# Historic vehicles
## an overview from a transport policy perspective

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# Historic vehicles: an overview from a transport policy perspective

***Abstract:***

Historic vehicles are the heritage of road transport that have surprisingly received little attention in the academic literature. This study presents an overview of the literature on historic vehicles, focussing on the three topics that dominate the policy debate on transport: environmental, safety, and congestion impacts. We observed that polluting emissions of HVs are per kilometre much higher (often a factor 5 or more) than those of moderns vehicles. The annual average mileage per vehicle per year of historic vehicles is much lower than other vehicles. The lower active and passive safety levels of historic vehicles are compensated by the way these vehicles are driven, resulting in the risk factors per kilometre being roughly equal or lower. The contribution of historic vehicles to congestion is negligible. However, the transport policy discourse is divided on the topic of historic vehicles. More comprehensive and effective laws and regulation are needed to protect this aspect of the heritage of road transport whilst concurrently avoiding or limiting the problems caused by them.

Keywords: Historic vehicles, policy, safety, environment, congestion, noise



## 1. Introduction

Historic vehicles (HVs[1]) are the heritage of road transport. They represent the origins of (motorized) vehicles and show society how far (motorized) vehicles have evolved since their inception in the nineteenth century.

HVs not only convey cultural heritage, but also enjoy large and diverse support from enthusiasts within the HV movement (Tam-Scott, 2009). HVs have a modest beneficial economic impact by creating revenues for various private businesses and providing jobs (Frost & Hart, 2006). Furthermore, HVs play a noticeable and symbolic role in social gatherings (e.g. wedding ceremonies) and monumental events (e.g. national days).

However, the significantly higher air pollution emissions of older vehicles (Zachariadis, Ntziachristos, & Samaras, 2001) and lower safety records (Robertson, 1981) compared with modern vehicles may compel policy makers to take action against the use of HVs which may threaten their future existence. The increasingly higher penetration of vehicles with relatively low emissions (for instance internal combustion engine vehicles, electric and hybrid vehicles) increases the relative share of emissions of HVs[2]. Therefore, from a policy perspective HVs are an interesting category of vehicles.

Nevertheless, there is hardly any research into HVs by scholars (Koshar, 2004), and only sporadic attention from interest groups. The Fédération Internationale des Véhicules Anciens (FIVA) is one of the main organisations that has contributed to publishing reports (in collaboration with the University of Brighton) mainly on the economic and cultural aspects of HVs and related events (Frost

[1] Throughout this report we abbreviate historic vehicles as HVs and historic vehicle as HV.

[2] Here we would like to emphasise that there is a clear difference between the problems and benefits of HVs that relate to the period of production, and the problems or benefits caused by the ageing effects of modern vehicles, used as a regular means of transport . The first problems and benefits relate to the specific characteristics of the vehicles, regardless of their age, such as design and technologies used (and implications for environmental pressure and safety). The second problems and benefits relate to the ageing of the vehicles. Zachariadis et al. (2001) and Faiz et al. (1995) discuss that as the age of the modern vehicle increases their emissions also increase, which requires inspection and maintenance programmes put in place by individual countries.

& Hart, 2006; Frost, Hart, & Kaminski, 2011; Kaminski, Smith, & Frost, 2013a), whereas some academic publications have looked at peripheral aspects of historic vehicles. These HV-related studies cover a variety of topics such as the historic development of the car culture, the technological and design development of cars and the evolution of consumer demand and manufacturers' response in shaping consumer expectations (Foster, 2003; Gartman, 1994; Koshar, 2004; Schafer & Victor, 1997). Other studies have focused on the environmental impact of scrapping old cars (see Van Wee, De Jong, & Nijland, 2011 for a review of the literature).

Finally, some studies have focused on classic car enthusiasts (Dannefer, 1980; Tam-Scott, 2009). Delyser and Greenstein (2015), two HV enthusiasts themselves, follow a classic car from being abandoned to becoming a fully restored car, while theorise on the processes of restoring a classic car.

The fact that in academic research little attention has been paid to HVs does not reflect their societal and policy relevance. In addition, due to the increasing numbers of historic vehicles, the topic will become more important in the future. Given this background, the aim of this paper is to reduce the gap in academic literature on HVs by focussing on three important research questions: 1) What information on HV ownership and use is available from reliable sources?, 2) what is the relative and absolute impact of HVs to environmental, safety and congestion problems (three areas that heavily dominate the policy debate on transport)? and 3) What are the contributions of HVs to the economy and society?

We answer these questions by studying available material including the academic literature, policy documents and government reports, plus exploring available data sources. We include these policy reports and explore databases because of the scarcity of academic studies in this area. Note that some of the studies published in non-academic literature were written by scholars. The sources in some cases only provide information for passenger cars, not for other vehicles. We have made this explicit throughout the study.

In section 2 we provide definitions for HVs, and discuss trends in the supply of HVs, and the relevant policy discourse. Our methodology in gathering the material for this overview study is described in section 3. HV ownership and use in several countries is discussed in sections 4 and 5 respectively. The environmental, safety and congestion impacts are discussed in sections 6 to 8, followed by the social appeal and economic effects of HVs in section 9. Section 10 offers a concluding discussion and future research perspectives.

## 2. Definition of HVs, trends in supply and demand, and the policy discourse on HVs

### 2.1. Definition

According to FIVA, historic vehicles are "mechanically propelled road vehicles which are:
- at least 30 years old;
- preserved and maintained in a historically correct condition;
- not used as means of daily transport;
therefore are part of our technical and cultural heritage." (FIVA, 2014; p. 3)

In 2009, the European Parliament officially endorsed HVs as vehicles of "historic interest" under Directive: 2009/40/EC and in 2014, modified its previous directive and recognised a vehicle as an HV if it had the following characteristics:

- It was manufactured or registered for the first time at least 30 years ago;
- Its specific type, as defined in the relevant union or national law, is no longer in production;
- It is historically preserved and maintained in its original state and has not undergone substantial changes in the technical characteristics of its main components. (DIRECTIVE 2014/45/EU-page 57)

The definitions above indicate that not every ageing vehicle is eligible to be defined as 'historic'. However, it is often impossible to check and verify the characteristics of vehicles mentioned in other studies and reports to distinguish historic vehicles from other vehicles over 30 years old. Therefore in this study we assume that all vehicles over 30 years are HVs.

Moreover, it should be mentioned that it is difficult to distinguish old vehicles in operation due to poverty and those HVs kept for their historic and heritage purposes. In this study we chose to only apply an age criterion. This may impact the findings, such as the applicable HV statistic in our analysis.

## 2.2. Trends in supply

On the supply side, an important factor leading to the current availability of HVs is the number of automobiles manufactured more than three decades ago. Most information is available for passenger cars, which in numbers represent the dominant category of HVs. Based on figures from the Worldwatch Institute (Worldwatch, 2015) and also from Rodrigue, Comtois, and Slack (2013), the worldwide auto (cars) production rate started to grow gradually from the early 1950s (estimated to be 8 million auto productions annually). This pace became more rapid in the 1960s (reaching approximately 20 million by the second half of the 1960s) and 1970s when the annual auto production reached 31 million in 1979 (Renner, 2003). The increasing trend continues today with production increasing from 41 million in 2000 to 67 million in 2014 (Statista, 2015). With more autos being produced, more vehicles will over time become historic vehicles.

A further increase in HVs can be expected due to the increasing survival rates of vehicles. According to statistics from the US, in the 1990s, the average survival rate for cars above 30 years was 6.6% (trucks 45.1 %), whereas this figure was 0.8% in the 80s and 0.4% in the 1970s (trucks 20.7 %)(Davis, Diegel, & Boundy, 2014). Combining both effects, the number of HVs can be expected to grow in the future.

## 2.3. The policy discourse

Policy makers face a dilemma with respect to historic vehicles. On the one hand, HVs are gaining in popularity and have become more relevant from an economic point of view. On the other hand, HVs are often the subject of environmental and safety concerns, since more recently manufactured vehicles are cleaner and safer (mainly due to the regulations and improvements made by vehicle manufacturers). The consequence of this dilemma results in policies that can be supportive or discouraging for HVs in several countries. We provide some examples in here.

In some countries, policy makers have taken measures to encourage scrapping old vehicles for environmental concerns and economic motives such as helping the car industry (Van Wee et al. , 2011), while in other countries (e.g. Sweden and UK) car owners were motivated to increase the lifespan of vehicles for a more sustainable car consumption culture (Nieuwenhuis, 2008). Note, that the mentioned policies do not distinguish between HVs (e.g. based on the EU or FIVA definitions) and other vehicles over 30 years.

Another example relates to the emissions caused by HVs. In several EU countries, local municipalities have introduced regulations to ban older vehicles from their (inner) city areas, to reduce local air pollution. These areas are normally referred as “Low Emission Zones”[3]. However, in some other cities, HVs were exempted from such regulations. Examples are London and several German cities. Moreover, in some countries, like Germany, UK and the Netherlands, HVs have road tax benefits.

# 3. Methodology in obtaining the sources of data

A search using the keywords “historic”, “classic”, “vintage” combined with “vehicle” or “car” or “auto” in the well-known academic databases – Scopus, Web Of Science (WOS), and Google Scholar – revealed hardly any relevant results, indicating the scarcity of published research in this field. Therefore, as explained in the introduction, we also considered government reports and non-academic literature. We included only those sources that had verifiable findings or were published by (independent) research institutes, excluding documents without references or a description of the methodology as well as documents published by interest groups.

In addition we used databases such as the “Transportation Energy” data book (edition 33) by Davis et al. (2014) published annually in the US since 1981, and databases by Eurostat that are regularly published by the European Commission. In some instances, we performed our own calculations, estimations or inferences by cross-checking different reports, tables and graphs. Finally, we sometimes relied on our own experience[4] and on results from discussions with experts in the field of historic vehicles (several discussions with FIVA members and other HV experts).

# 4. HV numbers, types and year of manufacture

## 4.1. HVs in numbers

We first look at the numbers of HVs because these numbers are related to the use of the vehicles and the economic (insurances, taxes, restoration costs, etc.) and wider societal impacts. According to FIVA, in 2006 there were 1,950,000 HVs in the EU, of which almost 80% were roadworthy (Frost & Hart, 2006). The total fleet of vehicles in the EU in 2006 was 255 million, thus HVs constituted almost 1% of the total EU fleet of vehicles in year 2006 (Nieuwenhuis, 2008).

From more recent sources available to us, we were able to establish a limited inventory of the overall number of registered historic vehicles and the total number of the entire vehicle fleet (modern and old) of a few European countries as presented in Table 1. The selection of these countries was based on data availability and verifiability from independent sources. This small sample of EU countries includes countries from different regions of the continent, although we do not claim these countries

[3] These areas can be found at the official website affiliated to EU commission: urbanaccessregulations.eu

[4] The second author of this paper has three historic cars, and has been a member of the vintage air-cooled VW club Holland since 1983.

to be representative of their neighbouring nations or Europe in general. Table 1 displays the numbers of HVs and their share in the total fleet of vehicles differ among these countries, ranging from below 0.6% in Germany to almost 6% in Greece. Adding up the HVs of these six countries, they constitute of about 1.8% of the total number of vehicles in the selected countries.

However, the data in table 1 should be treated with caution. According to the sources there are cases where a vehicle was not de-registered when scrapped, or simply not used anymore. This makes the data sources less reliable and results in an overestimation of the number of HVs. Moreover, standards for statistics vary between countries, so it is difficult to compare the aggregate numbers across countries. For example, statistics may or may not include some categories of vehicles and non-roadworthy vehicles. We contacted members of the HV community in some countries to verify the statistics. Based on their comments we conclude that Table 1 probably presents some overestimations.

**Table 1 Total HV and overall vehicle fleet sizes in some EU countries (data include all vehicle categories)**

| Country | Year | No. of HVs ( >30 years) | Total fleet (million) | HV % to total fleet of vehicles | Source |
|---|---|---|---|---|---|
| UK | 2010 | 805,588 | 35.50 | 2.27 | Driver and Vehicle Licensing Agency (DVLA) for the UK |
| Germany | 2013 | 313,815 | 53.00 | 0.59** | Kraftfahrt-Bundesamt (KBA), which is the German federal motor transport authority |
| Denmark* | 2012 | 79,055 | 2.20 | 3.59 | Centralregisteret for motorkøretøjer (CRM), which is the Danish central registry for motor vehicles |
| Netherlands | 2005 | 280,000 | 8.60 | 3.25 | Centraal Bureau voor de Statistiek (CBS), which is the Dutch institute for statistics |
| Greece | 2012 | 402,932 | 6.75 | 5.97 | Car Importers Association Representatives (CIAR) of Greece |
| Sweden* | 2013 | 213,363 | 5.37 | 3.97 | Motorhistoriska Riksförbundet (MHRF), which is the Swedish national federation for historic vehicles |

* Tractors were excluded from the total vehicle figures. For further explanation see section 4.2.
** This figure is for registered vehicles older than 30 years. The percentage of all historic vehicle (registered and unregistered) adds up to 0.97% of all vehicle fleet.

## 4.2. Breakdown of HVs by type

The numbers of HVs can be broken down by vehicle type. In 2011 in the UK, around 90% of the HVs were passenger cars and motorbikes, 5% buses, coaches and trucks, 2% military vehicles and the rest agricultural and steam vehicles (Frost et al., 2011). A dataset from the German Association of the Automotive Industry (Verband der Automobilindustrie [VDA]) for 2013 reveals that around 92% of HVs were cars, 2.5% motorbikes, less than 0.1% buses, 3% trucks and 2.1% tractors.

More recently, a FIVA survey conducted in 2014 among a sample of 19,432 HV owners across 15 EU countries (Araghi et al., 2016) provides a more accurate picture. This sample of owners registered the information of 43,612 HVs from which 72.6% were cars or vans and 19.7% motorbikes and scooters. This is not in line with the figures above on the composition of different type of vehicles in the HV fleet.

## 4.3. Breakdown HVs by year of manufacture

HVs can be further categorised according to their year of manufacture. This decomposition is potentially relevant to transport policy, since environmental and safety characteristics are greatly dependent on the year of manufacture. The FIVA survey in 2006 revealed that 30% of HVs in EU member states were pre 1940, 30% were built between 1940 and 1960, and the rest (40%) were built between 1960 and 1975. Note that 1975 was the most recent year for a vehicle to be considered as HV in the 2006 FIVA survey.

More recently, the German Association of the Automotive Industry (VDA) provided a breakdown of HVs by the year of manufacturing in Germany up to the end of 2013. Table 2 displays this breakdown in five-year incremental steps, categorizing all vehicles made after 1960 in one group. One can see that the VDA data (shown in table 2) are not consistent with the FIVA (2006) data. In Germany the share of historic vehicles produced between 1940 and 1960 is over 55%, whereas in the FIVA data, this is 30%. In the FIVA data, the relative numbers of vehicles produced after 1960 is much higher (40%) compared to the VDA data (5%). A side note on the comparison of these two data sets: in general the age of HVs in Germany is skewed more towards the first half of the twentieth century, whereas the FIVA figures (depicting the EU-wide picture) is skewed to the second half.



**Table 2 Historic Vehicle categorization in Germany by age (Source: VDA, 2013)**

| Year of manufacture | Percentage of total HVs |
|---|---|
| 1930 - 1934 | 19.6 |
| 1935 - 1939 | 19.8 |
| 1940 - 1944 | 24.8 |
| 1945 - 1949 | 16.0 |
| 1950 - 1959 | 14.5 |
| 1960 to later | 5.3 |

Table 3 presents the breakdown by age from the recent FIVA survey in 2014 (Araghi et al., 2016), where 7.6% of HVs were manufactured pre-1940, 25.5% between 1940 and 1960 and 66.9% of the vehicles were made after 1960. The age of the vehicles in the recent survey (2014) is skewed towards vehicles of less than 50 years of age. Again the age composition of HVs at the EU level contradicts the age composition of HVs in Germany. This may be an indication that in some countries there is a tendency to preserve vehicles longer than the rest, probably due to cultural differences. An alternative explanation is that the response rates vary between countries, depending on the age of vehicles, e.g. because of the way in which country approaches HV owners.

**Table 3 HV age categories in FIVA 2014 sample**

| Year of manufacture | % of total HVs |
|---|---|
| 1886 - 1900 | 0.6 |
| 1901 - 1920 | 0.7 |
| 1921 - 1940 | 6.3 |
| 1941 - 1960 | 25.5 |
| 1961 - 1983 | 66.9 |

## 5. HV use

In this section we present data for the annual mileage and the number of HVs in use. These two indicators are of paramount importance when it comes to assessing their potential impact on the environment, safety and congestion. In addition to these policy relevant criteria, HV use is relevant for HV-related businesses (e.g. insurance, maintenance and restoration companies). For mileage we consider both yearly use and HVs' share in the fleet mileage.

### 5.1. Average Kilometres driven by HVs (mileage)

The average distance driven by HVs can be calculated under two scenarios: 1) for active vehicles only, 2) for all HVs, including non-active vehicles. For each of these scenarios different average mileages are derived. For instance in the case of Netherlands, in 2006, average yearly mileage was 1950 kilometres for active HVs only, and 1050 km for all HVs, active and non-active (Rijkeboer, 2008).

Rijkeboer (2008) estimated the average annual mileage for HVs in the EU to be 2100 km. Furthermore, these data showed that around 50% of HVs were used for less than 500 km per year and that only 7% were used for more than 3500 km per year. Frost et al. (2011) report comparable figures in the UK for 2011, in which more than 50% of HVs were driven less than 800 km per year and only 18% were used at least weekly.

A more recent Dutch study of the historic vehicle association (FEHAC) revealed that 45% of HVs are used for less than 500 km per year (FEHAC, 2012), confirming the results of previous reports. Moreover, average mileage per HV decreased from 1950 km/year in 2006 to 1700 km/year in 2012 (a reduction of 13%). Finally, the 2014 FIVA survey showed that, on average, classic cars (72% of all HVs in the sample) were driven around 2500 km per year.

Figure 1 shows the relationship between the age of a vehicle and annual mileage in the Netherlands (Rijkeboer, 2008). Yearly use drops from 25,000 km for vehicles up to one year old, to below 5000 km for vehicles 22 years old. At this stage the trend plateaus, suggesting that vehicle use per year becomes almost constant. It can be speculated that those vehicles which are not dismantled after the first 25 years of age are normally owned by enthusiasts and are kept in relatively suitable conditions for prolonged use. These vehicles are driven less than 4500 km per year (Rijkeboer, 2008).

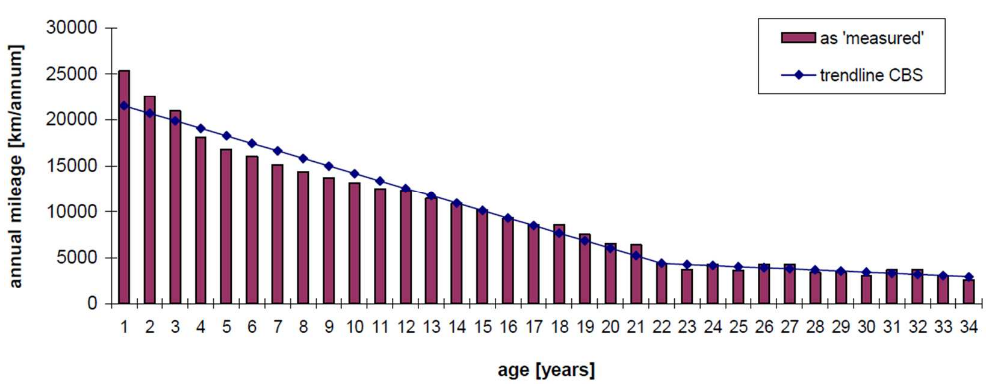


**Figure 1 Annual vehicle usage against age, Note: CBS stands for Dutch bureau of statistics. Source: Rijkeboer (2008)**

Data from the Transportation Energy Data Book - edition 33 (Davis et al., 2014) show that in the USA 60% of all cars over 20 years old[5] are driven less than 9600 km annually and 30% of these cars are driven less than 3200 km. These data confirm decreasing use with age, as in the Netherlands.

[5] the data book reports data for all cars over 20 years together, no disaggregation by age class for these data is provided.

A study conducted by the Dutch Planbureau voor de Leefomgeving[6] (PBL) found that in 2011 in the Netherlands cars manufactured in the 1970s were driven around 2000 – 2200 km/year, whereas those in the early 1980s were driven over 4000 km/year (Hoen et al., 2012), suggesting a decrease of yearly use with age, also within the category of historic cars.

### 5.2. The share of older vehicles still in use

Here we explore the share of HVs mileage among the whole fleet of vehicles. Using a report from the Driver and Vehicle Licensing Agency (DVLA), Frost et al. (2011) conclude that in 2010 in the UK the total vehicle miles driven was around 308 billion miles (493 billion km), and HVs drove around 750 million miles (1200 million km), implying HVs have a share of 0.24% of the total distance travelled by all vehicles on UK roads. In an earlier report Frost and Hart (2006) also provide figures at the EU level; the total distance travelled by modern vehicles was equal to 2.2 trillion km. For HVs the distance was 1.4 billion km, accounting for 0.06 % of the total distance travelled by all vehicles. The UK's higher proportion of HV kilometres is probably accounted for by the UK's reputation for having a relatively long standing HV culture.

Hoen et al. (2012) reported somewhat different figures for the year 2011 for the Netherlands. They conclude that cars manufactured in 1986 or before (by then: over 25 years old) had a share of 1.5% of the total distance travelled by all cars in the Netherlands. Note that this number also includes cars that are 25-30 years old. One possible explanation for this high percentage is that in the years preceding 2011 many cars older than 25 years were imported to the Netherlands, at least partly because of tax exemptions (Hoen et al., 2012). However, this trend has recently been reversed due to new tax rules in the Netherlands and as a result many cars over 25 years old are now being exported (Stolk, 2014).

We conclude that there is hardly any information on the share of HVs in the overall use of vehicles, and results show strongly diverging shares. The share in total use of vehicles older than 30 years is very likely below 1%. Moreover, the number of cars active in road transport declines rapidly with age.

## 6. Environmental impacts of HVs

Motorized vehicles produce various air pollutants such as $PM_{10}$, $NO_x$ and HC[7] emissions, which are generally considered to have a negative impact on health (Chapman, 2007). HVs come with old technology, which are relatively more polluting (Kim, Keoleian, Grande, & Bean, 2003; Zachariadis et al., 2001). In this section we report on the literature on the environmental impacts of HVs.

### 6.1. Vehicle Emissions

Over the course of years and often due to emissions regulations, vehicle manufacturers have introduced new innovations in engines, car aerodynamics and exhausts to produce cleaner, quieter and more fuel efficient vehicles. This means HVs have become relatively polluting compared to modern vehicles. On the other hand, the driving behaviour of HV enthusiasts might compensate some of the differences in per kilometre emissions. We did not find any source of information on the

[6] Netherlands Environmental Assessment Agency

[7] HC stands for hydrocarbons and refers to emissions from various unburned mixtures of hydrogen and carbon in fuel and rarely, oil.

driving behaviour of HV users. However, assuming that HVs are driven relatively carefully (see section 7 on HV safety) and with lower than average speeds, this might result in lower emissions compared to situations in which these vehicles would be driven as if they were modern vehicles. There are studies such as Kean, Harley, and Kendall (2003) which confirm that lower vehicle speeds result in lower emissions.

In this study we only focus on the share of passenger cars (among all HV categories) for total emissions, firstly because of the availability of sources, and secondly because this category constitutes the majority of HVs.

### 6.1.1. Non-$CO_2$ Emissions

Rijkeboer (2008) investigated several scenarios regarding the use of cars above 25 years old for the Netherlands. An emission calculation model was used to estimate CO, HC, $NO_x$, and PM as emission factors, under different scenarios. The model, based on data from Statistics Netherlands (CBS), distributes kilometres driven over age classes, and has age class specific emission factors. Figure 2 shows the share of 25+ cars in total emissions. In the “worst case scenario”, where old cars are used for “economic” reasons (i.e. cheap cars for daily purposes), the share in emissions of $NO_2$ and $PM_{10}$ would be just below 2%. HC was the pollutant with the highest share for 25+ cars, with a forecasted share of 15% for 2015 (Rijkeboer, 2008). Additionally, Rijkeboer (2008) assessed other scenarios in which historic cars were used mainly by “enthusiasts” and “mobile heritage” users. In the two latter scenarios, emissions were estimated to be more than 25% less than the worst case scenario. However, one should note that even if emissions of older cars remain constant, the share of 25+ cars in total emissions will increase, since the emissions of modern cars are decreasing.

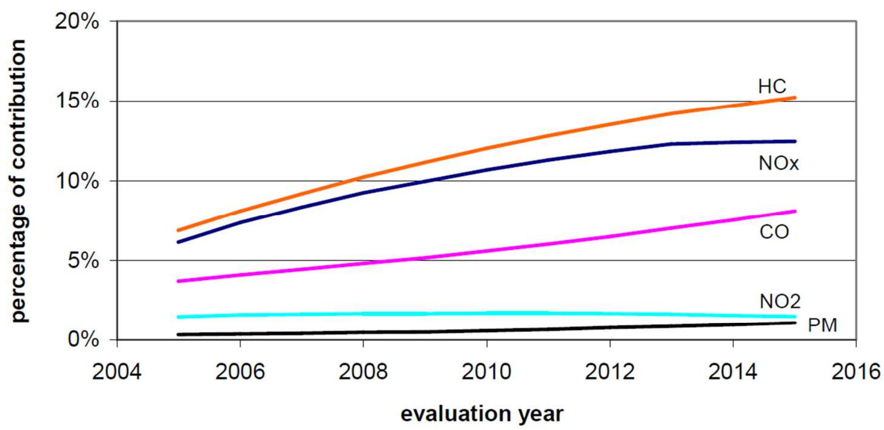


Figure 2 Annual contributions of passenger cars 25+ years to the overall car emissions. Source: Rijkeboer (2008)

The above findings of Rijkeboer’s study conflict somewhat with findings of a more recent study by PBL, which concludes that 25+ cars accounted for 10% of the $NO_x$ emissions and 5% of the $PM_{10}$ emissions of all cars in 2011. Furthermore, the mentioned study forecasted that in 2015, $NO_x$ shares would rise to 15% (Hoen et al., 2012). Again, one should note that, in 2015, this forecast is outdated because of the changes in Dutch policies which have resulted in many old cars being exported (see above).

The Institut für Energieund Umweltforschung (IFEU) used the so called ”Transport Emission Model” (TREMOD) to estimate the emissions for all transport for the period 1960-2011 for Germany (Knörr et al., 2012). Using figures for the distance driven and total fleet emissions for NOx and PM10, we calculated emission factors for the entire car fleet of Germany for the years 1960 through 2000, relative to the 2011 car fleet. We argue that the emission factors of previous years give an indication of the emission factors of current historic vehicles. For example, an emission factor for the fleet in 1970 mainly represents emission factors for cars produced between 1960 and 1970. Moreover these emission factors provide a basis for comparing the emission rates of HVs and recent cars. Table 4 shows the results. These are indicative only, firstly because we derived the values visually from figures, and secondly because the emission factors for fleets from decades ago are relatively uncertain.

The numbers in table 4 not only reflect changes in vehicle characteristics, but also in usage patterns (e.g. share of urban roads and motorways). Between 1960 and 1980 per kilometre emissions of $NO_x$ remained quite stable. But from 1980 we observe a reduction[8] in $NO_x$ to about one sixth of those in 1960-1980.

Between 1960 and 1990 per km emissions of PM[9] increased, but then dropped by 60% between 1990 and 2011. It is important to realize that these are average emission factors for the entire fleet, not for new cars. New cars in 2011 have much lower emission factors than those of the whole car fleet.

**Table 4 Fleet average emission factors of passenger car for $NO_x$ and PM10, in Germany, 1960-2011. Own calculations based on Knörr et al., (2012)**

| Year | $NO_x$ | $PM_{10}$ |
|---|---|---|
| | index 2011=100 | |
| 1960 | 583 | 163 |
| 1970 | 585 | 166 |
| 1980 | 611 | 197 |
| 1990 | 434 | 251 |
| 2000 | 178 | 212 |
| 2011 | 100 | 100 |

### 6.1.2. $CO_2$ emissions

Unlike for $PM_x$, $NO_x$, CO and HC, there are no per kilometre emission standards for vehicles for $CO_2$. Nevertheless, the EU did implement $CO_2$ policies (European Commission 2012 - IP/12/771) to reduce $CO_2$ emissions by new cars and vans to 130 (gr/km) by 2015 and to (on average, and measured under test conditions) 95 (gr/km) by 2020, compared with an average of 137.5 (gr/km) in 2011. The USA target for 2025 is to reduce $CO_2$ emissions to 143 (gr/mile) (Davis et al., 2014), which is approximately 90 (gr/km).

[8] $NO_x$ vehicle emissions are a mixture of nitrogen monoxide (NO), which is not a risk for health, and nitrogen dioxide ($NO_2$), which is a health risk. Before the introduction of three way catalytic converters on new petrol cars (starting around 1987, with a share of 100% since 1993) the share of $NO_2$ in total $NO_x$ emissions was relatively low (5-10%). Cars with a three way catalytic converter have a share of $NO_2$ of up to 55%. We conclude that the difference in $NO_x$ emission factors between historic petrol cars and modern cars is much larger than the difference in $NO_2$ factors. Consequently the decrease in the harmful $NO_2$ emissions is much less than the decrease in $NO_x$ emissions (Hoen et al., 2012).

[9] There is another issue about PM that we need to point out in here. Older diesel engine vehicles emit more PM than newer engines (Twigg, 2007), but modern vehicles have a higher share of ultra-small particulates (e.g. $PM_{2.5}$) in total PM emissions, and these particulates have a relatively more negative impact on human health than $PM_{10}$ (Gertler, Gillies, & Pierson, 2000).

An important question is: How do the $CO_2$ emissions of HVs per kilometre relate to modern vehicles? There is hardly any literature on this topic for all HVs but Knörr et al., (2012) offers some information on passenger cars. Implementing the same technique that was used to derive table 4, we calculated indicative emission factors for $CO_2$. Table 5 shows that between 1960 and 1980, $CO_2$ emissions per km per car increased by about 10% in Germany. Since then, these emission decreased by about 20% up until 2011. Again, these figures relate to fleet averages in real world conditions, and not to new cars under test conditions.

**Table 5 Fleet average emission factors of passenger car fleet for $CO_2$, Germany, 1960-2011. Own calculations based on Knörr et al., (2012)**

| Year | $CO_2$ (index 2011=100) |
|---|---|
| 1960 | 114 |
| 1970 | 122 |
| 1980 | 126 |
| 1990 | 119 |
| 2000 | 110 |
| 2011 | 100 |

Based on table 5, and assuming that historic cars are driven more carefully than average (see section 7), we conclude that the $CO_2$ emissions of HVs per km are somewhat higher (10-20%) than those of the current car fleet. Since the order of magnitude of the decrease in $CO_2$ emissions per km and the share of production-related $CO_2$ emissions in total emissions are about equal (Van Wee et al., 2000), we conclude that on a life cycle basis the $CO_2$ emission per km of historic cars is in the same order of magnitude as those of modern cars[10]. Moreover, since historic cars have a much lower yearly mileage, it follows that annual $CO_2$ emissions per car are much lower than those of modern cars.

## 6.2. Noise

Germany is one of the first countries to implement regulations for vehicle noise: the first regulations date back to 1937 and were updated in 1953, 1957 and 1966. However, international actions to control or lower vehicle noise levels did not come into effect until the 1970s (for motorcycles this was as late as 1980). Initial EU regulations for the noise emissions of cars were introduced in 1970 (Mais, 2014). Since then, noise emission standards have been periodically updated. Test conditions were also modified, which resulted in strongly reducing the potential effects of more tight standards.

In addition, the share of noisier diesel cars in the EU auto fleet has increased significantly over past decades. In practice between the mid-1980s and mid-2000s, the noise emissions of new cars per kilometre in the Netherlands did not decrease significantly, and those of lorries decreased by only 3-4 dB(A), much less than the change in maximum noise emissions under test conditions (Mais, 2014). Consequently, we conclude that although the test standards have been updated, the differences in noise emissions per km of historic cars and more recently built cars would be small or in other words HVs are only slightly louder than modern diesel cars.

[10] Note that maintaining and restoring an HV also results in $CO_2$ emissions, which have not been included in the above discussions. To the best of our knowledge there is no literature on this topic.

## 7. Safety impacts

Both the active (e.g. brakes, handling) and passive safety features (crash worthiness) of cars, vans and lorries have improved significantly since the 1940s. This was partly in response to regulations, but also because of 'autonomous' (not policy-induced) improvements made by the auto industry to enhance the safety features of vehicles, the introduction of crash zones and seat belts by Volvo and others being well known examples (Norin, Carlsson, & Korner, 1984).

The 2014 FIVA survey showed that 20 HV owners out of 19,432 were involved in an accident which resulted in casualties. Among these accidents 17 cases involved personal damage suffered by a driver or passenger(s) (0.08%) and 3 cases involved personal damage to third persons (0.01%). Note that if a HV owner was killed in an accident, s/he was not included in the study, leading to a potential (small) bias. The respondents in the FIVA survey reported 58.71 million kilometres in which 20 cases of accidents involving injuries occurred, resulting in 34 accidents involving injuries per 100 million vehicle kilometres.

To put these numbers into perspective, in the year 2013 in the UK, there were 183,670 cases of casualties due to road accidents (Mais, 2014). That year there were approximately 35 million vehicles in the UK (Grove, 2014), which on average drove approximately 12,640 kilometres (7900 miles) per year (Melbourne, 2014). This equals a total of 442 billion kilometres travelled by vehicles, which results in an average of 41.5 injuries per 100 million vehicle kilometres. This means that the accident rates of HV owners from the sample of 15 EU member states is around 20% less than the accident rate in the UK, which has one of the lowest number of fatalities and injuries per 100 million vehicle kilometres of all European countries (Wegman, 2013, based on OECD/ITF data). Thus, one may conclude that, although HVs have a lower safety level (crash worthiness, handling), per km HV casualties and fatalities are below the UK average.

How can we explain this contradiction? Again no previously published literature was found on this topic, so we refer to several contacts with HV enthusiasts and own expertise. The explanation is probably in the way historic cars are used. To protect their cars, HV owners drive more often than average in favourable weather conditions – they do not want to expose their vehicles to bad weather. Convertible historic cars generally leak water, making them less attractive to drive under rainy conditions. Moreover, HVs are hardly used in the winter and therefore they are rarely exposed to slippery conditions.

The importance of driving behaviour for accidents is confirmed by Martens (2014) referring to Rumar (1985), where it is concluded that the driver contributes fully or partly to 94% of all accidents and the malfunctioning vehicle to only 12%. There is an overlap because some accidents have multiple causes (Martens, 2014) and even if the driver is the cause, the severity of a crash is influenced by vehicle characteristics.

There is another indication that underpins our conclusion that HVs seem to have lower accident rates than modern vehicles, which is the existence of special and very cheap insurance for HV owners. For instance, in the Netherlands several companies offer insurances for as little as 50 euros (roughly $57 USD) per year for older cars (e.g., http://deoldtimerverzekering.nl/). The low premium set by market-based insurance companies expresses the low accident rates per vehicle basis, but not necessarily on a per km basis, since HVs are used less than modern vehicles. However, one caution worth noting is that driver characteristics also influence accident rates and insurance premiums, which is not the focus of this study.

## 8. Congestion impacts

Providing and improving accessibility is one of the crucial goals of transport policy making. One way to improve accessibility is by reducing congestion, both at the urban and inter-urban level. An important question from the perspective of this study is: what is the impact of HVs on congestion? We can provide a discussion for this topic only theoretically, due to a lack of literature.

If we assume the share of HVs in overall vehicle kilometres to be around 0.24% (based on UK figures from 2010; see section 5.2), a first rough estimate would be that HVs have a share of 0.24% in congestion. However, we think the share is probably (much) lower, for several reasons. First of all, many owners do not use their HVs on a daily basis. For instance, in the FEHAC survey less than 10% of respondents reported daily use which was defined as more than 3 times per week (FEHAC, 2012) and in the 2014 FIVA survey this number was around 2.4%. In addition, HV owners use their vehicles relatively frequently for events (see section 9), which are generally organized during the weekend.

Secondly, based on expert judgments, most owners have a modern vehicle available for daily use. Thirdly, many owners mainly (or exclusively) drive under conditions of good weather, whereas bad weather contributes to congestion (Koetse & Rietveld, 2009). Fourth, many HVs do not have a cooling system that is adequate for conditions of severe congestion, which discourages owners from driving under congested conditions. Combining these arguments, one can conclude that it is likely that the share of HVs in congestion is lower than 0.24% and therefore negligible.

## 9. Positive effects of HVs

This section discusses the positive effects derived from HVs. We categorize these into two groups: a) social and b) economic effects of HVs.

### 9.1. Social effects

The European Union (DIRECTIVE 2014/45/EU) mentions that classic vehicles are preserved for “heritage” purposes and represent an era or the historical period in which they were manufactured. This means that HVs, as with historic buildings or anything preserved in a museum, help to keep memories alive and thus have a societal impact. Most literature is limited to the social benefits of the owners and users only.

Tam-Scott (2009) and Dannefer (1980) extensively discuss the emotional bond between HVs, their owners and amongst enthusiasts themselves. The emotional relationship between owners and their vehicles results in enhanced durability of the vehicle thus guaranteeing prolonged usage of the vehicle (Nieuwenhuis, 2008). In the same article, 1669 readers of a popular UK-based classic car magazine were asked about reasons for the popularity of HVs. The prevailing reason was the “enjoyment” of owning an “unusual car”. The second reason was: “Having the satisfaction of being able to fix the car” and the third reason was about “finally” owning and driving the car that they dreamed of in childhood.

In the 2014 FIVA survey, respondents were asked about the most important aspect of HV ownership. The top three reasons were: "Recreational touring, taking part in events and shows" (41.6%), "Nostalgia" (27.1%) and "Doing maintenance and repairs" (19.9%). Both surveys show that enjoyment and recreational reasons are highly important when it comes to owning HVs.

### 9.2. Economic effects

The economic benefits of HVs occur in the form of purchasing spare parts, paying for services and maintenance, spending on related magazines, local clubs and so on, mainly by HV enthusiasts.

The 2014 FIVA survey revealed that each HV owner on average had spent €2335 on restoration costs, €840 on maintenance and repairs and €607 on purchasing accessories in the preceding year. These add up to a total of €3782 (note that this excludes purchasing vehicles, taxes and fuel costs). Assuming that there were around 1.5 million HV owners in the EU and multiplying these two figures, it would result in €5.7 billion in HV-related expenditure, of which 98% occurred within EU. Given that each job would cost the employer around €50,000 annually, the expenditure of HV owners could generate 114,000 jobs in EU. However, without HVs, enthusiasts would probably spend their money on other goods and services, so this estimated number of jobs does not entirely add to all jobs in EU. Furthermore, one should consider that these estimates were based on studies conducted on behalf of HV interest groups. In addition, it is important to note that turnover has a limited value for assessing the economic benefits.

Next we provide the results of two case studies. Researchers at the University of Brighton in collaboration with The Federation of British Historic Vehicle Clubs (FBHVC) have conducted a series of studies on a few HV-related events focusing on the economic benefits obtained from these events. Two key cases studied are the Goodwood Revival event and the Beaulieu International Autojumble. The first event has been held in Chichester (UK) since 1998. It is visited by more than 145,000 people per day. In 2012, the event generated over £12 million (approximately €15 million in 2012) revenue for the local community and £36 million gross turnover for the UK economy (Kaminski, Smith, & Frost, 2013b).

The second example is Beaulieu International Autojumble, held near Southampton, UK in 2012. This event generated nearly £3 million for the local economy and overall provided £11 million turnover for the national economy (Kaminski et al., 2013a).

## 10. Conclusion and gaps in literature

### 10.1. Conclusions

The aim of this study was to obtain an overview of the available literature discussing historic vehicles, in a field where academic articles hardly exist. We answered our three research questions by: a) looking at the trend of vehicles potentially becoming HVs (supply) and the policy discourse on HVs, b) providing information on HV use (i.e. annual mileage) and HV numbers, and furthermore discussing the effects of HVs on the environment, safety and congestion, as these are the most relevant effects from a policy viewpoint, and c) evaluating the societal and economic benefits associated with HVs. In this section, we first summarise our findings in table 6 and later present topics that require further research.

Table 6 Summary of topics discussed and the findings and level of certainty on each topic

| Topic | What is known | Types of sources | Level of certainty |
|---|---|---|---|
| Non-$CO_2$ emissions | • CO, HC, $NO_x$, and PM are the most critical pollutants<br>• Share of historic cars:<br>- $NO_x$ is 2% to 10%<br>- $PM_{10}$ is 2% to 5%<br>- HC is 15%<br>• Emissions of $NO_x$ & $PM_{10}$ are 5 & 2.5 times modern cars (respectively) | Independent research institutes i.e. PBL, IFEU, TNO | Moderate |
| $CO_2$ emissions | • $CO_2$ emissions by historic cars is 10% - 20% more than modern cars | Independent research institutes i.e. IFEU | Moderate |
| Noise | • Noise emissions of HVs per km has probably small difference with more recently build cars | Authors' reasoning based on EU noise test standards and regulations | Low |
| Safety | • historic vehicles are less safe than modern ones but driving behaviour might compensate for this to some extent<br>• Accident rates by a sample of HV owners from 15 EU states was around 20% less than the accident rate in the UK | Based on empirical evidence from a large survey and literature on driving behaviour | High |
| Congestion | • 2.5% - 10% of HV owners use daily<br>• HV mileage in UK was 0.24% of vehicle traffic thus the same share in congestion could be assumed | Empirical evidence<br>Expert opinion | Moderate |
| Social | • emotional bonding between HVs and their owners<br>• main reason for HV ownership: "enjoying", "Recreational touring" | Academic literature and empirical evidence | High |
| Economics | • €5.7 billion spent on HV restoration and repairs by owners (potentially generating 114000 jobs in EU)<br>• Other HV related economic benefits: participation in events, lodging, selling parts, charity events, ceremonies | • Based on empirical evidence from a large survey<br>• Several accounts and reports by interest groups on HV related events | • High<br>• Low |

By examining the literature and available data, the evidence shows that the number of vehicles over 30 years old is growing (again we continue to assume that all vehicles over 30 years old are HVs). This increases the relevance of historic vehicles from a policy perspective. However, statistics on HVs (which are needed for adequate estimates of social impacts) are poor.

Roughly, HVs comprise 1% of vehicle fleets across the EU. About 90% of HVs are either passenger cars or motorbikes. The share of HVs in country-specific vehicle fleets differs strongly (indication of the range: 0.6% to 6%).

The share of HVs in total mileage is approximately less than one percent, but again there is a range. One report from the Netherlands estimates the share of total mileage of vehicles that are 25 years and older to be around 1.5%.

$NO_x$ and $PM_{10}$ are proportionally the highest emissions associated with historic cars (note that in this part of the study information is only provided for cars). They represent a few percent in car-related emissions of those pollutants (see section 6 for details). The $CO_2$ emissions of the modern car fleet per kilometre is 10-20% lower than that of 30+ year-old cars. On a life cycle basis, the $CO_2$ emissions per km of 30+ cars will be about equal to the fleet average.

Technically, historic vehicles are less safe than modern ones. However, it seems that this is more than compensated for by driving behaviour and the weather conditions during which HVs are most often used, resulting in lower accidents/fatality rates per kilometre driven compared to fleet average values.

Given the use behaviour along with recent data from HV owners, we expect the contribution of HVs to congestion to be less than the estimated 0.24% share of these vehicles in total kilometres driven.

HV-related expenditure has economic benefits, but there is hardly any useful literature to express this in terms of the share in GDP or employment. We estimate that the expenditure of the HV enthusiast generates 114,000 jobs, EU wide. In addition, HVs have so-called external benefits for the wider public: people who do not pay for HVs meanwhile enjoy the cultural heritage of vehicles and viewing them.

After discussing the different aspects of HVs (such as: numbers of HVs active today, heritage and cultural values of HVs, safety concerns, environmental implications), we think that conducting more academic research by means of cost-benefit analysis (CBA) of HVs in general, or specific policies addressing HVs may be useful for getting an overall picture of the pros and cons of HVs for society or of specific policies. Such CBAs could also be used by the public and decision makers' to form an opinion regarding policy.

In this study, we attempt to contribute to a better understanding of the societal implications of HVs through providing the facts and figures about the advantages and disadvantages of HVs which are available to researchers, decision makers and wider society. We hope that future studies will provide independent information on the societal impacts of HVs. We also believe that there is a need to develop methods for the valuation of the emotional aspects of HVs for the wider society and maybe also vehicle owners.

To conclude, although the transport policy discourse is divided on the topic of historic vehicles, more comprehensive and effective laws and regulation are needed to protect the heritage of road transport whilst at the same time avoiding or limiting the problems caused by historic vehicles.

## 10.2. Direction for future research

During our review process, we sometimes faced contradictory statistics and data, which made it difficult to draw general conclusion on some topics. In such cases, we have opted to report the ranges of data on key issues such as HV ownership, usage and HV emissions. On the topics of safety, congestion, noise hardly any sources of data were available.

This brings us to possible further research areas. To estimate the share of HVs in congestion, safety and pollution, more reliable data on HV ownership (active and passive fleet) and HV use needs to be collected. Better estimations of real world emissions of air pollutants plus noise will enable decision makers to make informed decisions regarding the exclusion or inclusion of HVs in environmental zones. Finally, it is important to evaluate ex-ante the pros and cons of several HV-related policies, to be able to design policies that reduce societal impacts without jeopardizing the positive societal impacts of HVs.

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We thank the 2 reviewers for their useful suggestions and comments. Please note our response and our actions to each comment in below text in blue colour.

**Reviewer: 1**

**The authors have thoughtfully undertaken the suggestions made by all three reviewers. All that remains now is for English usage to be cleaned up. I look forward to seeing the paper published -- it will be a good contribution to the literature.**

We thank the reviewer for the nice words and for the encouraging comments!

We have indeed asked a native English editor to check the whole document for textual issues. We hope that the text in this version is fluent.

**Reviewer: 2**

**The authors' have done a lot of improvements of their paper.**

We thank the reviewer for this nice comment!

**This reviewer can suggest small amendments to the paper only:**
**(1) Page 4, line 22: I would avoid expression such as "grey" literature.**

We replaced the term “grey” literature with “non-academic” literature, in this page and also elsewhere in the manuscript.

**(2) Page 5, Table 1: Some comment to Table 1 is needed (cf. Germany vs. Greece, for example).**

On table 1, in the last column, we included the source name in its original language and also its translation to English for all the 6 items. We thank the reviewer for reminding us about this issue.

**(3) Page 5, line 51: Instead of "This is not in agreement" should be "This is not in line..."**

Correction was done based on the comment of the reviewer.

**(4) Page 9, line 47 and later on: Instead of acronym "PBL study" full name should be provided for the first time.**

The name PBL is first mentioned on page 8 line 1. On that page, we have mentioned the original Dutch name and the English translation of this name has been added as footnote to page 8.

**(5) References: Many spelling mistakes! References should be prepared carefully according to the line of Transport Reviews what is not the case.**

We thank the reviewer for raising this issue. We have thoroughly checked the References and followed the general guidelines set by the Transport Reviews journal regarding the format of the references. We have also included the Doi number for all the cited articles that were available.

**(6) Some editorial work is needed before publication!!!**

We have indeed asked a native English editor to check the whole document for textual issues. We hope that the text in this version is fluent.

Table 1 Total HV and overall vehicle fleet sizes in some EU countries (data include all vehicle categories)

| Country | Year | No. of HVs ( >30 years) | Total fleet (million) | HV % to total fleet of vehicles | Source |
|---|---|---|---|---|---|
| UK | 2010 | 805,588 | 35.50 | 2.27 | Driver and Vehicle Licensing Agency (DVLA) for the UK |
| Germany | 2013 | 313,815 | 53.00 | 0.59** | Kraftfahrt-Bundesamt (KBA), which is the German federal motor transport authority |
| Denmark* | 2012 | 79,055 | 2.20 | 3.59 | Centralregisteret for motorkøretøjer (CRM), which is the Danish central registry for motor vehicles |
| Netherlands | 2005 | 280,000 | 8.60 | 3.25 | Centraal Bureau voor de Statistiek (CBS), which is the Dutch institute for statistics |
| Greece | 2012 | 402,932 | 6.75 | 5.97 | Car Importers Association Representatives (CIAR) of Greece |
| Sweden* | 2013 | 213,363 | 5.37 | 3.97 | Motorhistoriska Riksförbundet (MHRF), which is the Swedish national federation for historic vehicles |

* Tractors were excluded from the total vehicle figures. For further explanation see section 4.2.

** This figure is for registered vehicles older than 30 years. The percentage of all historic vehicle (registered and unregistered) adds up to 0.97% of all vehicle fleet.

Table 2 Historic Vehicle categorization in Germany by age (Source: VDA, 2013)

| Year of manufacture | Percentage of total HVs |
|---|---|
| 1930 - 1934 | 19.6 |
| 1935 - 1939 | 19.8 |
| 1940 - 1944 | 24.8 |
| 1945 - 1949 | 16.0 |
| 1950 - 1959 | 14.5 |
| 1960 to later | 5.3 |

Table 3 HV age categories in FIVA 2014 sample

| Year of manufacture | % of total HVs |
|---|---|
| 1886 - 1900 | 0.6 |
| 1901 - 1920 | 0.7 |
| 1921 - 1940 | 6.3 |
| 1941 - 1960 | 25.5 |
| 1961 - 1983 | 66.9 |

Table 6 Summary of topics discussed and the findings and level of certainty on each topic

| Topic | What is known | Types of sources | Level of certainty |
|---|---|---|---|
| Non-$CO_2$ emissions | • CO, HC, $NO_x$, and PM are the most critical pollutants<br>• Share of historic cars:<br>- $NO_x$ is 2% to 10%<br>- $PM_{10}$ is 2% to 5%<br>- HC is 15%<br>• Emissions of $NO_x$ & $PM_{10}$ are 5 & 2.5 times modern cars (respectively) | Independent research institutes i.e. PBL, IFEU, TNO | Moderate |
| $CO_2$ emissions | • $CO_2$ emissions by historic cars is 10% - 20% more than modern cars | Independent research institutes i.e. IFEU | Moderate |
| Noise | • Noise emissions of HVs per km has probably small difference with more recently build cars | Authors' reasoning based on EU noise test standards and regulations | Low |
| Safety | • historic vehicles are less safe than modern ones but driving behaviour might compensate for this to some extent<br>• Accident rates by a sample of HV owners from 15 EU states was around 20% less than the accident rate in the UK | Based on empirical evidence from a large survey and literature on driving behaviour | High |
| Congestion | • 2.5% - 10% of HV owners use daily<br>• HV mileage in UK was 0.24% of vehicle traffic thus the same share in congestion could be assumed | Empirical evidence<br>Expert opinion | Moderate |
| Social | • emotional bonding between HVs and their owners<br>• main reason for HV ownership: "enjoying", "Recreational touring" | Academic literature and empirical evidence | High |
| Economics | • €5.7 billion spent on HV restoration and repairs by owners (potentially generating 114000 jobs in EU)<br>• Other HV related economic benefits: participation in events, lodging, selling parts, charity events, ceremonies | • Based on empirical evidence from a large survey<br>• Several accounts and reports by interest groups on HV related events | • High<br>• Low |

Table 4 Fleet average emission factors of passenger car for $NO_x$ and PM10, in Germany, 1960-2011. Own calculations based on Knörr et al., (2012)

| Year | $NO_x$ | $PM_{10}$ |
|---|---|---|
| | index 2011=100 | |
| 1960 | 583 | 163 |
| 1970 | 585 | 166 |
| 1980 | 611 | 197 |
| 1990 | 434 | 251 |
| 2000 | 178 | 212 |
| 2011 | 100 | 100 |

Table 5 Fleet average emission factors of passenger car fleet for $CO_2$, Germany, 1960-2011. Own calculations based on Knörr et al., (2012)

| Year | $CO_2$ (index 2011=100) |
|---|---|
| 1960 | 114 |
| 1970 | 122 |
| 1980 | 126 |
| 1990 | 119 |
| 2000 | 110 |
| 2011 | 100 |

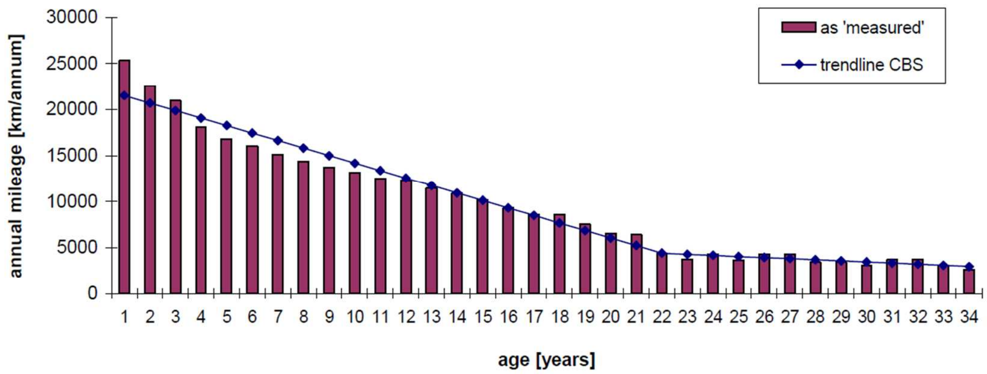


Figure 1 Annual vehicle usage against age, Note: CBS stands for Dutch bureau of statistics. Source: Rijkeboer (2008)

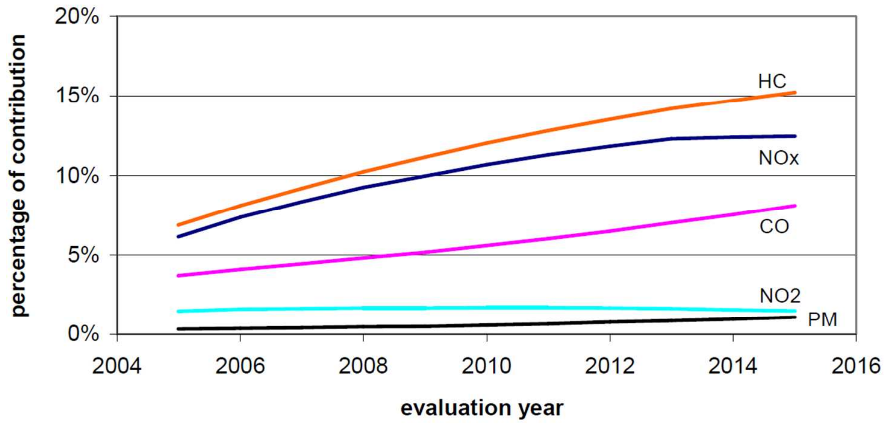


Figure 2 Annual contributions of passenger cars 25+ years to the overall car emissions. Source: Rijkeboer (2008)