RICARDO-AEA

Improvements to the definition of lifetime mileage of light duty vehicles

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Executive summary

The purpose of this study was to gather and analyse data in order to better understand the definition of lifetime mileage of light duty vehicles (LDVs) and hence evaluate the impact of mileage on the cost effectiveness of the EU's passenger car and light commercial vehicle CO_2 Regulations.

The key aims of this study were to:

i. Gather data on lifetime mileage and analyse the total mileages recorded for vehicles of different ages from the available datasets and;
ii. Establish how annual vehicle mileage varies with age for different types of vehicles to provide a better understanding of mileage accumulation rates.

1.1.1 Data gathering, processing and sampling

The focus of this study was on the UK's periodic technical inspection (MOT) vehicle database where utilisation of anonymous vehicle identification numbers (VEH_ID) within the database allowed for vehicles to be tracked from one year to the next. Drawing on this data, two new databases were created in the data processing task;

1. ***Lifetime mileage database*** – This database contained all relevant vehicles that:
    a) **passed** their MOT periodic technical inspection test in year i but were missing from the MOT database in year i+1; or
    b) **failed** their MOT in year i and were missing from the MOT database in year i+1.

    Both criteria made it likely that a vehicle had been removed from the road and was therefore assumed to be at end of life. This database contained vehicles from MOT databases dating back to 2006.

2. ***Annual mileage database*** – This database contained all relevant vehicles that passed their MOT in year i and had a subsequent pass in year i+1. These criteria allowed an annual mileage figure to be calculated for each vehicle as the mileage in year i and year i+1 was now known. This database contained vehicles only from the 2012 and 2013 MOT databases

1.1.2 Analysis of the lifetime mileages and retirement ages of light duty vehicles

A summary of the results of the analysis carried out to estimate lifetime mileages and retirement ages for different types of light duty vehicles is detailed below:

- Based on 2012-2013 data, on average, diesel cars (lifetime mileage of approximately 208,000 km) are driven a little under 25% further than petrol cars (lifetime mileage of approximately 160,000 km). For LCVs the average lifetime mileage is around 224,000 km, 7% higher than diesel car lifetime mileages and 30% higher than petrol car lifetime mileages;
- Looking at the historic datasets (from 2006-2013) a year on year increase in lifetime mileage is observed for passenger cars. This increase equates to a 33% rise in lifetime mileage between 2006 and 2013 (over 50,000km).
- For petrol cars the evolution over time is more flat with lifetime mileages fluctuating between 160,000 km and 170,000 km for the past six or seven years. Like diesel cars, average lifetime mileage for petrol cars has also increased over the 2006-2013 time frame; however in this case the increase is only 6%. For LCVs, the data indicates that there have been increases in average lifetime mileage between 2006 and 2013. According to the results the difference in average lifetime mileage between 2006 and 2013 is over 40,000 km (similar to diesel cars).

- The average retirement age of petrol cars in 2012-2013 was calculated to be 14.4 years while for diesel cars it was 14.0 years. This equates to petrol cars remaining in the vehicle parc around 3% longer on average. For LCVs, the data indicates that the average retirement age in 2012-2013 was 13.6 years. This figure indicates that LCVs retire 3% earlier than diesel cars (equating to around 6 months) and 6% earlier than petrol cars (equating to a little under one year).
- Looking at how retirement age has evolved over time, the historic datasets show that average retirement ages for petrol and diesel cars have been increasing year on year since 2006-2007. From 2006 to 2013, the average age of retirement increased by almost 7% for petrol cars and by almost 12% for diesel cars. For LCVs, the results show a slightly different trend; unlike cars, the average age of retirement for LCVs decreased considerably between 2007 and 2008, before rising again the following year. On the whole however, the average retirement age for LCVs increased by almost half a year between 2006 and 2013 – equating to a 3% rise.
- Analysing the link between lifetime mileage and mass indicates that there is not a strong relationship observed between these two parameters for cars or LCVs. As vehicle mass increases, lifetime mileage can increase or decrease, depending on the specific vehicle mass bins examined.

1.1.3 Analysis of annual mileage data and average age data for light duty vehicles

A summary of the results found in this analysis is detailed below;

- Based on data from the 2012-2013 dataset, petrol cars are driven on average a little under 10,800 km per year whereas for diesel cars the average annual mileage is much greater at roughly 16,800 km. These figures indicate that diesel cars are being driven around 36% further (annually) than petrol cars. For LCVs an average of a little under 15,500 km per year was calculated. This is 43% more than an average petrol car and 8% less than an average diesel car.
- The average age of petrol cars in the current fleet is higher than diesel cars. For petrol cars the average age is 9.6 years whilst for diesel cars the average is 7.8 years. The data also indicate that the average age of LCVs is 8.6 years.

1.1.4 Mileage accumulation rates

A summary of the results found in this analysis is detailed below:

- In order to analyse annual mileage as a function of time, mileage data points were derived by creating discrete age categories (bins) in order to generate a complete profile of annual mileage against vehicle age. The “trim mean” function has been applied to the data to allow averages at each year bin to be observed. This function uses the middle 90% of the data to remove outliers, which helps to increase the robustness for mixed and/or heavily-skewed distributions (as is the case for mileage data).
- The results show that annual mileage for petrol cars is relatively stable (around 10,000 km per year) through time until around year ten when annual mileage starts to decay. For diesel cars the decay in annual mileage starts earlier (from three years of age) and at a marginally increased rate to petrol cars. For LCVs, during years three and four there is a sharp drop in annual mileages. After peaking at 31,000 km in year three, the data indicate that there is around a 45% reduction in annual mileage for LCVs between the third and fourth year of a vehicle’s life. Finally, as for cars, after four years on the road, LCV annual mileages begin to decay steadily (and largely linearly) until end of life (EOL).
- For all vehicle types, the trend of the data points from ages four and onwards appear to follow a power distribution. Based on this, mileage accumulation rate functions were derived for petrol cars, diesel cars and LCVs.
- The subsequent results from analysing accumulated mileage over time show that this relationship is non-linear for cars and LCVs. With cars the most appropriate relationship is a quadratic function whilst for LCVs it is a cubic function that best models accumulated mileage.

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2 Introduction

Ricardo-AEA was commissioned to carry out research to improve the understanding of the lifetime mileages of light duty vehicles. The lifetime mileage of a vehicle is defined as the total distance driven during its entire lifetime[1].

A review of the EU CO_2 Regulations for passenger cars (Reg. No. 443/2009) and light commercial vehicles (LCVs) (Reg. No. 510/2011) is being prepared in view of setting CO_2 reduction targets beyond 2020. To support forthcoming work on an impact assessment of any new legislative proposals, there is a need for a better understanding of the impact of mileage on the cost effectiveness assessment of the light-duty vehicle Regulations.

The current CO_2 Regulations for passenger cars and LCVs use a regulatory metric based on measured test-cycle CO_2 performance (i.e. gCO_2/km). Whilst this metric provides an indication of comparative emissions performance on a unit distance basis, it does not reflect the total emissions released by vehicles over their full lifetimes. That is, vehicles that are used more intensively (i.e. those that have higher lifetime mileages) may contribute more to total CO_2 emissions from road transport compared to vehicles that are used less intensively.

There can be significant differences in the usage profiles of different vehicles and, in theory, it could be more cost effective to apply different targets to vehicles that are used more intensively (i.e. those with higher lifetime mileages) compared to those that have lower lifetime mileages. Whilst this would mean that the split of the burden of effort required to abate vehicle CO_2 emissions might change, there is the potential for the total costs associated with meeting future light duty vehicle legislative CO_2 targets to reduce as mileage-based weighting could improve the overall cost-effectiveness of the EU's car and LCV CO_2 regulations.

However, in order to be able to investigate the potential for applying lifetime mileage based targets, robust and detailed data analysis on mileage statistics is required.

2.1 Previous Work

Previous work performed by Ricardo-AEA in 2014 (Ricardo-AEA, 2014) looked at finding a correlation between vehicle size and lifetime mileage that could inform future, post-2020/21, policy on CO_2 emissions from light duty vehicles. This study included a wide ranging data collection task to source suitable mileage data from across the EU in order to investigate potential correlations as well as a cost analysis on the impact of a 'mileage-based' target system based on the findings from the data analysis. The study also looked at (in less detail) the mileage profiles of LDVs over their lifetimes (mileage accumulation rates).

It became apparent during the study that being able to deduce, from the mileage data, when a vehicle leaves the parc at the end of its life (and therefore knowing a vehicles actual 'lifetime mileage') is extremely challenging. It was agreed with the Commission that vehicles of 15 years age would be analysed in detail and that the mileage values of vehicles at this age would be assumed to be 'lifetime mileage'.

This new study has investigated this issue further in order to enable a better understanding of the true average lifetime mileages and average lifespan (in years) for passenger cars and light commercial vehicles to be developed. Additionally, further analysis of the rates at which vehicles accumulate mileage over their lifetimes has been carried out.

[1] Due to the scope of the study, this definition is limited to mileage driven in the vehicles country of registration.

2.2 Aim of study

The project consisted of the following tasks:

Gather data on lifetime mileage (preferably in addition to the data that has been used for previous studies on mileage) and analyse the total mileages recorded for vehicles of different ages from the available datasets

The aim here was to identify and review potential sources of reliable data on vehicle lifetime mileage. The key issue was to find data that is of sufficient sample size to perform a robust analysis. The data also needed to be sufficiently disaggregated to allow analysis on lifetime mileage versus vehicle age to be undertaken – that is, the data should ideally include date of first registration, or age of vehicle (in years) as a minimum requirement.

Earlier work performed by Ricardo-AEA assumed that light duty vehicles have an average lifespan of 15 years (Ricardo-AEA, 2014). However, this assumption was not based on analysis of the ages of vehicles when they leave the parc. This new study has investigated vehicle lifespan and vehicle lifetime mileage in more detail, using more advanced methods to establish the average vehicle mileage at end of life.

Establish a model describing how annual mileage varies as vehicles get older to provide better understanding of the mileage accumulation rates

The aim of this task was to build on the data collection and analysis stage presented above to develop a model for describing how annual mileage varies over time (as vehicles get older). It was concluded in the previous study that mileage accumulation rates are not linear; in particular, it was found that vehicles are driven more intensively (i.e. they have higher annual mileages) during the early stages of their lives. By contrast, previous impact assessment analysis for the Regulations assumes that mileage accumulates in a linear manner over the vehicle's whole lifetime (European Commission, 2012a).

A new model that more accurately describes how vehicle mileage varies with age could be used to underpin areas of the future impact assessment and to assist in post-2020/21 target setting. Knowing how the average mileage of a vehicle varies with vehicle age will help greatly in improving the assessments of cost effectiveness carried out in any future impact assessment on possible options for post-2020/21 legislation in this area.

A qualitative discussion on the impact of the inter Member State second-hand vehicle market

The analysis performed in the previous study focuses on the use of vehicles within each Member State and does not take into account the cross-border second-hand market.

If a vehicle is removed from the periodic technical inspection database within a Member State (such as the UK's MOT database or 'Contrôle technique' test databases from France and Belgium) this does not necessarily mean it has been scrapped. The vehicle may have been purchased second hand in another country and therefore "dropped off" the database in its country of first registration. Therefore, the level of cross border movement for used cars within Europe can be seen as an indicator for the robustness and accuracy of mileage datasets.

The goal of this task was to provide an initial scoping review of literature to identify data sources and evidence regarding cross border car sales to ascertain where this market is most prevalent.

2.3 Scope of study

2.3.1 Introduction to the UK MOT dataset

This section of the study introduces the mileage database analysed for this work – the publically available, anonymised, UK MOT[2] road-worthiness test database (UK Department for Transport, 2013a) and describes how it was utilised to undertake the tasks described in Section 2.2. As part of the previous work on this topic carried out in 2014, we were able to establish that this is the only database available to the contractor which includes the detail necessary for the current set of analyses. With this in mind, we stress that the analysis carried out for this study is fully representative for the UK car and van fleet, but will necessarily be less representative of conditions in other EU Member States.

The purpose of the UK's MOT test is to ensure that cars, other light vehicles (including some light goods vehicles), private buses and motorcycles over a prescribed age (three years for almost all light duty vehicles) are checked at least once a year to ensure that they comply with key roadworthiness and environmental requirements included in the UK's Road Vehicle Construction and Use Regulations 1986 and the Road Vehicle Lighting Regulations 1989, as amended.

The MOT database comprises two main groups of data, each divided into data for each calendar year as follows:

- Test results, containing;
    - Information about the time, place and final outcome of the MOT test.
    - Information about the vehicle tested.
- Test items, which contains information about individual reasons for rejection discovered during the test.

The latest version of the dataset has introduced a new unique ID variable in the Vehicle Test Result table. This allows users of the database to identify tests for the same vehicle and therefore track the vehicle's MOT test performance and mileage over time. It is this key feature which allows this study to be achievable.

The analysis focused on gathering lifetime mileage data from the MOT database for petrol cars, diesel cars and diesel LCVs for each calendar year from 2006 to 2013 inclusive.

For the duration of the study, the analysis of mileage statistics focused only on the years, fuel types and vehicles types shown below in Table 2-1.

Table 2-1 – Scope of analysis within the study

MOT Dataset	Petrol, cars		Diesel, cars		Diesel, LCVs	
	Annual mileages	Lifetime mileages	Annual mileages	Lifetime mileages	Annual mileages	Lifetime mileages
2006	×	✓	×	✓	×	✓
2007	×	✓	×	✓	×	✓
2008	×	✓	×	✓	×	✓
2009	×	✓	×	✓	×	✓
2010	×	✓	×	✓	×	✓
2011	×	✓	×	✓	×	✓
2012	✓	✓	✓	✓	✓	✓

[2] MOT refers to the "Ministry of Transport" test, the UK's periodic roadworthiness test.

MOT Dataset	Petrol, cars		Diesel, cars		Diesel, LCVs	
	Annual mileages	Lifetime mileages	Annual mileages	Lifetime mileages	Annual mileages	Lifetime mileages
2013	✓	✓	✓	✓	✓	✓

3 Methodology for extraction of mileage data from UK MOT Test records

3.1 Overview

Data extracted from the UK MOT datasets were analysed to derive vehicle mileage figures to assist in assessments of whether and how particular vehicle parameters (size, mass, fuel type, age) are correlated with lifetime distances travelled. Two particular sets of data were extracted;

1. Lifetime mileage (i.e. the number of miles (converted to kilometres) that the vehicle has travelled prior to being scrapped or otherwise permanently removed from the road) and;
2. Annual mileage.

This section describes the approach used to derive these data from the MOT test data sets.

The datasets in the MOT database have been anonymised to ensure that it is not possible to identify the particular vehicle (e.g. registration number or VIN[3] number) or its keeper. However, a unique numerical identifier has been added for each individual vehicle so that it is possible to track the different test results for a particular vehicle through each of the years. This feature enables the identification of records for the same vehicle in consecutive years (which forms the basis of our methodology).

The 2014 release of the MOT database contains test data from January 2005 up to and including December 2013. MOT computerisation was not fully implemented across the UK until April 2006 and therefore the dataset does not contain all tests performed between January 2005 and March 2006. It is because of this that on analysing the 2005 dataset, the number of records was found to be much lower than for the other years and a significant proportion have “NULL” values for the date of first registration field (necessary for the calculation of vehicle age). For this reason, the 2005 MOT test data were not used and the analysis was performed using data from 2006 to 2013.

3.2 Lifetime mileage

The aim of this part of the process was to identify vehicles that are thought to be at end-of-life (EOL) and create a database of such vehicles. Using this database, the average age at which a vehicle reaches its end of life was calculated. For vehicles which appear in the MOT test database in one year and not the next, it can reasonably be assumed that they were removed from the road at some point during the that year. Based on this assumption, vehicle lifetime mileage can be assumed to be that recorded as part of the vehicle’s final MOT test, with a proviso that they may have accumulated some additional mileage after the test but before being removed from the road (likely to be relatively small as the vehicle would have been in its last year of being used on the road). The table below summaries the criteria used for determining whether and when a vehicle has reached the end of its life.

Table 3-1: Process for developing lifetime mileage database from UK MOT datasets

MOT test result		Action
Year i	Year i+1	
✓ Pass	✓ Pass	Exclude (used in analysis of annual mileage – see Section 3.3).
✓ Pass	○ No record	Assume vehicle reaches EOL in Year i+1
× Fail	○ No record	Assume vehicle reaches EOL in Year i

[3] Vehicle Identification number (VIN)

The identification of such vehicles uses the VEH_ID field (the unique identifier for an individual vehicle in the MOT database).

The numbers of records identified via this process are shown in Table 3-2.

Table 3-2 Numbers of records extracted for lifetime mileage analyses for the different year pairs

Year-Pair	Total number of records extracted
2006-2007	3,182,034
2007-2008	3,215,604
2008-2009	3,131,924
2009-2010	3,086,820
2010-2011	>10,000,000
2011-2012	2,950,017
2012-2013	2,888,817

The anomalous results for 2010-2011 are investigated in more detail within Appendix 2. As the source of these anomalies is not clear, data from that year were excluded from the analysis stage.

3.3 Annual Mileage

The process for creating the output for the annual mileage analyses is similar to that for the lifetime mileage, except that the approach was to extract data for vehicles which have MOT test records in two consecutive years (in this case the year's 2012 and 2013 only). As before, this process is summarised in Table 3-3.

Table 3-3 - Process for developing annual mileage database from UK MOT datasets

MOT test result		Action
Year i	Year i+1	
✓ Pass	✓ Pass	Take forward for annual mileage analysis
✓ Pass	○ No record	Exclude (used in analysis of lifetime mileage – see Section 3.2).
× Fail	○ No record	Exclude (used in analysis of lifetime mileage – see Section 3.2).

The number of vehicles with a test in the first year which survive to have a test in the second year (and hence for which annual mileage values can be calculated) is significantly greater than the numbers of vehicles identified for inclusion in the lifetime mileage analysis in Section 3.2.

With this in mind, the data was subject to the following constraints;

- Odometer reading in first year > 0
- Odometer reading in following year > 0
- Odometer reading in year i+1 is not lower than the odometer reading in year i
- Difference in odometer readings between the two years < 100,000 miles (160,000 km)
- Test result in both years = Pass

- TEST_CLASS = 4 (passenger vehicles and light commercial vehicles only)

These constraints on the odometer readings were used to ensure that the outputs did not contain records with excessively high values (likely to be the result of errors in the recording of the odometer readings in the data).

The annual mileage was then calculated as the difference in odometer readings between the two years, multiplied by 365, divided by the number of days between the two tests, so it represents an equivalent mileage for a 365-day year when the test dates are not exactly one year apart.

The number of records extracted during this process is shown in Table 3-4.

Table 3-4 Numbers of records extracted for annual mileage analyses

Year-Pair	Total number of records extracted
2012-2013	18,410,563

3.4 Data sampling

To manage the size of the output data collected (Table 3-2 and Table 3-4) and to minimise the inclusion of unnecessary (e.g. data for motorcycles) or anomalous results, some constraints have been applied to the data extracted. These constraints are as follows:

- Vehicles where the model is recorded as “UNCLASSIFIED” were not included;
- The test date (in the first year only) lies within a particular week (e.g. 10/10/2012 to 16/10/2012 inclusive). No constraints are added for the second year as this would be overly constraining (vehicle owners can take their vehicle for MOT testing at any time during the year and hence it cannot be expected that MOT tests will be performed the same week each year).

The selection of a particular week for the test date was purely to manage the size of the output table. The choice of a week in October was made on the basis that the month has no public holidays that may influence the results. Furthermore, there is no peak in new car sales in October (March and September being the two months where sales peak in the UK, due to the six-monthly change in the age indicator on vehicle registration plates) meaning that there should not be higher than average MOT tests that month.

Additional work and analysis on this sampling process can be found in Appendix 2.

3.4.1 Sample sizes

The datasets extracted using the methodology above have been cleaned (removal of blank/null data) and the current sample sizes for each analysis (lifetime and annual) are as shown in Table 3-5, Table 3-6 and Table 3-7.

These sample sizes are considered to be both large enough to be representative and also small enough to be able to efficiently and correctly carry out the analysis under the constraints of the study.

Table 3-5 – Lifetime mileage analysis: sample sizes for vehicles that passed MOT in year i and did not appear in MOT database in year i+1

Records analysed	Numbers of vehicles sampled			
	Petrol cars	Diesel cars	Diesel LCVs	Total
2006-07	32,091	8,939	28,190	69,220
2007-08	32,033	9,666	31,984	73,683

Records analysed	Numbers of vehicles sampled			
	Petrol cars	Diesel cars	Diesel LCVs	Total
2008-09	32,698	10,208	30,643	73,549
2009-10	11,973	3,874	31,186	47,033
2011-12	30,958	11,629	34,359	76,946
2012-13	30,737	12,751	33,651	77,139
Total	**170,490**	**57,067**	**190,013**	**417,570**

Table 3-6 – Lifetime mileage analysis: sample sizes for vehicles that failed MOT in year i and did not appear in MOT database in year i+1

Records analysed	Numbers of vehicles sampled			
	Petrol cars	Diesel cars	Diesel LCVs	Total
2006-07	23,674	8,885	3,834	36,393
2007-08	24,302	8,894	3,610	36,806
2008-09	26,107	9,818	4,232	40,157
2009-10	26,767	9,350	4,335	40,452
2011-12	29,568	7,374	3,802	40,744
2012-13	27,436	6,367	3,511	37,314
Total	**157,854**	**50,688**	**23,324**	**231,866**

Table 3-7 – Annual mileage analysis: sample sizes

Analysed records	Petrol cars	Diesel cars	Diesel LCVs	Total
2012-13	**75,713**	**50,838**	**86,577**	**213,128**

4 Results

4.1 Lifetime mileages

This section presents the results from the analysis of lifetime mileages for the 2012-2013 year pair dataset (given that it is the most recent and therefore relevant) for passenger cars and LCVs. Individual analysis of the historic year datasets can be found in Appendix 2. It should be emphasised again that all following results are from UK datasets only.

The key areas of analysis investigated here are:

1. Evaluation of lifetime age and lifetime mileage values of petrol and diesel vehicles (including how these have evolved over time).
2. Lifetime mileage values for petrol and diesel vehicles in different kerb mass categories
3. Brief evaluation of the relationship between lifetime mileage and kerb mass

It became apparent whilst analysing lifetime mileage statistics from the sample of data that the conclusions being drawn were not what was expected. For both petrol and diesel passenger cars as well as for LCVs, average ages of retirement and lifetime mileages were considerably *lower* than was to be expected from previous work. It is surmised that the methodology detailed in Section 3.2 whereby a dataset of vehicles assumed to be at EOL was created from those vehicles that passed their MOT in year i but that were not present in the MOT database in year i+1 was not robust enough to yield consistent results (see Figure 6-7 for example in Appendix 2).

It is difficult to isolate exactly why this was the case; however it is likely that there are a number of reasons why these vehicles may not be present in the database in year i+1 other than being removed from the road due to not being roadworthy. These are explained below:

The statutory off road notice (SORN) – The methodology used assumes that vehicles present in one year's MOT database and not the next have reached the end of their lives and have been scrapped. This may not always be the case due to the UK's Statutory Off-Road Notice or SORN (www.gov.uk, 2014) procedure where motorists who do not wish to use their vehicles can legally declare them as being "off the road" (meaning that vehicle insurance, payment of vehicle excise duty (a circulation tax) and an MOT test pass are not required. Hence, it is possible that a vehicle absent from the MOT database in one year may not have reached the end of its life but is instead off the road for an indefinite period of time. Figures from 2009 show that SORN vehicles accounted for around 5%[4] of all vehicles registered in the UK. However, the existence of SORN vehicles is not, on its own, sufficient to fully account for the levels of deviation observed in the average values of lifetime mileage and vehicle retirement age (Swift Cover, 2010).

Cross border second hand market - The methodology performed to date focuses on the use of vehicles within the UK and does not take into account the cross-border second-hand market. A study by the European Commission (European Commission - DG Climate Action, 2010), provides some indications of the scale of cross-border movement of second hand vehicles. Whilst levels of cross-border movement are expected to be low in the UK, it could be argued that the reason for some inconsistent results using this methodology is to do with vehicles being assumed to have left the parc prematurely when in reality they have left the country and are continuing to accumulate mileage elsewhere. It should also be noted that the MOT test database does not include Northern Irish vehicles (confirmed by a post code review of the data) so there is the potential for vehicles to have moved from mainland Great Britain to Northern Ireland. Section 5 discusses this issue in further detail.

Theft – It is possible that vehicles present in the MOT database in year i and not present in year i+1 have left the official fleet because they have been stolen. However, only 28 vehicles per 10,000 vehicles registered in the UK (less than 0.3%) were stolen in the period between October 2011 and September 2012 (Honest John, 2013) and hence theft is unlikely to account for many of the vehicles that leave the fleet in any year of interest.

All these factor may partially explain the lower than expected retirement ages and lifetime mileage values found using this methodology.

Vehicle write-offs (in the UK, around 1.5% of cars are written off due to accident damage each year (HonestJohn.co.uk, 2013)) is one other reason that would cause a vehicle to not to appear for its MOT one year after passing. However, to give a true picture of vehicle lifetime age and mileage these vehicles should be included as written off vehicles have still reached the end of their life.

Some initial results using the first approach (pass in year i, not present in i+1) can also be found in Appendix 2 to further explain why the decision was taken not to use this approach.

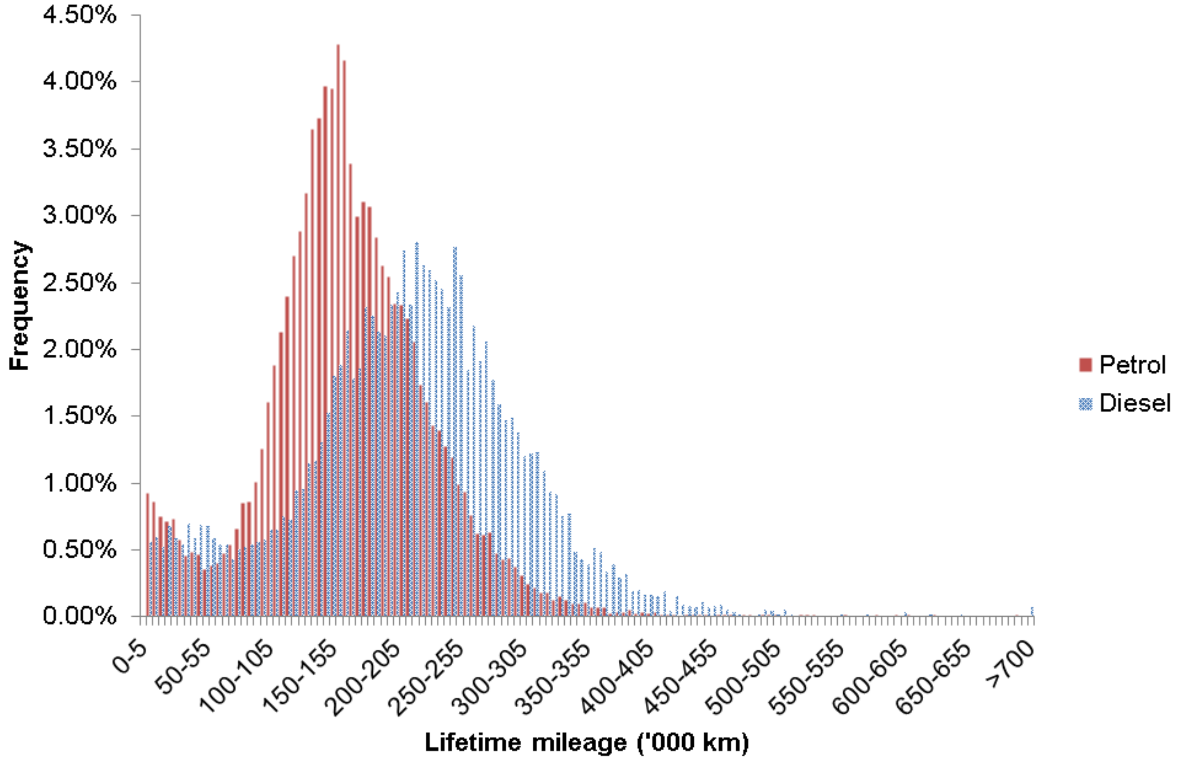
It is estimated that the above reasons for vehicles not appearing in the MOT database the year after passing could capture enough vehicles to skew some of the results (see Appendix 2). With this in mind, the additional analysis (for both cars and LCVs) was carried out using only those vehicles that ***failed*** their MOT in year i and were not included in the MOT database in year i+1. This approach should ensure that the vehicles being analysed are not affected by the issues listed above as these vehicles will have only been removed from the road as they have been deemed unroadworthy or have been written off. Table 3-6 presents the sample size of the datasets for these vehicles.

4.1.1 Passenger cars

4.1.1.1 Analysis of lifetime mileage data for petrol and diesel cars

Figure 4-1 presents the frequency distribution of lifetime mileage values for petrol and diesel cars for 2012-2013.

Figure 4-1 – Comparison of lifetime mileage (km) distribution between petrol and diesel passenger cars (2012-2013)



There are some interesting observations:

1. On average, diesel cars are driven further than petrol cars. On a like-for-like basis, diesel cars are significantly more fuel efficient than equivalent petrol cars and hence they tend to be chosen by those users who have high annual mileages. This result is expected based on previous analysis from the original mileage study.

2. The distribution of both petrol and diesel cars exhibit a spurious early peak in very low lifetime mileages. It has been most difficult to try to explain this. It was surmised that it may be artefact of cars only having 5 digit odometers until around the early 1990s and therefore once an odometer reaches 100,000 miles it will reset back to zero. Other theories that could explain the observation include early retirements due to accidents, however, again, this would not be expected to make such an impact on trend of results.

In order to test this theory – all vehicles greater than 16 years of age have been removed for the duration of the analysis on lifetime mileage. It is not expected that this additional constraint on the database will completely eradicate the issue but it will increase confidence and accuracy of the results. Also, it is possible that a small percentage of accurate/correct odometer readings have been omitted using this approach. However, under the limitations of the work, this approach was deemed sufficiently robust.

Therefore, making the above changes to be the database gives the following results (Figure 4-2).

Figure 4-2 – Comparison of lifetime mileage (km) distribution between petrol and diesel passenger cars (2012-2013) after adjustment for 5-digit odometer vehicles

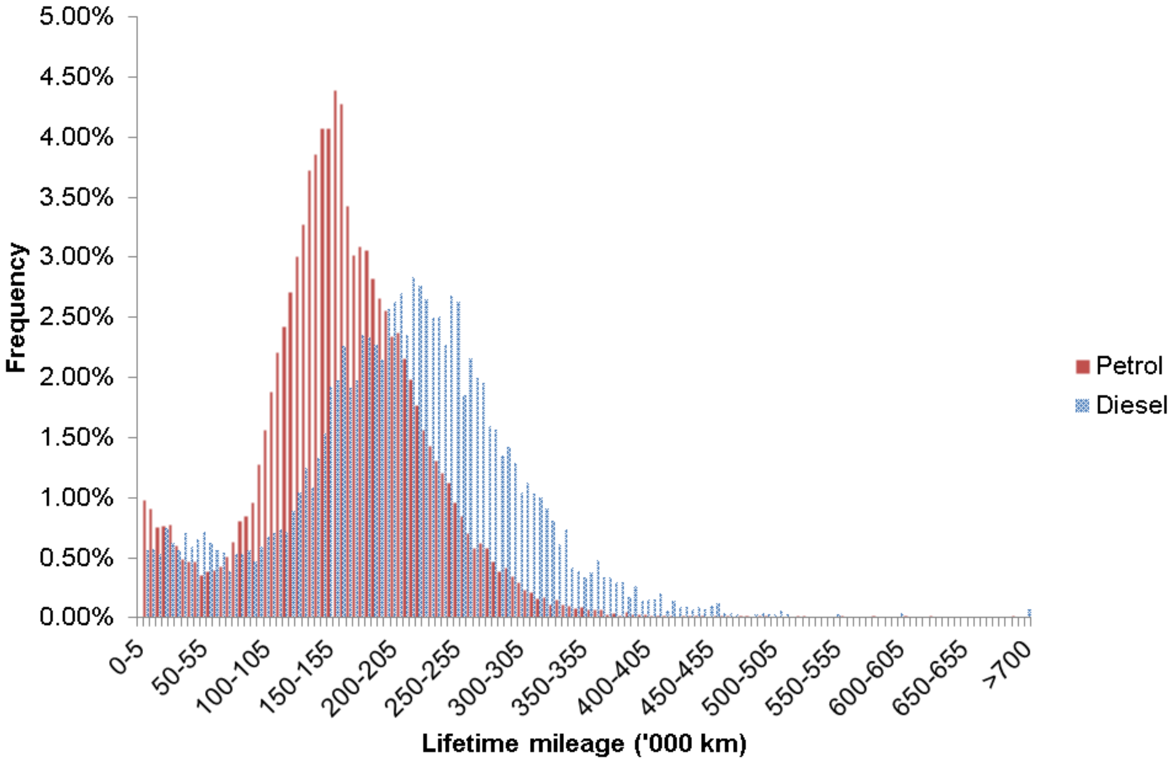
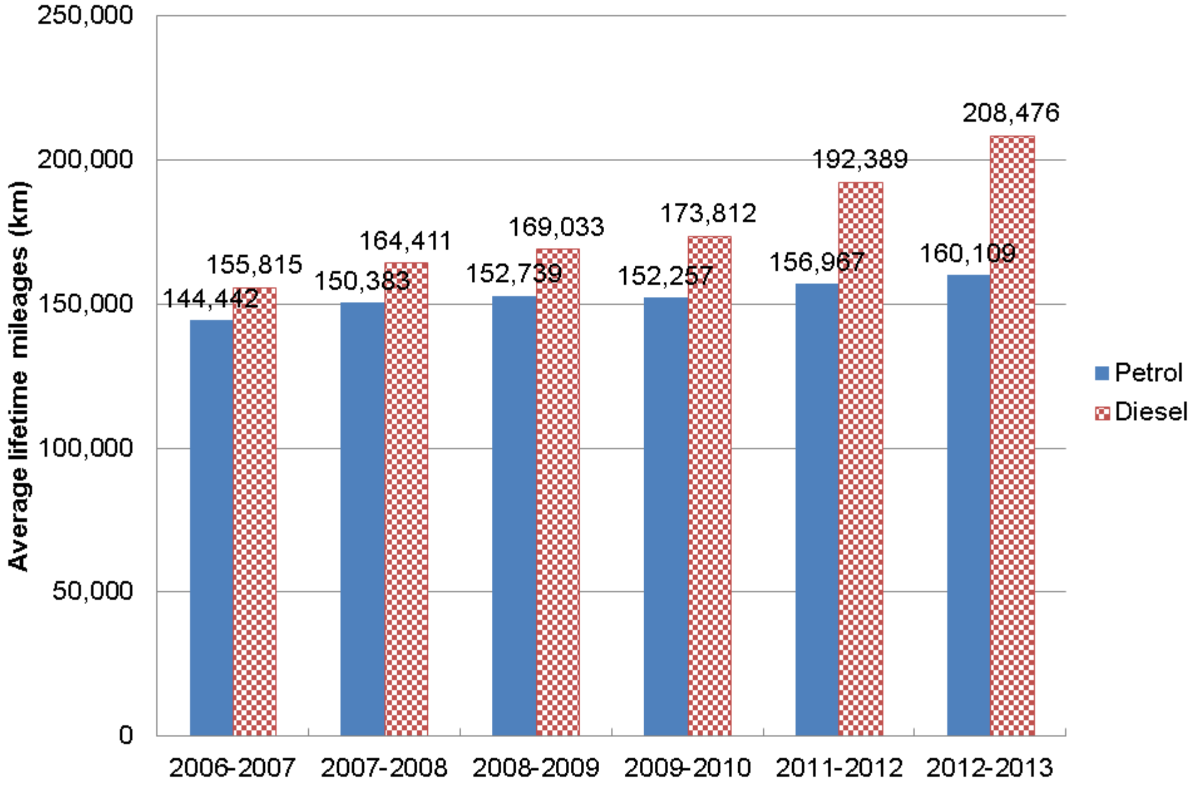


Figure 4-2 shows that petrol cars are driven around 160,000 km in their lifetime whilst diesel cars average 208,000 km. This means therefore that diesel cars are driven just under 25% further over the course of a lifetime.

Analysing the remaining lifetime mileage dataset that has been collated (dating back to 2006) allows the average lifetime mileage through time to be viewed. This evolution is shown in Figure 4-3.

Figure 4-3 - Evolution of lifetime mileages from 2006-2013 for passenger cars



The results observed in Figure 4-3 show, for diesel cars, a year on year increase in lifetime mileages from 2006 until 2013. The increase is steady until 2009-2010 and after this point the increase in lifetime mileage begins to rise quite sharply. This most likely reflects the impacts of the economic crisis as people held on to older cars for longer. According to the results the difference in lifetime mileage between 2006 and 2013 is over 50,000 km. This equates to a 33% increase, a significant rise.

For petrol cars the evolution over time is more flat with lifetime mileages fluctuating around 150,000 km and 160,000 km for the past six or seven years. In fact, like diesel cars, the average lifetime mileage of petrol cars has also increased in the 2006-2013 time frame, although in this case by only 10%.

It can therefore be concluded that lifetime mileage for both petrol and diesel passenger cars has increased since 2006 (albeit with a much greater rate of increase for diesel cars).

These results appear to go against results from the recent UK Travel Survey (UK Department for Transport, 2014) which reports a slight reduction in annual mileages in 2012 against 2002 values for passenger cars. However, it is possible for lifetime mileage to be increasing whilst annual mileage is decreasing as it will depend on how much lifetime age has increased by.

The results in Figure 4-3 for petrol cars can therefore be attributed to an increase in lifetime age (See Section 4.1.1.2).

It should be noted here that for historic results, the aforementioned issue of five-digit odometer vehicles skewing the results will be more pronounced (since there would be more of these such vehicles on the road in early years). The issue is also more pronounced for diesel vehicles as these vehicles are more likely to travel over 99,999 miles in their lifetime.

There is also a small drop in the average lifetime mileage in 2012-2013 due to removing vehicles older than 16 years old (around 1-1.5%). Therefore it can be assumed that further analysis of this 5-digit odometer issue may reduce the average lifetime mileage in later years further and help explain the inconsistency here versus the UK travel survey data.

With this in mind, care should be taken in using the results shown in Figure 4-3 for historic years (particularly for diesel cars).

4.1.1.2 Analysis of vehicle age at end of life for petrol and diesel cars

Figure 4-4 and Figure 4-5 show the distribution of the age of vehicles assumed to be removed from the road (retired). This visual depiction of retirement age distributions allows for detailed analysis of the lifetime age of passenger cars to be undertaken. Results here have been normalised to take into account changes in the fleet (varying vehicle sales as well as increasing dieselisation).

Figure 4-4 - Age distribution for petrol passenger cars at end of life in 2012-2013

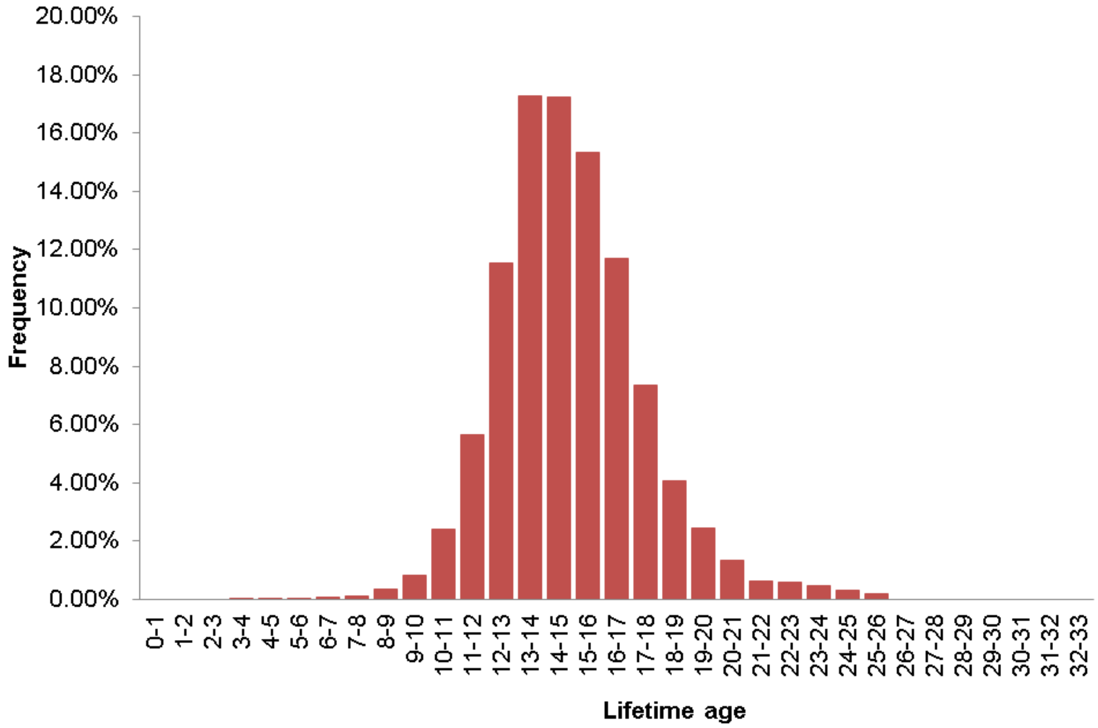
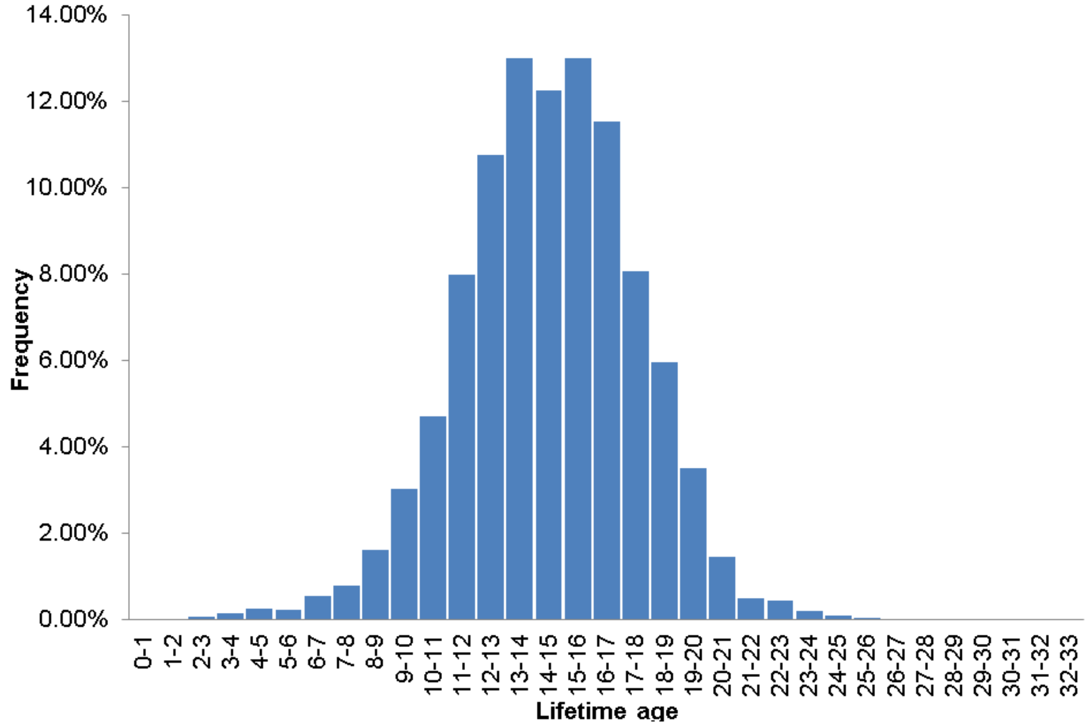


Figure 4-5: Age distribution for diesel passenger cars at end of life in 2012-2013



From the collated database, the average retirement age of petrol cars in 2012-2013 was calculated to be 14.4 years while for diesel cars it was 14.0 years. This equates to petrol cars remaining in the vehicle parc around 3% longer on average.

Table 4-1 below demonstrates in further detail when passenger cars are expected to leave the fleet. There are marginal differences between the retirement ages for petrol and diesel cars. The main difference is that it would appear diesel cars are more likely to be removed from the road prematurely. This may be partially explained by the higher annual mileages of diesel cars early in their lives and the likelihood that the numbers of vehicles written off in accidents will be proportional to distance driven. This means that the numbers of diesel cars written off will be approximately three time greater than the numbers of petrol cars written off.

Around 5% of diesel cars are removed from the road prior to their eleventh birthdays (compared to 5% of petrol vehicles being removed before they turn 12). This point is also validated in Figure 4-5 with early retirement ages for diesel cars occurring more frequently than the distribution shown in Figure 4-4 for petrol cars.

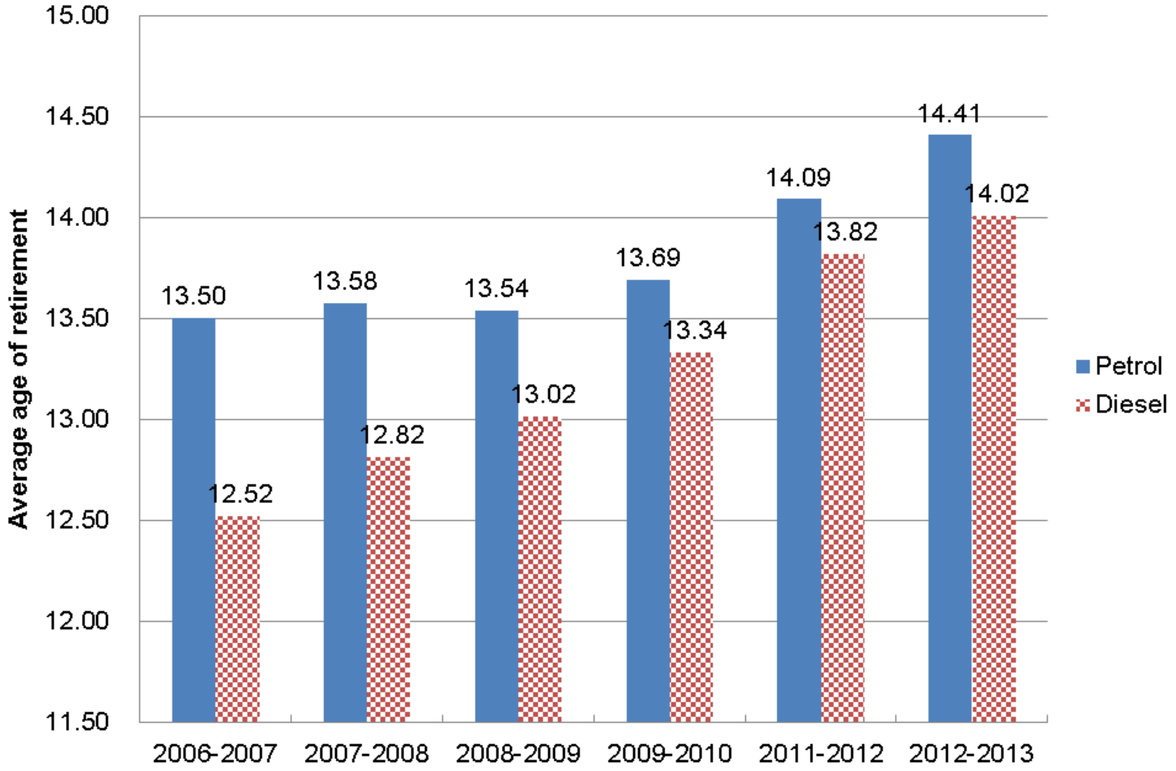
Table 4-1 – Further analysis of passenger car retirement ages (2012-2013) [5]

Age	*Expected age of retirement*	
	Petrol cars	*Diesel cars*
0-1	0.00%	0.00%
1-2	0.00%	0.00%
2-3	0.00%	0.06%
3-4	0.02%	0.14%
4-5	0.01%	0.24%
5-6	0.03%	0.22%
6-7	0.06%	0.53%
7-8	0.10%	0.78%
8-9	0.34%	1.60%
9-10	0.83%	3.02%
10-11	2.41%	4.71%
11-12	5.64%	7.99%
12-13	11.54%	10.75%
13-14	17.29%	12.99%
14-15	17.25%	12.26%
15-16	15.32%	13.01%
16-17	11.70%	11.53%
17-18	7.34%	8.06%
18-19	4.08%	5.97%
19-20	2.44%	3.49%
20-21	1.35%	1.44%
21-22	0.65%	0.49%
22-23	0.58%	0.42%
23-24	0.48%	0.20%
24-25	0.33%	0.07%
25-26	0.18%	0.03%

[5] Please note this data table should not be directly compared to Table 4-11 and Table 4-12 as both tables use differing source data as a starting point.

Finally, analysing the remaining lifetime mileage dataset that has been collated (dating back to 2006) allows the average retirement ages through time to be viewed. This evolution is shown in Figure 4-6.

Figure 4-6 - Evolution of average retirement age from 2006-2013 for passenger cars



The results presented in Figure 4-6 indicate that average retirement ages for petrol and diesel vehicles have been increasing year on year since 2006-2007. From 2006 to 2013, the average age of retirement increased by almost 7% for petrol cars and by almost 12% for diesel cars. Analysis of lifetime vehicle age was performed using the original mileage database before vehicles older than 16 years were removed (removing older vehicles to eliminate possible problems associated with mileage data from vehicles equipped five-digit odometers is only required in order to analyse mileage and not age).

4.1.1.3 Analysis of the correlation between lifetime mileage and vehicle mass for petrol and diesel cars

Previous work for the Commission (Ricardo-AEA, 2014) investigated the relationships between lifetime mileage and vehicle size characteristics (mass and footprint). The results from that study indicated that lifetime mileage tends to increase with mass and footprint for petrol cars, but for diesel cars, lifetime mileage is relatively insensitive to differences in mass or footprint. Now, with a more robust database of lifetime mileages, these relationships have been investigated in further detail.

Figure 4-7 and Figure 4-8 show the frequency weighted averages respectively for petrol and diesel cars for different mass categories. The "trim mean" function has been plotted to remove outliers. This function uses the middle 90% of the data, which helps to increase the robustness for mixed and/or heavily-skewed distributions (as is the case for mileage data). The data points plotted above and below the 'trim mean' show the upper and lower quartiles of the data. Detailed tables of the results shown in the graphs are provided in Table 4-2 and Table 4-3.

Table 4-2 - Petrol passenger car, lifetime mileage analysis results (2012-2013)

Mass Bin (kg)	Trim mean (km)	Lower quartile (km)	Upper quartile (km)
<800	122,845	98,790	144,921
800-900	144,336	116,764	172,226

Mass Bin (kg)	Trim mean (km)	Lower quartile (km)	Upper quartile (km)
900-1000	129,562	104,766	158,302
1000-1100	127,039	98,928	159,287
1100-1200	120,068	71,571	159,325
1200-1300	167,346	132,020	203,397
1300-1400	194,225	157,503	229,935
1400-1500	208,416	168,503	246,462
1500-1600	213,416	170,343	254,144
1600-1700	200,770	161,137	238,637
1700-1800	182,540	146,413	215,960
1900-2000	198,846	163,576	233,515
>2000	181,400	142,867	218,070

Figure 4-7 - Petrol passenger car, lifetime mileage by mass bin (2012-2013)

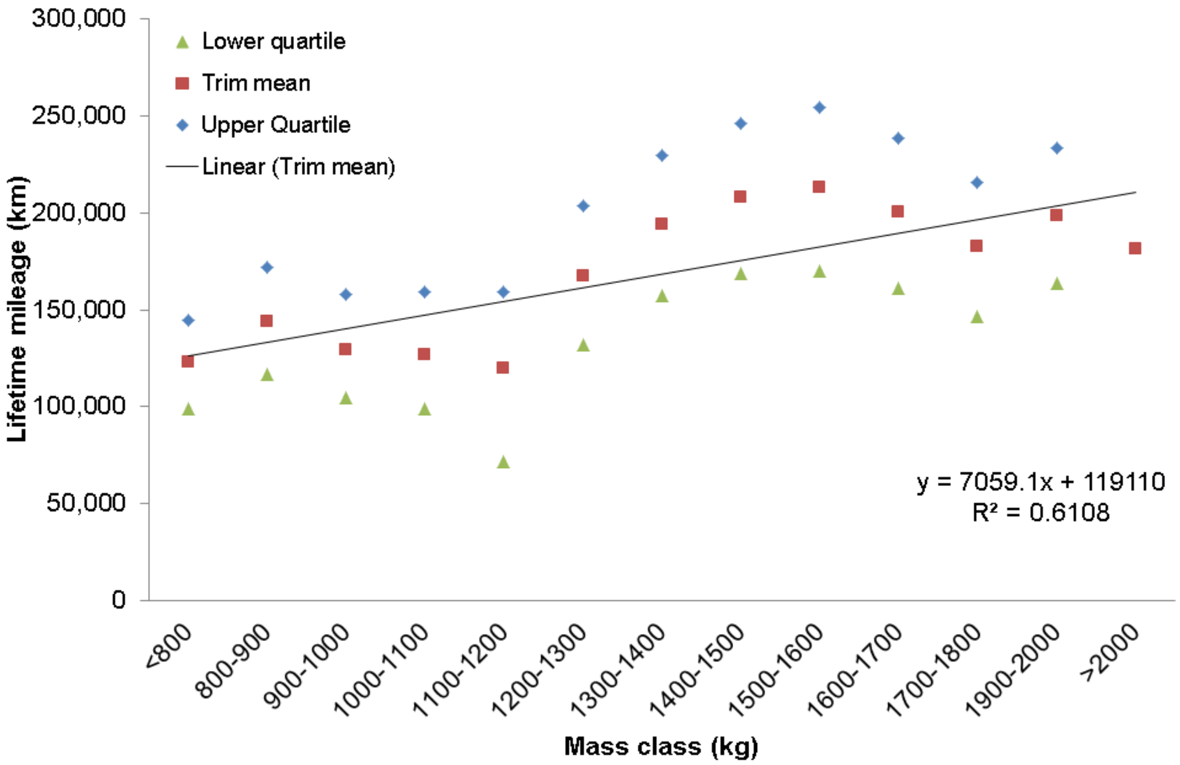
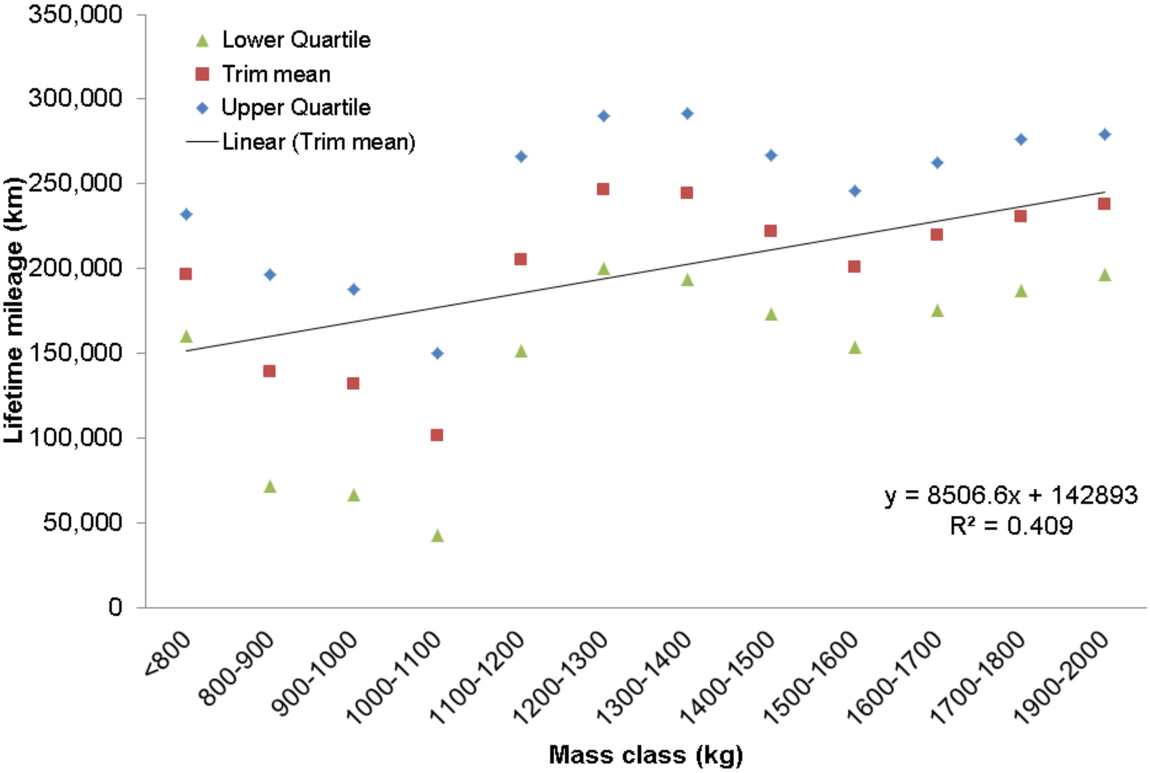


Table 4-3 – Diesel passenger car, lifetime mileage analysis results (2012-2013)

Mass Bin (kg)	Trim mean (km)	Lower quartile (km)	Upper quartile (km)
800-900	196,729	160,197	232,259
900-1000	139,447	71,761	196,810
1000-1100	132,056	67,035	187,862
1100-1200	101,899	42,970	150,295

Mass Bin (kg)	Trim mean (km)	Lower quartile (km)	Upper quartile (km)
1200-1300	205,522	151,557	266,347
1300-1400	246,464	200,252	290,241
1400-1500	244,416	193,555	291,542
1500-1600	221,932	173,178	266,978
1600-1700	201,120	153,612	245,727
1700-1800	220,213	175,771	262,399
1900-2000	230,642	186,912	276,266
>2000	237,798	196,314	279,492

Figure 4-8 – Diesel passenger car, lifetime mileage by mass bin (2012-2013)



The above results show that whilst there appears to be more of a link between increasing mass and increasing mileage for petrol cars than there is with diesel cars, there is not a strong relationship observed for either fuel type.

For petrol cars, lifetime mileage increases with mass from around 120,000 km for the lightest vehicle bins (<800 kg and 1100-1200kg) to around 213,000 km for the vehicles (1500-1600 kg) with highest mileage. Above 1600 kg, lifetime mileage tends to decrease with increasing mass. For petrol cars, the average lifetime distance travelled by vehicles in the mass category with highest average lifetime mileage is around 45% higher compared to that for vehicles in the mass category with the lowest average lifetime mileage.

For diesel cars, vehicles across the middle categories (i.e. vehicles with mass values between 1200 kg and 1400 kg) appear to be driven the furthest at around 250,000 km over their lifetimes. The overall levels of variation across all mass bands is much higher than it is in petrol cars. For example, diesel cars in mass bin 1000-1100kg have lifetime mileages of around 130,000 km, vehicles in mass bin 1200-1300kg have lifetime mileage values of 200,000 km and vehicles in mass bin 1700-1800 kg have lifetime mileage values of around 220,000 km. The link between mass and lifetime mileage is less clear for diesel cars.

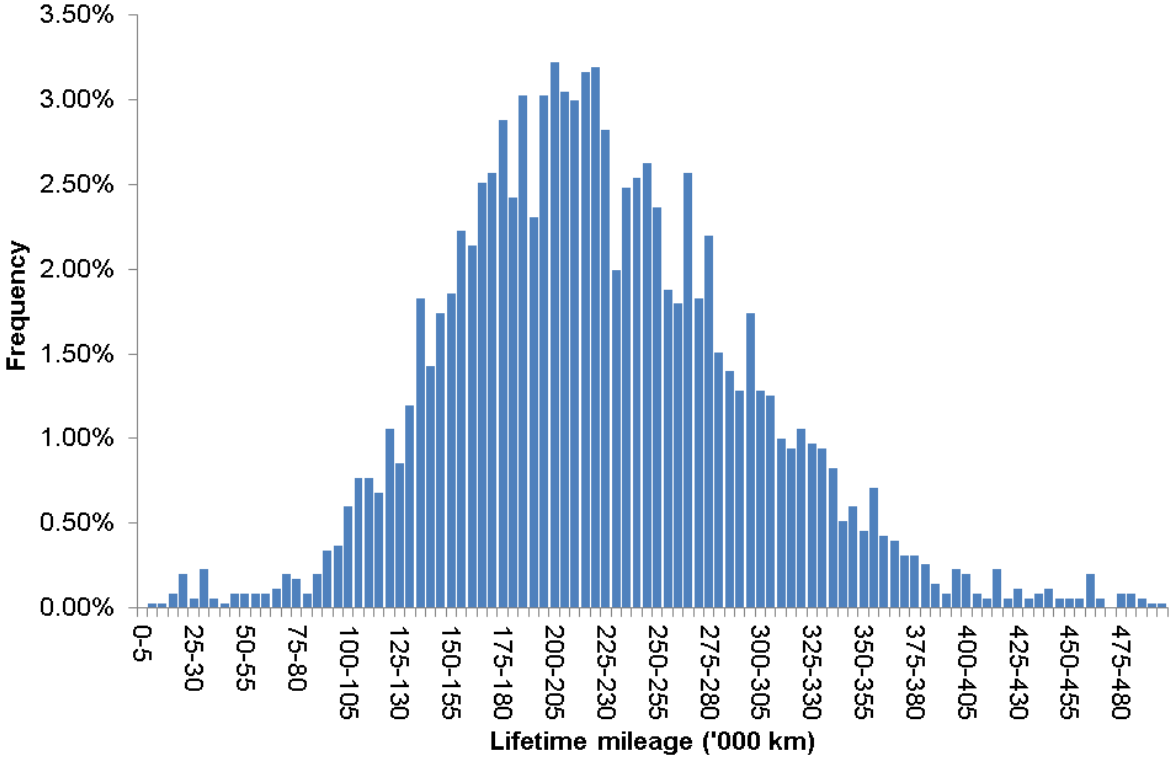
The calculated slopes of the lines are low and the correlation (R^2) is not very strong, so it is not possible to conclude that there is a strong relationship between vehicle mass (as an indicator of size) and lifetime mileage. Figure 4-7 and Figure 4-8 indicate that the relationship between mass and lifetime mileage may be non-linear.

4.1.2 Light commercial vehicles (LCVs)

4.1.2.1 Analysis of lifetime mileage data for LCVs

For LCVs, Figure 4-9 shows the distribution of lifetime mileages from the compiled dataset for 2012-2013 for light commercial vehicles. As with passenger cars, vehicles that are suspected to be fitted with five digit odometers (that will skew results) have been removed as best as possible.

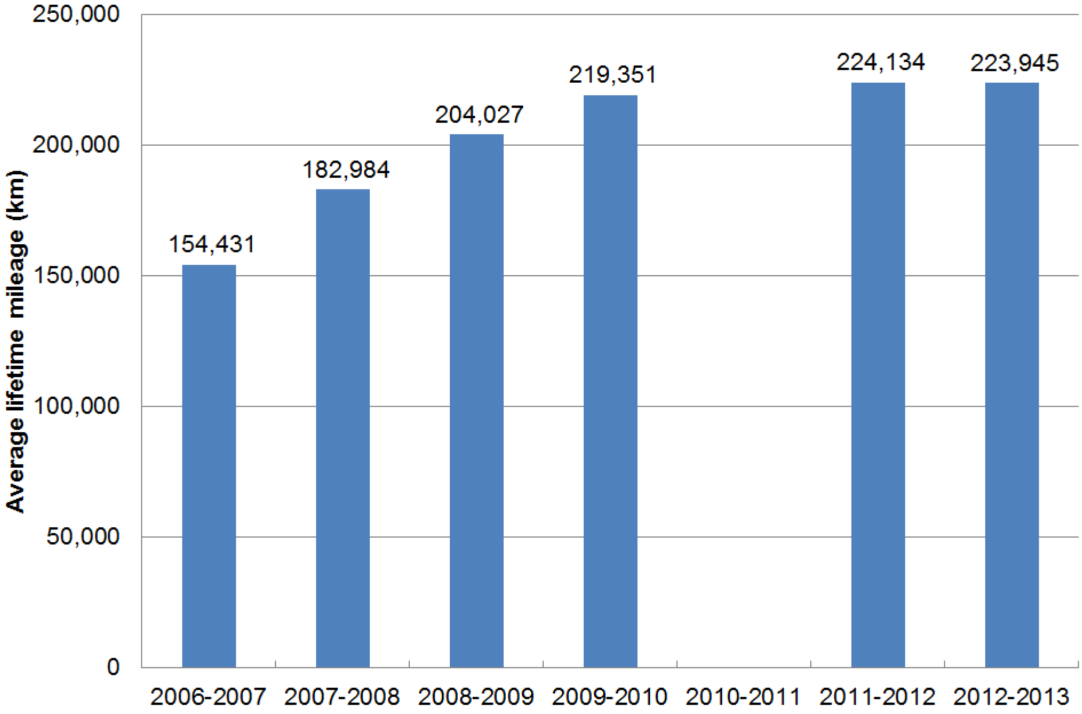
Figure 4-9 –Lifetime mileage (km) distribution for diesel LCVs (2012-2013)



The data indicates that the expected lifetime mileage for a LCV is around 224,000 km. This is 7% higher than the value for diesel cars and 30% higher than for petrol cars.

As for passenger cars, lifetime mileage data for LCVs was analysed for the period covering 2006 to 2013 in order to quantify the evolution in lifetime mileage over time (see Figure 4-10).

Figure 4-10 - Evolution of lifetime mileages from 2006-2013 for LCVs[6]

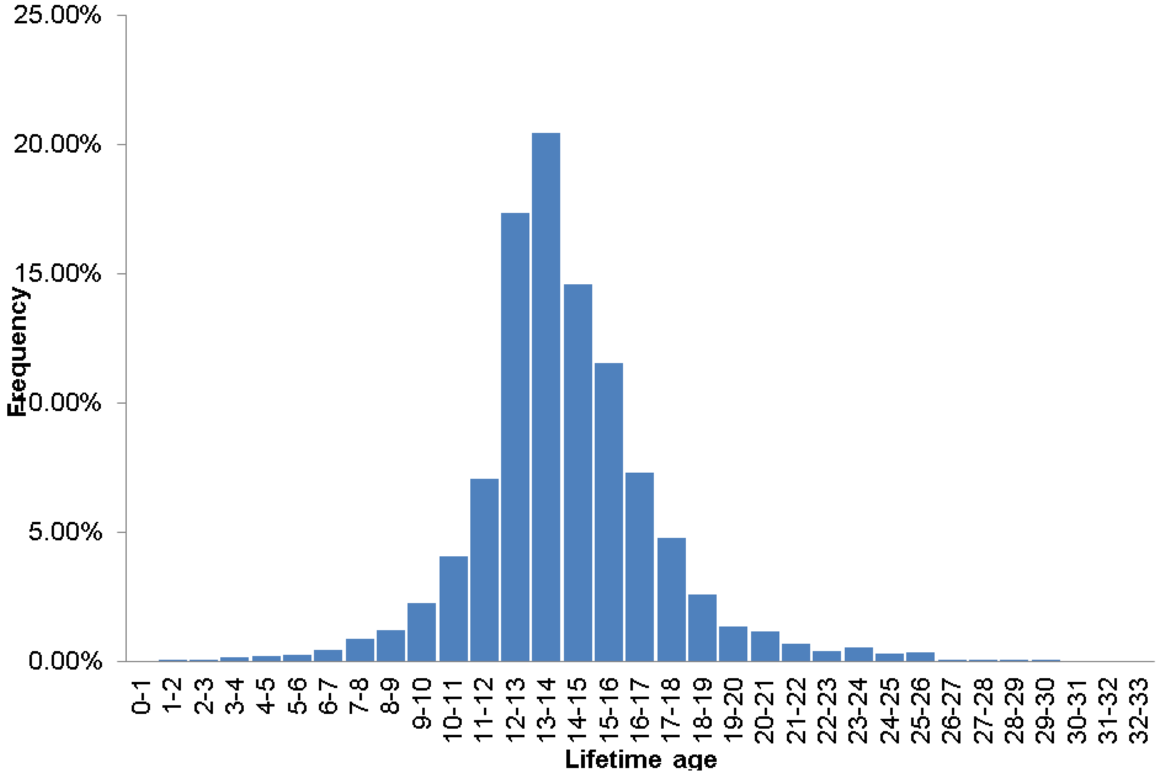


The data indicates that there have been increases in average LCV lifetime mileage between 2006 and 2013. The difference in average lifetime mileage between 2006 and 2013 is almost 70,000 km and therefore around a 45% rise (although almost 5% of this can be attributed to the rise in retirement age). However, in comparison to diesel cars in Figure 4-3, the shape of the trend above suggests that the increase in lifetime mileage for LCVs may be levelling out over time.

Figure 4-11 shows the frequency-weighted lifetime age distribution of LCVs at the point at which they are assumed to reach the end of their lives. As with passenger cars, the results below have been normalised to take into account varying sales.

[6] As with passenger cars the 2010-2011 MOT database was not analysed due to concerns about the validity of the database (see Section 3.2)

Figure 4-11 – 2012-2013, age distribution for diesel LCVs at end of life



The data indicates that the average retirement age of LCVs in 2012-2013 was 13.6 years. This figure indicates that LCVs retire 3% earlier than diesel cars (equating to around 6 months) and 6% earlier than petrol cars (equating to a just under whole year).

Table 4-4 below demonstrates in further detail when LCVs are expected to leave the fleet. As for diesel cars, around 4% of LCVs are removed from the road prior to their eleventh birthday. Figure 4-11 also indicates that the lifetime age profile of LCVs approximately follows the shape of a normal distribution. The distribution of the age profile is more regular than for petrol or diesel cars, with much lower levels of skewed data. .

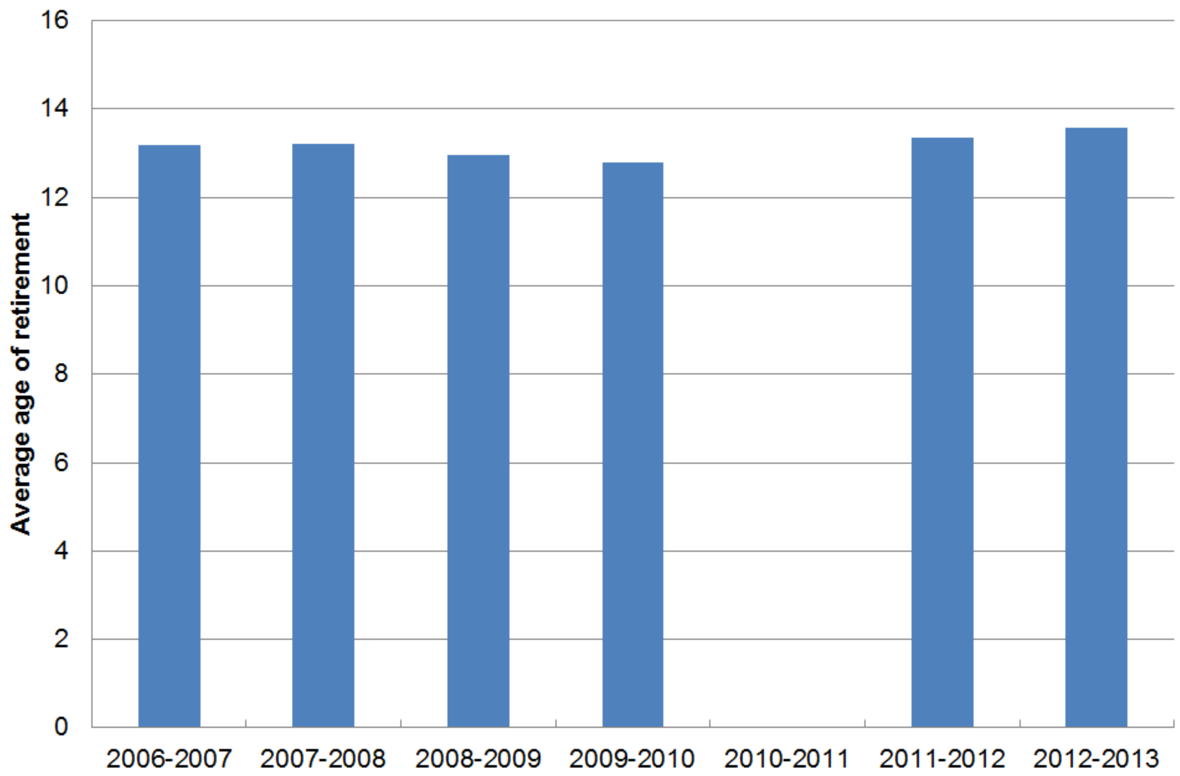
Table 4-4 - Further analysis of LCV retirement ages (2012-2013)

Age	Expected age of retirement LCVs
0-1	0.00%
1-2	0.05%
2-3	0.03%
3-4	0.15%
4-5	0.20%
5-6	0.23%
6-7	0.45%
7-8	0.88%
8-9	1.18%
9-10	2.25%
10-11	4.05%
11-12	7.08%
12-13	17.38%
13-14	20.45%
14-15	14.60%
15-16	11.53%
16-17	7.30%
17-18	4.78%
18-19	2.60%
19-20	1.33%
20-21	1.15%
21-22	0.68%
22-23	0.40%
23-24	0.55%
24-25	0.28%
25-26	0.33%

4.1.2.2 Analysis of vehicle age at end of life for LCVs

Finally, analysing the remaining lifetime mileage dataset for LCVs allows the average retirement ages through time to be viewed. This evolution is shown in Figure 4-12.

Figure 4-12 – Evolution of average retirement age from 2006-2013 for LCVs[7]



The results observed in Figure 4-12 show a slightly different trend than that of passenger cars (Figure 4-6). Unlike passenger cars, the average age of retirement for LCVs dropped considerably between 2008 and 2010 before rising after 2010[8].

On the whole however, the average retirement age has increased just less than half a year since 2006 – equating to a 3% increase.

4.1.2.3 Analysis of the correlation between lifetime mileage and vehicle mass for LCVs

This section examines the link between lifetime mileage and kerb mass in LCVs. Figure 4-13 shows the frequency weighted averages respectively for diesel LCVs for different mass categories. Once again the “trim mean” function has been plotted to remove outliers as have the upper and lower quartiles of the data. More details of the results shown in Figure 4-13 are provided in Table 4-5.

[7] As with passenger cars the 2010-2011 MOT database was not analysed due to concerns about the validity of the database (see Section 3.2)
[8] It should be noted that data from 2010-2011 is not presented here (as explained in the methodology) and so it is difficult to draw concrete conclusions from the rise in average age post 2010.

Figure 4-13 - Diesel LCV, lifetime mileage by mass bin (2012-2013)

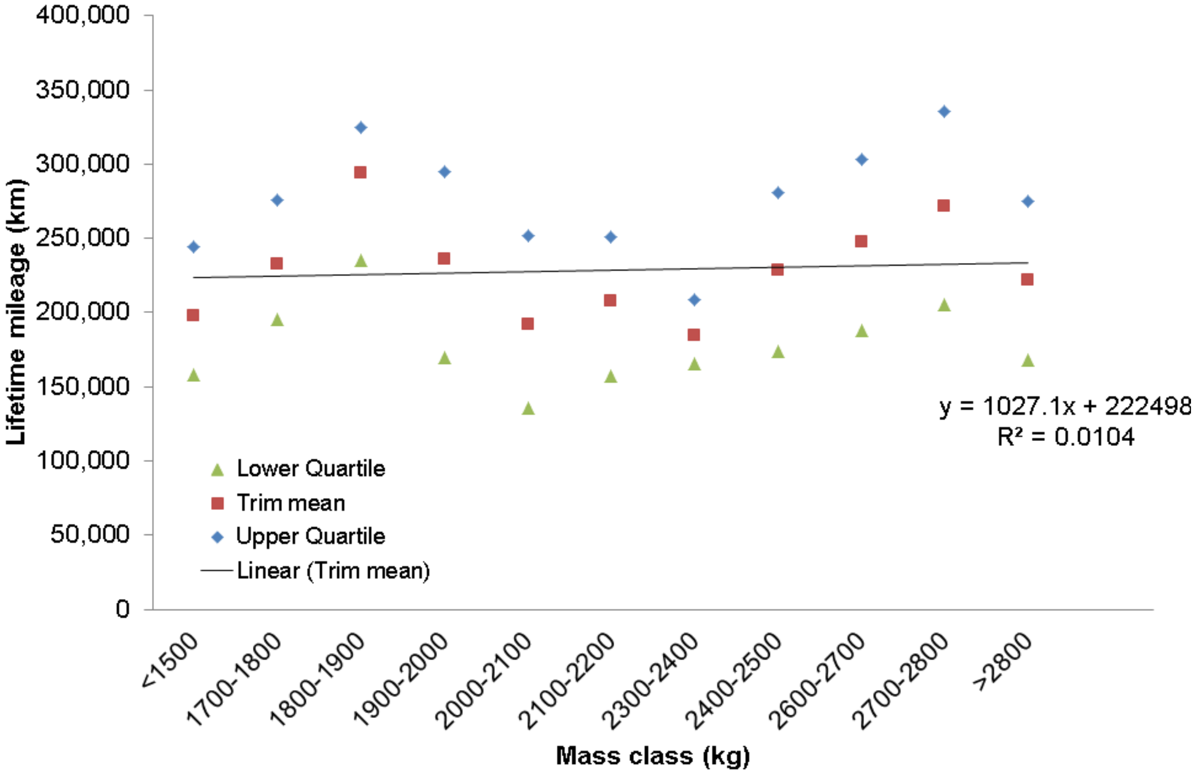


Table 4-5 - Diesel LCV, lifetime mileage analysis results (2012-2013)

Mass Bin (kg)	Trim mean (km)	Lower quartile (km)	Upper quartile (km)
<1500	198,271	157,749	244,322
1700-1800	232,654	195,691	276,241
1800-1900	294,136	234,817	324,630
1900-2000	235,797	169,603	294,904
2000-2100	192,459	135,816	252,124
2100-2200	207,654	157,674	251,197
2300-2400	184,782	165,576	208,578
2400-2500	228,181	173,871	280,617
2600-2700	247,364	188,284	302,998
2700-2800	271,651	205,642	335,345
>2800	222,315	168,332	274,770

The above results show that there is no single clear relationship between vehicle mass and lifetime mileage for LCVs. For example, between 1800 kg and 2400 kg, the data indicate that lifetime mileage is negatively correlated with mass (i.e. lifetime mileage decreases linearly as mass increases). By contrast, for vehicles above 2400 kg, lifetime mileage starts to increase, although these increases are not regular or consistent. For example whilst LCVs the 2700-2800 kg mass bin appears to be one of the most driven mass classes at around 270,000 km during their lifetime, vehicles that weigh above 2800 kg have a much lower average lifetime mileage value, at 222,000 km.

Once again, the calculated slope gradients of the lines are shallow and the correlation (R^2) is not very strong, so it is not possible to conclude that there is a strong relationship between vehicle mass (as an indicator of size) and lifetime mileage.

4.2 Annual mileages

This section details the results from the data extraction methodology process described in Section 3.3. These results relate to the vehicle mileages accumulated in the time period between 2012 and 2013 MOT tests. The key areas of analysis investigated here are;

1. Average annual mileage across fleet
2. Average fleet age and;
3. Annual mileage versus age of vehicle (Mileage accumulation rates)

All results below relate to the sample sizes in Table 3-7.

4.2.1 Passenger cars

4.2.1.1 Analysis of average annual mileage for petrol and diesel cars

Figure 4-14 and Figure 4-15 illustrate how annual mileage varies with vehicle age.

Figure 4-14 - Petrol passenger cars, annual mileage versus age (full dataset)

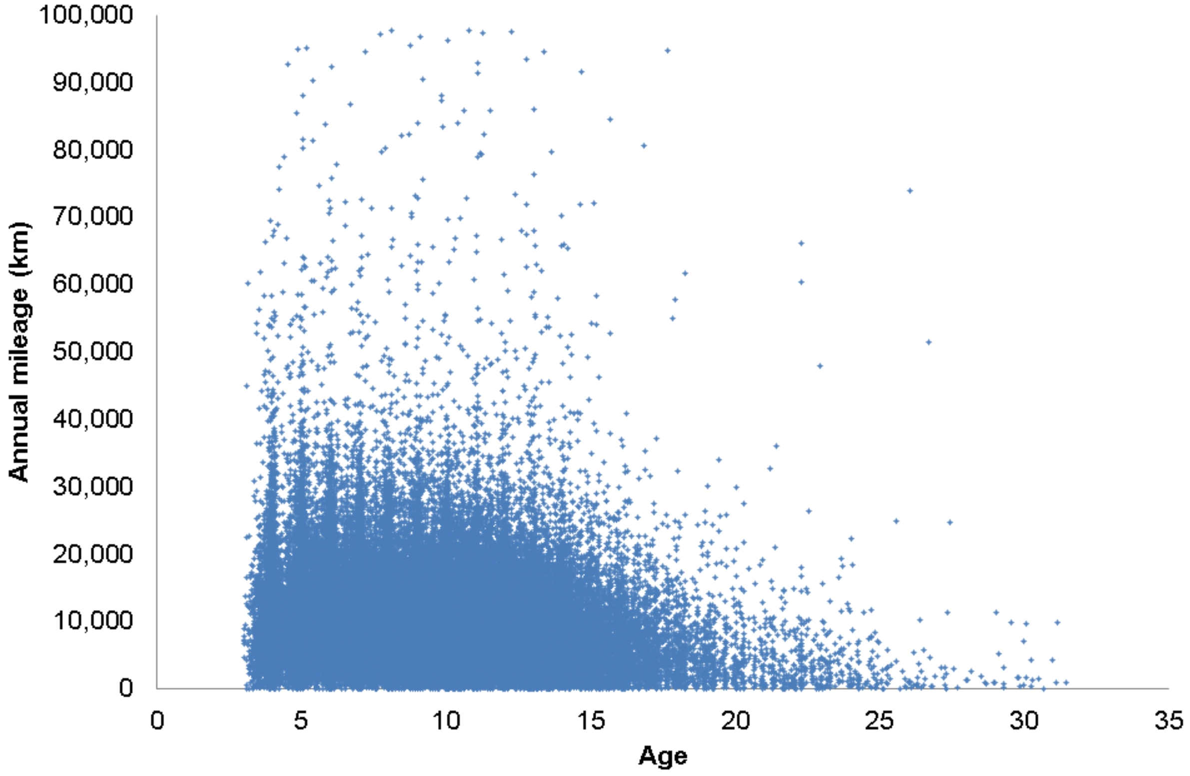
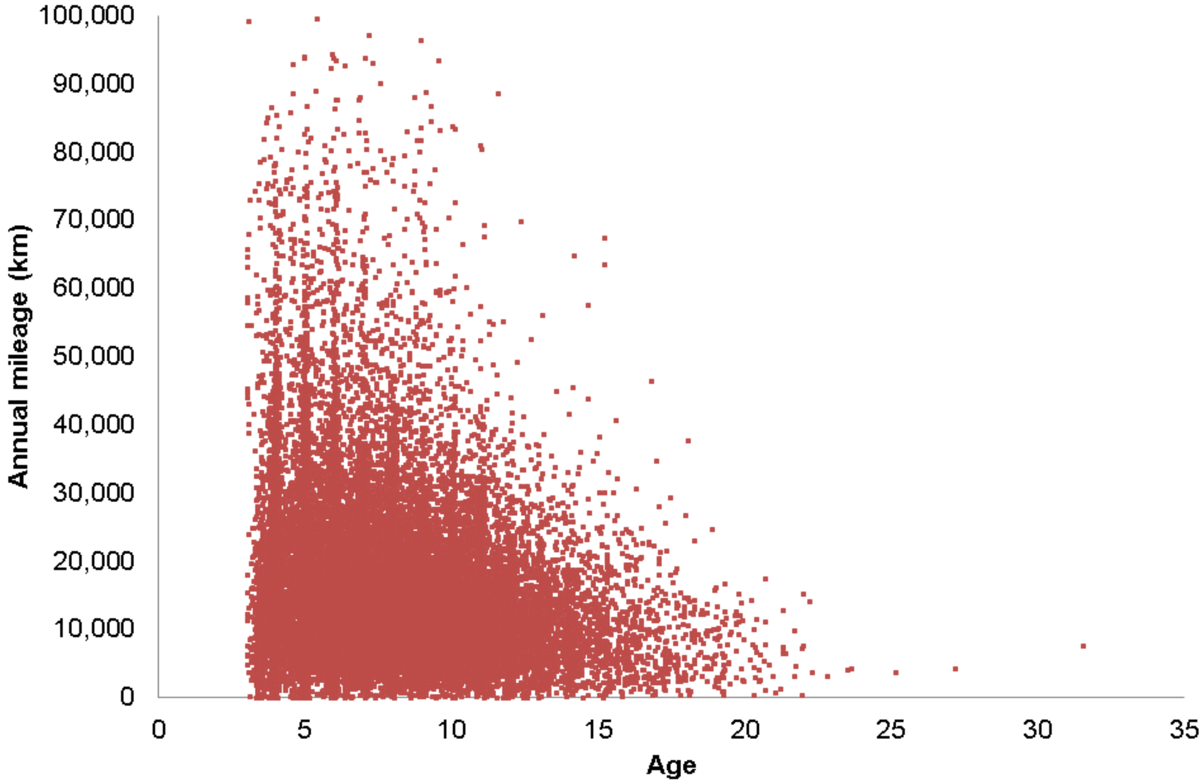


Figure 4-15 – Diesel passenger cars, annual mileage versus age (full dataset)



Two initial observations can be drawn from Figure 4-14 Figure 4-14 and Figure 4-15 above;

1. It is clear that our initial conclusion (detailed in Section 2.2) regarding annual mileage seems to be true. In the early years of the life of a vehicle, there are much higher annual mileages recorded; moving rightwards along the x-axis, annual mileages gradually decrease with increasing vehicle age and;

2. In terms of years of life accumulated, petrol vehicles appear more likely to outlive diesel vehicles (although diesel cars have much greater lifetime mileages). This is also evident from the lifetime mileage results analysis in Section 4.1.

Looking more closely at the dataset, frequency distribution plots of mileages driven (Figure 4-16 and Figure 4-17 for petrol and diesel passenger cars respectively) can assist in gathering information on the differences between petrol and diesel vehicles.

Figure 4-16 – Petrol passenger car, frequency distribution of annual mileages

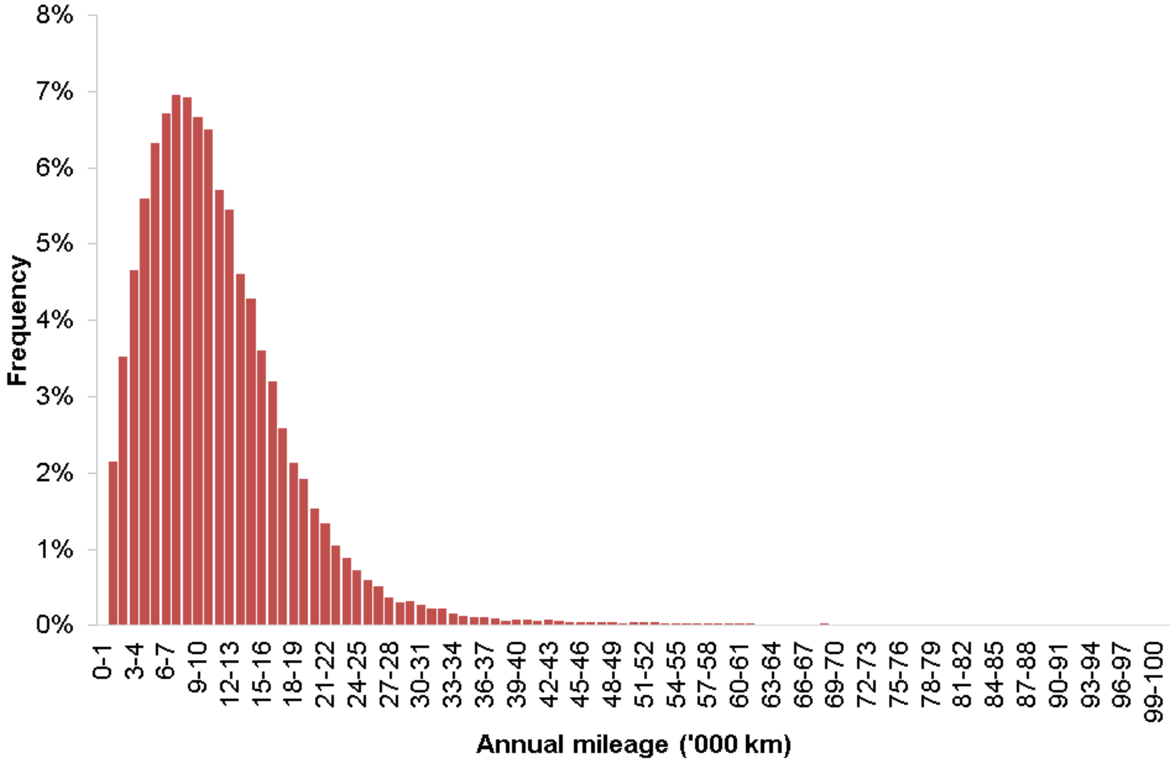


Figure 4-17 - Diesel passenger car, frequency distribution of annual mileages

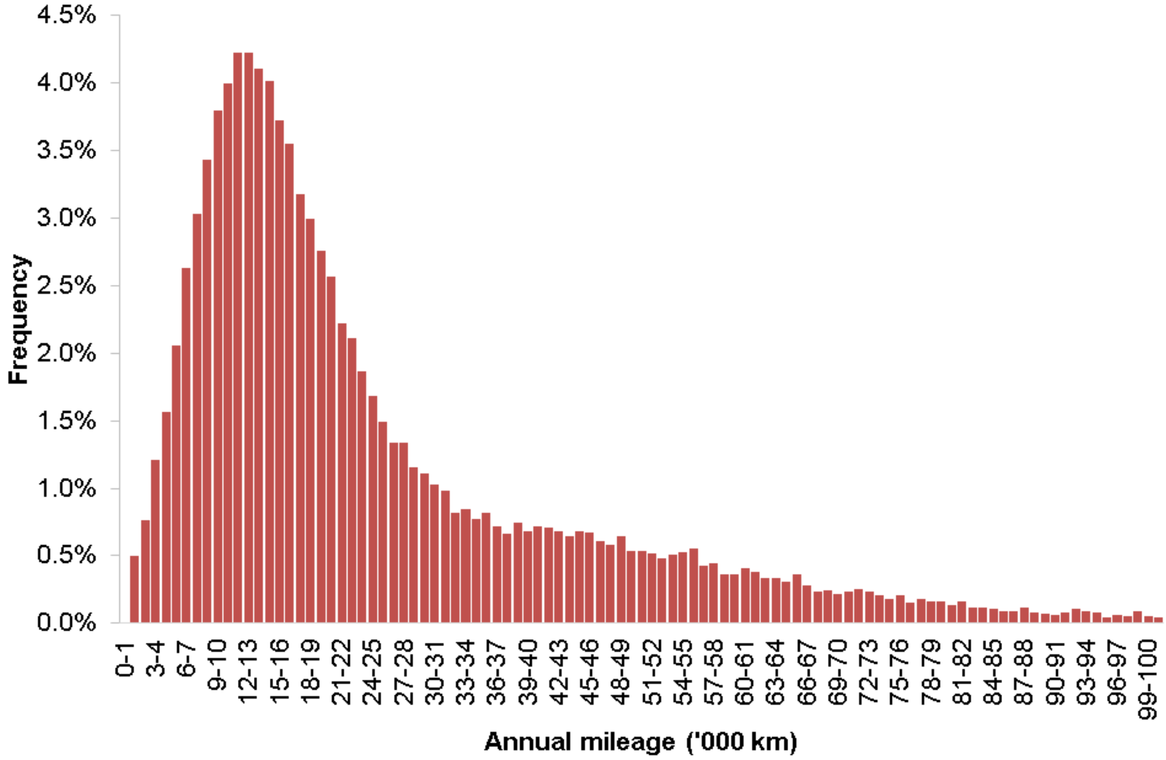


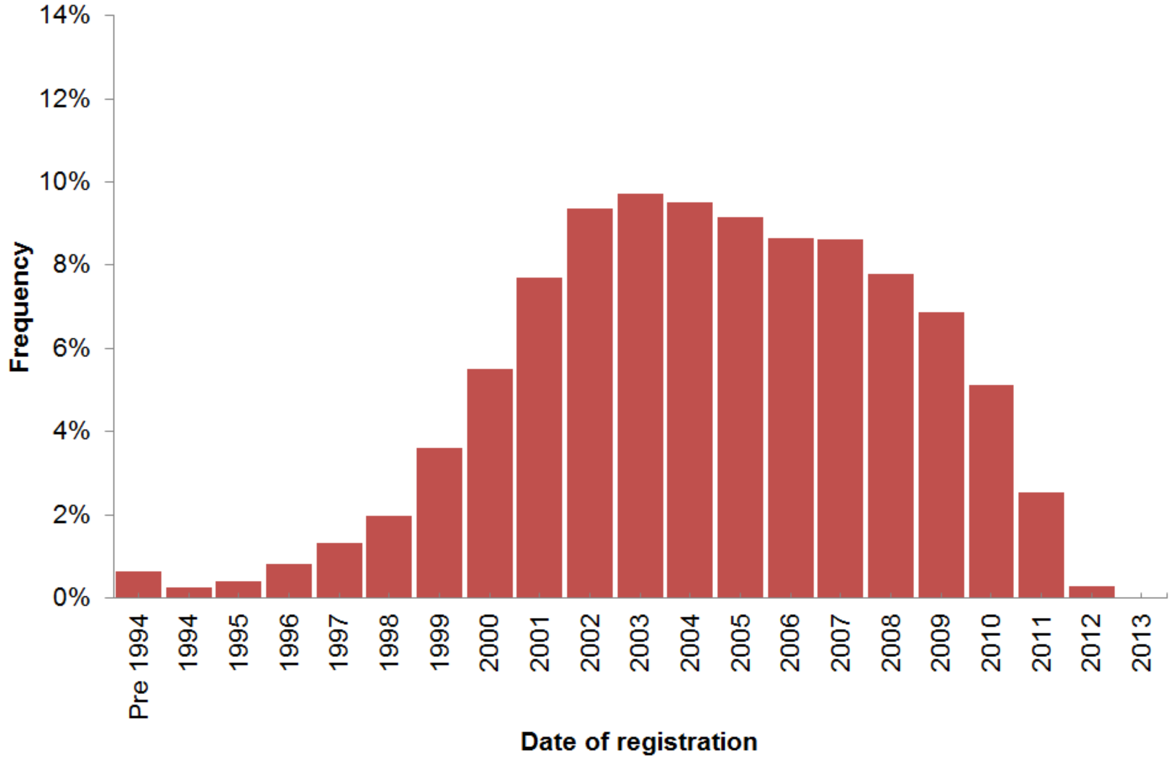
Figure 4-16 and Figure 4-17 clearly show the differences in the way petrol and diesel cars are driven. According to the dataset, petrol cars are driven on average a little under 10,800 km per year whereas for diesel cars the average annual mileage is much greater at roughly 16,800 km[9].
Therefore, as with the lifetime mileage analysis in the previous section, diesel cars are being driven further (annually) than petrol cars by around 36%.

Figure 4-17 also depicts a more obvious right hand tail of data than in Figure 4-16 signifying that diesel cars are much more likely to be driven substantially further on average than petrol cars.

4.2.1.2 Analysis of average fleet age for petrol and diesel cars

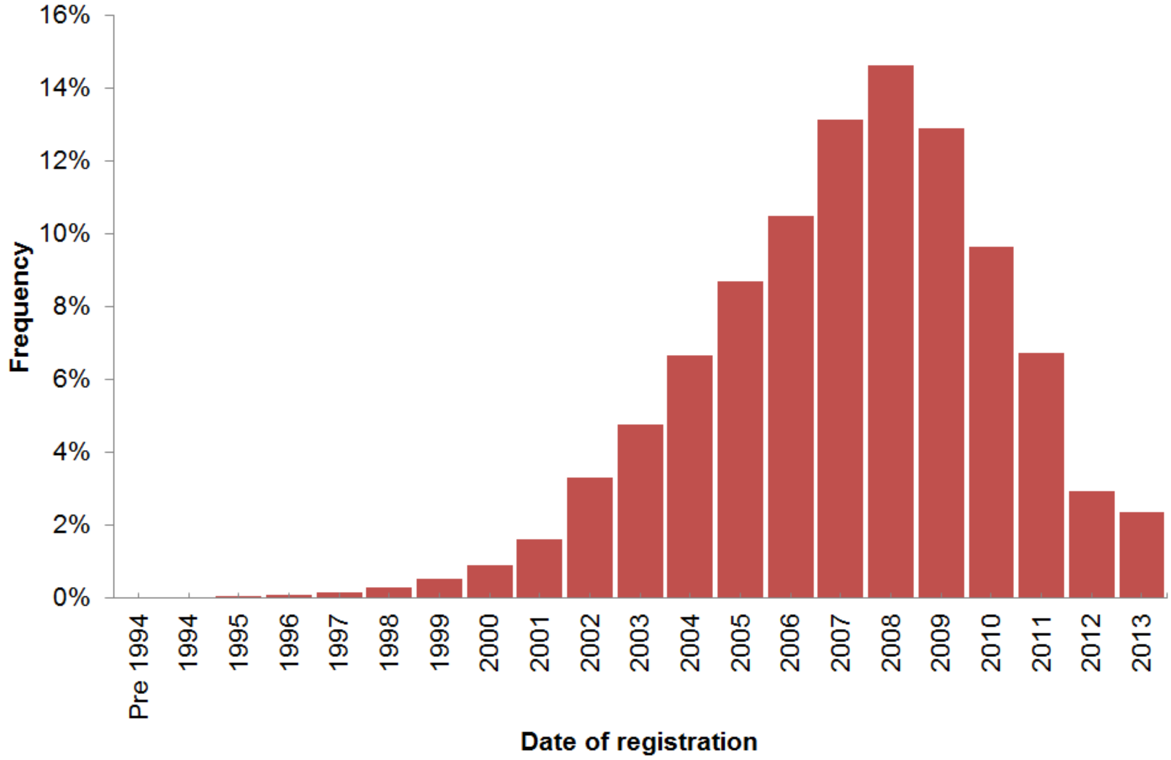
Figure 4-18 and Figure 4-19 below shows the age distribution of the passenger car fleet. Specifically they detail the distribution of different model years within the fleet. The results below have again been normalised for annual sales and dieselisation share.

Figure 4-18 – Date of registration frequency distribution plots for petrol passenger cars, as observed from 2013 MOT test data



[9] Please note this database contains very little information on vehicles in the first two years of life. Results here reflect that.

Figure 4-19 - Date of registration frequency distribution plots for diesel passenger cars, as observed from 2013 MOT test data



Some conclusions can be drawn from Figure 4-18 and Figure 4-19;

1. The average age of petrol cars is higher than diesel cars. For petrol cars the average age is 9.6 years whilst for diesel cars the average is 7.8 years.

2. This conclusion further backs up the evidence that petrol cars remain on the road longer. The reasons for this difference in average age could be because the annual mileages for diesels are significantly higher than petrol cars, so they wear out faster, despite the slightly higher mileage at EOL.

4.2.1.3 Mileage accumulation rates

Now that a substantial database of vehicle annual mileages and their respective ages has been compiled, this section of the study investigates, and attempts to model the rates at which vehicles accumulate mileage over time. Previously it has been assumed that mileage accumulates in a linear manner over the life of the vehicle. However, the data collated during this study indicates that this may not be the case.

Previous work in this area undertaken in the TRACCS project (EMISIA et al, 2013) is relevant here. In that study, information on the mileage of vehicles linked to their respective ages was provided for Denmark, which showed that newer vehicles are generally used more intensively than older vehicles.

What is also clear from TRACCS is that the relationship between annual mileage and age consists of two stages. First, the initial growth in mileage accumulation (up to a peak/maximum) and then a decay function taking over after this until the vehicle is removed from the road.

In the context of the data available from the UK MOT test database, there is most uncertainty surrounding the mileages in the first three years. In the UK, most vehicles are not required to undergo an MOT roadworthiness test until they are three years old; therefore, in most cases, the annual mileage calculation only returns results for vehicles of at least four years of age (i.e. only after they have been MOT tested in two consecutive years). Some vehicles, such as taxis, need to undergo MOT testing before reaching three years of age; however these vehicles alone would be unsuitable for investigating less than three year old vehicle mileages as their annual mileages are very high and not representative of typical passenger cars.

Therefore, given that there is no detailed source that presents annual mileages for vehicles in the first two years of life, the following analysis will assume that accumulated mileage after three years of age has been linearly achieved. This means that, for example, a vehicle found to have driven 60,000 km by three years, will be assumed to have driven 20,000 km in year one, 20,000 km in year two and 20,000 km in year three.

The results of this are found below in Table 4-6 for three year old cars.

Table 4-6 - Average accumulated mileage data for three year old cars from MOT database

Fuel type	*Average Accumulated Mileage (km)*
	Three year old vehicles from MOT database
Petrol	39,135 km
Diesel	76,996 km

Naturally the sample size of three year old vehicles in the MOT database was relatively small, so in order to cross check the results here, details from a travel survey undertaken by the UK Department for Transport (DfT) was used (UK Department for Transport, 2013b).

The results of this study compared to results from the MOT database are found below in Table 4-7 for three year old cars.

Table 4-7 - Average annual mileage data for 0-3 year old cars from MOT database and DfT travel survey

Fuel type	*Average Annual Mileage (km)*	
	Vehicles aged 0-3year old vehicles from MOT database	Vehicles aged 0-3 years from DfT National Travel Survey
Petrol	13,045 km	11,592 km
Diesel	25,665 km	20,930 km

Despite the MOT database showing annual mileages higher than that of the DfT statistics, given the consistent results from the two sources the robustness of the MOT database results is confirmed.

The above MOT annual mileage data on cars aged three years was therefore used as the first three data points in the modelling analysis. Subsequent data points were derived by allocating the database discrete age categories (bins) in order to generate a complete profile of annual mileage against vehicle age (Figure 4-20).

Figure 4-20 – Passenger car, annual mileage versus age (using age bin method)

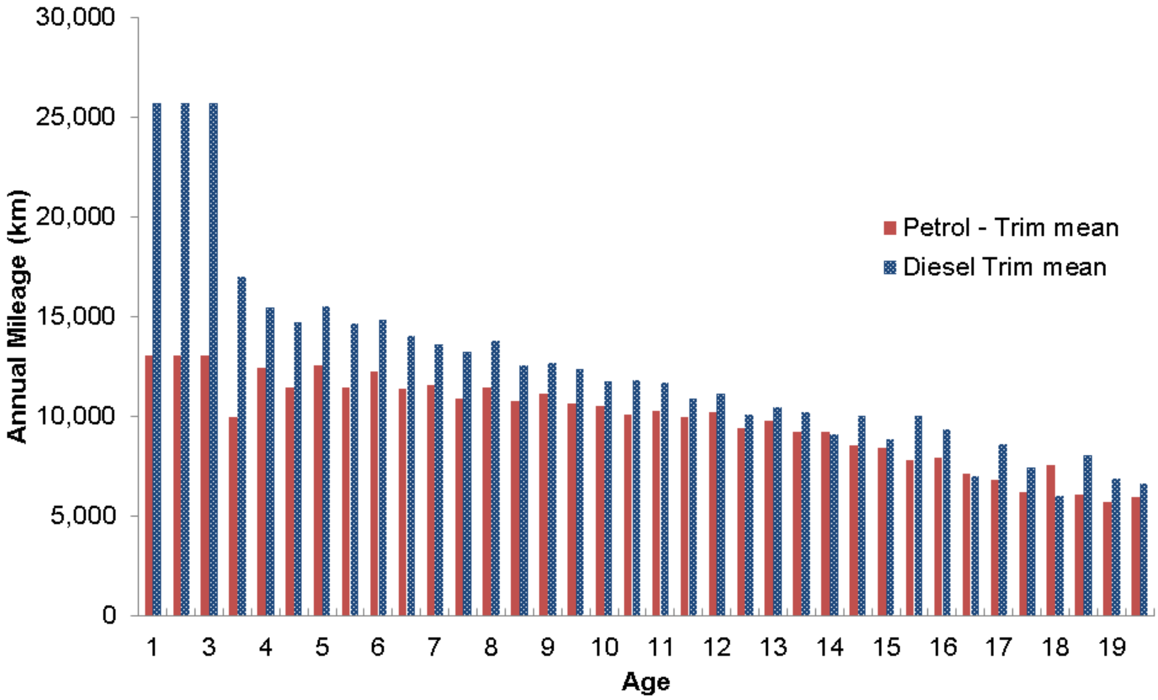


Figure 4-20 presents the annual vehicle mileage against vehicle age after the "trim mean" function has been applied to the data. This function uses the middle 90% of the data to remove outliers, which helps to increase the robustness for mixed and/or heavily-skewed distributions (as is the case for mileage data). Some further observations on Figure 4-20 are detailed below.

1. The most noticeable difference between petrol and diesel cars is their average annual mileage at three years. Diesel car annual mileage at three years of age is observed to be up to 2.5 times greater than for petrol cars of the same age. This difference is highly likely to be due to company cars. Most company cars in the UK are diesel cars and aged between 0 and 3 years. At three years of age, many of these vehicles move into the private second hand market where average annual mileages are much, much lower. For petrol cars, only a small proportion of new cars are company cars; most petrol cars are privately bought with low annual mileages from year 0;
2. Petrol cars exhibit a fairly constant annual mileage (between 10,000 km and 12,000 km) through time until around their tenth birthday when car usage appears to decay. In diesel cars the decay is immediate (from three years) and at an increased rate to petrol cars. This increased rate of decay means that in later years of life there is far less difference between the driving patterns of the two fuel types.

Table 4-8 presents the average annual mileages by age of vehicle for passenger cars.

Table 4-8 – Passenger car average annual mileages by age of vehicle

Age	*Annual Mileage (km)*	
	Petrol cars	*Diesel cars*
1	13,045	25,665
2	13,045	25,665
3	13,045	25,665
4	12,245	17,586
5	12,096	16,494
6	11,869	15,255
7	11,608	14,206

Age	*Annual Mileage (km)*	
	Petrol cars	*Diesel cars*
8	11,316	13,296
9	10,993	12,493
10	10,640	11,774
11	10,257	11,122
12	9,845	10,527
13	9,404	9,979
14	8,936	9,472
15	8,439	8,999
16	7,915	8,556
17	7,363	8,140
18	6,785	7,747
19	6,181	7,376

Figure 4-21 plots accumulated mileage against vehicle age and is the result of using the data in Table 4-8 to calculate accumulated mileage. Again, it should be noted here that in order to perform this analysis, annual mileages for three year old vehicles have been assumed to be the same as annual mileages driven in the first and second year of a vehicle's life[10].

Figure 4-21 – Accumulated mileage over time – Passenger cars

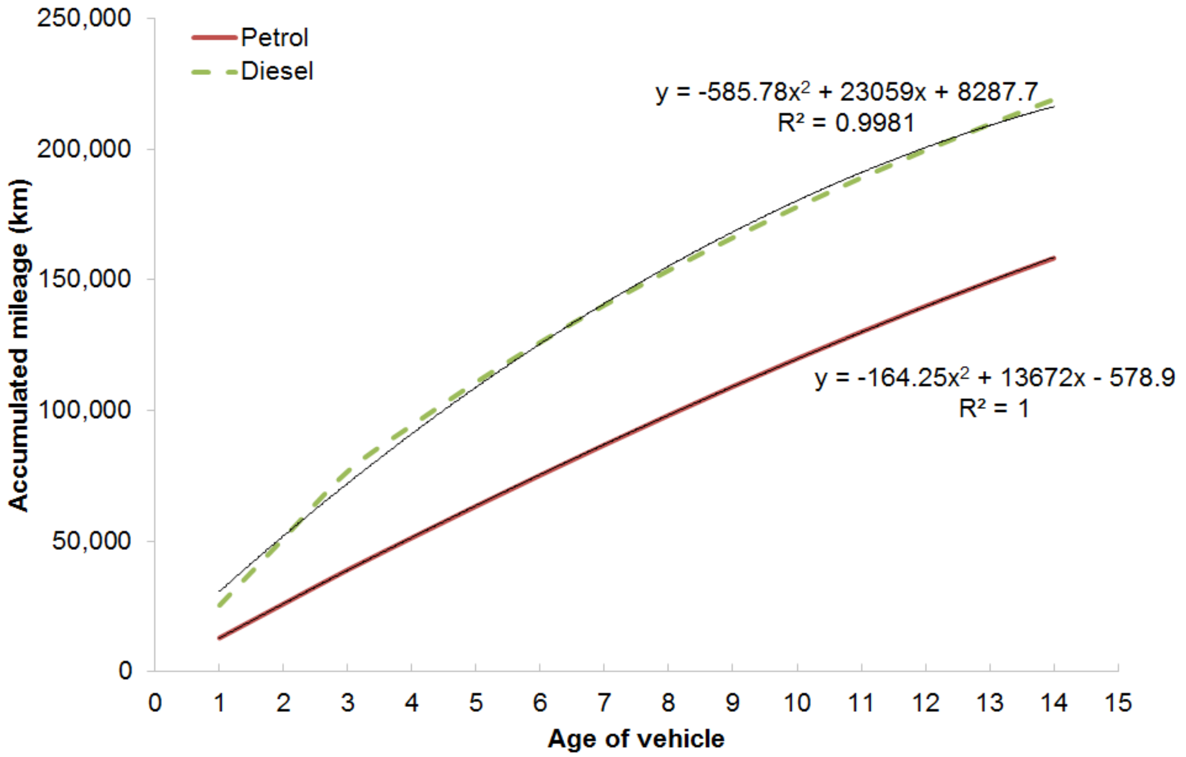


Figure 4-21 confirms what had already been established about the accumulation rate being non-linear (here a modelled quadratic function best matches the real data). However, it is noted that the

[10] It should also be noted here that this analysis is performed using a different dataset to that used in the lifetime age and mileage analysis. Given the assumptions made in both datasets (annual and lifetime), results shown here for final accumulated (lifetime) mileage will differ slightly to the lifetime mileage results calculated previously.

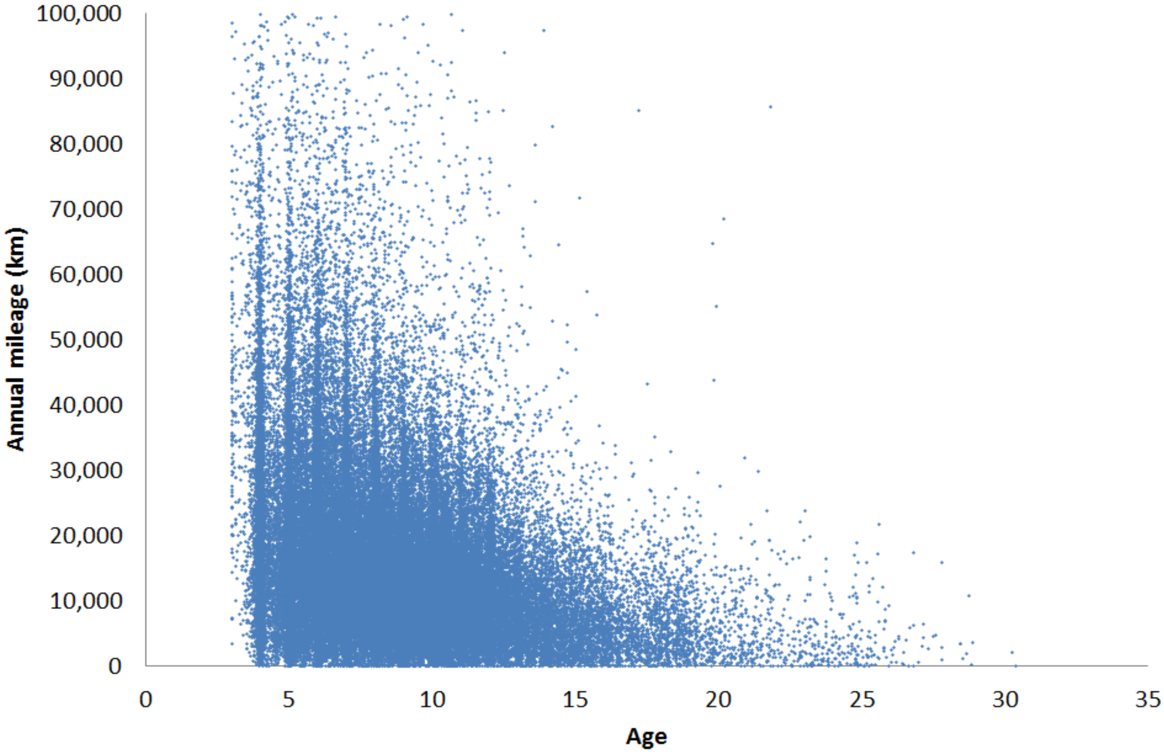
relationship between accumulated mileage and age is very close to being linear (particularly for petrol cars).

4.2.2 Light commercial vehicles

4.2.2.1 Analysis of average annual mileage for LCVs

Figure 4-22 illustrates how annual mileage varies with vehicle age for LCVs. As with passenger cars, similar trends can be seen in the mileage data collated for LCVs. Much higher mileages are being driven in early stages of the vehicles' lives than in later stages.

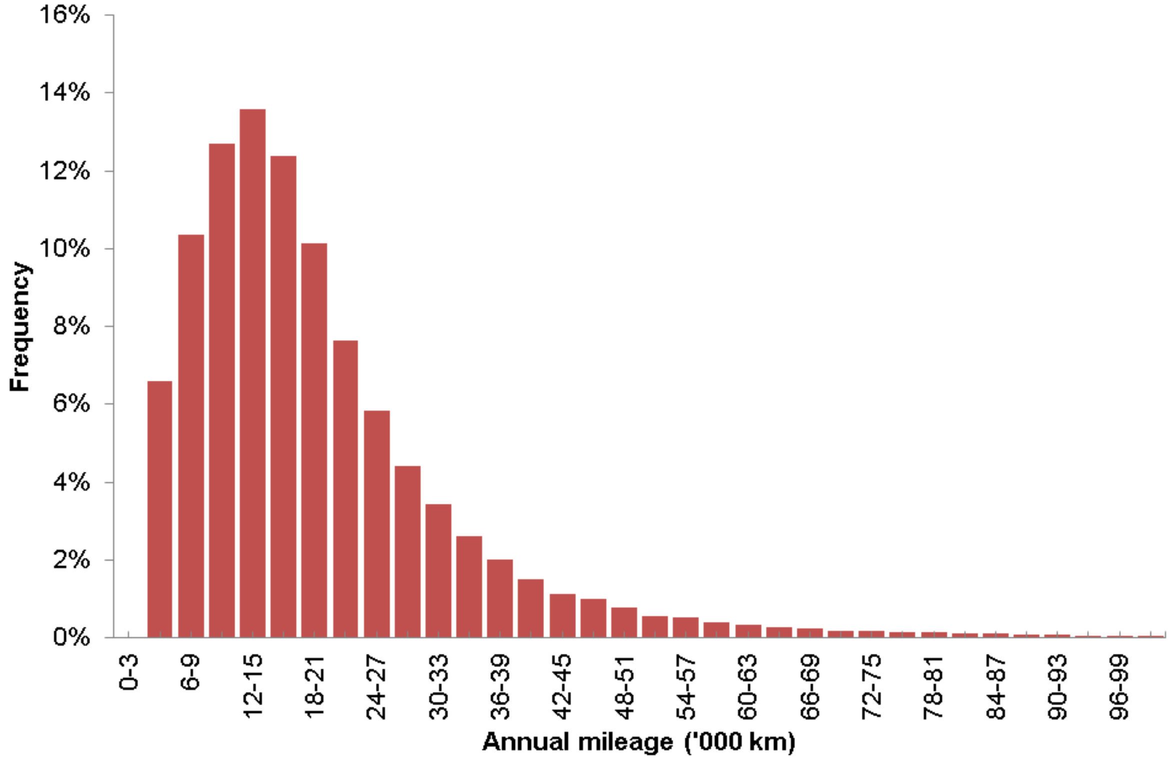
Figure 4-22 - Diesel LCVs, annual mileage versus age (full dataset)



4.2.2.2 Analysis of average fleet age for LCVs

After further manipulation of the dataset, frequency distribution plots of mileages driven (Figure 4-23) can assist in gathering information on the annual mileages driven by the LCV fleet.

Figure 4-23 – Diesel LCV, frequency distribution of annual mileages



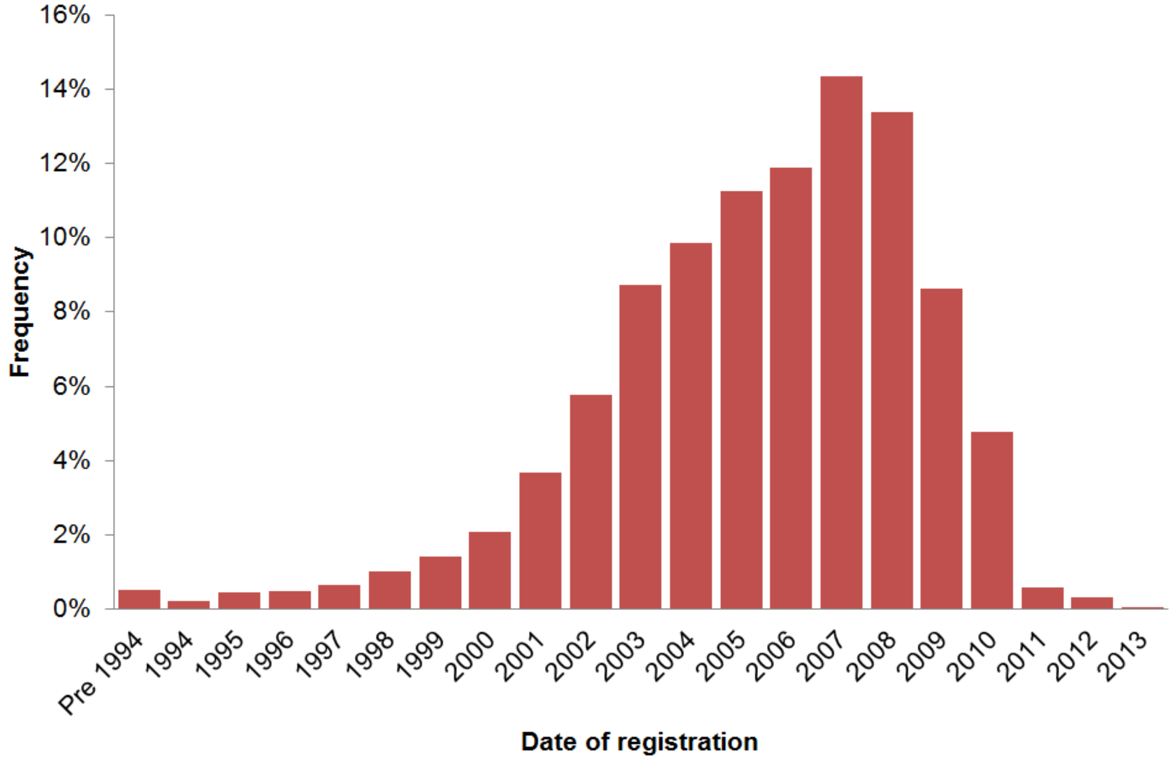
Based on the data shown in Figure 4-23, LCVs are driven on average a little under 15,500 km per year. This is 43% more than an average petrol passenger car and 8% less than an average diesel passenger car.

Figure 4-24 below shows the age distribution of the LCV fleet in terms of model year (MY) and normalised by sales.

The average age of LCVs is calculated to be 8.6 years. This is 9% less than petrol passenger cars and 10% greater than diesel passenger cars[11].

[11] Please note this database contains very little information on vehicles in the first two years of life. Results here reflect that.

Figure 4-24 - Date of registration frequency distribution plots for diesel LCVs



4.2.2.3 Mileage accumulation rates

Following the same methodology as described in Section 4.2.1.3, this section of the study looks at vehicle mileage accumulation rates.

For LCVs, the results for three year old LCV accumulated mileage are found below in Table 4-9.

Table 4-9 - Average accumulated mileage data for three year old LCVs from MOT database

Fuel type	*Average Accumulated Mileage (km)* Three year old vehicles from MOT database
Diesel	101,494 km

Therefore, the annual mileage at year one, two and three is assumed to be 33,831 km.

As for passenger car analysis, the data was categorised into equally-sized age bins of 0.5 years (from year 3 onwards) and average results for each age bin are shown below in Figure 4-25.

Figure 4-25 – Diesel LCV, annual mileage versus age (using age bin method)

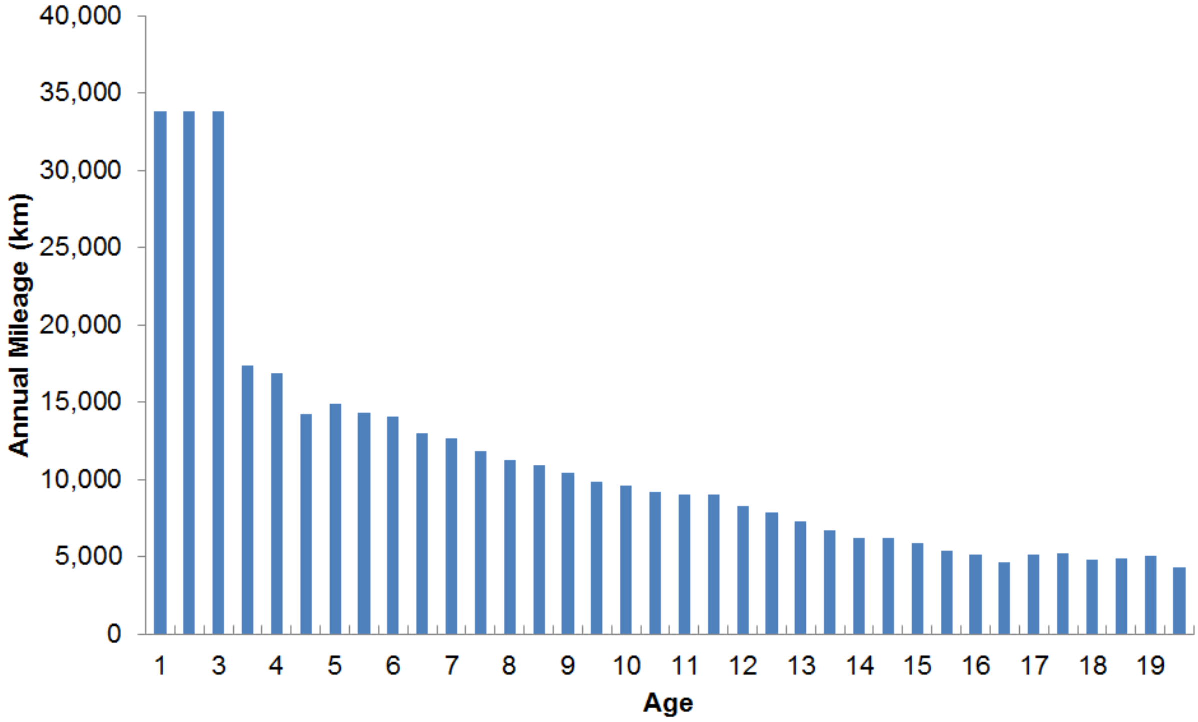


Figure 4-25 presents the "trim mean" function, which has been plotted to remove outliers.

The initial results are largely as expected from previous studies and can seemingly be split into two stages;

1. During years three and four there is a sharp drop in annual mileages. After peaking at 31,000 km in year three, the figure shows that there is around a 45% reduction in annual mileage for LCVs between the third and fourth year.
2. After the fourth year, annual mileages begin to decay steadily (and largely linearly) until EOL.

Table 4-10 presents the data for annual mileages by increasing vehicle age.

Table 4-10 – LCV average annual mileages by age of vehicle

Age	*Annual Mileage (km) LCVs*
1	33,831
2	33,831
3	33,831
4	19,020
5	17,206
6	15,208
7	13,569
8	12,185
9	10,991
10	9,944
11	9,013
12	8,177
13	7,420
14	6,727

Age	*Annual Mileage (km) LCVs*
15	6,091
16	5,503
17	4,956
18	4,446
19	3,968

Figure 4-26 plots accumulated mileage against vehicle age for LCVs and is the result of using the data in Table 4-10 to calculate accumulated mileage. Again, it should be noted here that in order to perform this analysis, annual mileages for LCVs in their first three years are assumed to be the same for each year[12].

Figure 4-26 – Accumulated mileage over time – LCVs

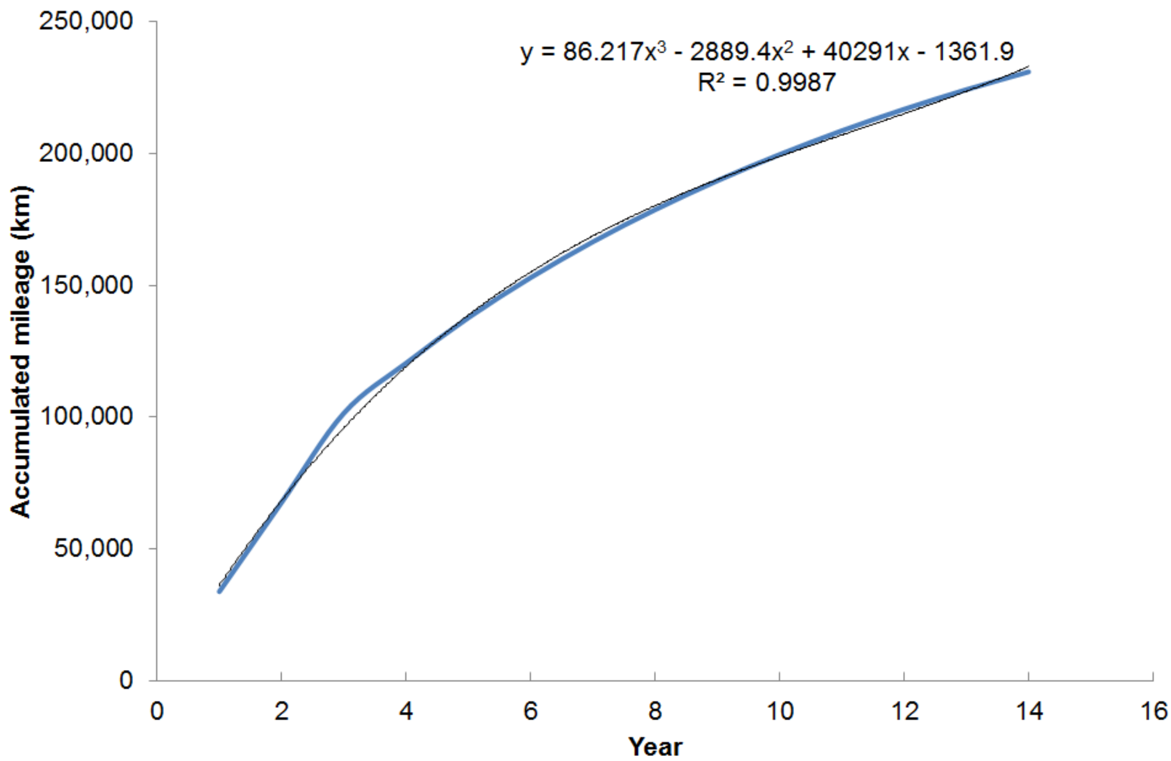


Figure 4-26 confirms what had already been established about the accumulation rate being non-linear. In terms of modelling this evolution, it was found that a cubic polynomial is a near perfect fit. Comparing the accumulation of mileage between cars (Figure 4-21) and LCVs (Figure 4-26) it is clear that for LCVs the relationship is a lot more non-linear.

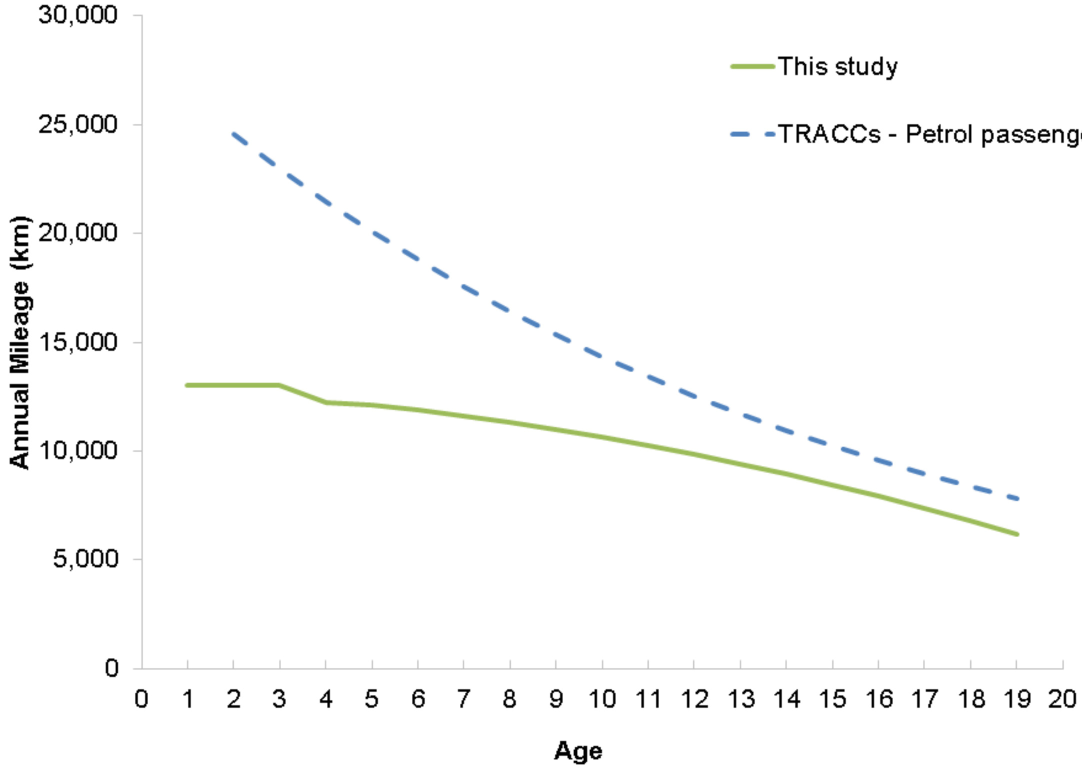
[12] It should also be noted here that this analysis is performed using a different dataset to that used in the lifetime age and mileage analysis. Given the assumptions made in both datasets (annual and lifetime), results shown here for final accumulated (lifetime) mileage will differ slightly to the lifetime mileage results calculated previously.

4.2.3 Comparison with alternative sources

In order to further assess the above analysis as being both accurate and representative of the rest of Europe, here we will compare Figure 4-21 and Figure 4-26 above with data from the TRACCs project (EMISIA et al, 2013)[13].

Figure 4-27 to Figure 4-29 below show the results of these comparisons for petrol and diesel cars as well as LCVs.

Figure 4-27 – Comparison of mileage accumulation rates for petrol passenger cars



[13] It should be noted that for this study, year one data from the TRACCs study has been removed as they have been found to be anomalous with respect to this study. This is because the average mileage data takes into account all vehicles registered in a particular twelve month period. This means a vehicle registered in January 2010, will have twelve months of mileage data and for example may have a full year annual mileage of 24,000 km. However, the data for 2010 will also include vehicles registered in every single month that year, but only the mileage travelled during 2010 will be taken into account. Hence the average mileage for a vehicle registered in December 2010 might only be 2,000 km. This will mean year one data is anomalously low.

Figure 4-28 - Comparison of mileage accumulation rates for diesel passenger cars

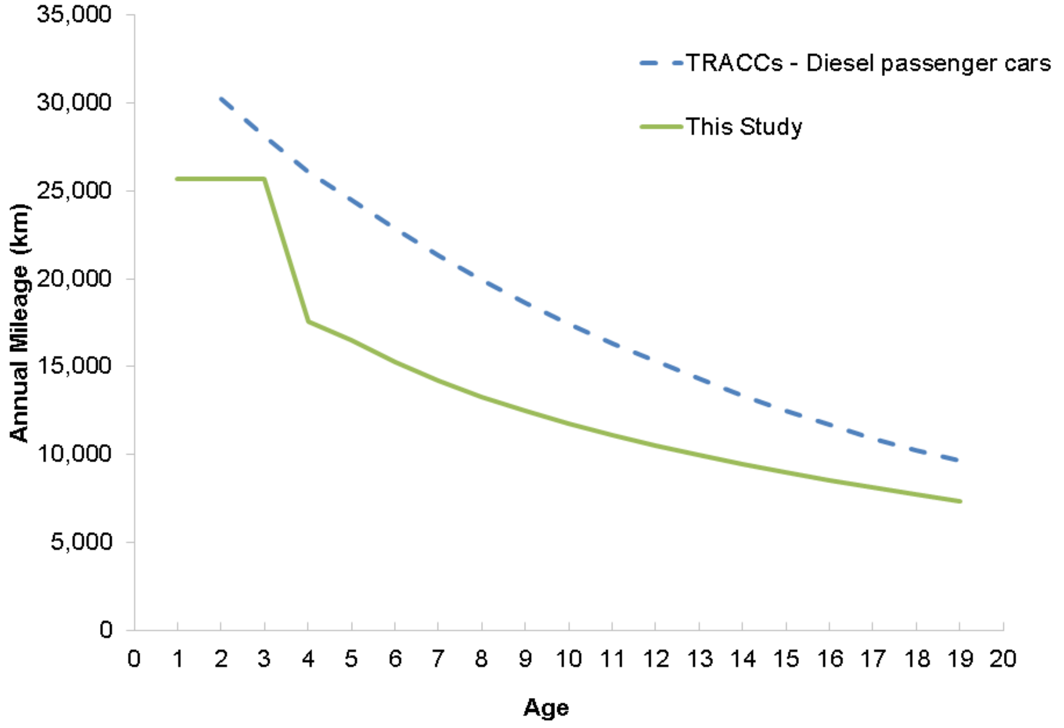
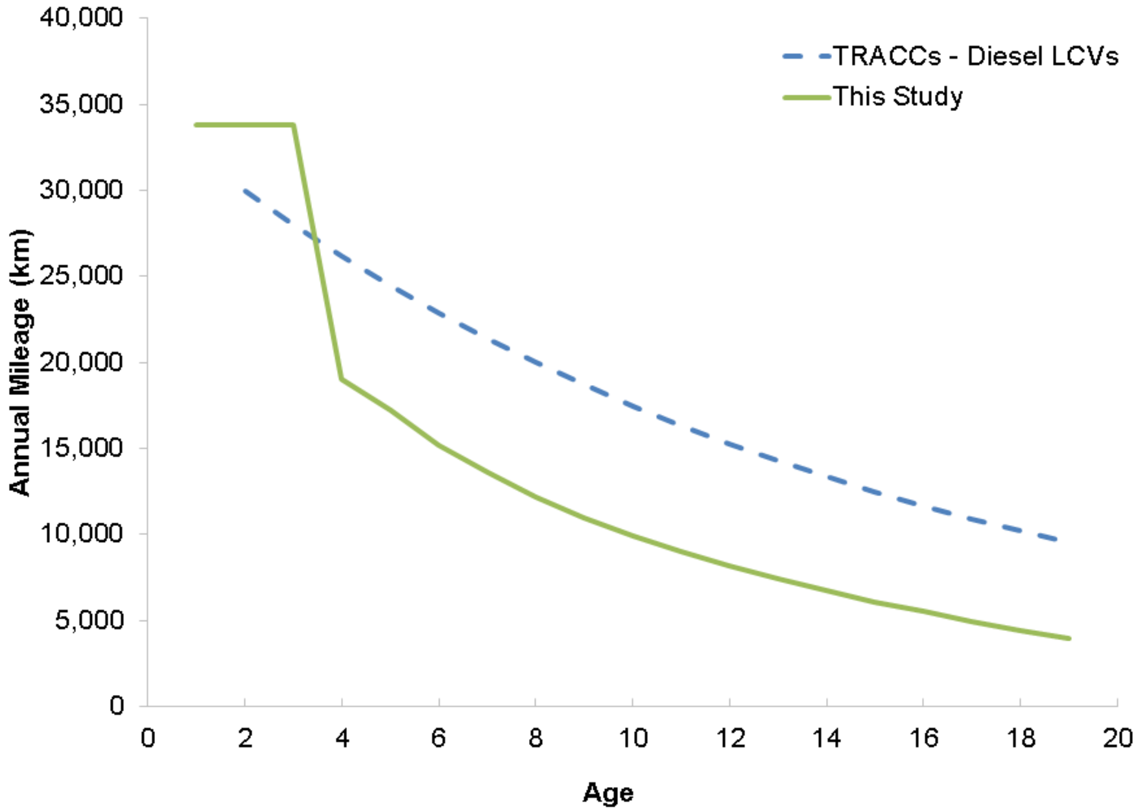


Figure 4-29 - Comparison of mileage accumulation rates for diesel LCVs



As can be observed there are some differences between the results obtained from this study and the TRACCS study. On the whole, it appears that results from this study show lower annual and cumulative mileage figures than the TRACCS study.

For diesel passenger cars (Figure 4-28), other than in years one and two, both this study and the TRACCS work show a similar shape of mileage decay (albeit with this study predicting diesel car mileages to be lower than the TRACCs study).

For petrol cars (Figure 4-27) the differences between the two studies are more obvious. The TRACCS study estimated that annual mileages for three-year old petrol cars mileages are more than double the figures identified from the UK's MOT database. The two curves also depict differing shapes with this study showing that from three to six years the annual mileages are fairly constant and the TRACCS study indicating that the decay in mileage starts from year three onwards.

For LCVs (Figure 4-29) there are similarities in the results obtained from this study and the TRACCS project. Whilst the data from the UK MOT database indicates higher average annual mileages than the TRACCS data for LCVs in year 3 of a vehicle's life, between year 3 and year 4, the MOT data indicates a sharp decline in annual mileage (to the extent that in year 4, the MOT data gives an average annual mileage figure that is significantly lower than the equivalent figure from the TRACCS study). From year 4 onwards, the *rate* of mileage decay is very similar for both datasets, albeit the actual annual averages from the UK MOT data are lower.

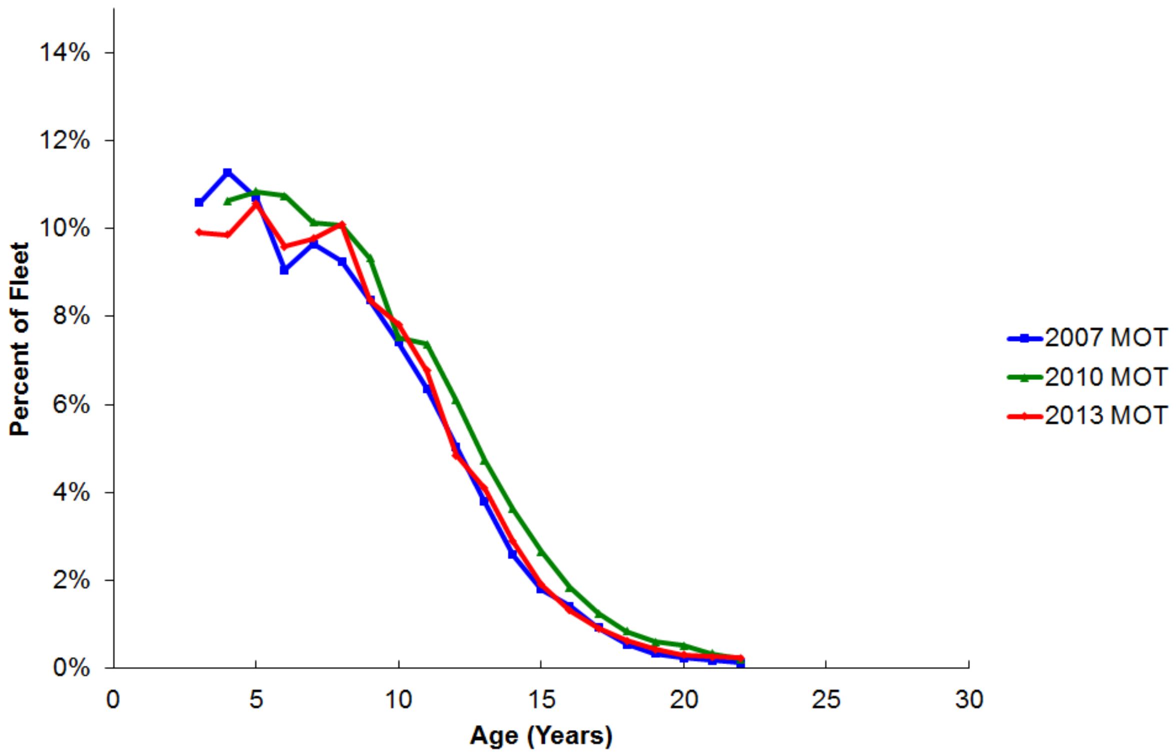
Whilst this study has modelled the above curve using actual periodic testing records, the TRACCS study is largely based on high level Danish data and so we would expect there to be differences between the studies in the end results.

4.3 Further analysis of age-related characteristics of the vehicle fleet

As discussed previously, using the MOT databases, age profiles can also be plotted. In this case (Figure 4-30) the 2007, 2010 and 2013 datasets (in full, i.e. non-sampled) are shown (normalised by vehicle sales).

It is notable that the shape of the age profiles from the complete MOT test data changes over time, with the peak in the distribution moving from three years of age in 2007 (the thick blue line) to seven years in 2010 (the thinly dashed green line). This is indicative of a peak in the supply of new vehicles in 2003. In 2013, the peak in the MOT data distribution is less clear-cut, presumably as vehicle retirements have affected what would otherwise have been a peak at approximately 10 years of age.

Figure 4-30 – Age profile of 2007, 2010 and 2013 full MOT dataset for light duty vehicles (normalised by vehicle sales)



4.3.1 Survival rate curves

Vehicle survival rate curves (also known as scrappage rate curves) have also been considered in this study. The rate at which vehicles are scrapped allows estimates on the probability of a vehicle surviving as a function of its age to be made.

In order to analyse the percentage of fleet ***remaining*** *(i.e. survival rates)* versus vehicle age, historic vehicle sales statistics (per year) as well as data on the age of vehicles currently in the 2013 fleet were required.

For this study, data from the UK Department for Transport's (DfT) Vehicle Licensing Statistics publication (UK Department for Transport, 2013c) have been used. A sample of the full dataset taken from DfT is shown in Table 4-11.

Using the figures from Table 4-11, it is a straightforward calculation to estimate survival rates.

For example, if in 2013 it is found that there are "X" number of five year old vehicles still in circulation within the UK parc, it can be calculated that the percentage still remaining on the road in 2013 is "X" / 2,112,000, where the latter figure is the total number of newly registered cars in 2008 (i.e. five to six year old vehicles).

Table 4-11 – Survival rate in 2013 of passenger cars by year of first registration

Year	Age (Years)	Cars registered for the first time (thousands)	Cars by number of keepers and year of registration, 2013 (thousands)	Survival rate
1999	14-15	2334.9	625.6	26.8%
2000	13-14	2257.3	1,082.7	48.0%
2001	12-13	2585.9	1,523.7	58.9%
2002	11-12	2682.1	1,888.6	70.4%

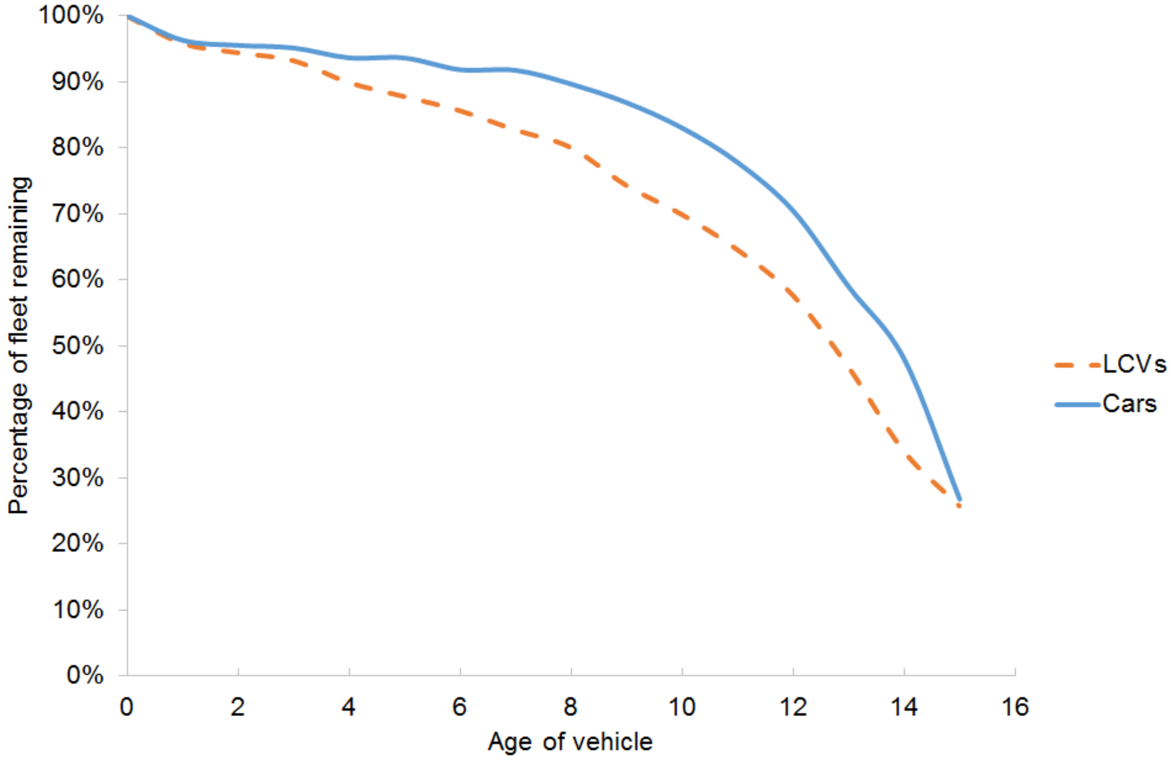
Year	Age (Years)	Cars registered for the first time (thousands)	Cars by number of keepers and year of registration, 2013 (thousands)	Survival rate
2003	10-11	2646.1	2,057.5	77.8%
2004	9-10	2599.1	2,156.6	83.0%
2005	8-9	2443.4	2,121.2	86.8%
2006	7-8	2340.0	2,097.7	89.6%
2007	6-7	2390.1	2,192.2	91.7%
2008	5-6	2112.0	1,939.0	91.8%
2009	4-5	1968.0	1,841.8	93.6%
2010	3-4	1996.3	1,868.8	93.6%
2011	2-3	1907.4	1,814.1	95.1%
2012	1-2	2010.8	1,920.4	95.5%
2013	0-1	2225.1	2,142.1	96.3%

Table 4-12 – Survival rate in 2013 of LCVs by year of first registration

Year	Age (Years)	LCVs registered for the first time (thousands)	LCVs by number of keepers and year of registration, 2013 (thousands)	Survival rate
1999	14-15	231.9	59.5	25.6%
2000	13-14	244.7	83.1	34.0%
2001	12-13	274.0	128.1	46.8%
2002	11-12	283.6	163.4	57.6%
2003	10-11	317.9	205.1	64.5%
2004	9-10	341.0	238.3	69.9%
2005	8-9	329.7	244.9	74.3%
2006	7-8	328.3	262.8	80.0%
2007	6-7	340.1	281.4	82.7%
2008	5-6	291.0	249.2	85.6%
2009	4-5	190.0	166.8	87.8%
2010	3-4	226.1	203.3	89.9%
2011	2-3	263.0	245.2	93.2%
2012	1-2	242.4	228.8	94.4%
2013	0-1	274.4	263.1	95.9%

The results of the above process for select years is shown below in Figure 4-31.

Figure 4-31 – Survival rate curves calculated from DfT Vehicle Licensing Statistics



For cars, it can be seen that in 2013, over three-quarters (78%) of cars reached their eleventh birthday and well over half (59%) reached the 13-year mark.

For LCVs, the survival rate is lower. Only 65% of LCVs reach eleven years of age and around 34% reach 13 years of age.

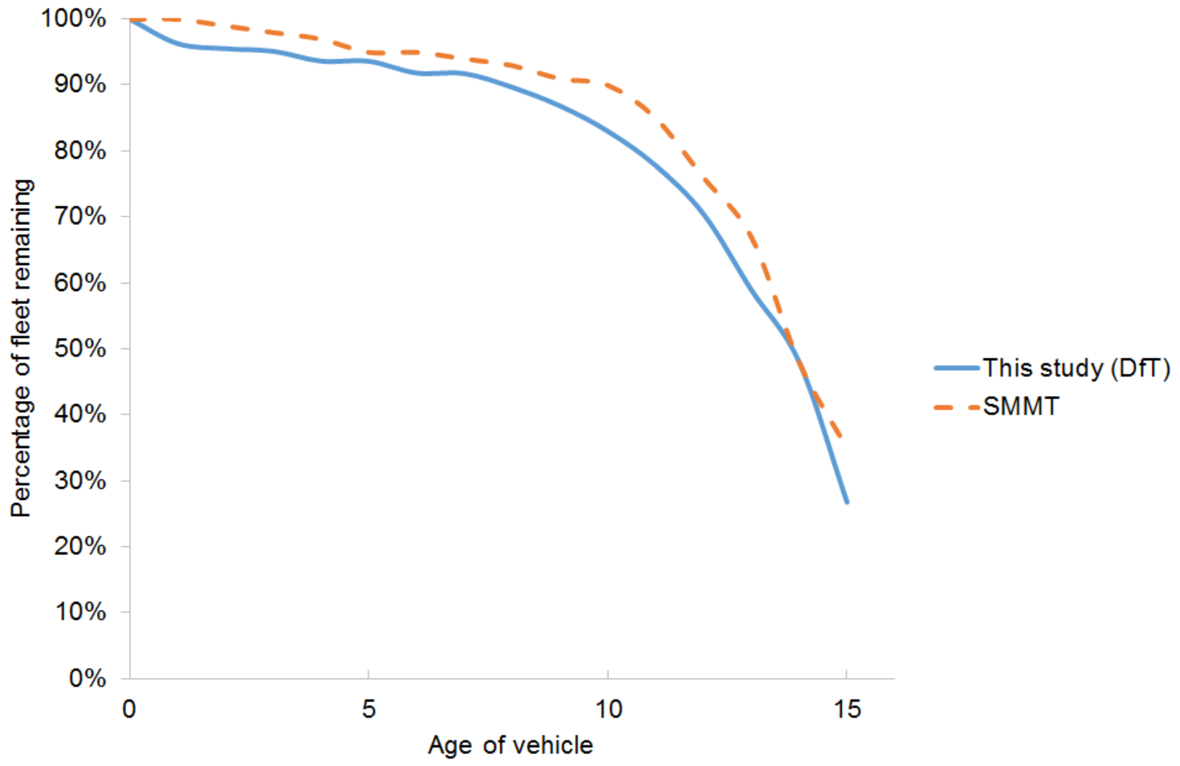
Interestingly after 15 years, the survival rate for cars and LCVs are very similar. This can probably be attributed to the rate at which annual mileage decreases over time compared to cars (see Table 4-10). The observed low annual mileages in later years for LCVs is most likely a factor as to why the survival rate begins to align more with the car survival at later stages of life.

4.3.2 Comparison of survival curves with alternative sources

In order to validate the above analysis, we have compared the data in Figure 4-31 with data from "The Used Car Market Report 2013" (BCA, 2013). This study quotes a UK-specific survival rate curve taken from the UK Society of Motor Manufacturers and Traders.

Figure 4-32 below shows the results of the comparison and it can be concluded that whilst some variations between the two sources exist, the survival rate curve derived in this study is very similar to the SMMT's data.

Figure 4-32 – Comparison of car survival rate curves with 2012 SMMT data



5 Inter Member State second-hand vehicle market

The aim of this task was to assess qualitatively the potential impact that the inter Member State second-hand vehicle market might have on the conclusions from the rest of the study.

The majority of vehicle sales transactions within the EU are for second-hand, rather than new, vehicles. For example, in 2012 there were 7.1 million second-hand car sales in the UK and 2.0 million new car sales, giving approximately 78% of all car sales being of second-hand vehicles (BCA, 2013).

In most cases, the transfer of a vehicle to a new owner would not result in it being lost from the national database systems (such as the UK MOT Test database used in this study). However, a portion of these sales would result in the vehicle being exported, in which case it would disappear from the original database and so influence the results of analyses of the data (particularly of the removal of vehicles from the database to derive lifetime mileage estimates).

There have been some disincentives to cross-border sales of second-hand vehicles, such as import duties and high fees and administrative burdens of registering the vehicle in the new State (DG SANCO, 2014). However, efforts have been made to ease the barriers to re-registration (for example, EC COM (2012) 164 - Proposal for a regulation simplifying the transfer of motor vehicles within the EU (European Commission, 2012b)). This easing of the barriers to importing vehicles might be expected to lead to an increased level of inter Member State sales of second-hand vehicles.

A report for DG CLIMA (European Commission - DG Climate Action, 2010) provides estimated data for the number of vehicles exported in 2008, as shown in Table 5-1.

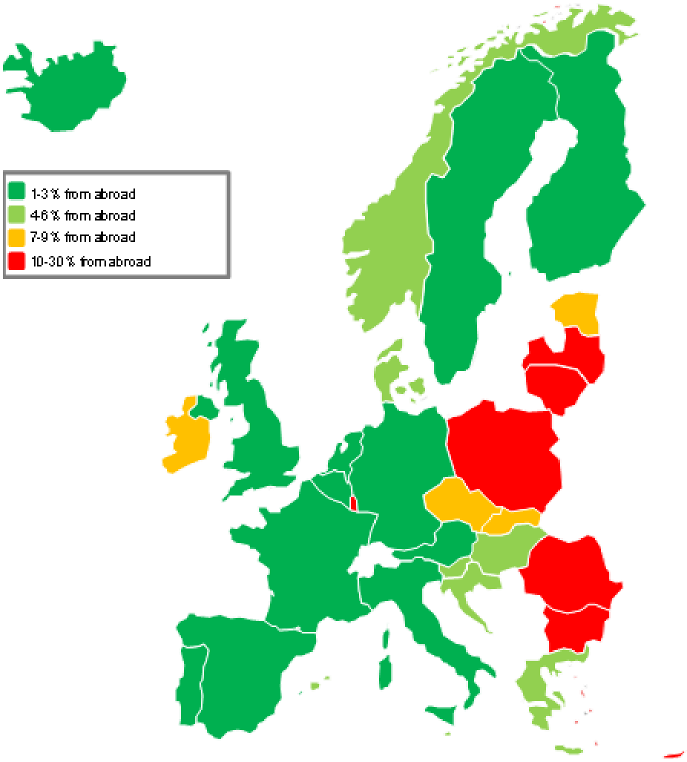
Table 5-1 - Numbers of second-hand vehicles imported and exported by Member States in 2008

Member State	Import	Export	New Registrations
AT	32,534	71,661	326,460
BE	173,369	417,600	603,493
BG	164,466	1,421	55,236
CY	24,485	151	28,444
CZ	206,456	9,056	202,823
DE	232,649	1,832,395	3,313,565
DK	43,000	55,000	183,746
EE	17,054	5,054	27,555
ES	89,315	253,857	1,327,048
FI	27,252	1,884	156,006
FR	103,612	279,453	2,509,219
GR	398,206	606	289,500
HU	28,818	3,198	174,837
IE	59,024	1,058	179,770
IT	67,623	412,912	2,385,564
LT	296,978	257,875	25,217
LU	16,701	29,530	56,387

Member State	Import	Export	New Registrations
LV	43,524	2,621	21,872
MT	4,185	126	5,666
NL	100,171	360,944	584,572
PL	1,144,033	39,904	375,936
PT	11,050	8,674	268,787
RO	223,307	44,325	307,409
SE	32,438	22,242	293,251
SI	20,249	50,032	78,857
SK	103,948	1,183	96,940
UK	30,952	78,893	2,418,953

The levels of imports of second-hand vehicles being imported is illustrated in the report by Gfk Belgium (DG SANCO, 2014) as a coloured map of Europe, as reproduced in Figure 5-1.

Figure 5-1 Map showing levels of imports of second-hand vehicles



Source - Gfk Belgium (DG SANCO, 2014)

From the data in Table 5-1, it can be seen that the number of second-hand vehicles exported from the UK in 2008 was just over 79,000. The total number of vehicles identified in the 2008 UK MOT data which were not in the 2009 data was about 3.1 million. Therefore, it can be seen that the level of exports from the UK, and hence the number of vehicles removed from the MOT data which may not have been at the End of Life (EOL), is about 2.5% of the total vehicle removals. A brief assessment has been made of the impact that this might have on the average EOL age as described in Section 4.1 of this report. It is likely that the majority of second-hand vehicles exported will be reasonably young, so this 2.5% of the total removals from the fleet was distributed across the vehicle which were removed from the MOT data at ages of less than 10 years. The effect of this was to increase the average age at EOL by approximately 0.1 years. Clearly, the EOL age calculated from the UK fleet is not very sensitive to the export of second-hand vehicles. Other Member States may be more sensitive.

Table 5-2 below shows the intra-EU export data from Table 5-1 expressed as a percentage of the new vehicle registrations for the same Member State.

Table 5-2 Vehicle export data expressed as percentages of the new vehicle registrations

Member State	Total exports as percentage of new registrations	Intra EU only exports as percentage of new registrations
AT	22.0%	19.3%
BE	69.2%	32.5%
BG	2.6%	0.5%
CY	0.5%	0.3%
CZ	4.5%	1.6%
DE	55.3%	47.0%
DK	29.9%	28.1%
EE	18.3%	7.9%
ES	19.1%	18.6%
FI	1.2%	0.8%
FR	11.1%	9.9%
GR	0.2%	0.1%
HU	1.8%	0.9%
IE	0.6%	0.5%
IT	17.3%	16.3%
LT	1022.6%	35.1%
LU	52.4%	50.5%
LV	12.0%	4.5%
MT	2.2%	2.0%
NL	61.7%	48.5%
PL	10.6%	1.8%
PT	3.2%	1.0%
RO	14.4%	14.4%
SE	7.6%	5.6%
SI	63.4%	3.1%

Member State	Total exports as percentage of new registrations	Intra EU only exports as percentage of new registrations
SK	1.2%	1.1%
UK	3.3%	2.2%

As can be seen, the UK has a relatively low level of exports of second-hand vehicles compared to the number of new vehicle registrations. Other Member States have very much higher levels, which would lead to significant uncertainties in the results if the same methods described in this report were applied to the assessment of EOL age and mileage in those Member States.

The above assessment has looked at the potential effect of the export of second-hand vehicles from one EU Member State to another on the statistics of EOL age in the originating Member State. It would be expected that those vehicles could then continue to be used in the destination Member State, leading to an increase in the EOL life and age. Assuming that the vehicles imported to the UK have been re-registered (as required by law), they would then need to be presented for MOT tests annually and so the increased lifetime mileage would then appear in the statistics as described earlier in this report. From Table 5-1, it can be seen that the inter Member State imports into the UK are even lower than the exports, so the effect of these imports on the calculated EOL age would be very small. In Member States with higher levels of imported vehicles, the effect could be greater.

However, it is worth considering the use of the vehicles after they have been exported from one Member State to another. It has been shown that the export of second-hand vehicles from the UK is low (as is the import into the UK) and hence has little effect on the calculated EOL age and mileage. The reasons for a vehicle being removed from the UK MOT database are, therefore, related to the vehicle reaching its EOL (major failure, uneconomic repairs, etc.). There is also the issue of theft which could be a factor. In 2011, 41% of stolen cars were recovered compared with 51% in 2008 and 70% in 2002. In 2011 alone, 65,000 British-registered vehicles were stolen and never recovered (Telegraph, 2012).

If usage and maintenance patterns are similar in other Member States, then the vehicles will be removed from the road at a similar point, independent of which Member State part or the majority of the mileage was accumulated in. Equally, if the normal pattern of use in a Member State would involve keeping the vehicle on the road to a significantly higher mileage than in the UK (through repairing faults which would be uneconomic in the UK or less strict enforcement of roadworthiness rules), then the higher mileage would be accumulated by both vehicles which were imported as second-hand and those which were first registered in that Member State

Thus, the degree to which the results for EOL age and mileage calculated here are representative of those in other EU Member States will depend more on the usage patterns in those other States than on second-hand vehicle imports and exports.

An aspect that would influence the conclusion above is that of mileage fraud or odometer clocking. As individual Member States implement systems similar to the UK MOT database (or the UK Vehicle Operators and Services Agency (VOSA) database that contains details of each vehicles history), the prevalence of mileage fraud within the Member State should reduce (that is a key aim of such systems) (EReg Annual Conference, 2011). However, there will still be the potential for mileage fraud when the vehicle is exported, unless the systems in the different Member States are linked. Thus the recorded mileage of the vehicle would change (with the associated effects on the vehicle value) but the true distance covered by the vehicle in its lifetime would not and so the analysis of lifetime mileage presented here would remain valid (subject to the comments above about different usage patterns in different States).

6 Conclusions

In order to provide a framework for this section and inform discussion, the project conclusions are set out against the aims of the project.

The key aims of this study were to:

i. Gather data on lifetime mileage (preferably in addition to the data that has been used for previous studies on mileage) and analyse the total mileages recorded for vehicles of different ages from the available datasets and;
ii. Establish a model describing how the annual mileage varies as the vehicles get older based on all years of life to provide better understanding of the mileage accumulation rates

6.1.1 Data gathering, processing and sampling

The focus of this study was on the UK MOT vehicle database where utilisation of anonymous vehicle identification numbers (VEH_ID) within the database allowed for vehicles to be tracked from one year to the next. Two databases were created in the data processing task;

1. ***Lifetime mileage database*** – This database contained all relevant vehicles (light duty vehicles) that passed their MOT in year i but were not found in year i+1 OR vehicles that failed their MOT in year i but were not found in year i+1. Both criteria made it likely that a vehicle had been removed from the road and was therefore assumed to be at end of life. This database contained vehicles from MOT databases dating back to 2006

2. ***Annual mileage database*** – This database contained all relevant vehicles (light duty vehicles) that passed their MOT in year i and had a subsequent pass in year i+1. This criteria allowed an annual mileage figure to be calculated for each vehicle as the mileage in year i and year i+1 was now known. This database contained vehicles only from the 2012 and 2013 MOT databases

Once these two databases (containing millions of vehicles) had been created, some processing was required to get them in to a manageable form for analysis. The approach taken was only to use data where the MOT testing took place in the month of October for each year between 2006 and 2013. This ensured that the datasets analysed were of a manageable size. Analysis was carried out to ensure that data from the month of October was representative of the whole year before continuing.

6.1.2 Analysis regarding lifetime mileages and retirement ages of light duty vehicles

A summary of the results found in this analysis is detailed below;

- Based on 2012-2013 data, on average, diesel cars (lifetime mileage of approximately 208,000 km) are driven a little under 25% further than petrol cars (lifetime mileage of approximately 160,000 km). For LCVs the average lifetime mileage is around 224,000 km, 7% higher than diesel car lifetime mileages and 30% higher than petrol car lifetime mileages;
- Looking at the historic datasets (from 2006-2013) a year on year increase in lifetime mileage is observed for passenger cars. This increase equates to a 33% rise in lifetime mileage between 2006 and 2013 (over 50,000km).
- For petrol cars the evolution over time is more flat with lifetime mileages fluctuating between 160,000 km and 170,000 km for the past six or seven years. Like diesel cars, average lifetime mileage for petrol cars has also increased over the 2006-2013 time frame; however in this case the increase is only 6%. For LCVs, the data indicates that there have been increases in average lifetime mileage between 2006 and 2013. According to the results the difference in average lifetime mileage between 2006 and 2013 is over 40,000 km (similar to diesel cars).

- The average retirement age of petrol cars in 2012-2013 was calculated to be 14.4 years while for diesel cars it was 14.0 years. This equates to petrol cars remaining in the vehicle parc around 3% longer on average. For LCVs, the data indicates that the average retirement age in 2012-2013 was 13.6 years. This figure indicates that LCVs retire 3% earlier than diesel cars (equating to around 6 months) and 6% earlier than petrol cars (equating to a little under one year).
- Looking at how retirement age has evolved over time, the historic datasets show that average retirement ages for petrol and diesel cars have been increasing year on year since 2006-2007. From 2006 to 2013, the average age of retirement increased by almost 7% for petrol cars and by almost 12% for diesel cars. For LCVs, the results show a slightly different trend; unlike cars, the average age of retirement for LCVs decreased considerably between 2007 and 2008, before rising again the following year. On the whole however, the average retirement age for LCVs increased by almost half a year between 2006 and 2013 – equating to a 3% rise.
- Analysing the link between lifetime mileage and mass indicates that there is not a strong relationship observed between these two parameters for cars or LCVs. As vehicle mass increases, lifetime mileage can increase or decrease, depending on the specific vehicle mass bins examined.

6.1.3 Analysis regarding annual mileages of light duty vehicles

A summary of the results found in this analysis is detailed below;

- Based on data from the 2012-2013 dataset, petrol cars are driven on average a little under 10,800 km per year whereas for diesel cars the average annual mileage is much greater at roughly 16,800 km. Therefore, as with the lifetime mileage analysis, diesel cars are being driven further (annually) than petrol cars by around 36%. For LCVs an average of a little under 15,500 km per year was calculated. This is 43% more than an average petrol car and 8% less than an average diesel car.
- The average age of petrol cars in the current fleet is higher than diesel cars. For petrol cars the average age is 9.6 years whilst for diesel cars the average is 7.8 years. The average age of LCVs is calculated to be 8.6. This is 9% less than petrol passenger cars and 10% greater than diesel passenger cars.

6.1.4 Mileage accumulation rates

A summary of the results found in this analysis is detailed below;

- In order to analyse annual mileage as a function of time, mileage data points were derived by allocating the database discrete age categories (bins) in order to generate a complete profile of annual mileage against vehicle age. The “trim mean” function has been applied to the data to allow averages at each year bin to be observed. This function uses the middle 90% of the data to remove outliers, which helps to increase the robustness for mixed and/or heavily-skewed distributions (as is the case for mileage data).
- The results show that annual mileage for petrol cars is relatively stable (around 10,000 km per year) through time until around year ten when annual mileage starts to decay. For diesel cars the decay in annual mileage starts earlier (from three years of age) and at a marginally increased rate to petrol cars. For LCVs, during years three and four there is a sharp drop in annual mileages. After peaking at 31,000 km in year three, the data indicate that there is around a 45% reduction in annual mileage for LCVs between the third and fourth year of a vehicle’s life. Finally, as for cars, after four years on the road, LCV annual mileages begin to decay steadily (and largely linearly) until EOL.
- The trend of the data points from ages four and onwards appear to follow a power distribution. Based on this, mileage accumulation rate functions were derived for both petrol cars, diesel cars and LCVs.
- The subsequent results from analysing accumulated mileage over time show that this relationship is non-linear for cars and LCVs. With cars the most appropriate relationship is a quadratic function whilst for LCVs it is a cubic function that best models accumulated mileage.

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Appendices

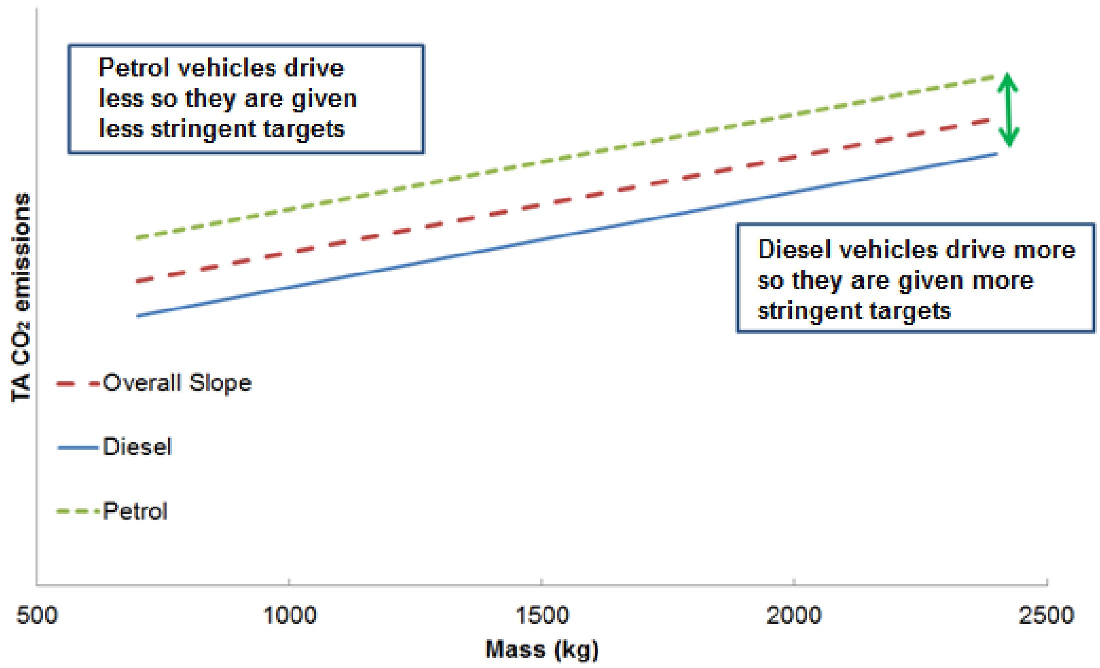
Appendix 1: Fuel specific targets

Appendix 2: Additional analysis

6.1 Appendix 1 – Fuel specific targets

A final analysis was also performed which investigated the impact of having fuel specific targets. Since it has been confirmed that diesel vehicles are driving significantly further on average over their lifetime then it may be more cost effective to set more stringent targets for diesel passenger cars and less stringent ones for petrol cars. In the following analysis, specific targets have been chosen for petrol and diesel vehicles that ensure the overall fleet target remains unchanged.

Figure 6-1- Illustrative example of fuel specific target slopes



Applying such target slopes to the CO_2 database allows segment-specific post 2020/21 targets to be calculated under both a mass and footprint system. Figure 6-2 and Figure 6-3 show how a CO_2 target system based on fuel type would affect the target required for each segment. As described above, there would be less stringent targets for petrol vehicles and more stringent targets for diesel cars.

Figure 6-2 - Comparison of target CO_2 emissions (g/km) per car segment in order to attain a hypothetical post-2020 CO_2 reduction target under the current regulatory system for car CO_2 emissions and a hypothetical fuel-specific target system with mass as a utility parameter

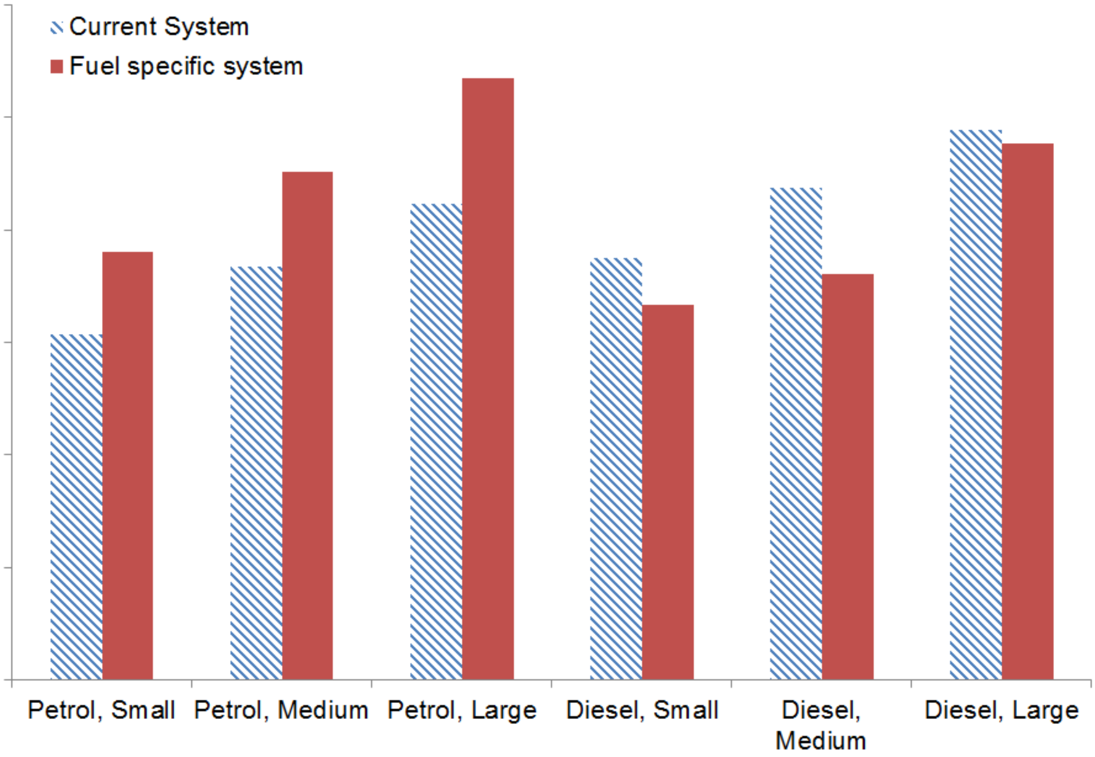
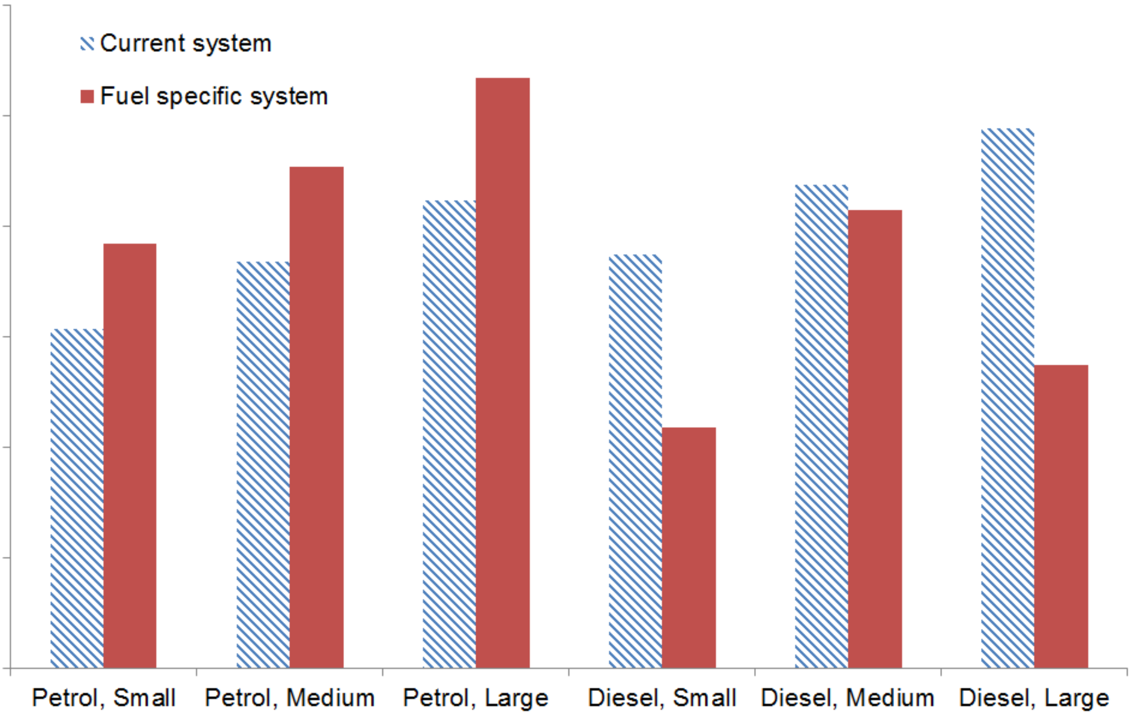


Figure 6-3 - Comparison of required CO_2 emissions per car segment in order to attain a hypothetical post 2020 CO_2 reduction target under current system and fuel specific target system with footprint as a utility parameter



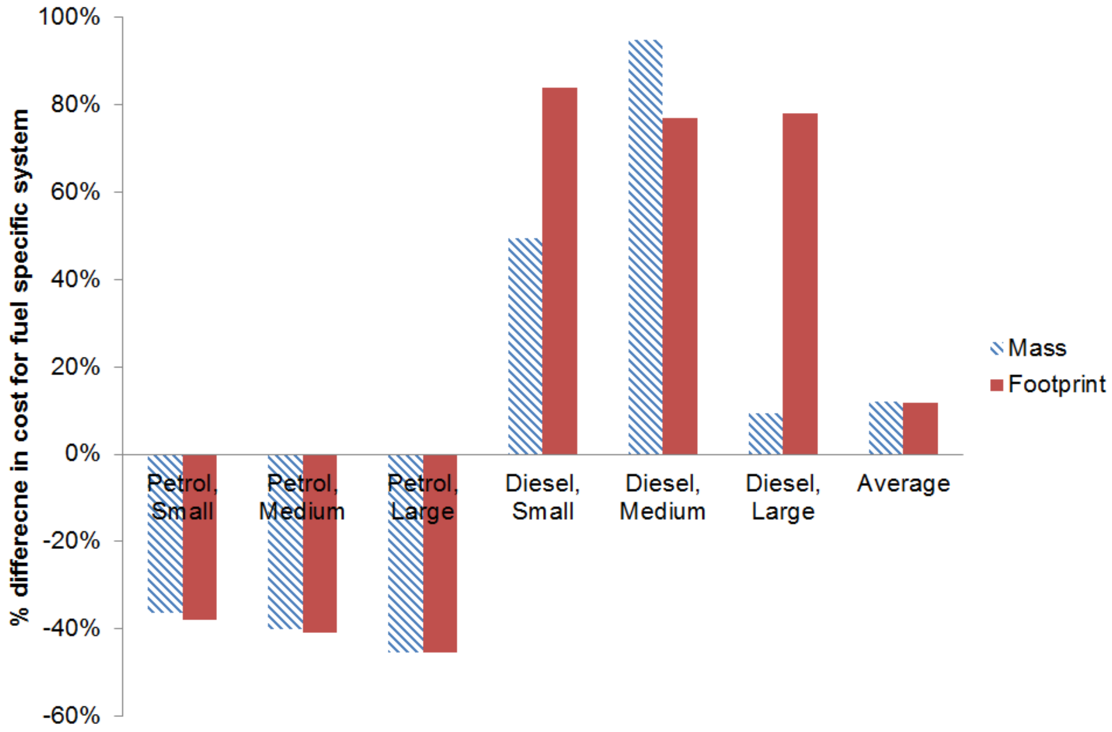
In terms of investigating the costs (and therefore cost effectiveness) of a CO_2 regulatory system based on mileage variations by fuel type, a cost optimisation procedure was applied.

The percentage cost difference between a fuel-specific system and the current regulatory system is shown in Figure 6-4. As would be expected, there would be reduced costs for compliance with the fleet-wide target for petrol vehicles (due to a less stringent target being applied here). The opposite is true for diesel segments.

However what is most intriguing is the overall cost for compliance. This is calculated to be around 9% greater than with a single target system. The reason for this can most likely be attributed to an added constraint for manufacturers in now having two targets to meet (one for petrol cars and one for diesel cars). Under the current car CO_2 Regulation, manufacturers can distribute the effort to meet their targets across six vehicle segments in order to achieve their overall targets. However, with a two slope system in place, manufacturers would only be able to distribute abatement effort across the three vehicle segments within each fuel type (thus essentially halving the level of flexibility they have in ways to reach their target). It is thought that it is this reason that results in the increase in overall cost for a two slope system (versus the current system).

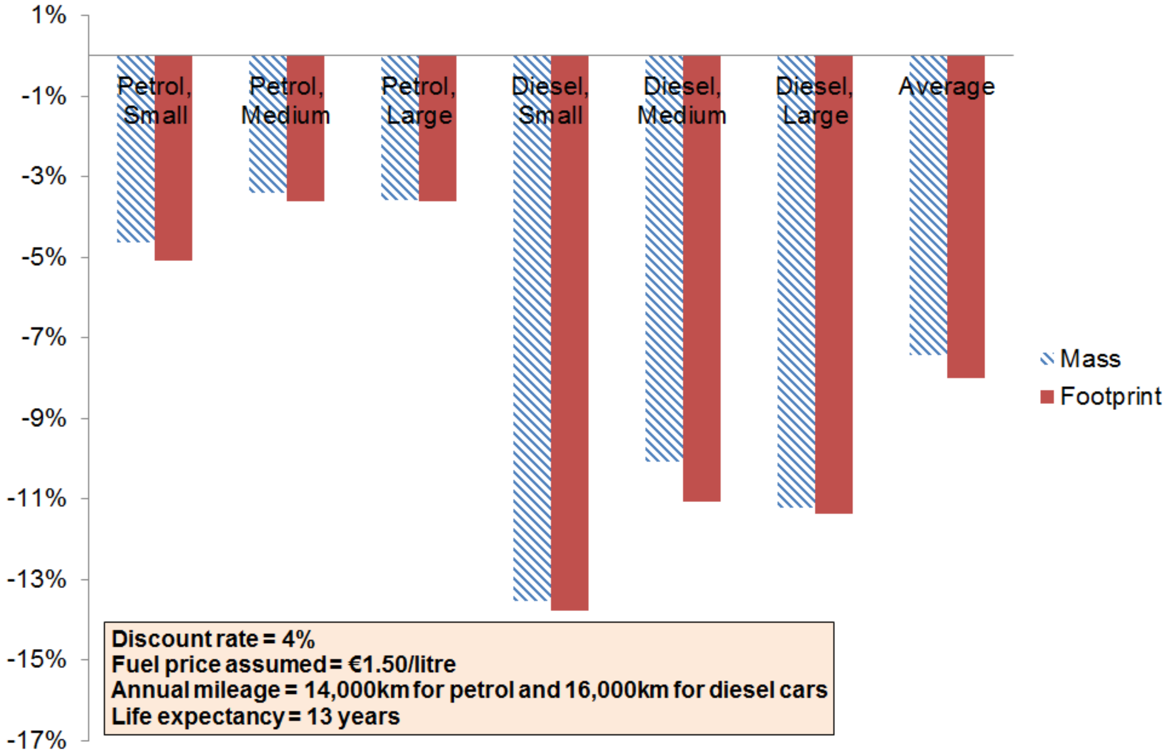
It should be noted that this analysis involves a modelled approach to show how manufacturers may behave in order to achieve their specific targets at minimum cost. In reality their exact behaviours to achieve target compliance may differ.

Figure 6-4 - Percentage difference in average manufacturing costs of achieving a hypothetical post 2020 CO_2 reduction target of the current system compared to a fuel specific system for cars



Performing the same analysis as above but now taking account of fuel savings from the reduced vehicle efficiencies yields this results shown in Figure 6-5.

Figure 6-5 - Percentage difference in average consumer costs of achieving a hypothetical post 2020 CO_2 reduction target of the current system compared to a fuel specific system for cars



In this case, average savings under a fuel specific system versus the existing system is 7.4% for a mass based utility parameter and 8% for a footprint based utility parameter[14].

6.2 Appendix 2 – Additional analysis

6.2.1 Data Sampling

The idea behind this additional analysis is to test the sampled 'October only' data against the full relative year MOT dataset to gauge the representativeness of the sampled dataset. In short, we want to be certain that only looking at data from October will give us results that we would still get if we analysed a full year of data.

In order to visualise this representativeness, age profiles of the sampling data for each year pair were plotted and compared to a select number of age profiles for the full MOT dataset. The results of this analysis can be seen below in Figure 6-6.

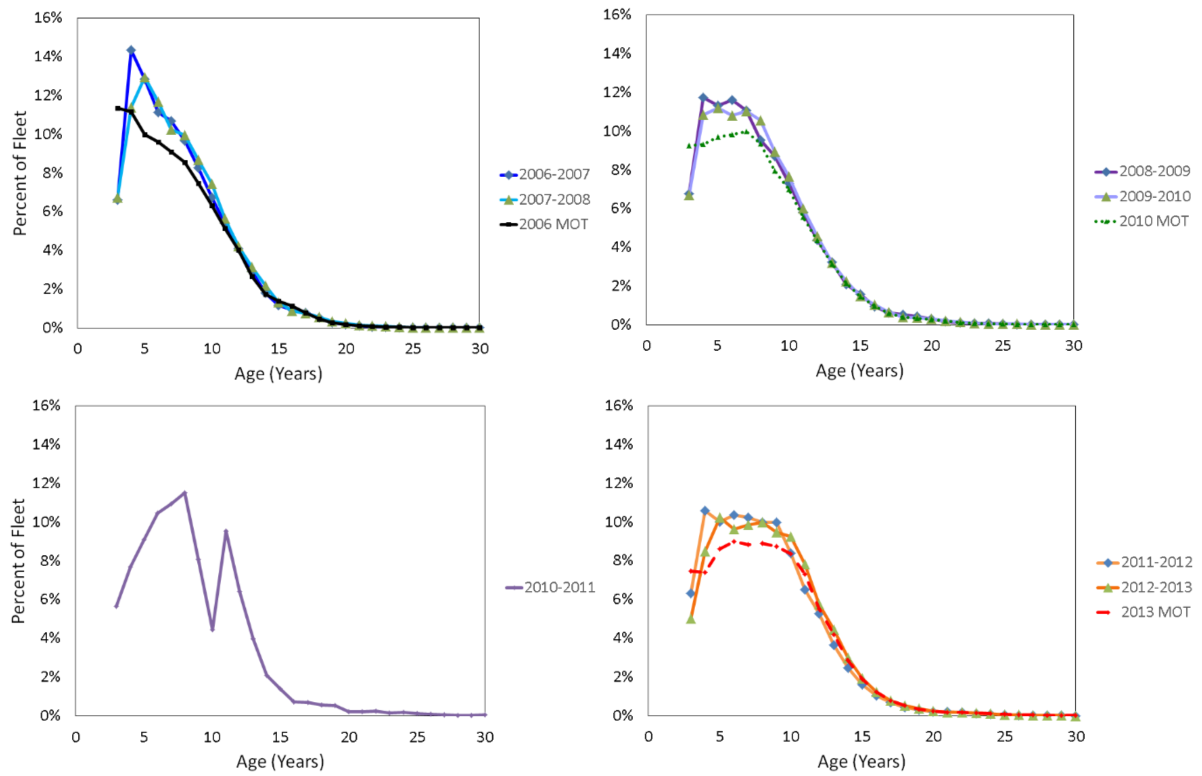
Figure 6-6 shows results from sampling the data in October each year. The age profiles of the sample data lines up fairly well with the equivalent year's full dataset which suggests that the data from the sampling month are fairly representative.

Figure 6-6 also portrays the 2010-2011 year pair data as anomalous. Brief investigations have not clarified the reason for this anomaly, but have confirmed that the results remain anomalous when a different set of dates are chosen for the extraction. As the aim of the process was to obtain a representative sample of lifetime mileage data and time on the project was limited, it was decided to not use the results for that year pair in the current analyses.

[14] Fuel savings calculated on the basis of diesel cars travelling 16,000km annually for 13 years and petrol cars travelling 14,000km annually for 13 years as per the existing impact assessment.

In conclusion, this sense check of representativeness of the sampled data was positive and, therefore, this study used the data sampled from October (not including results from the 2010-2011 year pair).

Figure 6-6 – Age profiles from sampled data in the month of October versus age profiles from equivalent full MOT databases (from 2006-2013)



6.2.2 2012-2013 Lifetime mileage results using alternative data extraction methodology

This section shows in more detail why a decision was made to abandon using one of the two lifetime mileage datasets that were compiled during the study.

The dataset in question was compiled using vehicles that were present in year i and not in year i+1, suggesting they had been removed from the road. However, Section 4.1 discusses the alternative reasons these vehicles may not be present in year i+1. Here the magnitude of how these reasons could adversely affect the robustness of the dataset is approximately considered.

Table 3-5 and Table 3-6 show the sample sizes of vehicles for the two approaches used in this study to determine vehicle lifetime age and mileage. The approach in question is around 55% of the total of these two approaches.

UK new car registrations are around 2 million per year and the stock has increased by about 200,000 per year since 2005. Therefore, for the UK, *roughly* 1.8 million cars are removed from road each year.

Table 6-1 – Analysis of the two approaches to obtain lifetime mileage vehicle databases used in this study

Methodology approach	Number of vehicles this captures	Reason for removal from MOT database
Approach 1	~810,000 vehicles (45% fail in year i and no-show in year i+1)	Removed from road due to not being roadworthy when assessed during the annual MOT test Vehicle written off between testing year i and year i+1
Approach 2	~990,000 vehicles (55% pass in year i and no-show in year i+1)	Removed from road before being presented for MOT because not considered likely to be road worthy
		Accident write-offs
		Exports
		SORN
		Theft

From Table 6-1 it can be seen that there are three additional reasons within Approach 2 for vehicles to be removed from the MOT database (see shaded red cells above). This confirms the unsuitability of this approach in this study.

Analysing the ages and of these “retired” vehicles in Figure 6-7, Figure 6-8 and Figure 6-9 it can clearly be seen that the results generated are not consistent with the expected results. Diesel vehicles in particular show a very low retirement age on average and this was a major driver in not taking this approach forward for further analysis.

Figure 6-7 – 2012-2013 Age distribution for petrol passenger cars at end of life (normalised for sales)

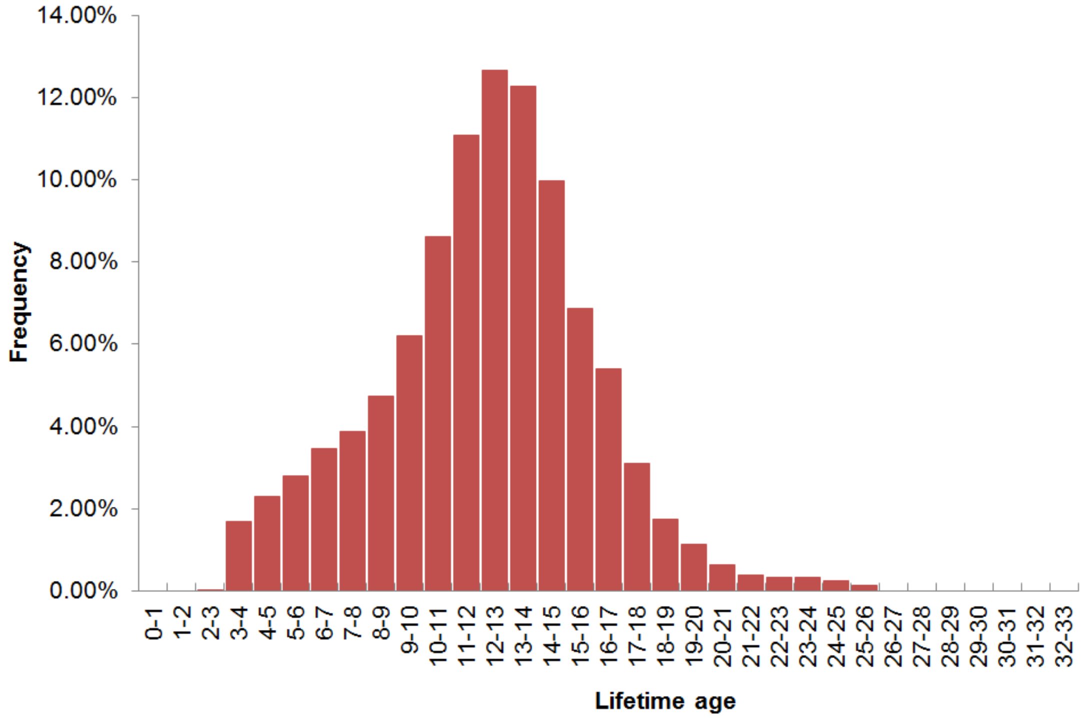


Figure 6-8 – 2012-2013 Age distribution for diesel passenger cars at end of life (normalised for sales)

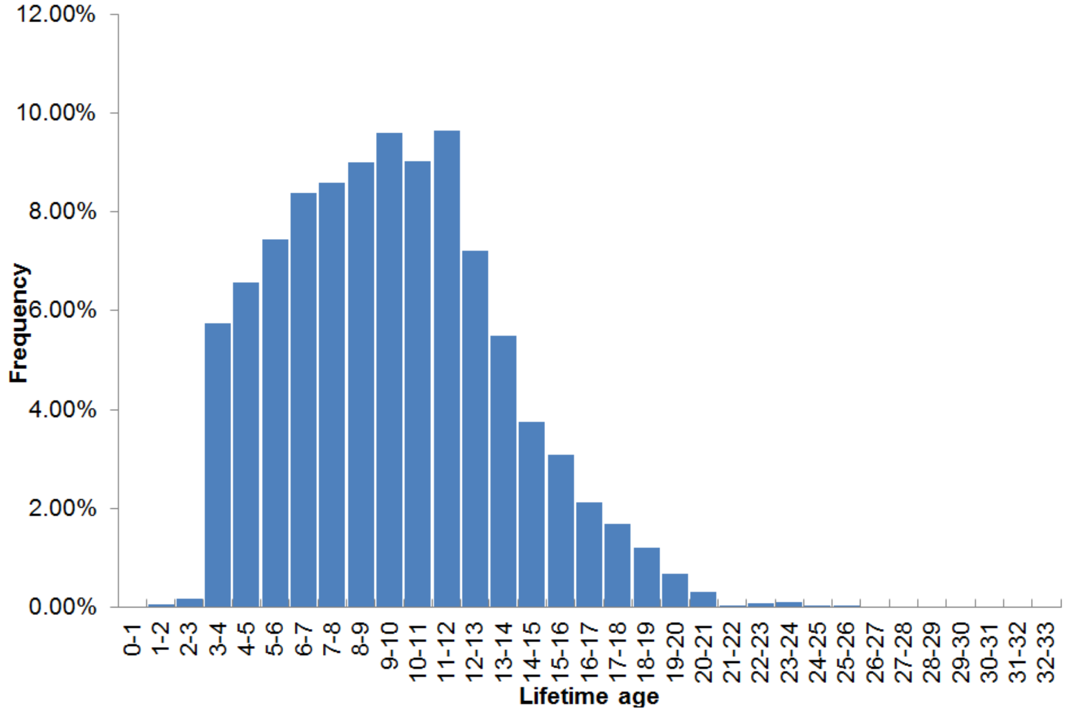
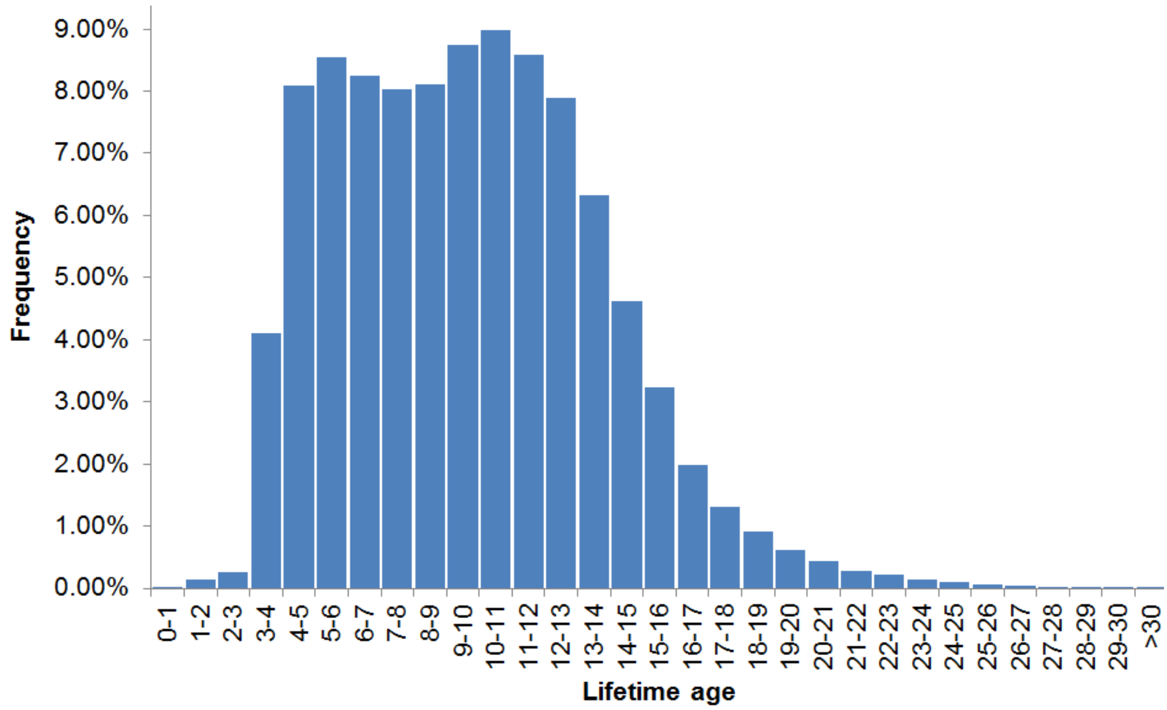


Figure 6-9 – 2012-2013 Age distribution for diesel LCVs at end of life (normalised for sales)



6.2.3 Key data tables

Table 6-2 – Modelled accumulated mileage values for LDVs (2012-2013 dataset)

Age	*Modelled Accumulated mileage*		
	Petrol cars	*Diesel cars*	*LCVs*
1	12,929	30,761	36,126
2	26,108	52,063	68,352
3	38,959	72,193	95,834
4	51,481	91,151	119,090
5	63,675	108,938	138,635
6	75,540	125,554	154,989
7	87,077	140,997	168,667
8	98,285	155,270	180,188
9	109,165	168,371	190,068
10	119,716	180,300	198,825
11	129,939	191,057	206,977
12	139,833	200,643	215,039
13	149,399	209,058	223,531
14	163,132	219,483	228,100

Table 6-3 – Normalised LDV fleet age proportions (2012-2013 dataset)

Model Year	*LDV fleet age proportions*		
	Petrol cars	*Diesel cars*	*LCVs*
Pre 1994	0.7%	0.09%	1%
1994	0.3%	0.15%	0.2%
1995	0.4%	0.18%	0.4%
1996	0.8%	0.27%	0.5%
1997	1.3%	0.41%	0.6%
1998	2.0%	0.66%	1.0%
1999	3.6%	1.11%	1.4%
2000	5.5%	1.80%	2.1%
2001	7.7%	3.00%	3.7%
2002	9.4%	5.51%	5.8%
2003	9.7%	7.01%	8.7%
2004	9.5%	8.70%	9.9%
2005	9.1%	10.10%	11.2%
2006	8.6%	11.02%	11.9%
2007	8.6%	12.48%	14.4%
2008	7.8%	12.70%	13.4%
2009	6.9%	10.30%	8.6%
2010	5.1%	7.02%	4.8%
2011	2.6%	4.48%	0.6%
2012	0.3%	1.78%	0.3%
2013	0.0%	1.32%	0.0%

Table 6-4 – LDV evolution of lifetime mileages

Year Pair	*Evolution of lifetime mileage (km)*		
	Petrol cars	*Diesel cars*	*LCVs*
2006-2007	144,442	155,815	154,431
2007-2008	150,383	164,411	182,984
2008-2009	152,739	169,033	204,027
2009-2010	152,257	173,812	219,351
2011-2012	156,967	192,389	224,134
2012-2013	160,109	208,476	223,945

Table 6-5 - Normalised LDV evolution of lifetime age

Year Pair	*Evolution of lifetime age (years)*		
	Petrol cars	*Diesel cars*	*LCVs*
2006-2007	13.50	12.52	13.17
2007-2008	13.58	12.82	13.20
2008-2009	13.54	13.02	12.95
2009-2010	13.69	13.34	12.80
2011-2012	14.09	13.82	13.36
2012-2013	14.41	14.02	13.58

Table 6-6 – LDV annual mileage proportions (2012-2013 dataset)

Model Year	LDV annual mileage proportions		
	Petrol cars	Diesel cars	LCVs
0-1,000	0.00%	0.0%	0.0%
1,000-2,000	2.14%	0.5%	1.7%
2,000-3,000	3.52%	0.8%	2.2%
3,000-4,000	4.66%	1.2%	2.8%
4,000-5,000	5.60%	1.6%	3.2%
5,000-6,000	6.32%	2.1%	3.5%
6,000-7,000	6.71%	2.6%	3.7%
7,000-8,000	6.95%	3.0%	4.1%
8,000-9,000	6.92%	3.4%	4.3%
9,000-10,000	6.67%	3.8%	4.4%
10,000-11,000	6.50%	4.0%	4.6%
11,000-12,000	5.71%	4.2%	4.5%
12,000-13,000	5.46%	4.2%	4.5%
13,000-14,000	4.62%	4.1%	4.3%
14,000-15,000	4.28%	4.0%	4.2%
15,000-16,000	3.61%	3.7%	3.8%
16,000-17,000	3.21%	3.5%	3.5%
17,000-18,000	2.59%	3.2%	3.4%
18,000-19,000	2.14%	3.0%	3.2%
19,000-20,000	1.92%	2.8%	2.8%
20,000-21,000	1.54%	2.6%	2.5%
21,000-22,000	1.35%	2.2%	2.3%
22,000-23,000	1.06%	2.1%	2.1%
23,000-24,000	0.89%	1.9%	2.0%
24,000-25,000	0.72%	1.7%	1.8%
25,000-26,000	0.59%	1.5%	1.6%
26,000-27,000	0.52%	1.3%	1.5%
27,000-28,000	0.37%	1.3%	1.3%
28,000-29,000	0.31%	1.2%	1.3%
29,000-30,000	0.32%	1.1%	1.1%
30,000-31,000	0.28%	1.0%	1.1%
31,000-32,000	0.23%	1.0%	1.0%
32,000-33,000	0.22%	0.8%	0.9%
33,000-34,000	0.16%	0.8%	0.8%
34,000-35,000	0.13%	0.8%	0.7%
35,000-36,000	0.11%	0.8%	0.7%
36,000-37,000	0.11%	0.7%	0.6%
37,000-38,000	0.10%	0.7%	0.5%
38,000-39,000	0.07%	0.7%	0.5%
39,000-40,000	0.08%	0.7%	0.5%
40,000-41,000	0.08%	0.7%	0.4%
41,000-42,000	0.07%	0.7%	0.4%
42,000-43,000	0.07%	0.7%	0.4%

43,000-44,000	0.06%	0.6%	0.4%
44,000-45,000	0.05%	0.7%	0.3%
45,000-46,000	0.05%	0.7%	0.3%
46,000-47,000	0.04%	0.6%	0.3%
47,000-48,000	0.05%	0.6%	0.3%
48,000-49,000	0.05%	0.6%	0.2%
49,000-50,000	0.04%	0.5%	0.2%
>50,000	0.75%	13.0%	3.30%

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