	348.5	423.4	622.4	832.7

1 Billion EUR in 1995-prices. Data calculated from EC (2006).

From 2005 to 2030 population in the EU-25 is expected to increase by 11.2 million persons, composed of an increase in the EU-15 of 14.7 million and a decrease in the EU-10 of 3.5 million persons. In the same period, GDP in constant prices is expected to increase on average by 1.8% p.a. in EU-15 and by 3.5% p.a. in EU-10, thereby narrowing the gap in GDP per capita between EU-15 and EU-10 Member States. However, in 2030 GDP per capita in the EU-15 is still expected to be about twice as high as the GDP per capita in the EU-10.

With the demographic and economic assumptions in Table 5.1, both the car stock and the number of ELVs increase considerably in all 25 Member States, however, due to the approaching saturation level, the increase will be less than the growth in GDP.

The past and projected development in car density is shown in Figures 5.1 and 5.2. The average car density increases from 0.47 in 2005 to 0.62 in 2030. However, what is noticed from Figures 5.1 and 5.2 is that the difference between EU-15 and EU-10 diminishes and the density approaches a saturation level.

Figure 5.1 Projected development in the car density against time

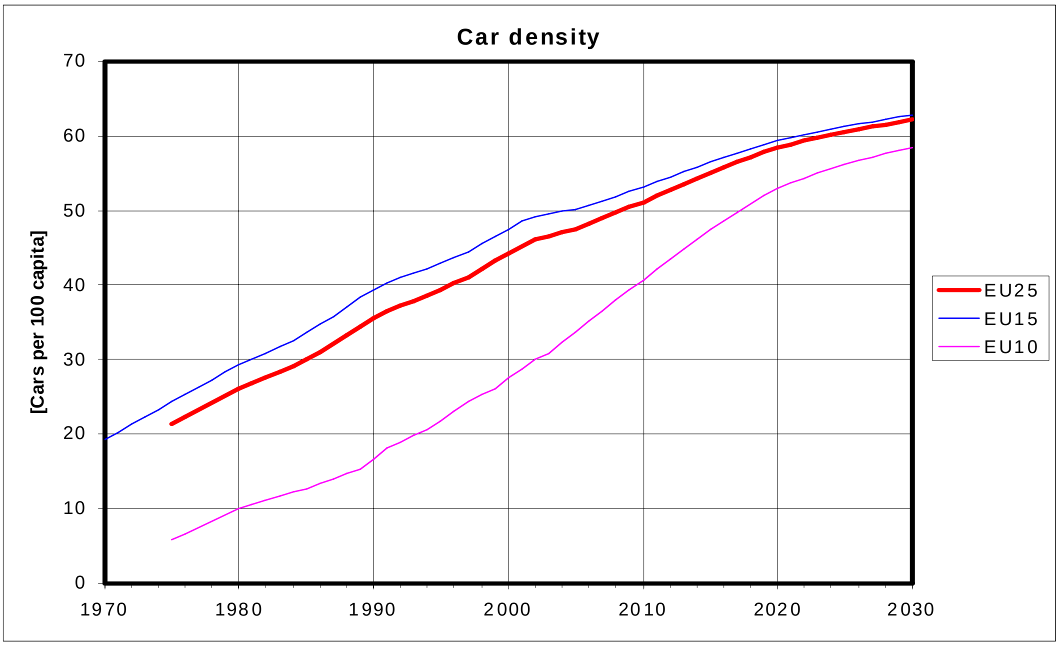
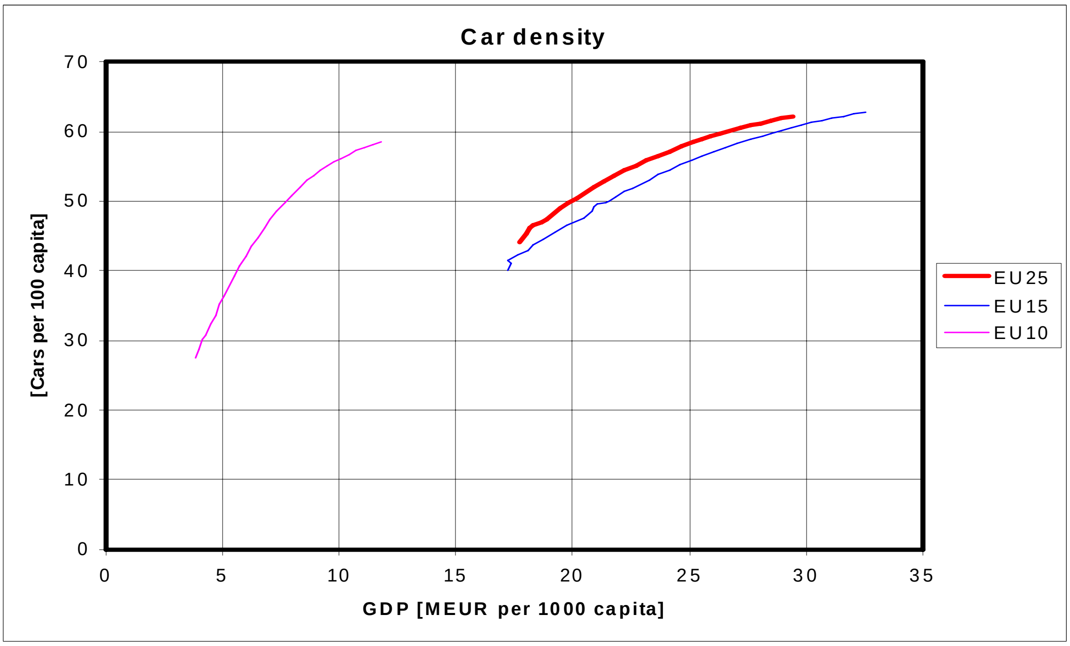
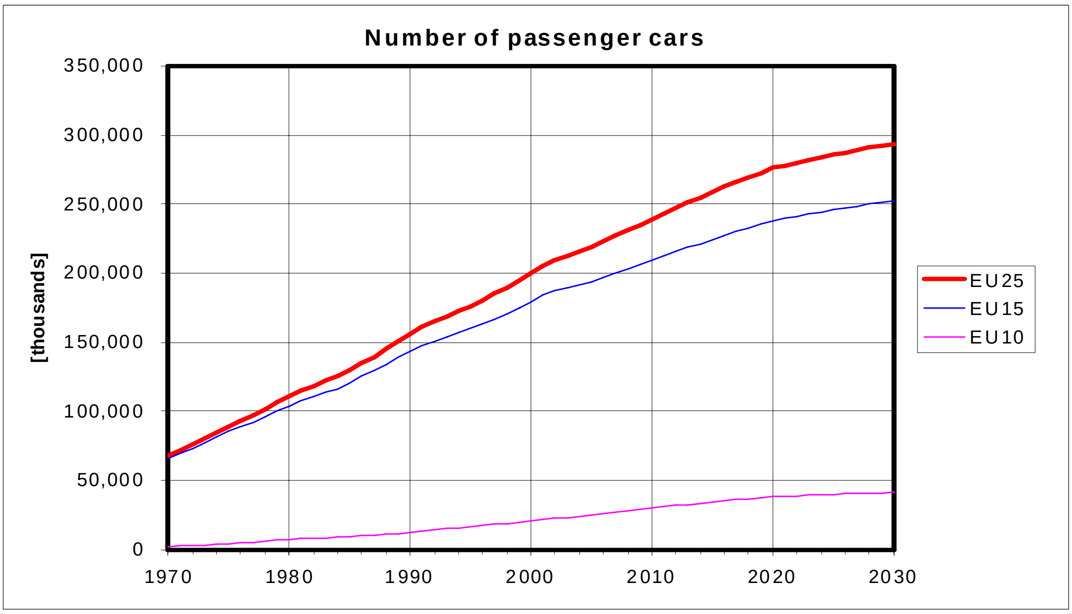


Figure 5.2 Projected development in the car density against GDP per capita



The development in the stock of cars that is projected on the basis of the car density is shown in Figure 5.3 and the projected quantities are presented in Table 5.2. On average, the stock of cars increases by 1.2% p.a. (1.1% p.a. for EU-15 and 2.0% p.a. for EU-10), compared to a GDP-growth of 1.9% p.a. (1.8% p.a. for EU-15 and 3.5% p.a. for EU-10) indicating a beginning slight decoupling between the car stock and economic growth.

Figure 5.3 The projected development in the stock of cars



As shown in Table 5.2, the projected stock of passenger cars is expected to increase by around 75 million cars over a 25-year period in the EU-25. This is based on the assumption that the current trends will continue and that no major changes in transport technology and taxation regulation will occur.

Table 5.2 Stock of passenger cars: actual stock (1995-2000) and projected (2005-2030)

thousands	1995	2000	2005	2010	2020	2030
EU-25	176 034	199 692	218 896	238 773	275 942	293 710
EU-15	159 680	179 103	193 945	208 886	237 908	252 402
EU-10	16 354	20 589	24 951	29 887	38 034	41 309

Source: Data for 1995 and 2000 are from Eurostat

Finally, the projected development in the number of ELVs is shown in Figure 11 and projected quantities are given in Table 5.3. Figure 5.4 also includes an alternative projection where the lifetime of cars in the EU-10 is assumed to be 20 years. In the figure a time lag is apparent between the development in the stock of cars and the number of ELVs. The slower increase in the stock after 2020 is only partly observed in ELVs after 2025.

On average the number of ELVs are expected to increase by 1.6% p.a. (1.4% p.a. for EU-15 and 3.1% p.a. for EU-10), an increase comparable to the GDP- growth of 1.9% p.a. In total, an additional 6 million ELVs need to be managed in 2030 compared to 2005. This is equal to an increase of 50% over the 25 year-period.

Comparing the baseline and the alternative projection, an increase of the lifetime of cars in the EU-10 reduces the number of ELVs in 2030 by app. 25%. However in relation to the number of ELVs from the EU-25 the reduction is minor.

Figure 5.4 Projected development in the number of ELVs

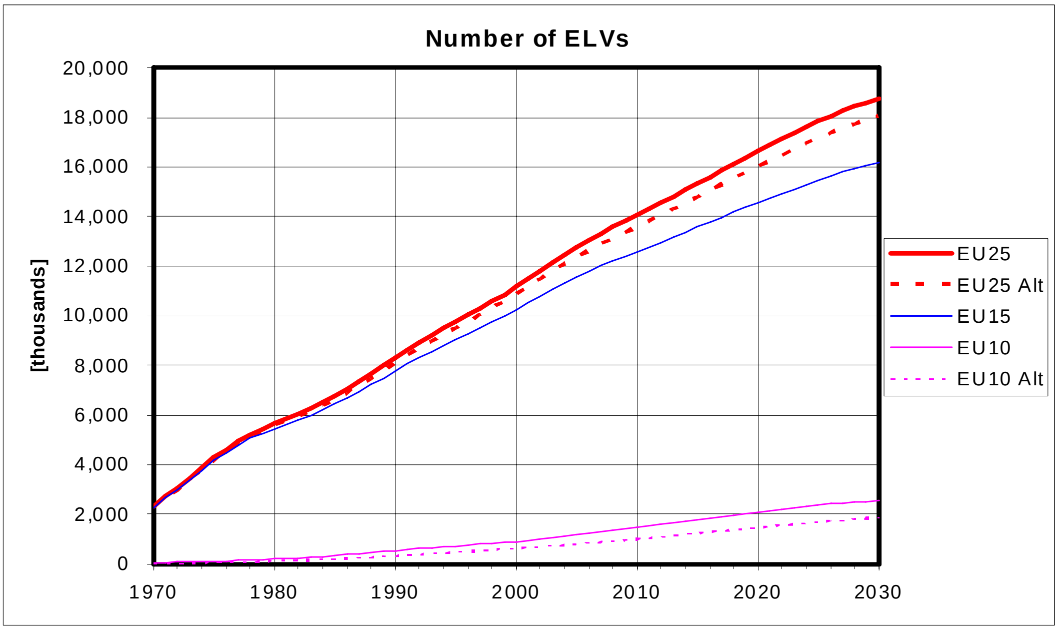


Table 5.3 Number of ELVs, 2005 – 2030

Thousand	2005	2010	2015	2020	2030
EU-25	12 770	14 077	15 347	16 642	18 756
EU-25 Alt	12 385	13 599	n.a.	16 032	18 077
EU-15	11 583	12 595	13 579	14 565	16 206
EU-10	1 187	1 482	1 767	2 077	2 550
EU-10 Alt	802	1 004	n.a.	1 467	1 871

Another model uncertainty is the estimated of saturation level. The estimated saturation levels for Cyprus, the Czech Republic, Estonia and Latvia appear relatively high. Thus, in Table 7 the saturation level is fixed at 62% for these four countries. This corresponds to the estimate by Dargay and Gately (1997) .

Compared to the estimations in Table 3.1, the statistical fit is almost identical and the maximum GDP-elasticity is slightly larger in the new estimates.

Table 5.4 Alternative estimation results for the Gompertz curves

GDP dependent Eq. (1)						
	γ	α	β	R^2		GDP-elasticity
CY	62.0	-6.843	-0.223	0.98		2.52
CZ	62.0	-2.876	-0.350	0.99		1.06
EE	62.0	-1.525	-0.294	0.96		0.56
HU	62.0	-1.968	-0.177	0.99		0.72
LT	62.0	-3.447	-0.852	0.90		1.27
LV	62.0	-3.240	-0.536	0.93		1.19
MT	62.0	-0.001	0.571	1.00		0.00
PL	62.0	-3.779	-0.418	1.00		1.39
SI	50.1	-12.527	-0.462	0.99		4.61
SK	44.6	-2.201	-0.358	0.99		0.81

Figure 5.5 and Table 5.5 show the baseline and alternative development in ELVs for the EU-10 till 2030. The figure shows two scenarios for alternative development: the 62% saturation level for the four EU-10 Member States and an alternative lifetime of 20 years for cars.

Based on from the figures, a change in the saturation level for the four EU-10 states changes the projection marginally, only. The lower long-run saturation level is counter-balanced by the slightly larger GDP-elasticities, giving almost the same number of ELVs in 2030. In the very long-term, restricting the saturation level use reduces the number of ELVs.

Figure 5.5 Projected development in the number of ELVs for EU-10, compar ing the baseline projection, alternative saturation level and alternative lifetime projections

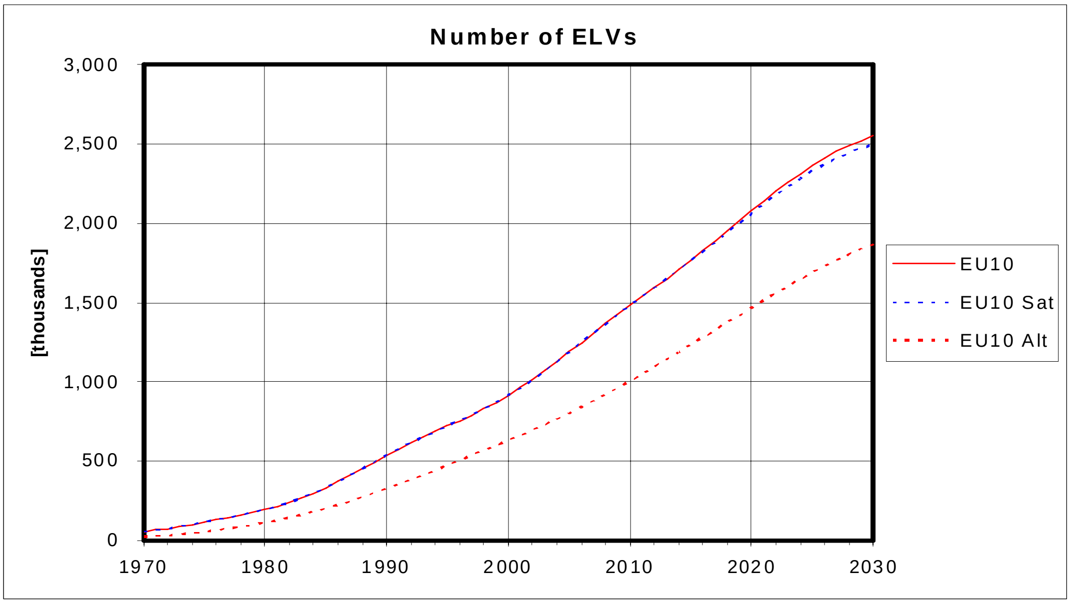


Table 5.5 Number of ELVs, 2005 – 2030, baseline projection and alternative saturation levels

Thousand	2005	2010	2020	2030
EU-25	12 770	14 077	16 642	18 756
EU-25 Sat 62%	12 770	14 077	16 627	18 704
EU-15	11 583	12 595	14 565	16 206
EU-10	1 187	1 482	2 077	2 550
EU-10 Sat 62%	1 187	1 481	2 063	2 498

6. European policy on end-of-life vehicles

6.1. Directive on end-of-life vehicles

The overall reasons for introducing the ELV directive are that the different national measures concerning end-of life vehicles should be harmonised in order to minimise the impact of end-of life vehicles on the environment, and to ensure the smooth operation of the internal market and avoid distortions of competition in the Community (Directive 2000/53/EC).
In November 1996 the European Parliament called on the Commission to legislate on end-of-life vehicles, among other waste streams, on the basis of product liability (scadplus). Later, in 1997, the European Commission adopted a proposal for a Directive.

The Directive 2000/53/EC on end-of-life vehicles was adopted on 18 September 2000 and by 21 April 2002 Member States should have transposed the Directive into national regulation. As of 1 July 2002, the directive applied for vehicles[4] put on the market from this date, and as of 1 January 2007 it also applied for vehicles put on the market before 1 July 2002.

The Directive aims at preventing waste from vehicles, increasing the recovery and reuse of end-of-life vehicles and their components, and at improving the environmental performance of the economic operators involved in end-of-life vehicles. This will require that the manufacturers of vehicles, materials and equipment design and produce vehicles which facilitate the dismantling, reuse, recovery and recycling of ELVs.

The directive aims at making vehicle dismantling and recycling more environmentally friendly, it sets quantified targets for reuse, recycling and recovery of vehicles and their components and pushes producers to manufacture new vehicles also with a view to their recyclability.

Prevention in the ELV directive refers to the limitation or elimination of hazardous substances in vehicles and to increased reuse and recovery. Thus, the directive does not aim to limit the number of ELVs.

The Directive also includes provisions for the collection of ELVs through producer responsibility systems. Member States must ensure that ELVs are transferred to an authorised treatment facility and to set up a system for a certificate of destruction. Such a certificate will be issued to the holder/owner of the vehicle when it is transferred to an authorised treatment facility free of charge. The certificate is a condition for deregistration of the vehicle.

The Directive sets targets for reuse, recovery and recycling of vehicles. Thus, Member States are to take measures to ensure that the economic operators meet the targets in Table 6.1.

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[4] The Directive specifies the types of vehicles covered by the scope in Article 3.

Table 6.1. Directive on end-of-life vehicles: targets

	Rate of reuse and recovery	Rate of reuse and recycling
By average weight per vehicle and year in 2006	85%	80%
By average weight per vehicle and year in 2015	95%	85%

Source: Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of-life vehicles

Every three years Member States are to report to the European Commission on the implementation of the ELV directive, and based on this information the European Commission is to publish a report on the subject. The Commission has recently published the first report (EC 2007a).

In the next section we compare the reported data on the number of ELVs with the estimated values from the ELV projection model.

6.2. Comparison of data and projections

6.2.1. Comparison of the reported data by Member States and the estimated data

The report from the Commission covers the first reporting period from 1 April 2002 to 21 April 2005 for the EU-15, and from 1 May 2004 to 1 May 2005 for the 10 new Member States (EC 2007a and 2007b).

Of the EU-15 Member States six have reported data for all the three years, one has reported data for two years and three Member States have reported data for one year. Two of the new Member States have reported data for 2004, EC (2007b). Based on these data for few countries and very short time-series we compare the reported and the estimated data for 2002-2004 in Figure 6.1[5]. Only countries that reported data for two and three years are shown.

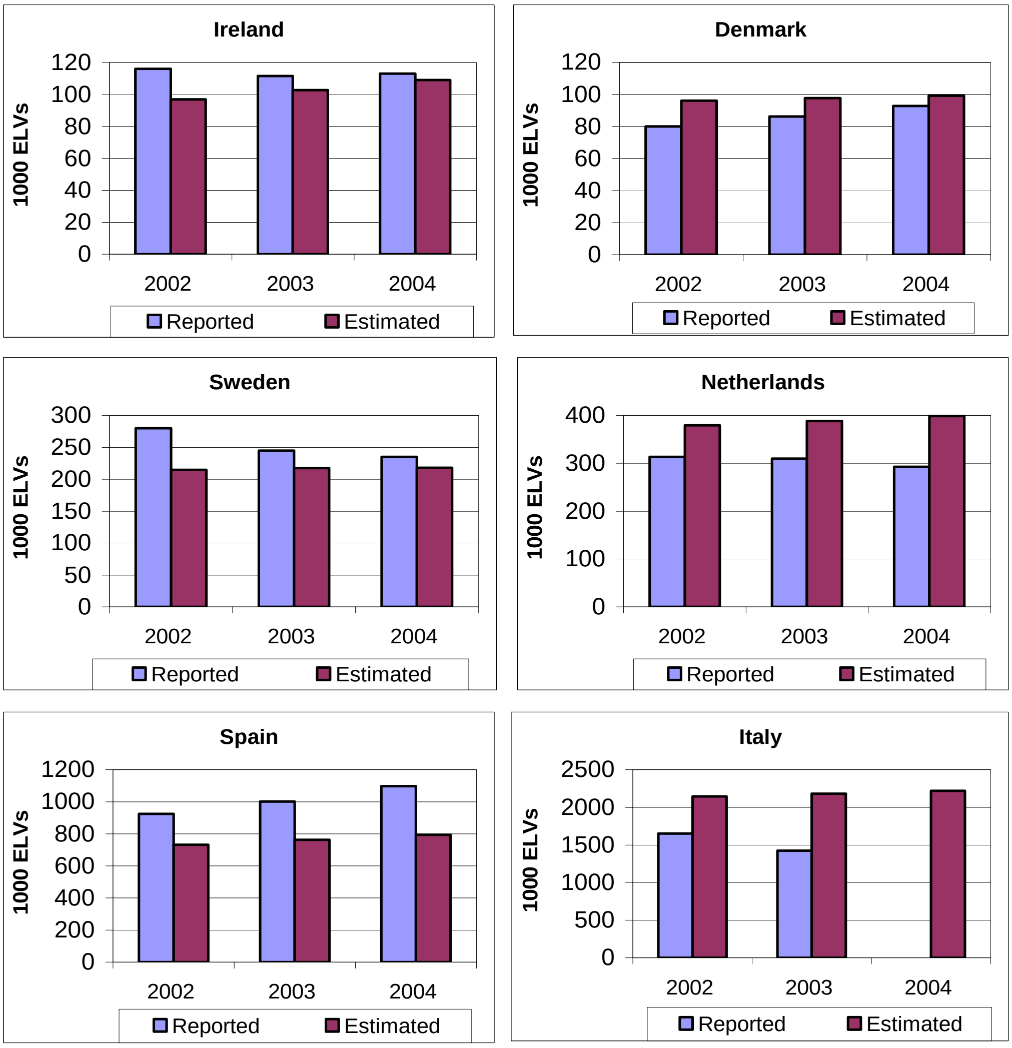
The data reported by Member States are the number of vehicles *collected* and transferred to authorised treatment facilities. In comparison, the data estimated by the ELV projection model are the *generated* ELVs. Thus, would be reasonable if the estimated data are higher than the reported ones as it would mean that the collection rate is less than 100%.

For Denmark, the Netherlands and Italy the estimated amounts of ELVs are higher than the reported (collected) amounts whereas the opposite is true for Ireland, Sweden and Spain. The estimates that are closest to the actual collected amount of ELVs seem to be the ones for Denmark (~ -10%), Ireland (~ +10%), Sweden (~ +15%) and possibly the Netherlands (~ -20%). The estimated and reported figures for Spain and Italy deviate with around 30%.

Luxembourg reports a relatively low number of collected ELVs both measured per capita and considering the fact that Luxembourg has the highest density of cars.

[5] Portugal has reported a very low number of ELVs (83-5185) which is why the figures are not presented. Luxembourg also reports a relatively low number of collected ELVs (4400-4800).

Figure 6.1 Comparison of the reported and estimated number of ELVs



Source: The reported data are from EC (2007b)

The difference between the reported and the estimated figures may depend on several factors. In calculating the stock of cars, we have assumed the life time of cars in a country to be constant throughout the estimation period. The Gompertz function used for calculating the stock of cars, estimates the long-term stock of cars rather than the short-term shown in Figure 6.1. Also, model is calibrated on the basis of the age distribution of cars in one year (2004). Export and import of used cars are not included in the model either. Finally, data shown in Figure 6.2 are from the first reporting made on the ELV Directive, and perhaps not all arisings of ELVs may have been collected in the first three years or the a data reporting system for ELVs is not yet fully implemented. The latter should result in more ELVs than actually reported.

6.2.2. Comparison of the projection of ELVs

As part of the preparation for the Commission's report, a study was undertaken by GHK and BIO Intelligence Service (2006). The report's Annex 2 estimates the number of ELVs in 2004 and projects the development till 2015.

According to the European Automobile Manufacturerer's Association, ACEA, 11.3 million vehicles were deregistrated in the EU-15 in 2004. Figures for the EU-10 are estmated under the assumption that 5.3% of the current vehicle stock is deregistrated every year. The estimated figure for the EU-10 is 1.3 million vehicles, but this figure may include some double counting if vehicles are deregistrated in the EU-15 and then exported to the new Member States.

In total, the export to countries outside the EU was 995 000 vehicles while the export to other Member States was 2 068 000 vehicles[6]. To take these exports into account, GHK and BIO Intelligence Service uses a midpoint estimate of a maximum and minimum estimate of ELVs requiring treatment in the EU:

Minimum estimate:	Deregistrated no of ELVs in EU-25 – ELVs exported to other Member States – ELVs exported to countries outside the EU
Maximum estimate:	Deregistrated no of ELVs in EU-25 – ELVs exported to countries outside the EU

The midpoint estmate of ELVs requiring treatment in the EU is 10.6 million.

Then, the report uses the annual growth rate in vehicle stock in the EU-15 (for the period 1995 to 2002) of 2.4% p.a. to project the number of ELVs for the period 2005-2015.

GHK and BIO Intelligence Service (2006) estimates that 13.8 million number of ELVs will require treatment in the EU in 2015. In comparison, the ELV model presented in this paper estimates that 15.3 million ELVs will arise in 2015, which is approximately 11% higher. The main reason for the difference is the export of used cars which has been subtracted in the GHK and BIO Intelligence Service figure.

6.2.3. Projected waste quantities from ELVs

GHK and BIO Intelligence Service (2006) also estimates the weight of ELVs. They estimate that the average weight per vehicle in 2015 is 1025 kg[7]. Using this figure, and deducting 2 million used cars as net exports, the projected waste quantity from ELVs is likely to be around 14 million tonnes in 2015.

In a report from the European Commission on targets for 2015, they indicate that the weighted averages for all car manufacturers show that an ELV will weigh around 1280 kg in 2019, (EC 2007c). Using this figure and deducting net exports again, the projected waste quantity from ELVs is likely to be around 3 million tonnes higher in 2015, i.e. 17 million tonnes.

The environmental impact from the management of the ELVs is presented in EC (2007d).

6.2.4. Recycling and recovery rates in 2004

The recycling and reuse and the recovery and reuse rates for 2004 reported by 10 Member States are shown in Table 6.2. All the countries have a recovery and reuse above 75% whereas the recycling and reuse rate is very low, around 2%. Sweden, Denmark and the Netherlands have almost met the 85% recovery target for 2006.

[6] The net export of vehicles from the 15 old to the 12 new Member States was 620 000 vehicles per year.

[7] Examples of estimates are presented: in the UK the average vehicle weight was expected to increase from 1025 kg in 1997 to 1030 kg in 2000; in the Netherlands from 911 kg in 2003 to 915 kg in 2004; and in Germany from 910 kg in 1985 to 1000 kg in 2000, GHK and BIO Intelligence Service (2006).

Table 6.2 Recycling and recovery rates in 2004

In per cent	Recycling and Reuse	Recovery and reuse	Other forms of disposal
Austria	77.5	0.5	22
Belgium, Flemish region	80	1	19
Belgium, Walloon region	80	1	19
Denmark	83	2	15
Germany	77	3	20
Lithuania	76	3	21
The Netherlands	83	2	15
Slovenia	75	5	20
Spain	75	2	23
Sweden	84	1	15
United Kingdom	79	2	19

Source: EC (2007b).

Cars comprise a host of materials such as ferrous metals, plastics, glass, tyres, batteries etc. and the environmental effects will depend on how each of these materials are reused, recycled and recovered. Thus, if the projections should be extended to include the environmental effects from the management of ELVs, detailed information on quantity of the various materials in used cars and the management of it is necessary.

GHK and BIO Intelligence Service (2006) includes case studies for a number of countries where some information on the composition of cars and the recycling of the various materials and components can be identifed. However, as no complete information for all EU Member States exists, a series of assumptions would have to be made.

7. Final remarks

The model presented in this paper is a simple approach to quantifying long-term average developments in the number of end-of-life vehicles (ELVs). Annual changes in the level of ELVs may differ considerably from what the model calculates e.g. due to postponing scrapping of cars/improved maintaining of older cars when GDP decreases.

In addition, the simplifying assumption of zero import and export of older cars implies that observed national numbers of ELVs may be different from those projected by the model.

Moreover, the model does not explicitly take into account inter-country variations in the costs of vehicles to users. However, reflecting different transport infrastructures and partly different user costs, the model accounts for national differences in the saturation level and income/GDP elasticity.

Further, the model allows different lifetime functions in different countries, that is, different mean lifetime of cars and average age of the car stock. The data and estimations reveal considerable national differences in the car density, the saturation level and the average age of the car stock.

Using a baseline projection of demographic and economic development until 2030, the model calculates a slower growth in the stock of cars than in GDP, but the number of ELVs increases approximately proportionately to GDP. A beginning saturation in the stock of cars is not transformed to a slower increase in ELVs until after 2025. That is, there is a delay between a saturation of the stock of cars and the corresponding saturation in the number of ELVs. Finally, for EU-25 Member States, the number of ELVs that have to be managed in 2030 is projected to increase by around 50% or 6 million ELVs relative to 2005.

Alternative assumptions related to the saturation level and lifetime for vehicles in EU-10 countries change the total number of ELVs in 2030 marginally, only.

GHK and BIO Intelligence Service (2006) showed that export of used cars and light commercial vehicles reduces the estimated number of ELVs by some 2 million. This means that the export is important for the projections and if the model is to be improved, this would be an issue to study further.

The model for the stock of cars and the ELVs may also be used to estimate other waste streams such as used tyres and car batteries. This would require assumptions on the frequency of changing tyres, average weight of tyres among other things.

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I. Appendix: Country codes

Country codes for EU-15 and EU-10

EU-15		EU-10	
AT	Austria	CY	Cyprus
BE	Belgium	CZ	Czech Republic
DE	Germany	EE	Estonia
DK	Denmark	HU	Hungary
EL	Greece	LT	Lithuania
ES	Spain	LV	Latvia
FI	Finland	MT	Malta
FR	France	PL	Poland
IE	Ireland	SI	Slovenia
IT	Italy	SK	Slovakia
LU	Luxembourg		
NL	The Netherlands		
PT	Portugal		
SE	Sweden		
UK	United Kingdom		