NAEI ROAD TRANSPORT INVENTORY

Development of the Road Transport Fleet Turnover Model

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CONTENTS

Appendices

1. FOREWORD

This report is the result of improvement work that was done in 2021 and implemented into the NAEI published in 2022 which covered up to the calendar year 2020. This report is being published to ensure the methodology of the NAEI is as clear and transparent as possible. Where references to the 'latest' data are made in the following report, this refers to data for calendar year 2020, published in 2022.

2. EXECUTIVE SUMMARY

The National Atmospheric Emissions Inventory (NAEI) currently uses a fleet turnover model to calculate the composition of the UK vehicle fleet and road transport emissions over a time-series from 1990 and forward to 2030. The model has been derived from historical vehicle licensing records from the DVLA and estimates, dating back some years, on how annual mileage changes with vehicle age.

This report describes in detail the analysis of a new, more comprehensive and up-to-date set of vehicle licensing and annual mileage data from MOT records provided by DfT, covering years between 2007 and 2019 (licensing data back to 1994 and MOT data also available for 2020). These have been supplemented with additional DfT data from the Continuing Survey of Road Goods Transport (CSRGT) and National Travel Survey and used to develop revised vehicle survival rate and mileage with age profiles that vary by year and have been used to update the NAEI's fleet turnover model. The model has been used to calculate a consistent time-series in the composition of the fleet in terms of the proportion of vehicle kilometres travelled by vehicles of different Euro emission standards from 2005 to 2019. By combining with new assumptions on fleet turnover for future years, including revised forecasts from industry sources that were previously unavailable on sales of new HGVs and buses, the fleet composition has also been calculated for 2025 and 2030.

Vehicle survival and mileage rates decrease as vehicles age, but the new data reveal this trend has slowed in recent years indicating that older vehicles of almost all types are surviving longer and doing greater mileage now than in the past. As a consequence, the new fleet turnover model now indicates that a larger share of the vehicle kilometres are done by older vehicles complying with earlier Euro emission standards than is estimated by the current NAEI model.

The fleet compositions derived from the fleet turnover model for 2019 have been compared with Automatic Number Plate Recognition (ANPR) data for different vehicle and road types provided by DfT for the same year. For all vehicle types there is a tendency for the ANPR data to show a somewhat older fleet than is implied by the fleet turnover model, although the agreement is better with the model based on the new survival and mileage rates than the current model.

The revised fleet turnover model was used to estimate current and future NO_x and $PM_{2.5}$ emissions from UK road transport. The calculations were done in the NAEI road transport emissions model which also incorporated new speed data.

The fleet changes have led to an overall increase in NO_x emission estimates for all years in the historical inventory compared with a version where only the speeds were changed. The differences are particularly large in the earlier part of the time-series, but are smaller in more recent years. The changes are in competition with the reductions achieved in all years by using the new speeds[1] which have not yet been used in the NAEI, such that in 2005 there is an overall increase of around 40 ktonnes in NO_x emissions when changes in both speeds and fleets are accounted for compared with current NAEI estimates, but an overall reduction of around 13 ktonnes in 2019. Overall emissions are projected to be higher by 7 ktonnes in 2030 compared with current NAEI projections. A similar pattern is found for exhaust emissions of $PM_{2.5}$, but the fleet changes have a much smaller effect in 2030. The fleet changes do not affect the non-exhaust emissions of $PM_{2.5}$ and for these the effect of speeds are more dominant leading to an overall increase in emissions in all years.

The significance of these changes have been considered in the context of their impact on national totals and compliance with national emission ceilings under the UK National Emissions Ceilings Regulation 2018 (NECR) and the Gothenburg Protocol under the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (CLRTAP). The changes made to the fleet turnover model combined with changes to speeds have increased the national inventory to the extent that the UK will now exceed the NECR ceiling in 2011 as well as 2010 and 2012. The UK will be able to apply for an adjustment to these emission estimates for 2011 as permitted under the Adjustment Mechanism, and which it currently does for 2010 and 2012.

The fleet compositions currently used in the NAEI for recent years are "calibrated" against fleets derived from Automatic Number Plate Recognition (ANPR) data provided by DfT. These are only available for certain years meaning it is difficult to derive a consistent historical time-series in fleet evolution. The new fleet turnover model is not calibrated but is based directly on the survival rates and mileage rates derived for different years in this study. Being based on a large number of records, these data do in our opinion provide a better reflection of vehicle usage by age suitable for the construction of an emissions inventory on a ***national scale over a consistent historical time-series*** and as the foundation of a fleet turnover model that can be used in predicting the composition of the fleet at national level for future projections. **It is therefore proposed not to make an 'ANPR calibration' to the fleet composition used in the NAEI in future.** However, it is recommended that ANPR data are continued to be used for defining the share of petrol and diesel cars on different road types and in defining the composition of localised fleets in some very specific areas of interest rather than for a national roll-out, recognising this is becoming a priority for local assessments and air quality modelling for Defra.

The new fleet turnover modelling approach is considered compliant with current guidelines for reporting national emissions inventories under the requirements of the UNECE CLRTAP, NECR and UNFCCC and is consistent with, or an improvement of, methods used by other countries in Europe.

In conclusion, from 2022:

- **The new vehicle survival and mileage rates, varying by year, were used in the NAEI's fleet turnover model and updated annually with new vehicle registration data and MOT mileage data provided by DfT.**

- **The new NAEI fleet turnover model was used in projecting future emissions with assumptions on new vehicle sales confirmed annually with DfT as well as confirmation or otherwise on use of survival rates and mileage with age rates carried forward to future years**

We note that fleets derived from local ANPR data are always likely to show differences with the national fleet derived from trends in national statistical sources. This should not prevent the fleet turnover approach described in this report being used for the NAEI and projections on a

[1] Basemap speeds implemented in 2022.

national scale, but will require further analysis and potential adjustment in certain parameters such as mileage where the evolution of a fleet needs to be modelled on a local scale.

3. INTRODUCTION

3.1 THE CURRENT SITUATION

The National Atmospheric Emissions Inventory (NAEI) provides a consistent time-series in estimates of emissions from road transport in the UK back to 1990 and projected forward to 2030. The outputs from the NAEI are also spatially resolved and used for national scale modelling of air pollutant concentrations by the Pollution Climate Mapping (PCM) approach in Defra's "Modelling Ambient Air Quality" (MAAQ) programme, as well as other modelling programmes for Defra.

The inventory is highly dependent on a fleet turnover model that calculates the composition of the UK vehicle fleet in terms of the mix of different vehicle sub-categories (Euro standards, fuel types and in some cases types of technologies) in the fleet. The model has been derived from historical vehicle licensing records from the DVLA and estimates, dating back some years, on how annual mileage changes with vehicle age. The model produces a consistent time-series in the fleet composition for each type of vehicle from 1990 to 2035 expressed in terms of the fraction of vehicle kilometres done by each vehicle sub-category (Euro standard, fuel type). Historical and projected values in the absolute numbers of vehicle km travelled are available from DfT for each main vehicle category (car, LGV, HGV, bus, motorcycle) and road type based on DfT's traffic statistics and National Traffic Forecasts. The role of the fleet turnover model is to split the vehicle kilometres into the relevant Euro standard and fuel types. For the current year (2021) and recent years in the inventory, use has also been made of Automatic Number Plate Recognition (ANPR) data from DfT which shows the mix of Euro standards and fuel types observed on UK roads.

The NAEI fleet turnover model is currently based on historical trends in vehicle survival rates. These define the probability that vehicles of different ages have remained in the fleet since first registered and rates were derived from analysis of vehicle licensing records from DfT back in 2011/12. The survival rates are then applied to new vehicle sales data (new registrations) each year to determine the complete composition of the fleet in all years back to 1990 and, using projected vehicle sales data, forward to 2035. The NAEI currently uses old and unpublished data provided by DfT showing how annual mileage drops off with vehicle age. This is used in conjunction with vehicle survival rates to estimate the proportion of vehicle kilometres (vkm) done by vehicles of different ages in the fleet. For current years, the calculated fleet compositions in these terms have been calibrated with data from ANPR.

3.2 RECENT EVIDENCE AND ASSUMPTIONS REQUIRED FOR DEVELOPMENT OF A REVISED FLEET TURNOVER MODEL

The method described above has underpinned the NAEI road transport inventory and projections and has fed into the PCM modelling for some time. Separate to this, the NAEI team had also been holding discussions with groups at DfT in 2019/2020 (Environmental Analysis, Road Traffic Statistics, Environmental Statistics, National Transport Model teams) where it was suggested that recent licensing data show a tendency for older diesel cars to be kept and registered for longer than they were in the past. A meeting on this topic was held at DfT involving these teams, as well as JAQU and representatives from Defra on 3rd July 2019 and it was suggested that up-to-date information held by

DfT should be explored for use in the NAEI. As well as detailed licensing data, the DfT also now hold records from MOT tests which show up-to-date mileage with age data.

These new data held by DfT refer to the fleet at national level and would benefit from being further explored and analysed to see if they could be used in the NAEI fleet turnover model to calculate a more precise and consistent time-series in the mix of vehicle sub-categories and their activities in the fleet. A decision would then be made as to whether the fleet turnover model can be used to provide the necessary data for the next compilation of the NAEI published in early 2022 (the 2020 NAEI) as well as the PCM used in modelling done for the Air Quality Standards Regulations reporting, going forward.

In 2020, a draft report was submitted to Defra showing results from our initial exploration of the up-to-date vehicle licensing records and MOT mileage data (Ricardo, 2020b). Our analysis confirmed that survival and mileage with age rates have slowed in recent years indicating that older vehicles of most (but not all) types are surviving longer and doing greater mileage now than in the past. This means that a larger share of the vehicle km are done by vehicles meeting earlier, less stringent emission standards than the NAEI model currently estimates, which in turn leads to a higher inventory estimate in road transport emissions of NO_x than is currently estimated. Use of this revised data reduces the gap between the fleet compositions predicted by a fleet turnover model based on these rates and compositions implied by local authority ANPR data, but a gap still remains. This most likely reflects genuine differences between in-service fleets operating locally and fleet compositions based on a model derived from national fleet and mileage records.

Our initial exploration and development of a revised fleet turnover model revealed that several gaps in data availability needed to be addressed and decisions made on certain assumptions that were key to predicting fleet turnover in future years. Further work was also necessary to fully implement the revised fleet turnover model so that it could be used to estimate emissions consistently across the full historical time-series for the NAEI back to 1970 and forward to 2030.

This report brings together findings from our initial exploration and development of a revised fleet turnover model and addresses the outstanding issues recommended for further consideration before a final decision could be made on implementing a revised fleet turnover model into the 2020 NAEI. The issues remaining to be addressed were:

- What mileage with age functions should be used for HGVs and buses given that mileage data from HGVs are not available for these vehicle types from MOT-type vehicle inspection records?
- What survival and mileage rates should be assumed for future years? Our initial work suggested three alternative scenarios based on short-, medium- or long-term averages of rates for historical years. After discussions with DfT, it was agreed to use the mean of the last three historic years for projected years.
- What new vehicle sales projections to assume for HGVs and buses? Such data are currently provided by DfT for passenger cars and light goods vehicles (LGVs), but no such data are available for HGVs and buses, so this task considered alternative sources of data to be used for informing NAEI projections

This report then shows results obtained from a full implementation of a revised fleet turnover model brought up-to-date with the latest vehicle licensing and MOT mileage data and with the above outstanding issues addressed. The report focuses on showing trends in UK NO_x and PM emissions over the time-series from 2005-2019 and projected to 2030 compared with the current NAEI time-series.

The model results are also based on a version of the emissions model with the full implementation of the new set of speeds data. A separate report has already been provided showing the origin, analysis and implementation of the revised speeds and the impact they have on emissions when compared against a version of the model using the current fleet turnover assumptions (Ricardo, 2021). It has already been agreed to implement the new speeds in the 2020 NAEI version and they have already been incorporated in results underpinning the PCM results for the Air Quality Directive 2020 (AQD 2020) reporting.

3.3 REPORT STRUCTURE

This report provides details of the approaches adopted to analyse the DfT fleet and mileage data and their use in constructing a new fleet turnover model. It also discusses assumptions for fleet turnover in future years including new HGV and bus vehicle sales forecasts and HGV and bus mileage with age data that were not previously available. The results on the national vehicle fleet composition and UK NO_x and PM emissions calculated when using revised input data in an updated fleet turnover model are presented and compared with the fleet and emissions currently calculated by the NAEI emissions model.

The report is structured to cover the different elements of the study:

- Analysis of a long-time series of detailed vehicle licensing data to generate vehicle survival rates (1990-2019)
- Analysis of MOT mileage data to generate functions describing how average annual mileage changes with vehicle age (2007-2019)
- Analysis of data on HGV mileage with age based on information provided by DfT from the Continuous Survey of Road Goods Transport and mileage profiles developed for buses inferred from ANPR data.
- Analysis of DfT's most recent set of ANPR data for 2019
- Assumptions agreed for defining new HGV and bus vehicle sales forecasts and fleet turnover rates to assume for future years
- The combination of the above analyses to generate an updated fleet turnover model, showing how the time-series (1990-2019) in vehicle fleet composition compares with that currently used in the NAEI
- The trends in UK road transport emissions when the revised fleet turnover model and assumptions are used compared with the current emission trends. Results are shown for NO_x and $PM_{2.5}$ emissions for 2005-2030.

A further section considers the validity of the fleet turnover modelling approach in the context of international guidelines for reporting national emission inventories under the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (CLRTAP), the UK National Emissions Ceilings Regulation 2018 (NECR) and the United Nations Framework Convention on Climate Change (UNFCCC). This section also considers how the approach compares with methods used by other countries in Europe.

4. ANALYSIS OF VEHICLE LICENSING DATA AND SURVIVAL RATES

The NAEI fleet turnover model is currently based on historical trends in vehicle survival rates. The vehicle survival rates define the probability that vehicles of a given age have remained in the fleet since they were first registered, and were initially derived from analysis of vehicle licensing records from DfT in 2011/12. Typical survival rates were developed for each main vehicle type by averaging trends over several (typically 5-10) consecutive years, but these are not updated each year, i.e. it is assumed that the vehicle lifetime pattern by age remains unchanged.

For the purposes of this work, we have analysed more up-to-date published licensing data from DVLA/DfT and bespoke (unpublished) licensing data from DVLA/DfT for all vehicle types.

4.1 OVERVIEW OF THE DVLA/DFT LICENSING DATA ANALYSED

The vehicle licensing statistics provide information on the number of licensed vehicles at the end of the year by year of first registration for Great Britain from 1994 to 2019. Licensing data allows age-dependant survival rates to be derived which can be used to develop a profile showing how vehicles of the same type but of different ages have survived with time according to the licensing situation for a particular calendar year. Profiles can be developed that apply to different calendar years. These profiles could be used as an alternative to the older static profile of vehicle survival rates currently used in the NAEI to improve fleet composition estimates.

4.1.1 Data Content and Quality

DfT provided licensing data for petrol and diesel cars and LGVs, rigid and artic HGVs, buses & coaches, and motorcycles. The licensing data were provided by body type (physical structure of vehicles) rather than taxation class. It was presented in a tabular format with rows representing the year of first registration (data from 1950 to 2019) and columns representing the end of a calendar year (from 1994 to 2019). The licensing data refers to the number of vehicles licensed at the end of a calendar year.

In general, the data quality is good and consistent in most cases. There were however instances where the number of vehicles of a particular year-of-registration was higher in one year than it was in the previous year when a decrease would be expected as vehicles were scrapped or otherwise taken out of service. According to DfT, this is not an issue with the quality of the data but reflects the fact that some owners might take their vehicles off the road for certain year(s) (e.g. Statutory Off Road Notification (SORN)) and then re-register to bring them back in use. However the number of such instances was very small and did not affect the analysis that was undertaken.

4.2 DATA PROCESSING

Based on the information provided on DVLA/DfT's datasets, the survival rate has been calculated as the ratio of the number of licensed vehicles first registered in year X and have remained in year Y by the number of licensed vehicles first registered and have remained by the end of year X. As an example, to calculate the survival rate for 16 year old diesel cars in 2016, the ratio of the number of licensed diesel cars first registered in 2000 that have remained at the end of 2016 divided by the number of licensed diesel cars first registered and remaining at the end of 2000 is derived.

Licensing data at the end of years earlier than 1994 for all vehicle types were not available. So for example, to calculate how many 12 year old diesel cars survived at the end of 2002, it would be necessary to divide the number of licensed diesel cars that were first registered in 1990 and remained at the end of 2002 by the number of diesel cars registered and survived at the end of 1990; such data were not being given in the DfT's datasets. To deal with this, survival rates were determined from trends in adjacent years where data for a given vehicle age were available. Gap filling of this nature inevitably becomes more apparent further back in time, but only becomes significant for vehicles older than 15 years in years before 2008.

4.3 TRENDS IN SURVIVAL RATES

4.3.1 Cars

The proportion of diesel and petrol cars survived in all years between 1994 (dark green line and dot) and 2019 (light green line and dot) is depicted in Figure 4-1 for diesel cars and Figure 4-2 for petrol cars, showing a decrease in survival rate with vehicle age. The same pattern of falling survival rate with increasing age is seen across all years and is typical of that previously observed and in the trend currently used in the NAEI, as vehicles age and are taken out of service. However, closer inspection shows subtle changes in trends occurring over time.

By way of example Figure 4-3 shows the year-dependant survival rates of 3, 10 and 16 year old diesel cars compared against the current NAEI rate. These profiles show that the proportion of older diesel cars (16 years old) that have survived is higher in the latest years (0.28 in 2019) than it is in the earlier years (0.14 in 2009). The same applies for petrol cars (as shown in Figure 4-4). Thus, it is safe to assume that older diesel and petrol cars have tended to survive longer in recent years than they had in earlier years. Figure 4-5 and Figure 4-6 presents the same data in a slightly different way, covering more age groups in a single plot for diesel cars and petrol cars, respectively. It is notable that a higher proportion of 13 year old cars survived in recent years than in the past. The same conclusion cannot be drawn for newer or middle age cars which show a relatively constant survival rate over time. In other words, it is really the older cars which are showing a tendency to survive longer than they used to. The survival rates for older cars are tending to be higher than currently assumed in the NAEI.

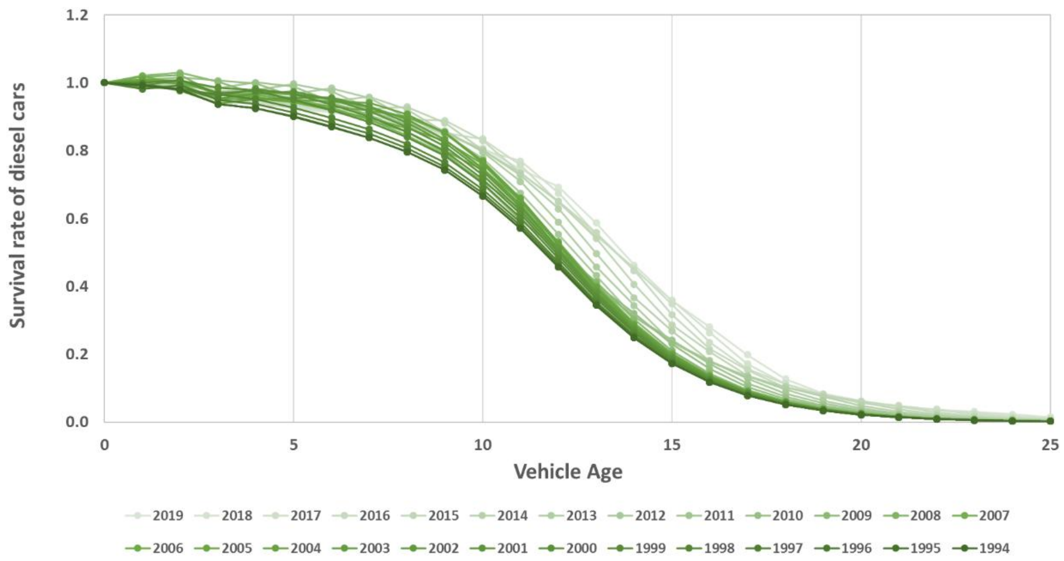


Figure 4-1 Survival rate for diesel cars with vehicle age in different calendar years

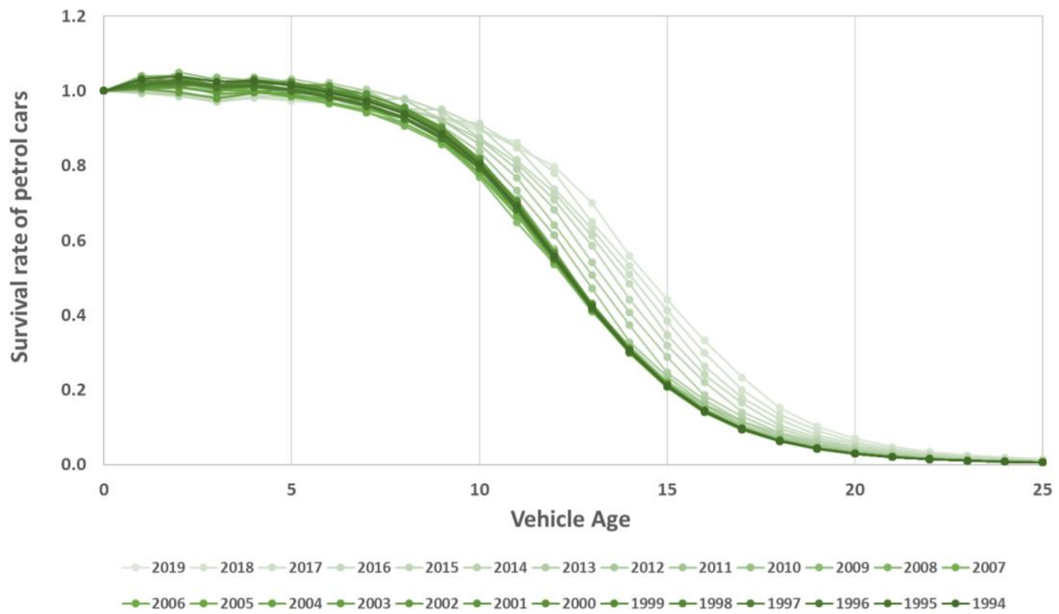


Figure 4-2 Survival rates for petrol cars with vehicle age in different calendar years

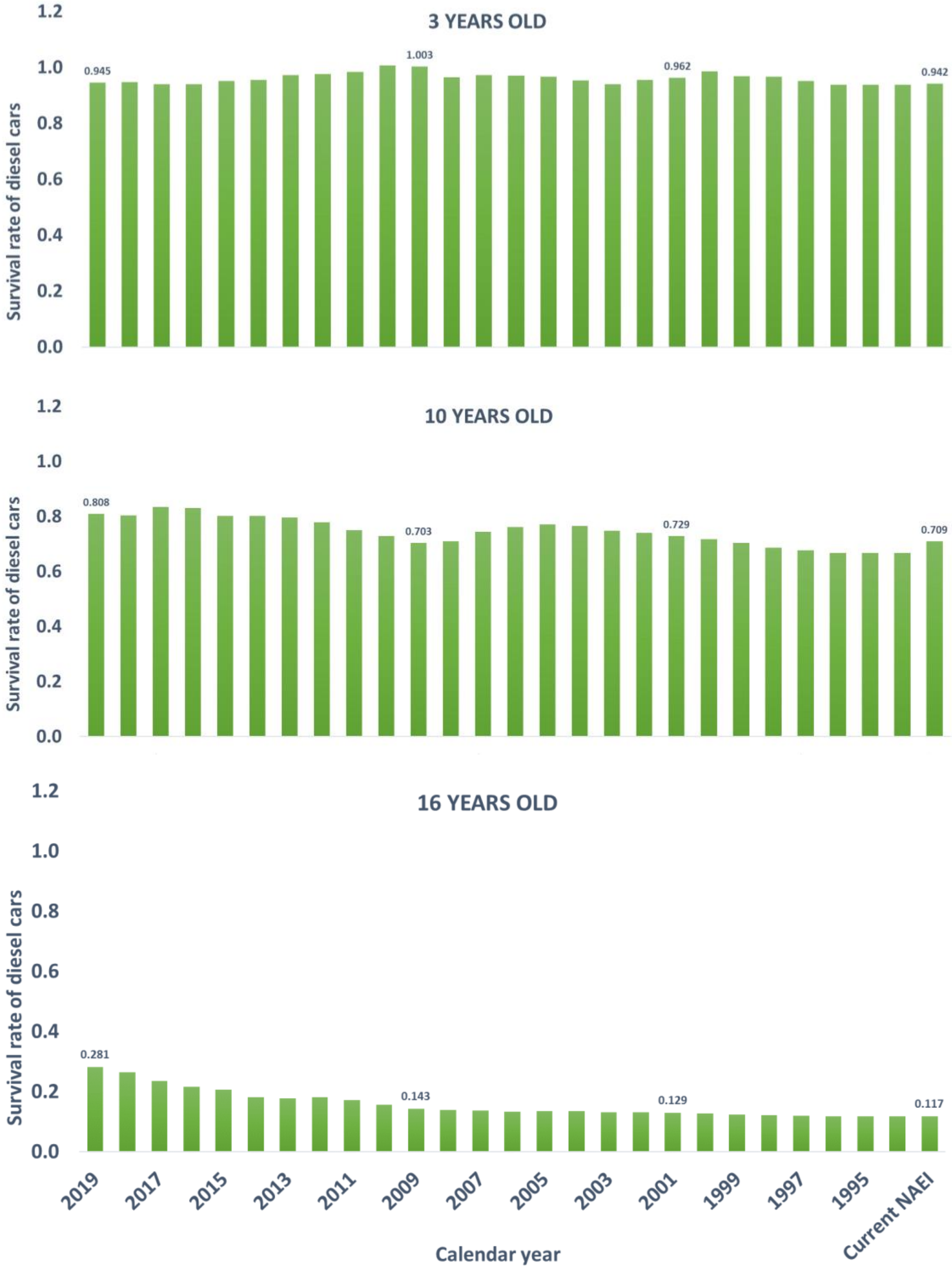


Figure 4-3 Year-dependant survival rates for 3, 10 and 16 years old diesel cars for all calendar years compared against the current NAEI rate

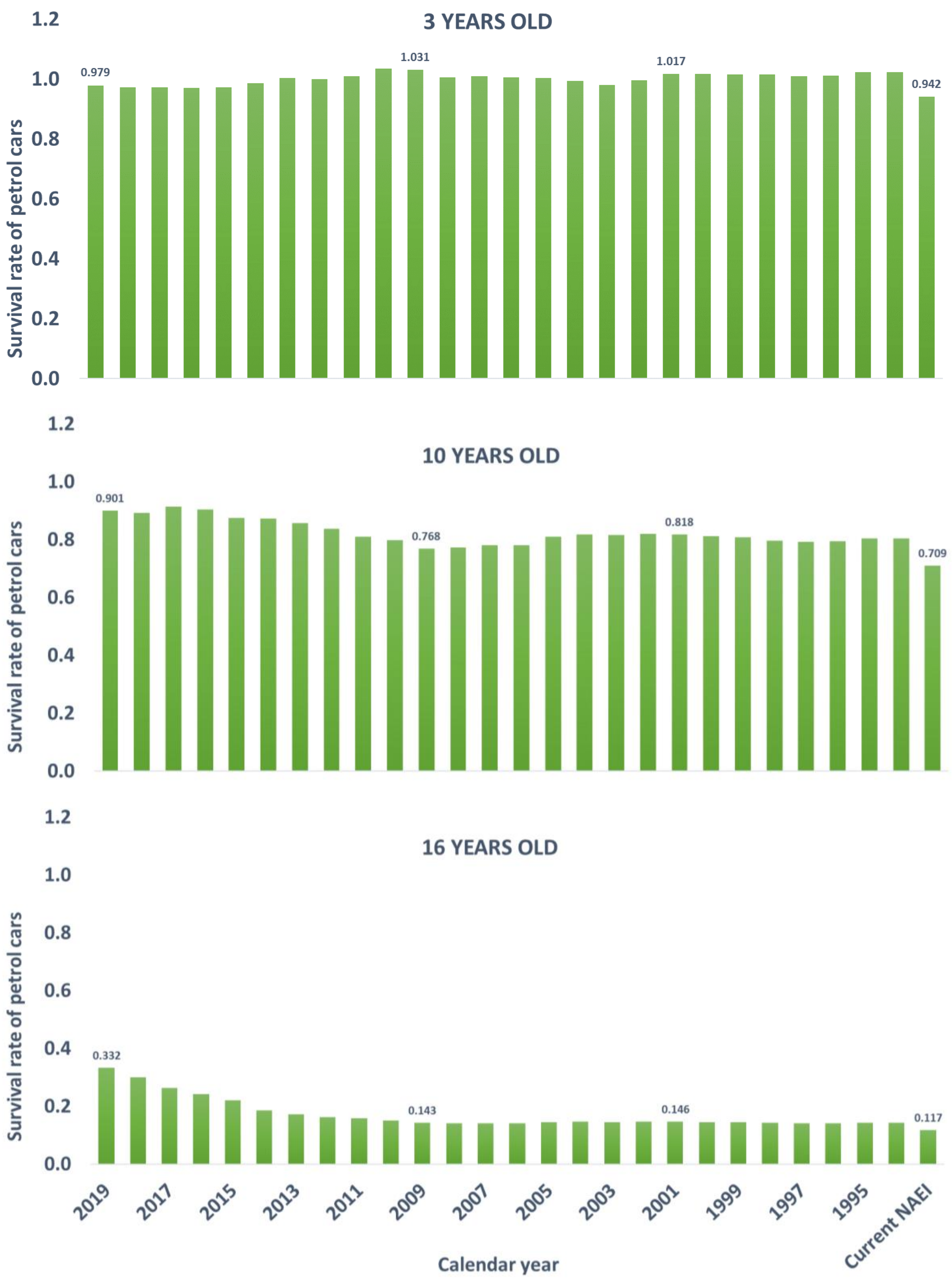


Figure 4-4 Year-dependant survival rates for 3, 10 and 16 years old petrol cars for all calendar years compared against the current NAEI rate

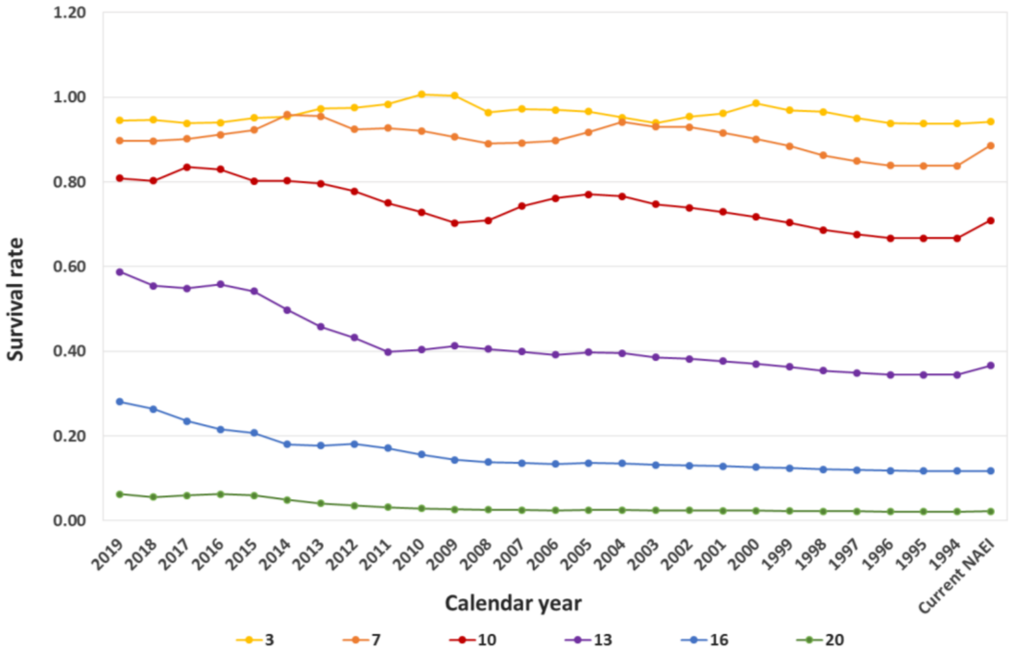


Figure 4-5 Survival rates for 3, 7, 10, 13, 16 and 20 years old diesel cars over time

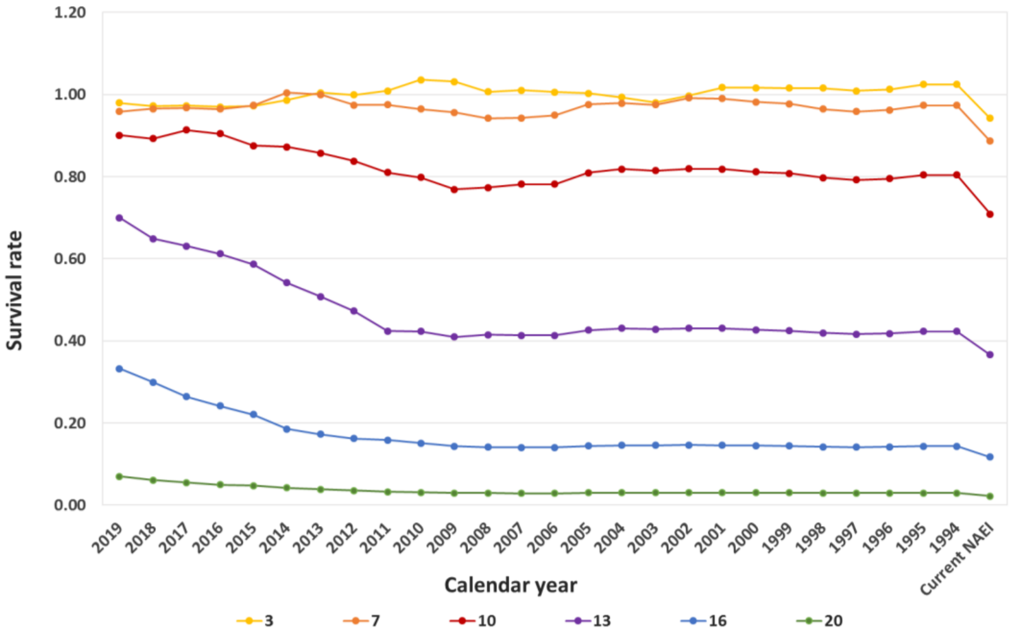


Figure 4-6 Survival rates for 3, 7, 10, 13, 16 and 20 years old petrol cars over time

4.3.2 Diesel LGVs

Figure 4-7shows the trend in the survival rates for diesel LGVs for all years and its decline with vehicle age. As shown in Figure 4-8, it is apparent that older diesel LGVs tend to survive longer than they used to, but rates for newer vehicles have shown less of a change over time, always having remained at high levels, the same conclusion as for petrol and diesel cars. Figure 4-9 shows the profiles of survival rates for 3, 7, 10, 13, 16 and 20 year old diesel LGVs; for 13 year old diesel LGVs, it becomes notable that a higher proportion of them have survived in recent years than they used to in the past.

The survival rates for older LGVs in recent years are tending to be higher than currently assumed in the NAEI, but rather lower than currently assumed in the NAEI in years before around 2010.

The conclusion of the licensing data analysis for cars and diesel LGVs was discussed with DfT in early October 2020. It is possible that vehicles are surviving longer as they become better engineered and more reliable, better designed to protect the driver in accidents and thus being better protected against accidental damage.

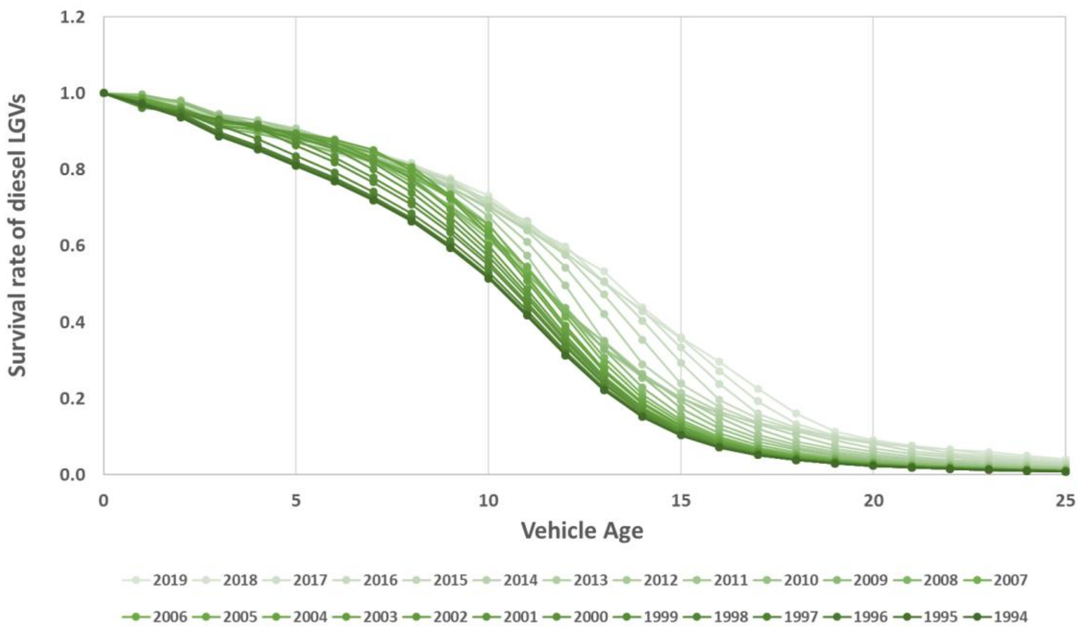


Figure 4-7 Survival rate for diesel LGVs with vehicle age in different calendar years

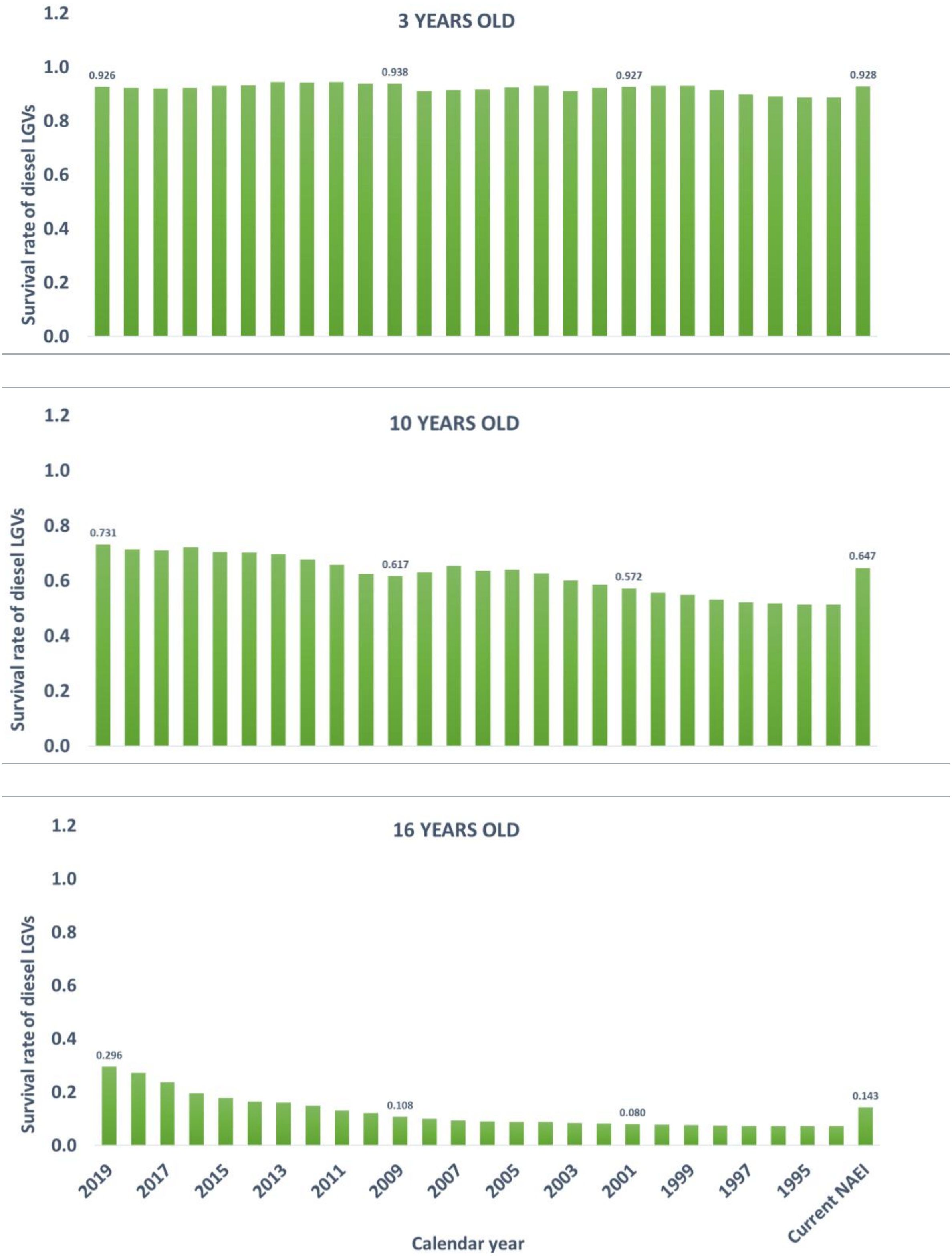


Figure 4-8 Year-dependant survival rates for 3, 10 and 16 year old diesel LGVs for all calendar years compared against the current NAEI rate

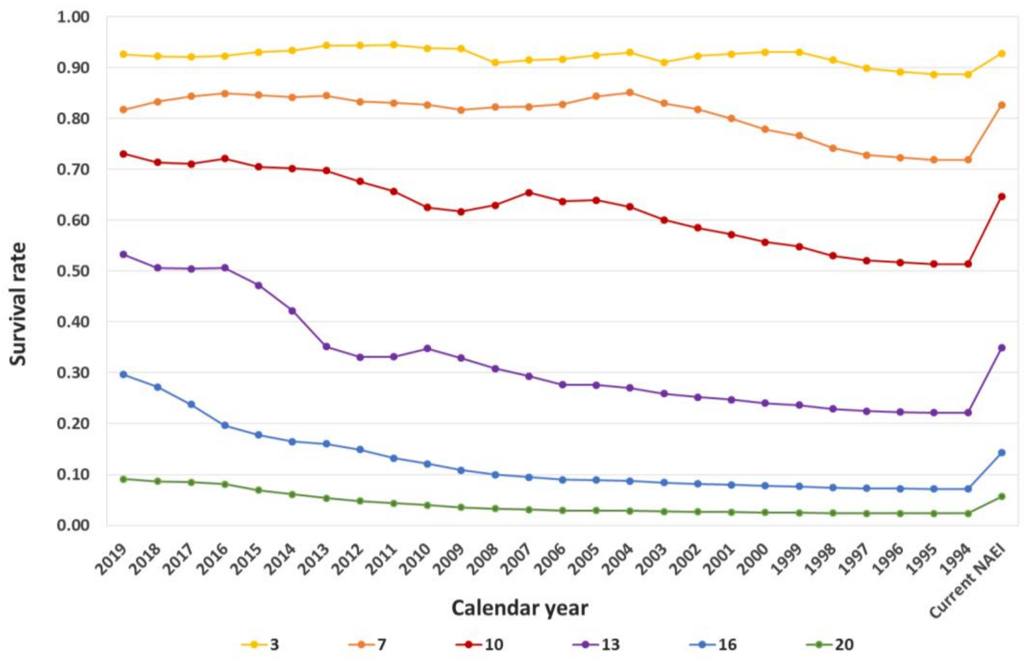


Figure 4-9 Survival rates for 3, 7, 10, 13, 16 and 20 years old diesel LGVs over time

4.3.3 HGVs

Figure 4-10 and Figure 4-11 show the trend in the survival rates for artic and rigid HGVs for all years, respectively and the decline in the survival rate with vehicle age. What is observed for both artic and rigid HGVs is that older vehicles used to survive longer in earlier years than in more recent years which is in contrast to what is observed for cars and diesel LGVs. For newer HGV vehicles, there is small variation in survival rate per year, as shown in Figure 4-12 and Figure 4-13. This behaviour is also evident in Figure 4-14 for artic HGVs, and in Figure 4-15 for rigid HGVs, with artics having a more characteristic trend. In spite of this trend, there is a tendency for a higher proportion of the oldest vehicles surviving than is currently assumed in the NAEI for most years.

As discussed in early October 2020 with DfT, the market for HGVs is quite different from cars and LGVs and that could explain the difference in the survival rate trend of older HGVs compared to older cars and diesel LGVs. There is a market for selling abroad older HGVs which results in fewer of them surviving in the UK fleet now than in the past. This may be driven by a requirement to use more fuel efficient, less polluting vehicles on UK roads making the retainment of older vehicles less economical.

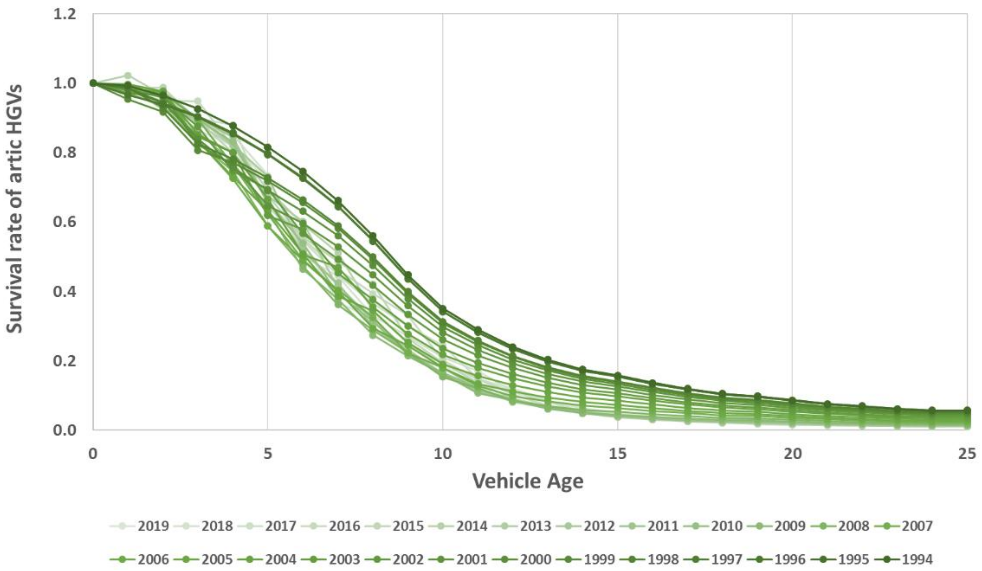


Figure 4-10 Survival rate for artic HGVs with vehicle age in different calendar years

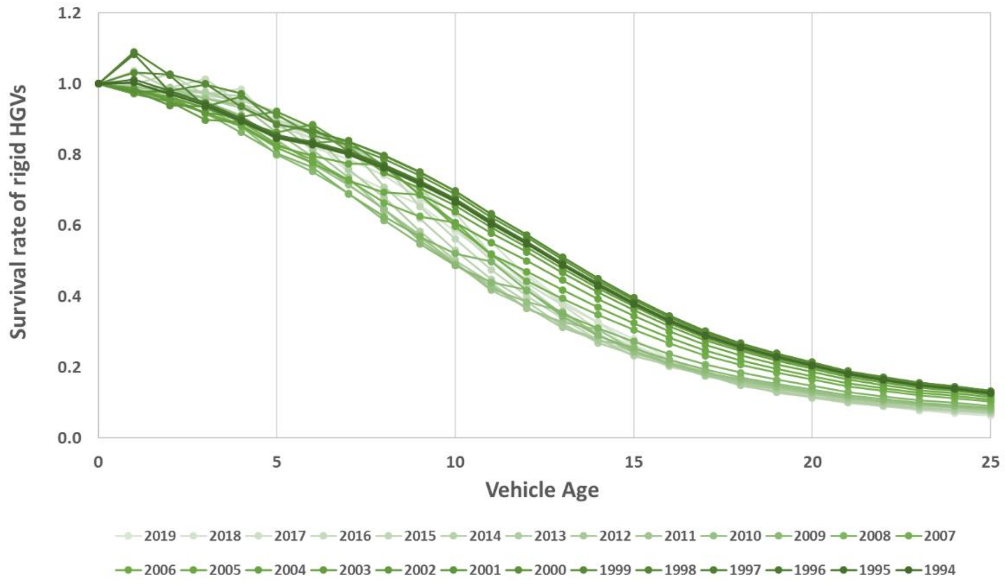


Figure 4-11 Survival rate for rigid HGVs with vehicle age in different calendar years

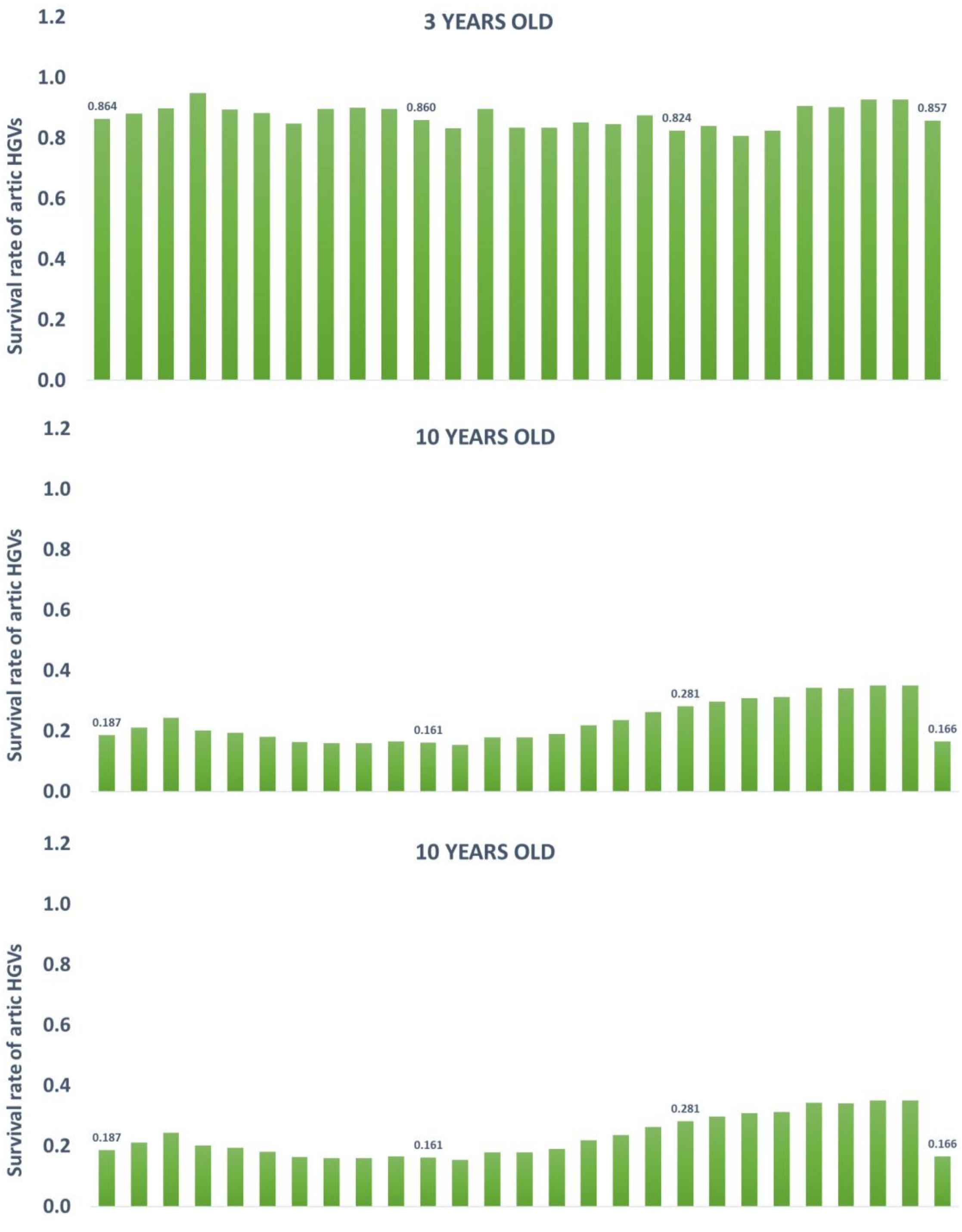


Figure 4-12 Year-dependant survival rates for 3, 10 and 16 years old artic HGVs for all calendar years compared against the current NAEI rate

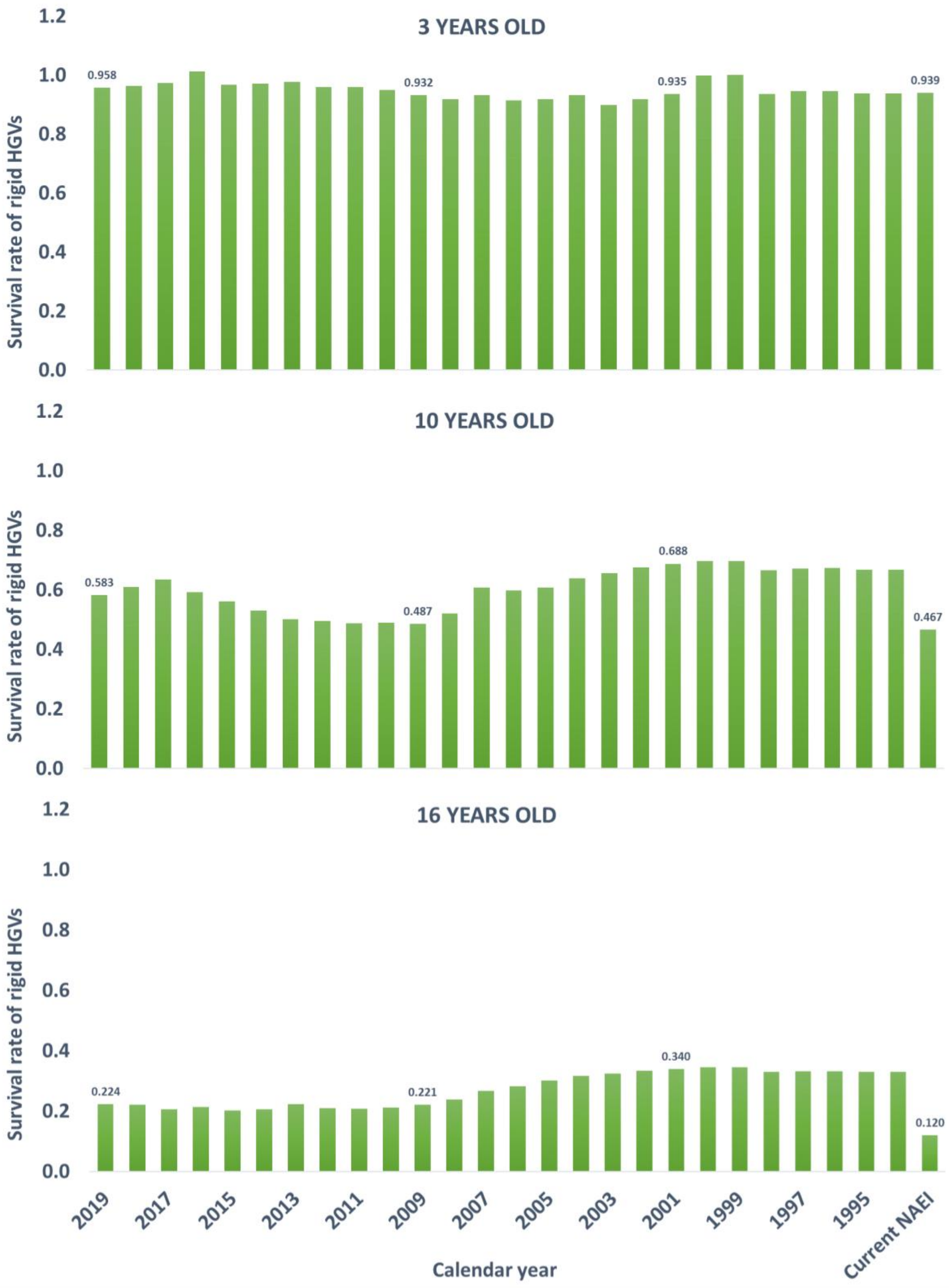


Figure 4-13 Year-dependant survival rates for 3, 10 and 16 years old rigid HGVs for all calendar years compared against the current NAEI rate

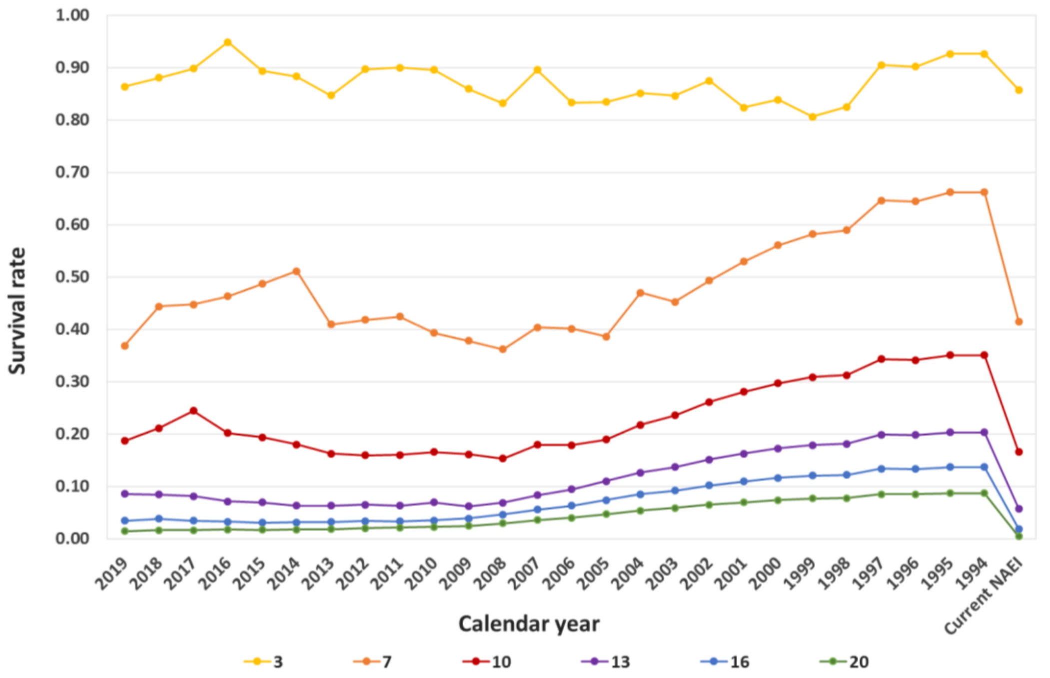


Figure 4-14 Survival rates for 3, 7, 10, 13, 16 and 20 years old artic HGVs over time

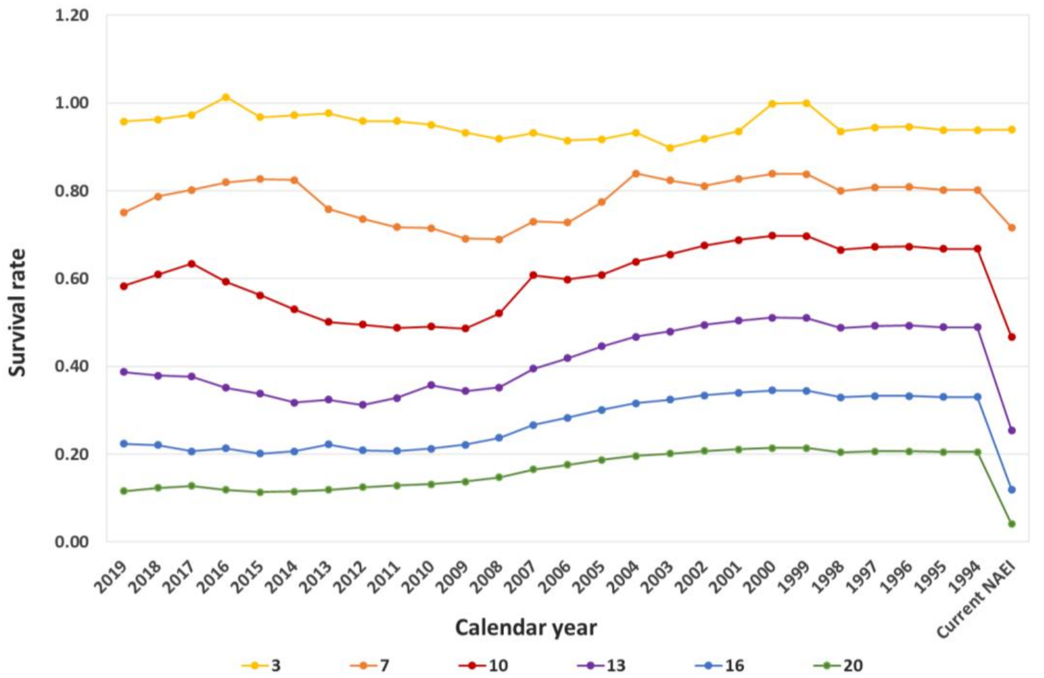


Figure 4-15 Survival rates for 3, 7, 10, 13, 16 and 20 years old rigid HGVs over time

4.3.4 Buses & Coaches

The analysis of licensing data for buses & coaches is shown in Appendix A1. Buses & coaches follow the same behaviour as cars and diesel LGVs, with older bus vehicles tending to survive more in recent years than they did in earlier years. The survival rates for older buses are tending to be higher than currently assumed in the NAEI.

4.3.5 Motorcycles

The analysis of licensing data for motorcycles per engine size is shown in Appendix A1. The trend in survival rates of motorcycles over time is rather mixed and variable between different size groups.

4.4 SUMMARY OF VEHICLE SURVIVAL RATES

Summary tables showing in detail the survival rates for all vehicle types are presented in Appendix A2.

It should be noted that licensing data were not available for 2020 in time for this improvement programme. Such data may be influenced by the effects of COVID-19 restrictions on new vehicle registrations, ownership and scrappage behaviour. Once data become available, these may be analysed in the same manner for the 2020 NAEI compilation, yielding survival rates specific to 2020, but it does not affect the general approach being demonstrated in this report.

5. ANALYSIS OF MILEAGE WITH AGE DATA

The NAEI published in 2021 used unpublished data provided by DfT many years ago showing how annual mileage decreases with vehicle age. This is used in conjunction with vehicle survival rates to estimate the proportion of UK vehicle kilometres done by vehicles of different ages in the fleet. DfT now holds additional and more up-to-date information which were analysed to update the mileage with age data used in the NAEI.

The most comprehensive and potentially most useful data held by DfT are from MOT service test records which when analysed show how annual mileage changes with the age of vehicle. However, these data are restricted to passenger cars, LGVs and motorcycles. No equivalent data are available for HGVs and buses. Moreover, the MOT data are only available for vehicles from the age they first come in for testing, i.e. 3 years and older. Alternative data from DfT's National Travel Survey (NTS) were used to fill this 0-3 year age gap for passenger car mileage. Analysis from Automatic Number Plate Records (ANPR) also provided by DfT were used to fill 0-3 year age gaps for LGV and motorcycle mileage as well as providing information to infer mileage with age trends for buses. For HGVs, mileage with age data were derived from information provided by DfT's Continuing Survey of Road Goods Transport (CSRGT).

This Section describes how mileage with age profiles were developed from these different data sources.

5.1 MILEAGE DATA FROM MOT RECORDS

5.1.1 Overview of the MOT Data Analysed

Anonymised MOT test data[2] can provide information on the accumulated mileage of each vehicle tested and the vehicle's age. Mileage data for the same vehicle between successive years on MOT records allows the annual mileage of the vehicle to be derived. This can be used to develop a profile showing how, on average, annual mileage varies with vehicle age. This would be an alternative to profiles developed from older, unpublished mileage with age data from DfT that the NAEI currently uses which are partly based on travel surveys. Such a profile of mileage with age data is potentially extremely useful when combined with the vehicle survival rates to enable a full picture of fleet composition in terms of total km travelled by year of registration representative of the UK fleet. In relative terms, the distribution of vkm by age from the fleet turnover model can be compared with the age mix of vehicles appearing on roads according to ANPR data. In developing this work, an initial kick-off meeting and a further follow up meeting was held in 2020 between Ricardo and DfT's Vehicle Licensing Statistics team[3], specifically on the MOT data set.

5.1.1.1 Data Content and Quality

The anonymised MOT test data, made available by DfT, includes data from millions of MOT records from 2005 to 2020. In the kick-off meeting with DfT, it was advised that the data for the calendar years 2005 and 2006 were not as complete as other years and these have therefore not been analysed. Overall, from 2007 to 2020, the data includes over 450 million rows and 14 columns and the columns include:

- Unique vehicle ID
- MOT test date
- First use date
- Vehicle class

[2] https://data.gov.uk/dataset/e3939ef8-30c7-4ca8-9c7c-ad9475cc9b2f/anonymised-mot-tests-and-results

[3] Vehicle Licensing Statistician, Vehicles & Admin Statistics, Department for Transport

- Test type (e.g. normal test, re-test)
- Test result
- Test mileage
- Postcode area
- Vehicle make and model
- Fuel type
- Cylinder capacity

In general, the data quality is good and consistent. There is a negligible amount of data where, for example, vehicle IDs are duplicated or vehicle colours are given in the fuel type field. Vehicle odometer reading (mileage) is not currently mandatory, though it is recorded in around 95% of cases[4].

For the vast majority of vehicles an MOT test is not required until the vehicle is three years old. This means there is not sufficient data in the MOT data set to develop a mileage with age profile up to this age. In the absence of this data, alternative data sets were used to develop mileage with age profiles, which are described in Section 5.2.

5.1.1.2 Counts

This sub-section provides an overview of the number of observations. This helps to, for example, provide context to which vehicle/fuel type groups have enough observations for analyses.

Figure 5-1 shows the overall counts by MOT year and vehicle type. The vehicle type is assigned based on the vehicle class field (“test_class_id”) and supplemented by a body type lookup table provided by DfT in September 2020, which allowed a better split of cars and LGVs. Cars dominate the number of observations by vehicle type, followed by LGVs. Note that the MOT data does not include records of heavy-duty vehicles (HDVs). This was also discussed with DfT in September 2020 and the DVSA were contacted to enquire about sourcing a data set for HDVs. The DVSA confirmed that they do not hold such a data set. To address this data gap in mileage with age data for HGVs and buses, an alternative source of data was explored and this is discussed further in Sections 5.4 and 5.5.

Figure 5-1 shows a general trend of increasing number of observations from 2007 to 2020, except for the decrease in 2017. DfT suspected that the 2017 data were accidentally cut off by the original data handlers. However, the quantity of data records is still sufficient that the omission of some data is not considered to lead to any biases for the analyses carried out.

[4] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/206882/experimental-statistics-mot-data.pdf

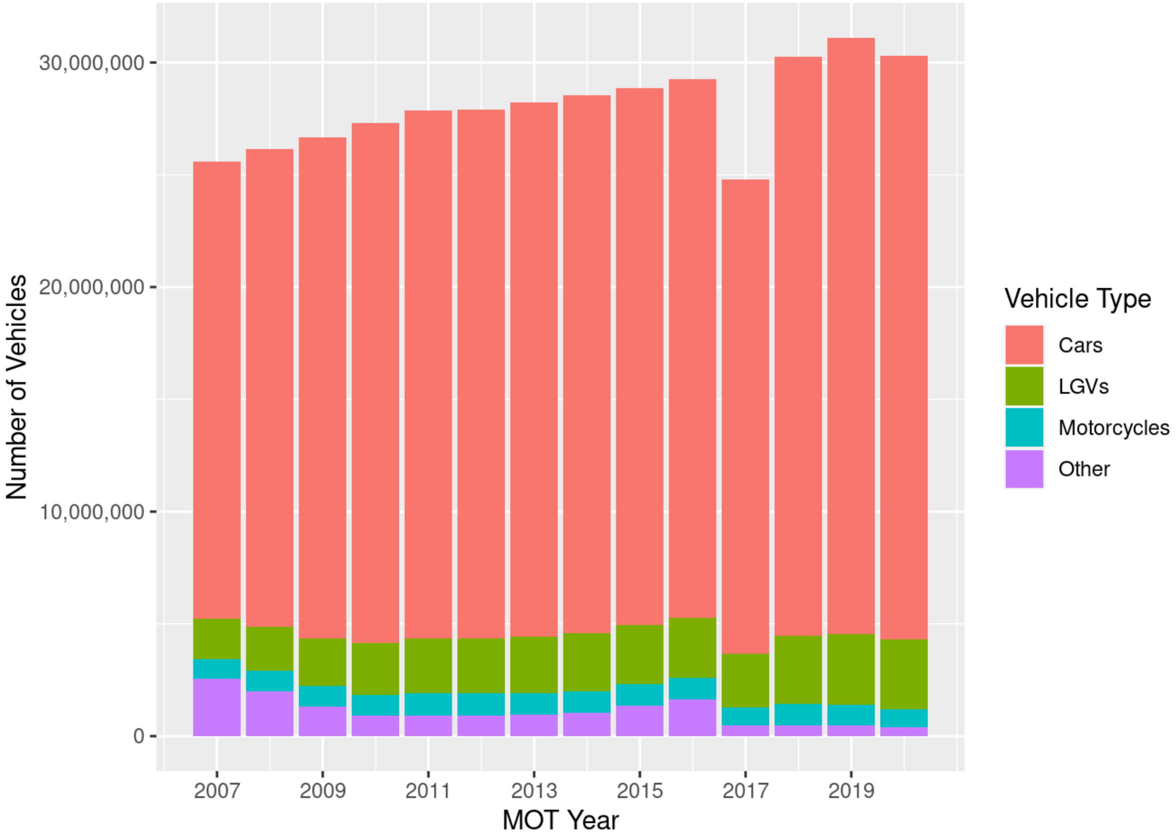


Figure 5-1 Overall counts by MOT year and vehicle type.

5.1.2 Data Processing and Observations

As mentioned in Section 5.1.1, a profile of annual mileage with vehicle age can be developed from the MOT data, by linking vehicle records across the MOT time series. A vehicle age column is not included in the data set but was calculated here as the “MOT test date” minus “First use date”. This approach was verified by DfT.

Some filtering of the data was done to improve the robustness of the results. Only vehicles that passed the MOT test were included. This was done to avoid double counting of a vehicle within the same MOT year (e.g. it might fail the MOT test one week and then pass the next week). Odometer readings between 10 and 500,000 miles only were included and any duplicate entries, where the same data was repeated across rows, were removed.

To estimate the annual mileage increase, the vehicle mileage increase and the age increase (in years) were calculated at the individual vehicle level. The annual mileage increase was calculated as the mileage increase divided by the age increase. Limits were also set on the age increase between tests. Limits of between 0.9 and 1.1 years (10.8 and 13.2 months) were set, so as to try to capture the most conventional annual MOT tests. Once the annual mileage increase was estimated, a further limit of between 10 and 100,000 miles was set on the annual mileage increase, which is deemed to be a reasonable range for an annual mileage increase.

The annual mileage increase was grouped by age, at 0.1 year age increments, and the median mileage increase for each group was calculated. Figure 5-2 shows a histogram of the number of vehicles within each age group for cars within MOT years 2017 to 2019. This analysis is also done in DfT, 2013[5] (Figure 1), with similar results. The peaks all sit on whole number age groups, for example, 4.0 years, 5.0 years. This is expected as tests are expected to coincide with the vehicle first use date due to the annual nature of the MOT test cycle. There are still a non-negligible number of tests that fall in the mid-point between years. It is not known whether this could be expected or due to errors in the raw data.

Age is shown as the age at second test within a pair of linked records. For example, if a vehicle was 3 years old for the first linked test and 4 years old for the second linked test, then the vehicle age would be given as 4 years. There are therefore no estimates made for vehicles below 4 years old.

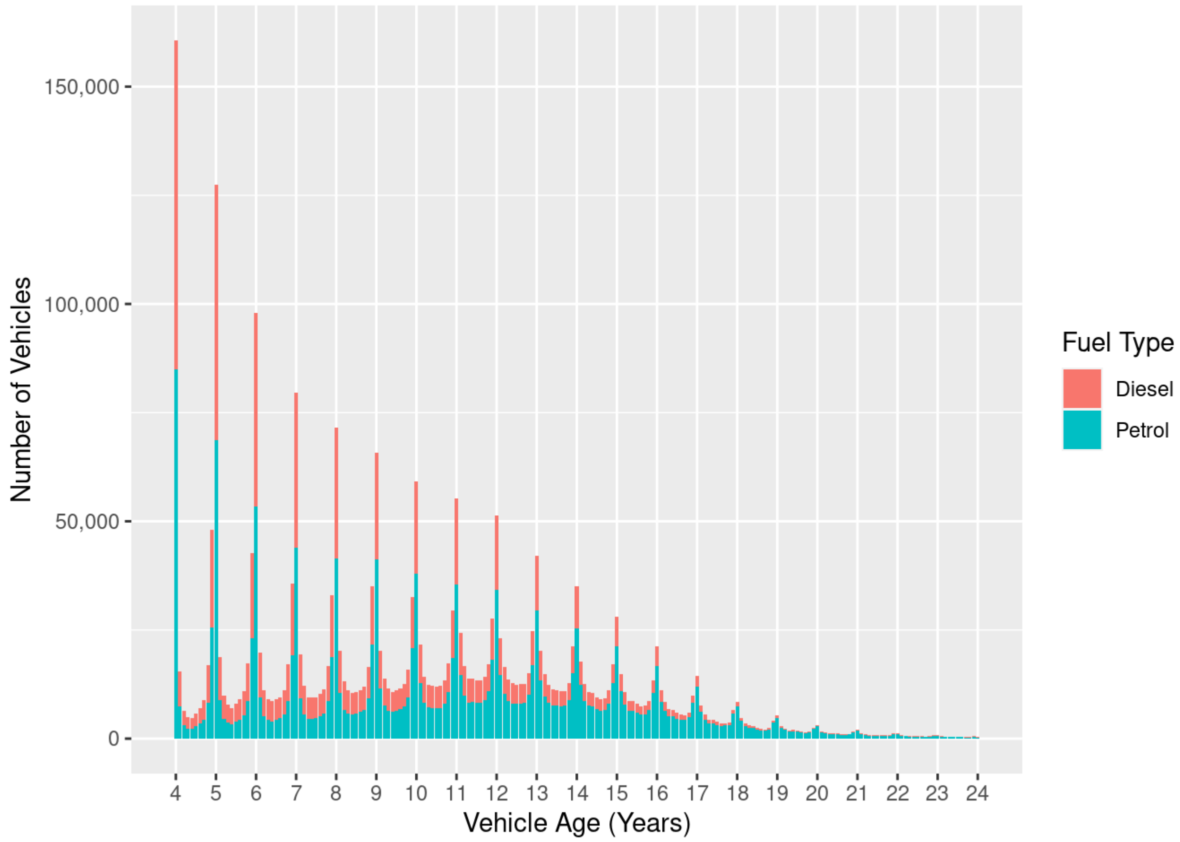


Figure 5-2 Histogram of the number of cars by vehicle age and fuel type for the MOT years 2017 to 2019.

Figure 5-2 shows the median annual mileage increase by vehicle age and MOT year for diesel cars (top facet) and petrol cars (bottom facet). The vehicle ages were grouped into bands that differ by 0.1 years, as was done for Figure 5-2 The different coloured lines show the trends for each of the MOT years. If a paired test was between the MOT years 2008 and 2007, for example, then the mileage increase would be assigned to the vehicle for the MOT year 2008. Therefore, there is no line for the MOT years 2007 as this would require the inclusion of the MOT year 2006.

[5] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/206882/experimental-statistics-mot-data.pdf

Figure 5-3 shows that although the magnitude of the median mileage increase is different between petrol and diesel cars, the gradient of the decrease in mileage with age is similar. There is a pattern for both petrol and diesel cars that the rate that mileage decreases with age is less for more recent MOT years (nearer 2019) than older MOT years (nearer 2007). The 2020 MOT year stands out as being slightly different to other MOT years in that the mileages in all age groups are lower than for other MOT years. To make this more visible, Figure 5-4 brings to the fore the data for 2020 with data for other MOT years greyed out. This feature is almost certainly due to the impact of COVID-19 restrictions reducing mileage travelled in 2020. However, the same pattern is observed of decreasing annual mileage with increasing vehicle age though it would appear to be at a lower rate shown by the smaller gradients for 2020 MOT year in Figure 5-4, particularly for diesel cars. This could indicate that COVID restrictions were impacting journeys done on newer cars more in relative terms than on older cars.

The MOT data showed mileages done by some vehicles over 20 years old. However, the number of counts was small for this older age group and so it can be seen that there is increased 'noise' in the trends for vehicles older than 20 years. In further analysis, smoothing of the data was done for this age group.

Another notable pattern is that the median annual mileage increase tends to be consistently lower for whole number ages (for example, 4.0 or 5.0 years) than other ages (for example, 4.3 years or 5.8 years). It is not understood why this pattern occurs. As can be seen from Figure 5-2, most MOT tests are done on whole number age groups. Taking the mileage with age for whole number year groups produces a similar trend as for any other age group. Going forward in the analyses, only the data for whole number vehicle ages was used.

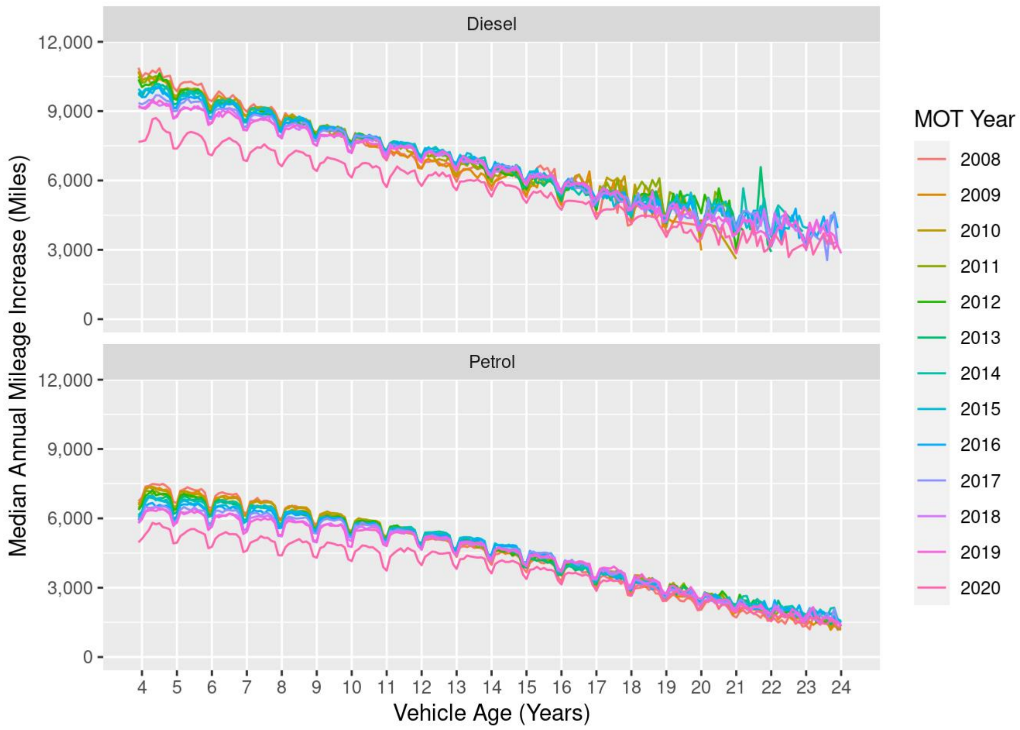


Figure 5-3 Median annual mileage increase by vehicle age and MOT year (coloured lines) for diesel cars (top facet) and petrol cars (bottom facet).

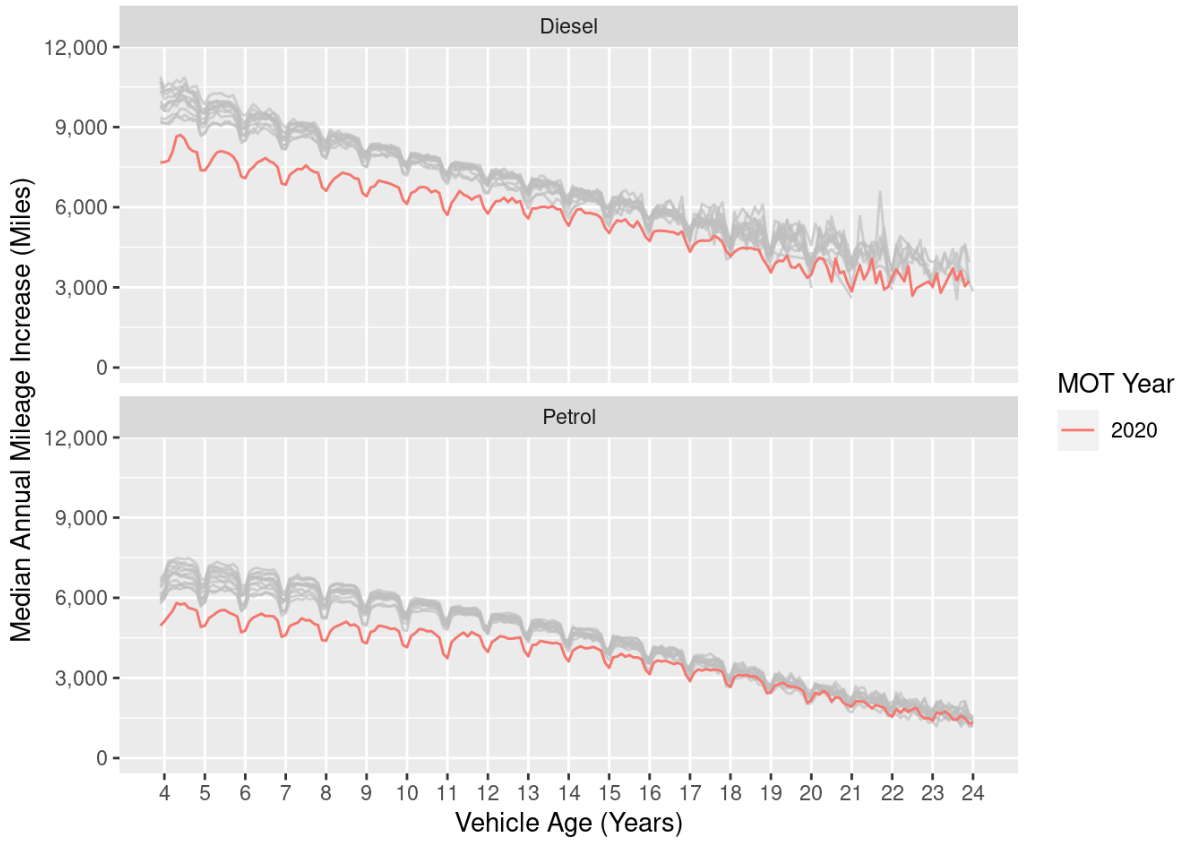


Figure 5-4 Median annual mileage increase by vehicle age and MOT year for diesel cars (top facet) and petrol cars (bottom facet). Same as Figure 5-3 but with data for MOT year 2020 highlighted in red and other MOT years greyed out.

5.1.3 Mileage with Age Indices

5.1.3.1 Cars

The emissions model, from which results are presented in Section 8.1, uses indices to represent how vehicle mileage changes with age. These indices are then used with vehicle survival indices to determine relative changes in total vehicle kilometres with age. Figure 5-5 shows the mileage with age indices by MOT Year for petrol and diesel cars. The results from Figure 5-5 have been indexed to mileage with age at 4 years = 1 so that the results can be directly compared to the current NAEI assumptions and the mileage with age derived from the DfT's National Travel Survey (NTS)[6]. Further details on the NTS data are given in Section 5.2.1. The black circles and triangles show the mileage with age index values for the DfT's NTS and the NAEI current assumptions respectively. Figure 5-5 shows that the mileage with age indices based on the MOT data analysis sit broadly within the range of the DfT NTS and current NAEI values. However, the MOT data for more recent years are tending to show a slower decline with age than was shown by MOT data for earlier years. The NAEI values, which show a faster decline in annual mileage with age, align more closely to the older MOT years and the NTS data aligns more closely with the more recent MOT years. This may be expected as the NAEI assumptions are derived from older DfT data and the NTS data is derived from more recent survey data. Because of this notable timeseries trend, a year-dependent mileage with age index has been carried forward into the emissions modelling.

[6] https://www.gov.uk/government/collections/national-travel-survey-statistics

For hybrid and electric cars there was only enough data to look at the most recent MOT years. Preliminary analyses suggested a similar pattern of mileage with age to petrol cars and it is suggested that the mileage with age data for petrol cars is applied to these vehicles. It would be useful to review this again in the near future when more hybrid and electric vehicles have entered the fleet.

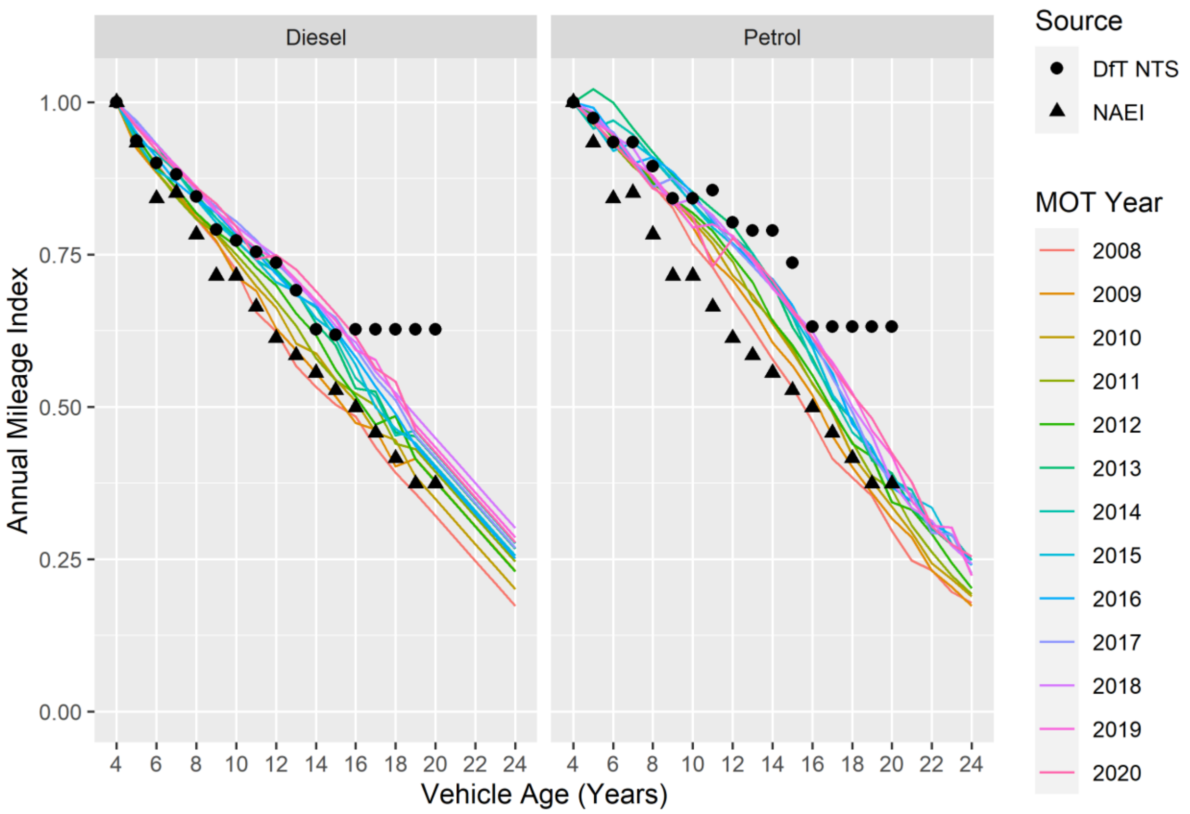


Figure 5-5 Mileage with age index by MOT Year (coloured lines) for diesel (left) and petrol (right) cars. The black shapes show the data from the DfT NTS (circles) and the current NAEI assumptions (triangles).

5.1.3.2 Diesel LGVs

Figure 5-6 shows the mileage with age index by MOT Year (coloured lines) for diesel LGVs. The black circles show the values from the current NAEI assumptions. Compared to cars in Figure 5-5, there is a significantly larger rate of decrease in the mileage with increasing age in the early lifetime of the vehicle, though this flattens out slightly from an age of around 10 years old. Unlike cars in Figure 5-5, there is not such a clear trend in how the mileage with age varies by MOT year. The black circles in Figure 5-6 show the current NAEI mileage with age indices where the mileage at age 4 is indexed to 1. The trends compare well, especially in the early and late lifetime of the vehicle. From around 10 years old to 16 years old, the current NAEI assumptions show mileage with age decreasing at a slower rate than the MOT data. Unlike passenger cars, the profile in annual mileage with age for diesel LGVs in 2020 did not appear appreciably different to the data for other years.

Mileage with age indices have not been developed for petrol LGVs because there are insufficient data to develop robust results. This, combined with the low proportion of the NAEI fleet being petrol LGVs, means the overall emissions results will not be sensitive to petrol LGV mileage with age assumptions. The existing NAEI mileage with age assumption for petrol LGVs is therefore retained.

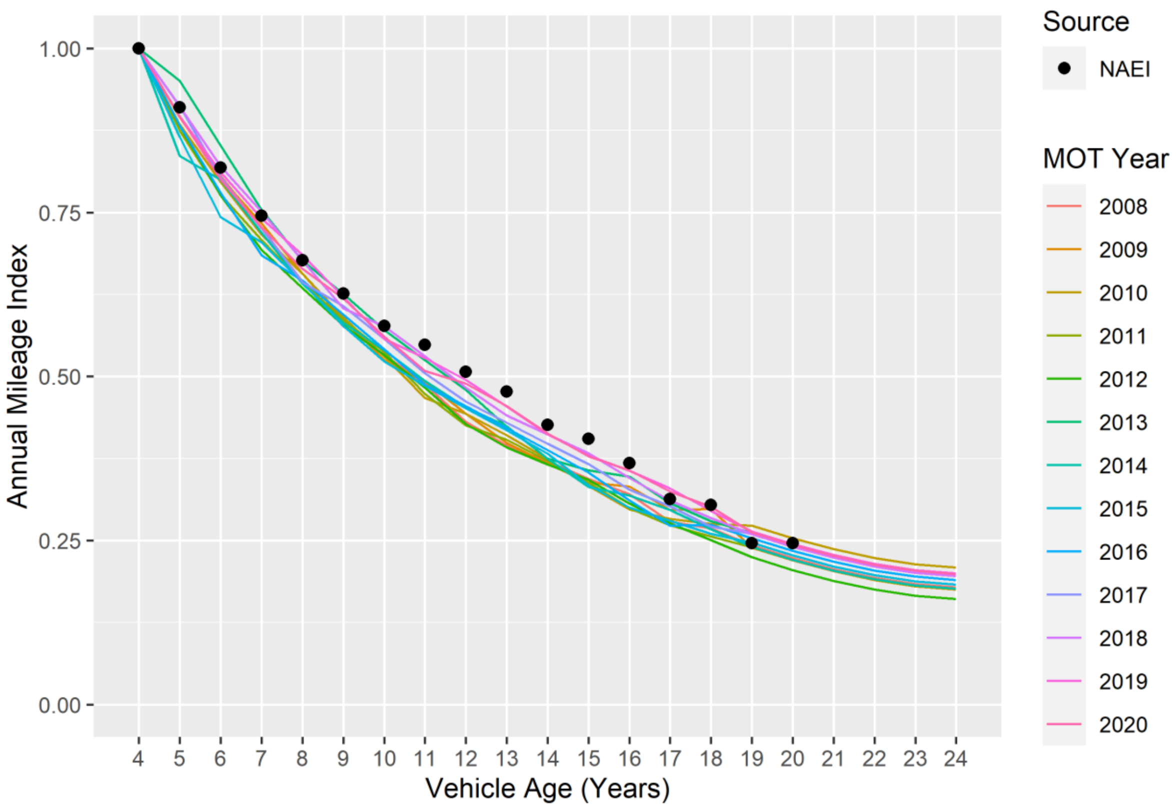


Figure 5-6 Mileage with age index by MOT Year (coloured lines) for diesel LGVs. The black circles show the values from the current NAEI assumptions.

5.1.3.3 *Motorcycles*

Figure 5-7 shows the mileage with age index by MOT Year (coloured lines) for motorcycles. The data for each MOT year has been smoothed across all ages to reduce the noise in the data. The trend line for motorcycles is similar to that of diesel LGVs with the rate of decrease in the mileage with increasing age occurring at a higher rate in the early lifetime of the vehicle. The overall magnitude of the decrease in the mileage with age increase is less than LGVs though and more similar to the magnitude for cars.

Due to the previous absence of any mileage data, the NAEI currently assumes there are no changes in annual mileage with age for motorcycles. If plotted in Figure 5-7, the NAEI values for each year would be equal to 1. Introducing mileage with age functionality into the motorcycles model therefore offers a significant improvement to the inventory for these vehicles and will have the effect of giving a greater share in motorcycle vehicle kilometres to newer vehicles than is currently the case in the NAEI. This is because the annual mileage is lower for older vehicles and so a larger proportion of overall vehicle kilometres is now done by newer vehicles.

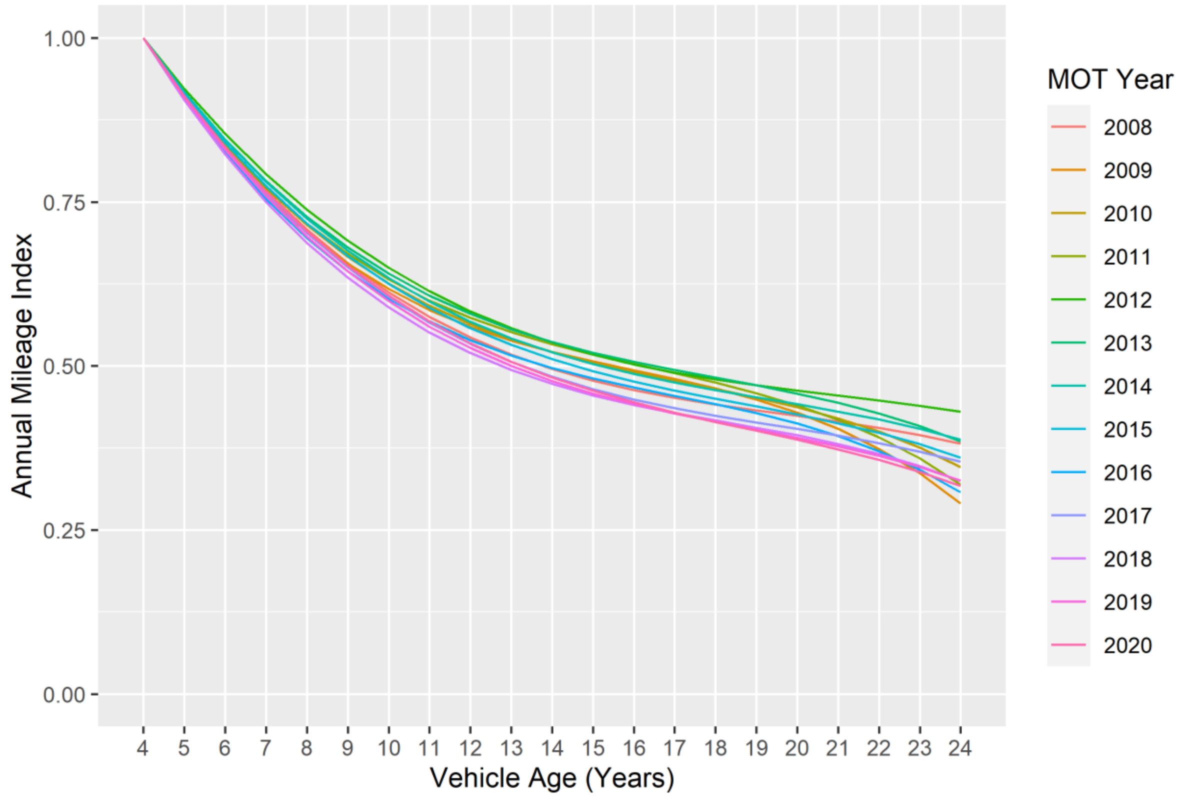


Figure 5-7 Mileage with age index by MOT Year (coloured lines) for motorcycles.

5.2 GAP FILLING MILEAGE WITH AGE RESULTS FOR ALL LIGHT DUTY VEHICLE TYPES AND AGES

As mentioned in Section 5.1, and presented in the results above, the MOT data only makes it possible to generate estimates of the mileage with age patterns for vehicles of ages 4 years and above. Alternative data sets have therefore been explored to generate a mileage with age pattern for vehicles below that age.

5.2.1 Cars

A dataset from DfT's National Travel Survey (NTS) was used to fill the mileage with age data gap for cars 0-4 years in age. The NTS data[7] comes from a DfT household survey to monitor trends in personal travel in England. This includes odometer readings from vehicle owners. From this a bespoke dataset was provided by DfT giving the annual mileage of 4-wheeled cars by age, averaged over 10 years to increase the sample size, in order to generate trends in annual mileage for cars during the first four years in vehicle age. The relative mileage with age data for the period 2010-2019 was applied.

Whereas the profiles for ages 4 years and above come from MOT data and are year-dependent, the mileage profile for 0-3 years old vehicles based on NTS data is not. Reasonable consistency between

[7] https://www.gov.uk/government/collections/national-travel-survey-statistics

mileage trends shown by the MOT data and NTS data for vehicles in their early life above 4 years old provides some confidence in using the NTS data to define a mileage with age profile for cars in the 0-3 years old age bracket.

5.2.2 Diesel LGVs

The NTS does not provide mileage data for LGVs so an alternative approach had to be developed to gap fill the mileage with age profile for vehicles less than 4 years old. In this case, a method was developed that used ANPR and licensing data from DfT. A more thorough description in the use of ANPR data is provided in Section 7, but the basic principle used here is that the age structure of vehicles on the road observed by ANPR reflects a combination of both the age structure of the UK vehicle population, as defined by vehicle registration data and survival functions developed from it as described in Section 4, and usage patterns, as defined by how mileage changes with vehicle age. Therefore, by combining ANPR data with licensing data one can infer a profile defining how annual mileage changes with age. This approach becomes more valid the greater the number of ANPR observations are made, i.e. that the ANPR data are sufficiently representative of UK vehicle usage as a whole. This method was reviewed by the Transport Statistics team in DfT in May 2021.

Figure 5-8 shows the relative annual mileage by age (years) for diesel LGVs from the ANPR/Licensing data for ages 0-4 years. The black points are the actual data points and the black line is a simple line through these points (i.e. no smoothing applied). This implies no change in mileage in the first 2 years of the life of a diesel LGV.

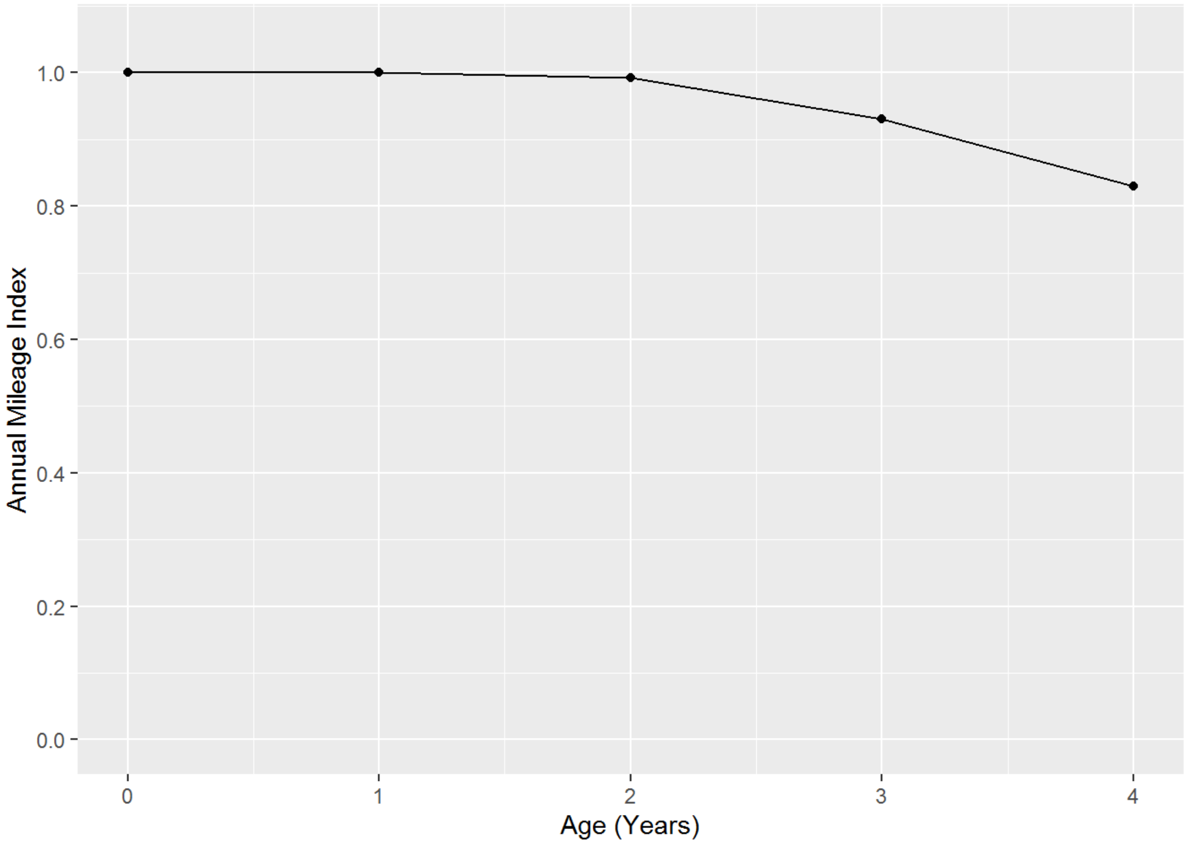


Figure 5-8 Relative annual mileage by age (years) for diesel LGVs inferred from ANPR/Licensing data for ages 0-4 years. The black points are the actual data points and the black line is a simple line through these points (i.e. no smoothing applied).

5.2.3 Motorcycles

Similar to LGVs, the NTS does not provide mileage data for motorcycles so the same alternative approach based on ANPR data was used to gap fill the mileage with age profile for vehicles less than 4 years old.

Figure 5-9 shows the relative annual mileage by age (years) for motorcycles from ANPR/Licensing data for ages 0-4 years. The black points are the actual data points and the blue line is the line of best fit. This line is a linear fit, fixed to force the intercept through 1 at age zero years.

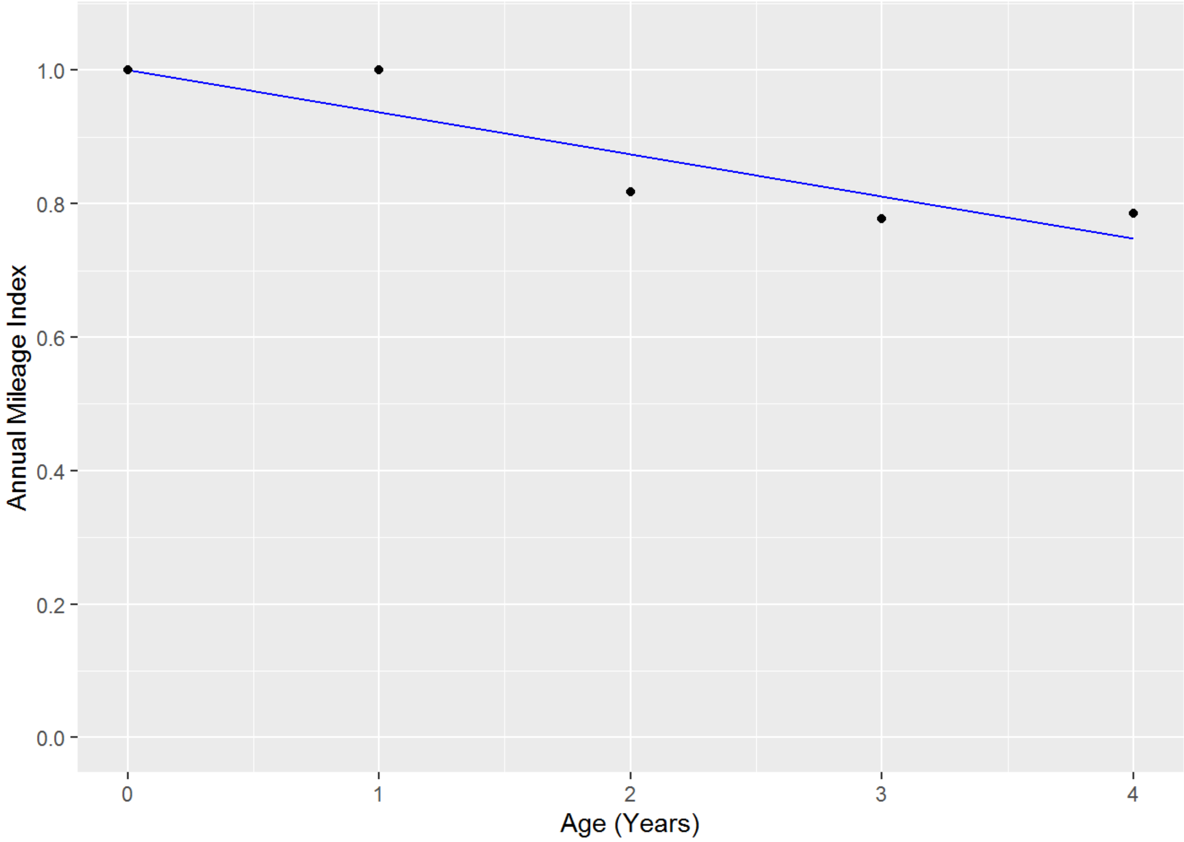


Figure 5-9 Relative annual mileage by age (years) for motorcycles inferred from ANPR/Licensing data for ages 0-4 years. The black points are the actual data points and the blue line is the line of best fit.

5.3 SUMMARY OF MILEAGE WITH AGE RESULTS FOR ALL LIGHT DUTY VEHICLE TYPES AND AGES

A complete set of indices representing mileage with age profiles was developed for cars, LGVs and motorcycles using the methods described above. Figure 5-10 shows the mileage with age indices by vehicle type and age, for ages 0 to 24 years. The pattern for the first four years, based on NTS data or ANPR/licensing data, is not year dependent, whereas the profiles for ages above 4 years, based on the analysis of MOT data for each calendar year back to 2008, is year dependent. Table 5-1 shows the mileage with age indices developed for select calendar year and vehicle ages.

Because MOT mileage data were unavailable or incomplete for years prior to 2008, and in the absence of other data, the mean mileage with age indices for the calendar years 2008 to 2010 were applied for all years prior to 2008.

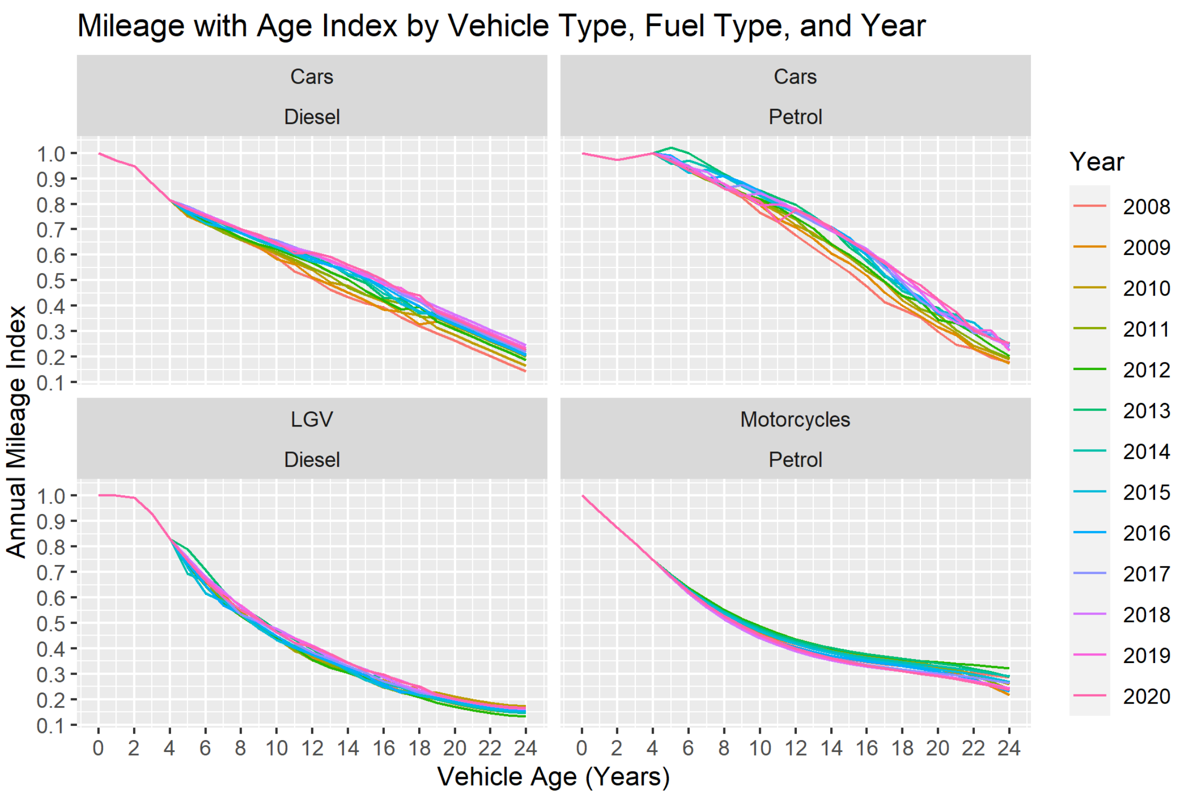


Figure 5-10 Mileage with age indices by vehicle type, age, and year.

Table 5-1 Mileage with age indices developed for select calendar year and vehicle ages.

Vehicle and Fuel Type	Year	Age - 1 Year	Age - 3 Years	Age - 5 Years	Age - 10 Years	Age - 16 Years
Diesel Cars	2005	0.97	0.88	0.76	0.59	0.40
	2010	0.97	0.88	0.76	0.60	0.42
	2015	0.97	0.88	0.76	0.63	0.46
	2020	0.97	0.88	0.78	0.65	0.50
Petrol Cars	2005	0.99	0.99	0.97	0.79	0.51
	2010	0.99	0.99	0.97	0.80	0.54
	2015	0.99	0.99	0.97	0.83	0.60
	2020	0.99	0.99	0.97	0.81	0.61
Diesel LGVs	2005	1.00	0.93	0.74	0.44	0.26
	2010	1.00	0.93	0.73	0.44	0.25
	2015	1.00	0.93	0.72	0.43	0.25

Vehicle and Fuel Type	Year	Age - 1 Year	Age - 3 Years	Age - 5 Years	Age - 10 Years	Age - 16 Years
	2020	1.00	0.93	0.74	0.47	0.30
Motorcycles	2005	0.94	0.81	0.68	0.46	0.36
	2010	0.94	0.81	0.68	0.47	0.37
	2015	0.94	0.81	0.68	0.47	0.36
	2020	0.94	0.81	0.68	0.45	0.33

5.4 MILEAGE DATA FOR HGVS

Mileage data from MOT records were not available for HGVs and profiles showing how annual mileage changes with vehicle age has been an evidence gap which has persisted in the NAEI for many years. However, discussions with DfT in June 2021 found that mileage data could be extracted by DfT from the Continuing Survey of Road Goods Transport (CSRGT)[8]. A bespoke set of data were provided by DfT for rigid and articulated HGVs combined showing the average annual mileage done by year of registration in the calendar year 2019. The sample size was over 95,000 vehicles, but separate data for rigids and artics could not be provided.

Figure 5-11 shows relative annual mileage by age (years) for HGVs from the CSRGT data. The black points are the actual data points and the coloured lines are lines of best fit. The mileage with age profiles are relatively flat between age zero and 5 or 6 years, with a steeper decline in mileage with age once a vehicle is more than 6 years old. The profile flattens from age 18 years. Smoothed profiles were generated under the following assumptions:

- Linear fit to data aged 5 years and under to capture the fairly flat profile for younger vehicles (red line).
- An independent linear fit to data for vehicles aged 6 to 17 years to capture the steeper profile evident for these older vehicles (blue line).
- Assume that the profile is flat from age 18 years and the index value calculated as the average of the indices for vehicles aged 18 to 24 years (dark cyan line).

To ensure the mileage with age index was equal to 1 at age zero years, the resulting combined fits were renormalised. The results from this renormalised dataset, shown in Figure 5-12, were subsequently used. In the absence of further information, no year-dependence in the relative mileage with age profiles was assumed.

[8] Methodology note: https://www.gov.uk/government/publications/road-freight-domestic-and-international-statistics-guidance

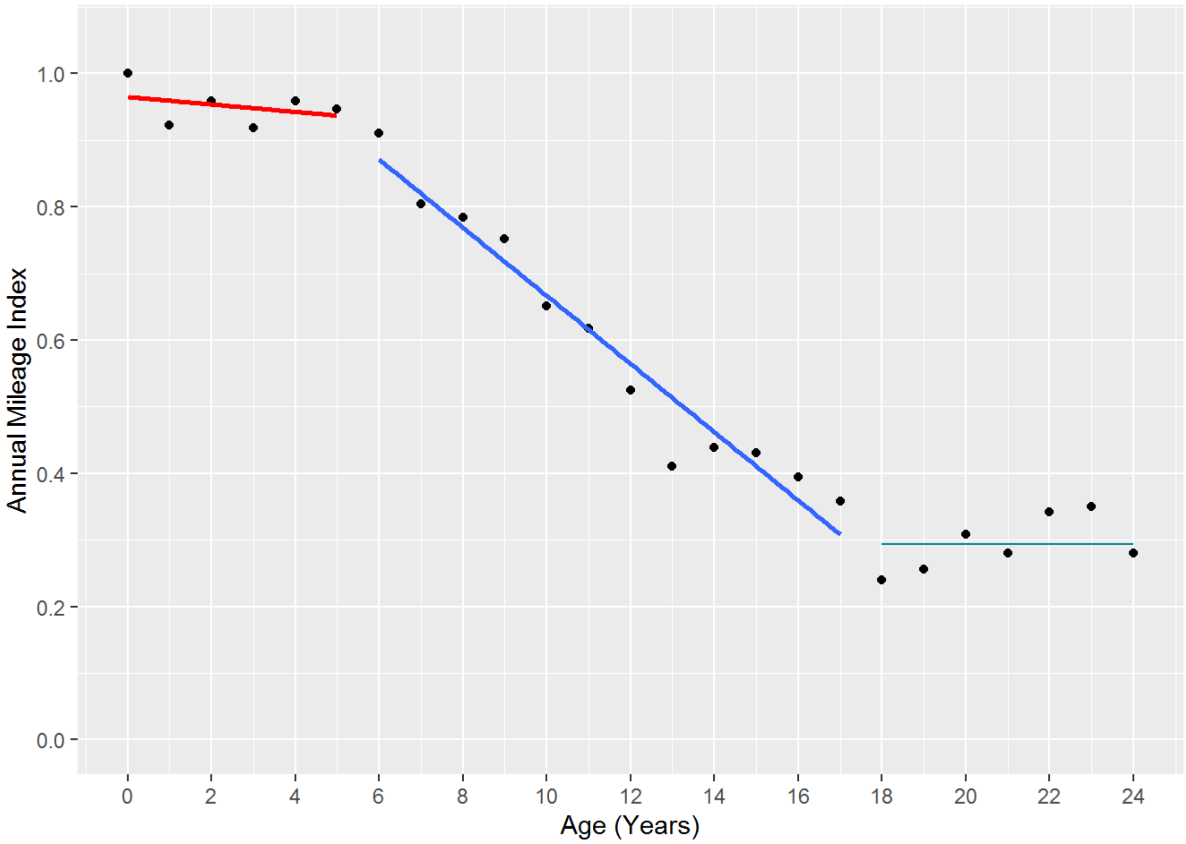


Figure 5-11 Relative annual mileage by age (years) for HGVs from CSRGT data. The black points are the actual data points and the coloured lines are lines of best fit.

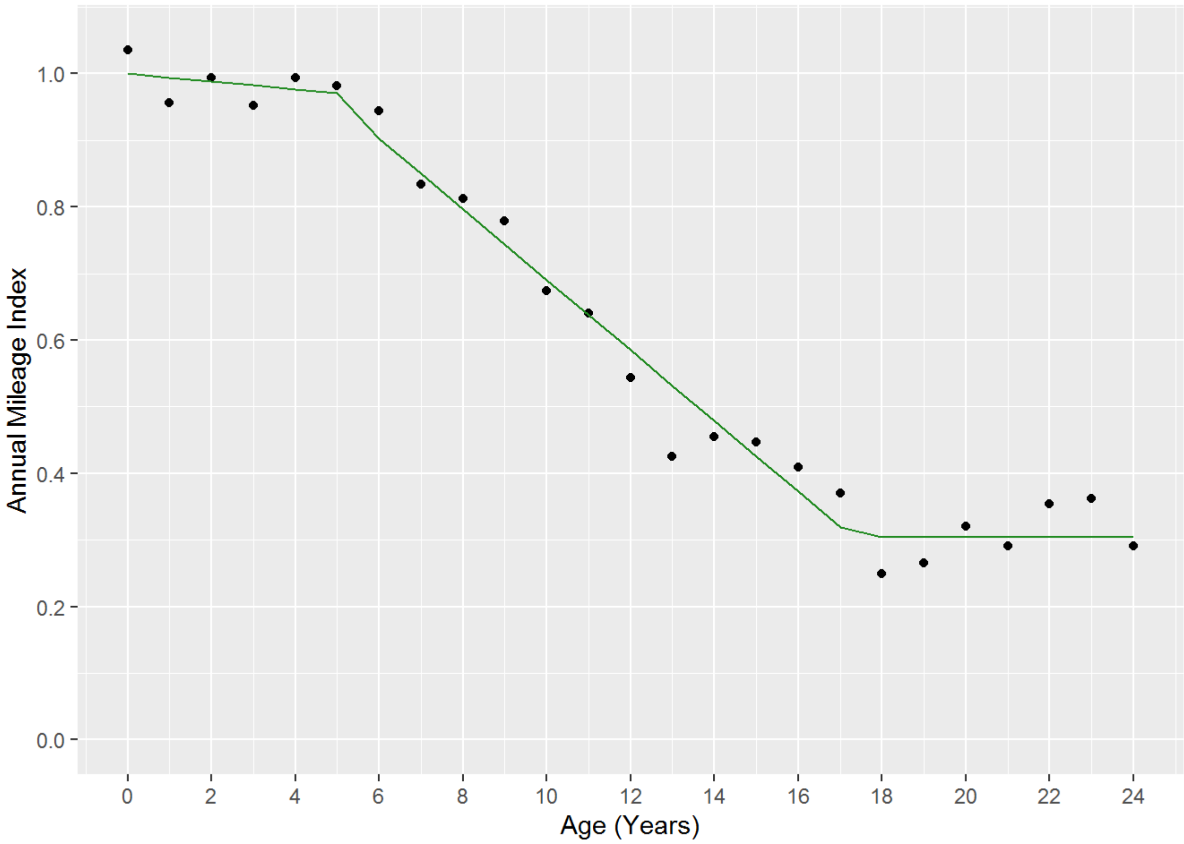


Figure 5-12 Relative annual mileage by age (years) for HGVs from CSRGT data. The black points are the actual data points and the green line shows the renormalised fit, indexed to age zero years = 1.

5.5 MILEAGE DATA FOR BUSES

As for HGVs, mileage data from MOT records were not available for buses. Moreover, there were no survey data equivalent to the CSRGT data for HGVs showing how annual mileage varies with age for buses. In this case, it was necessary to rely on analysis of ANPR and licensing data to infer mileage with age profiles similar to the approach used to fill the 0-4 age gaps in the profiles for LGVs and motorcycles.

Figure 5-13 shows the relative annual mileage by age (years) for buses derived from this approach. The black points are the actual data points and the coloured lines are lines of best fit in four distinct periods of mileage with age behaviour. Firstly, the relative mileage with age profile for buses is flat for new vehicles up to 4 years old, then declines more steeply with age up to around 11 years before levelling off again for ages 11-14 years. The relative mileage with age profile then shows a third period of approximately linear steep decline between age 15 and 20 years, and finally remains flat for vehicles aged 20 years and older. Smoothed profiles were generated under the following assumptions:

- Mileage with age index set equal to 1 for age 0 and 4 years (black line).
- Loess[9] fit from ages 5 - 14 years (red line).
- Liner fit to data between age 15 and 19 (dark cyan line).
- Flat profile from age 20 years. The index value is calculated as the average of the index for vehicles aged 20 to 24 years (purple line).

As for HGVs, in the absence of further information, no year-dependence in the relative mileage with age profiles was assumed

[9] The Loess (locally estimated scatter plot smoothing) method is a moving regression technique and is a generalisation of moving average and polynomial regression. It is a non-parametric strategy which means that it finds a curve of best fit without assuming the data must fit a predefined distribution or shape.

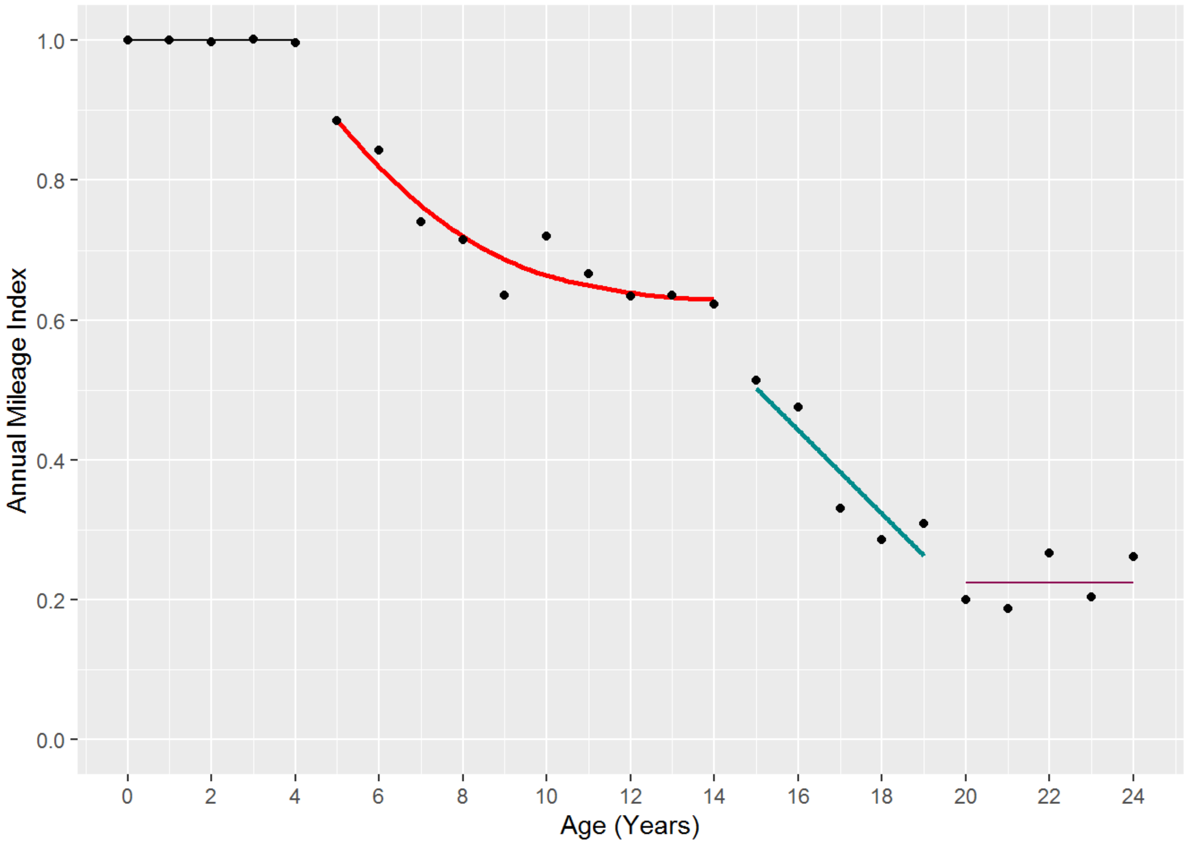


Figure 5-13 Relative annual mileage by age (years) for buses from ANPR/Licensing data. The black points are the actual data points and the coloured lines are lines of best fit.

5.6 SUMMARY TABLE OF MILEAGE WITH AGE PROFILES

Table 5-2 shows the relative mileage with age indices for petrol cars, diesel cars, diesel LGVs and motorcycles. Different profiles are available for different years making best use of the MOT mileage data and this table shows indices for the years 2005 and 2019. A further extract of the data were shown for some selected ages for selected calendar years in Table 5-1. Also shown in Table 5-2 are indices currently used in the NAEI.

Table 5-3 shows the indices for petrol LGVs, HGVs and buses which are not available for different years. The same profiles would be used for all years. Also shown are the indices currently used in the NAEI for HGVs and buses. The indices for petrol LGVs have not been changed from the values currently used in the NAEI due to lack of new data.

Table 5-2 Relative mileage with age indices for petrol cars, diesel cars, diesel LGVs and motorcycles.

Vehicle Type	Age (Years)	Relative Annual Mileage Index			
		2005		2019	
		New Fleet	NAEI19	New Fleet	NAEI19
Petrol Cars	0	1.00	1.00	1.00	1.00
	1	0.99	0.95	0.99	0.95
	2	0.97	0.93	0.97	0.93
	3	0.99	0.84	0.99	0.84
	4	1.00	0.75	1.00	0.75
	5	0.97	0.70	0.97	0.70
	6	0.93	0.64	0.95	0.64
	7	0.90	0.64	0.90	0.64
	8	0.87	0.59	0.88	0.59
	9	0.84	0.54	0.84	0.54
	10	0.79	0.54	0.79	0.54
	11	0.75	0.50	0.80	0.50
	12	0.70	0.46	0.78	0.46
	13	0.66	0.44	0.74	0.44
	14	0.61	0.42	0.70	0.42
	15	0.56	0.40	0.65	0.40
	16	0.51	0.38	0.61	0.38
	17	0.45	0.35	0.57	0.35
	18	0.40	0.31	0.52	0.31
	19	0.36	0.28	0.46	0.28
	20	0.32	0.28	0.42	0.28

Vehicle Type	Age (Years)	Relative Annual Mileage Index			
		2005		2019	
		New Fleet	NAEI19	New Fleet	NAEI19
	21	0.28	N/A	0.35	N/A
	22	0.24	N/A	0.30	N/A
	23	0.21	N/A	0.30	N/A
	24	0.18	N/A	0.22	N/A
Diesel Cars	0	1.00	1.00	1.00	1.00
	1	0.97	0.95	0.97	0.95
	2	0.95	0.93	0.95	0.93
	3	0.88	0.84	0.88	0.84
	4	0.81	0.75	0.81	0.75
	5	0.76	0.70	0.78	0.70
	6	0.73	0.64	0.76	0.64
	7	0.69	0.64	0.73	0.64
	8	0.66	0.59	0.70	0.59
	9	0.63	0.54	0.67	0.54
	10	0.59	0.54	0.64	0.54
	11	0.56	0.50	0.62	0.50
	12	0.52	0.46	0.60	0.46
	13	0.48	0.44	0.58	0.44
	14	0.46	0.42	0.55	0.42
	15	0.43	0.40	0.52	0.40
	16	0.40	0.38	0.48	0.38
	17	0.37	0.35	0.47	0.35
	18	0.34	0.31	0.42	0.31
	19	0.31	0.28	0.38	0.28
	20	0.28	0.28	0.35	0.28
	21	0.25	N/A	0.32	N/A
	22	0.22	N/A	0.29	N/A
	23	0.19	N/A	0.26	N/A
	24	0.16	N/A	0.23	N/A
Diesel LGVs	0	1.00	1.00	1.00	1.00
	1	1.00	0.95	1.00	0.95
	2	0.99	0.93	0.99	0.93
	3	0.93	0.84	0.93	0.84

Vehicle Type	Age (Years)	Relative Annual Mileage Index			
		2005		2019	
		New Fleet	NAEI19	New Fleet	NAEI19
	4	0.83	0.75	0.83	0.75
	5	0.74	0.70	0.74	0.70
	6	0.67	0.64	0.67	0.64
	7	0.60	0.64	0.62	0.64
	8	0.54	0.59	0.57	0.59
	9	0.48	0.54	0.52	0.54
	10	0.44	0.54	0.46	0.54
	11	0.40	0.50	0.44	0.50
	12	0.36	0.46	0.41	0.46
	13	0.33	0.44	0.38	0.44
	14	0.31	0.42	0.34	0.42
	15	0.28	0.40	0.32	0.40
	16	0.26	0.38	0.30	0.38
	17	0.24	0.35	0.27	0.35
	18	0.23	0.31	0.25	0.31
	19	0.21	0.28	0.22	0.28
	20	0.19	0.28	0.20	0.28
	21	0.18	N/A	0.19	N/A
	22	0.17	N/A	0.18	N/A
	23	0.16	N/A	0.17	N/A
	24	0.16	N/A	0.17	N/A
Motorcycles	0	1.00	1.00	1.00	1.00
	1	0.94	1.00	0.94	1.00
	2	0.87	1.00	0.87	1.00
	3	0.81	1.00	0.81	1.00
	4	0.75	1.00	0.75	1.00
	5	0.68	1.00	0.68	1.00
	6	0.62	1.00	0.62	1.00
	7	0.57	1.00	0.57	1.00
	8	0.53	1.00	0.52	1.00
	9	0.49	1.00	0.48	1.00
	10	0.46	1.00	0.45	1.00
	11	0.44	1.00	0.42	1.00

Vehicle Type	Age (Years)	Relative Annual Mileage Index			
		2005		2019	
		New Fleet	NAEI19	New Fleet	NAEI19
	12	0.42	1.00	0.39	1.00
	13	0.40	1.00	0.37	1.00
	14	0.38	1.00	0.36	1.00
	15	0.37	1.00	0.34	1.00
	16	0.36	1.00	0.33	1.00
	17	0.35	1.00	0.32	1.00
	18	0.34	1.00	0.31	1.00
	19	0.33	N/A	0.30	N/A
	20	0.32	N/A	0.29	N/A
	21	0.31	N/A	0.28	N/A
	22	0.29	N/A	0.27	N/A
	23	0.28	N/A	0.26	N/A
	24	0.25	N/A	0.24	N/A

Table 5-3 Relative mileage with age indices for Petrol LGVs, HGVs and buses

Age (Years)	Relative Annual Mileage Index					
	Petrol LGVs		HGVs		Buses and Coaches	
	New Fleet	NAEI19	New Fleet	NAEI19	New Fleet	NAEI19
0	1.00	1.00	1.00	1.00	1.00	1.00
1	0.95	0.95	0.99	1.03	1.00	1.03
2	0.93	0.93	0.99	1.03	1.00	1.03
3	0.84	0.84	0.98	0.97	1.00	0.97
4	0.75	0.75	0.98	0.93	1.00	0.93
5	0.70	0.70	0.97	0.88	0.89	0.88
6	0.64	0.64	0.90	0.80	0.82	0.80
7	0.64	0.64	0.85	0.78	0.76	0.78
8	0.59	0.59	0.80	0.74	0.72	0.74
9	0.54	0.54	0.74	0.60	0.69	0.60
10	0.54	0.54	0.69	0.62	0.66	0.62
11	0.50	0.50	0.64	0.53	0.65	0.53
12	0.46	0.46	0.58	0.53	0.64	0.53
13	0.44	0.44	0.53	0.50	0.63	0.50
14	0.42	0.42	0.48	0.46	0.63	0.46

Age (Years)	Relative Annual Mileage Index					
	Petrol LGVs		HGVs		Buses and Coaches	
15	0.40	0.40	0.43	N/A	0.50	N/A
16	0.38	0.38	0.37	N/A	0.44	N/A
17	0.35	0.35	0.32	N/A	0.38	N/A
18	0.31	0.31	0.30	N/A	0.32	N/A
19	0.28	0.28	0.30	N/A	0.26	N/A
20	0.26	0.28	0.30	N/A	0.22	N/A
21	0.23	N/A	0.30	N/A	0.22	N/A
22	0.21	N/A	0.30	N/A	0.22	N/A
23	0.18	N/A	0.30	N/A	0.22	N/A
24	0.15	N/A	0.30	N/A	0.22	N/A

6. USING A FLEET TURNOVER MODEL TO FORECAST FLEET COMPOSITION IN FUTURE YEARS

6.1 APPROACH AND ASSUMPTIONS REQUIRED

Combining the survival rates (Section 2) and mileage rates (Section 3) with data on new vehicle registrations (sales) is the basis of the approach used in the fleet turnover model to define the proportion of UK vehicle kilometres (vkm) done by vehicles of different ages or registration years and Euro standards.

By way of example if, after 5 years, 80% of diesel cars have survived and their annual mileage has decreased to 50% of what it was when the vehicle was new (these are illustrative, not actual examples), then the combined effect of 0.8 x 0.5 = 0.4 is applied to the vkm of a 5 year old vehicle relative to that done by a brand new one. This method is used to determine the relative vkm done by vehicles of different ages/registration years; the absolute vkm is calculated by applying these fractions to the total vkm done by this vehicle type in a year on UK roads based on DfT's traffic statistics (or traffic forecasts for future years).

This approach is consistent with that generally used in national emission inventories (and recommended in the EMEP/EEA Emissions Inventory Guidebook) where the aim is to derive the total vkm travelled by different vehicle sub-categories using national statistical information. This is discussed again in Section 10.

Fleet compositions calculated in this way from a fleet turnover model have the advantage in that they can be readily used to forecast the fleet composition in future years from assumptions on new vehicle sales which the NAEI receives from DfT. However, key to this is:

a) Making decisions on how current fleet turnover behaviour on vehicle survival rates and mileage with age rates carries forward to future years; and
b) Making predictions of future sales of new vehicles to which the fleet turnover assumptions are applied.

Our initial exploration and development of a revised fleet turnover model described in a draft report submitted to Defra in October 2020 based on the latest vehicle licensing records and MOT mileage data provided by DfT at that time highlighted several gaps in data availability needed to be addressed and decisions made on certain assumptions that were key to predicting fleet turnover in future years. The data gaps have now been addressed and attention has also been given to the decisions and assumptions necessary to predict the future fleet in two main areas:

- What averaging period of historical survival rates and mileage with age rates should be applied to future years?
- New vehicle sales forecasts for HGVs and buses which have thus far been unavailable to the NAEI; sales forecasts for passenger cars and LGVs have always been made available from DfT for the NAEI emission projections, but no equivalent data have been available for HGVs and buses.

6.2 SURVIVAL AND MILEAGE WITH AGE RATES TO ASSUME FOR FUTURE YEARS

In our initial work done in 2020 we considered three scenarios referring to different survival rate and mileage with age indices assumed for future years.

- S1 – in which the rates for future years are maintained at the rates for 2019
- S2 – in which the rates for future years are maintained at the mean of the rates for the past 5 years (2015-2019)
- S3 – in which the rates for future years are maintained at the mean of the rates for the past 10 years (2010-2019)

Our report in 2020 presented results showing the fleet compositions predicted in 2025 and 2030 for each of these scenarios and subsequently the NO_x emissions calculated from these assumptions. This was to show the sensitivity to these fleet turnover assumptions based on the status of the revised fleet turnover model at that time, i.e. before further improvements were made to HGV and bus mileage with age profiles had been developed in this latest study. This was to assist making a decision on what assumptions should be used for future NAEI emission projections.

Results from each of these scenarios were presented in our previous report (Ricardo, 2020b) and are shown again in Appendix A3 of this report in terms of the fleet compositions in 2018, 2025 and 2030. The results from our previous work indicated that in comparison with the existing NAEI fleet compositions, the new turnover model generally shows an older fleet than the current model for all vehicle types, most evident in current or recent years (2018); the differences become smaller in future years. It was also evident that for cars and LGVs, scenario S3 provides a newer fleet than S1. This is because S1 is based on the rates for 2019 alone where both survival rates and mileage rates are proportionately larger for older vehicles than was the case in earlier years whereas S3 is based on rates averaged for the previous 10 years so will be further influenced by the lower survival and mileage rates for older vehicles that was the case in earlier years. However, the differences between the results for the different S1-S3 scenarios were not found to be large.

After presenting these scenarios and results from them at meetings with Defra and DfT in December 2020 and following further communications in 2021, it was agreed that a further scenario should be adopted by the NAEI (S4) which uses survival and mileage with age rates for all future years that are the mean of the rates for the past 3 full years of available data (2017-2019). This is a compromise on the basis that using rates for the most recent year going forward makes the projections subject to the influence of short-term events, whereas a 5-year average may be too long a period to reflect changing patterns of behaviour. The assumption of using a 3-year averaging period can be modified in future.

Fleet composition and emission results from use of these assumptions in a fleet turnover model that encompasses the findings shown in Sections 4 and 5 are presented in Sections 8 and 9.

6.3 NEW VEHICLE SALES PROJECTIONS FOR HGVS AND BUSES

As well as the fleet turnover assumptions discussed in Section 6.2, key drivers in predicting the composition of the fleet and emissions in future years are predicted sales of new vehicles.

The NAEI has been provided with new vehicle sales forecasts on a regular basis from DfT for passenger cars and LGVs, including the splits between traditional petrol and diesel internal combustion engine (ICE) vehicles, hybrid electric and battery electric vehicles. The latest forecasts were provided by the Environmental Analysis team at DfT in January 2021. These assume all currently firm and funded policies as of January 2021. For cars, this includes the plug-in car grant (finishing in 2020) and impact of the EU CO_2 2020-2021 and 2030 regulations.

New vehicle sales projections for HGVs and buses have never been available from sources in DfT, so previously the NAEI has inferred what growth in vehicle sales would be necessary from current levels to sustain the growth in UK vehicle km travelled by these vehicles according to traffic forecasts which are provided by DfT and based on pre-existing vehicle survival and mileage rates. The key assumption implied by this approach is that any growth in vehicle km arises due to a growth in vehicle population, not due to a change in mileage done by existing HGVs and buses. This has not been considered a reliable assumption to make, but one that has been necessary in the absence of other information.

Possible alternative sources of data on forecast sales of new HGVs and buses have been further explored in this study. In the absence of forecasts of new registrations of heavy-duty vehicles from DfT, data showing forecasts of new heavy duty engine production have been used as a proxy for trends in sales of new vehicles. These were taken from our analysis of a database of an industry market research organisation, IHS[10]. Ricardo subscribes to the IHS database for other engine-related projects undertaken for industry and it is a highly respected source. The IHS database includes forecasts on production data of internal combustion engines of light vehicles and medium/heavy commercial vehicles from 2010 up to 2028 for both EU countries and the UK. The dataset includes the production of new engines of earlier Euro standards that are exported to other countries. The figures for the UK alone were considered strongly influenced by the production of engines in the UK used for export, so were not considered suitable as a proxy for new vehicle registrations. Instead the data for the EU as a whole were analysed as a more balanced indicator of trends in new vehicle registrations in the UK and across the EU. Trends from this database were applied to the latest published new registrations of heavy duty vehicles (HDVs) for the UK published by DfT.

Table 6-1 presents the trend of future sales of HGVs and buses from the current NAEI and the new methodology. The figures represent the percentage change in new registrations between successive years forecast to 2030. The reduction between 2019 and 2020 shown from analysis of the IHS data reflects the impact of COVID restrictions. There is also a drop in new registrations between 2024 and 2025 which is anticipated because of the introduction of proposed Euro 7 legislation in 2025. Our industry experts indicate this normally happens with the introduction of new legislation as many in the market pause to see how it will affect price and performance before production and sales eventually bounce back. Note the dates for introduction and the limits on Euro 7 emissions are still at proposal stage with the Commission, so the impacts of Euro 7 itself on emissions are not included in NAEI projections.

Table 6-1 Trend in future sales of HGVs and buses between years up to 2030 estimated from the IHS database (new method) compared with trends currently assumed in the NAEI inferred from DfT traffic forecasts.

Sales trend between successive years	Buses_(new method)	Buses_(current NAEI)	HGVs_(new method)_	HGVs_(current NAEI)
2020/2019	-16%	13%	-20%	0.42%
2021/2020	6%	12%	16%	0.41%

[10] https://ihsmarkit.com/products/automotive-truck-commercial-vehicle-forecasts.html

Sales trend between successive years	Buses_(new method)	Buses_(current NAEI)	HGVs_(new method)_	HGVs_(current NAEI)
2022/2021	14%	10%	6%	0.41%
2023/2022	6%	9%	6%	0.40%
2024/2023	4%	8%	2%	0.40%
2025/2024	-2%	7%	-2%	0.39%
2026/2025	3%	6%	2%	0.39%
2027/2026	1%	5%	1%	0.38%
2028/2027	3%	4%	3%	0.38%
2029/2028	6%	2%	5%	0.37%
2030/2029	8%	1%	7%	0.37%

The current fleet projections model for buses does not account for the anticipated growth in sales of electric buses. These would be included in DfT's traffic forecasts, but a distinction in the Internal Combustion Engine (ICE) and electric bus fleet is necessary to account for the fact that only the ICE buses will contribute to exhaust emissions, whereas both contribute to non-exhaust emissions of PM. The figures for buses in Table 6-2 refer to ICE buses only and this information is needed in order to estimate the fleet composition of ICE buses by Euro category. Further research was undertaken for sources of data on sales of electric buses so that the proportions of these in the fleet could be estimated and used to derive the vehicle km splits for buses between ICE and electrically powered vehicles.

There is a very limited literature on predictions of sales of electric buses. Whilst industry forecasts were seen to be available from an internet search, these require subscriptions to detailed data sources. Instead of subscribing to data, headline summaries of sales forecasts available from internet searches were used. Automotive World[11] reports forecasts for electric buses according to Accuracy, a global independent advisory firm; it estimated that the UK will increase the current bus fleet from approximately 1,000 to 2,800 electric vehicles by 2024. In the newly released Electric Vehicle Outlook 2020 by Bloomberg New Energy Finance (BNEF)[12], it is estimated that by 2030 the electric share of buses will be 50% of the total global bus fleet. DfT[13] has already published new registrations for all buses up to 2020 including data for battery electric buses and coaches. The above data sources have been combined together to estimate the electric bus fleet in the UK up to 2030 and our estimates on their future sales is concluded in Table 6-2. As for Table 6-1, this shows the percentage change between successive years forecast to 2030. With such limited information available, for the years that there are no quoted data, linear growth in the sale of vehicles is assumed.

[11] Accuracy: UK's electric bus fleet set to be the largest in Europe by 2024 | Automotive World

[12] https://www.sustainable-bus.com/news/electric-vehicle-outlook-2020-bnef-electric-buses/

[13] https://www.gov.uk/government/collections/vehicles-statistics

Table 6-2 Trend on future sales of electric buses between years up to 2030.

Trend	Electric buses
2020/2019	118%
2021/2020	343%
2022/2021	60%
2023/2022	38%
2024/2023	27%
2025/2024	19%
2026/2025	16%
2027/2026	14%
2028/2027	12%
2029/2028	11%
2030/2029	10%

7. ANALYSIS OF DFT'S ANPR DATA FOR 2019

The NAEI currently uses DfT's anonymised Automatic Number Plate Recognition (ANPR) data from a network of around 250 sites in the UK to define the on-road fleet composition in different (recent) years. These show the proportion of vehicles of different Euro standards on UK roads and can be compared with fleet compositions calculated from a fleet turnover model developed from the survival rates and mileage rates discussed in Section 4 and Section 5. The ANPR data has been collected annually (since 2007) at over 256 sites in the UK on different road types (urban and rural major/minor roads, and motorways) and regions. Measurements are made at each site on one weekday (8am-2pm and 3pm-9pm) and one half weekend day (either 8am-2pm or 3pm-9pm) each year in June and are currently available for years 2007 to 2011, 2013, 2015 and 2017. Since 2011, measurements are made biennially. The principal aim of the ANPR data collected by DfT is to provide statistics on Vehicle Excise Duty evasion. Further background information can be found in the following DfT document: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/847468/vehicle-excise-duty-evasion-statistics-notes-and-definitions.pdf

There are approximately 1.2-1.7 million observations recorded from all the sites each year. The ANPR datasets provided to the NAEI team in the past covered the following data fields:

- Body Type
- Fuel Type
- Age
- Engine Size
- Road Type
- Government Office Region
- Number of ANPR observations.

As part of this improvement task, the NAEI team has carried out a further assessment of the ANPR data provided by DfT. An initial meeting with the data provider at DfT (Vehicles & Admin Statistics team) was held on 7th July 2020 to further explore the nature of the ANPR data and whether a different format can be provided which may improve or lead to different interpretation of the on-road fleet composition.

Following on from the initial meeting, DfT has provided a refined version of the 2019 ANPR dataset including the following changes:

- “Year of first registration” to be provided instead of “age”
- Additional data field which contains DfT's internal Euro standard classification[14]
- Minor roads to further split by urban minor and rural minor
- Provision of another version of ANPR dataset that are weighted by traffic flow information specific to that ANPR site, to remove any biases.

DfT advised that they could only readily provide 2019 ANPR data in this new format because the 2019 ANPR data has been processed in a new DfT system, and unfortunately they were unable to do the same for the earlier years of dataset due the level of effort required. The 2019 ANPR dataset contains approximately 1.2 million observations.

A further meeting was held with the DfT data provider on 6th October 2020 to discuss our initial findings and observations of ANPR analysis. This led to further refinement of the 2019 ANPR dataset provided by DfT. The final 2019 ANPR dataset provided by DfT is now additionally weighted by the number of billion vehicle km (bvkm) observed for the vehicle types, road types, and underlying regions in year 2018, processed in a comparable way with the Vehicle Excise Duty (VED) evasion statistics. This dataset is referred to as ‘bvkm-weighted’ version of 2019 ANPR dataset hereafter. DfT consider the weightings to give a better reflection of how the traffic is distributed nationally in each vehicle sub-category.

Table 7-1 shows the comparison of fleet composition for different vehicle types in 2019, as informed by the ‘unweighted’ version (which is the type of the ANPR dataset provided by DfT in the past) and the ‘bvkm-weighted’ version of 2019 ANPR dataset additionally provided for this improvement task. The Euro standard mix inferred from the 2017 unweighted ANPR dataset is also included in Table 7-1 for reference. The 2017 ANPR data are currently used in the NAEI.

The main observation from Table 7-1 is that the 2019 bvkm-weighted ANPR dataset implies that the fleet composition is older on the road for all vehicle types, in particular for rigid and artic HGVs, when compared to the 2019 unweighted ANPR dataset.

The significance of the on-road fleet compositions derived from ANPR data compared with fleet compositions from a fleet turnover model derived from the survival rates and mileage with age described in section 4 and section 5, is discussed in section 8.

The NAEI also uses the ANPR data to inform the proportion of diesel cars on urban/rural/motorway roads. The 2019 unweighted and bvkm-weighted versions give very similar results on all road types:

% of diesel cars	2019 unweighted ANPR	2019 bvkm-weighted ANPR
Urban	44.4%	44.5%
Rural	50.9%	50.3%
Motorway	56.3%	55.5%

[14] DfT confirmed that they have assigned Euro standard in the ANPR data based on assumptions, rather than Euro categorisation recorded in the licensing data (e.g. according to manufacturers’ specification). DfT also thinks that the NAEI allocations are more reliable than their assumptions.

Table 7-1 Euro standard mix by vehicle type and road type inferred from three sets of ANPR datasets: 2017 unweighted, 2019 unweighted and 2019 bvkm-weighted ANPR data. Values for the 2019 bvkm-weighted column are highlighted in red (or blue) if the % is higher (or lower) when compared to the 2019 unweighted ANPR column.

Vehicle Type	Euro standard	Urban			Rural			Motorway		
		2017 unweighted ANPR	2019 unweighted ANPR	2019 bvkm-weighted ANPR	2017 unweighted ANPR	2019 unweighted ANPR	2019 bvkm-weighted ANPR	2017 unweighted ANPR	2019 unweighted ANPR	2019 bvkm-weighted ANPR
Petrol cars	Pre-Euro 1	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Euro 1	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Euro 2	2%	1%	2%	2%	1%	2%	1%	0%	1%
	Euro 3	18%	13%	14%	17%	12%	14%	14%	9%	11%
	Euro 4	28%	24%	24%	27%	22%	23%	25%	20%	21%
	Euro 5	27%	27%	27%	28%	27%	26%	29%	26%	26%
	Euro 6_1	13%	13%	13%	13%	13%	13%	14%	14%	14%
	Euro 6_2	12%	22%	21%	13%	24%	23%	16%	30%	28%
	Euro 6_3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Diesel cars	Pre-Euro 1	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Euro 1	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Euro 2	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Euro 3	8%	6%	7%	8%	7%	8%	5%	4%	5%
	Euro 4	23%	20%	21%	23%	20%	20%	18%	16%	17%
	Euro 5	36%	37%	37%	34%	36%	36%	34%	34%	34%
	Euro 6_1	18%	18%	17%	19%	18%	17%	22%	20%	19%
	Euro 6_2	15%	19%	18%	16%	19%	19%	21%	26%	24%
	Euro 6_3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Diesel LGVs	Pre-Euro 1	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Euro 1	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Euro 2	1%	1%	1%	1%	1%	1%	1%	0%	1%

Vehicle Type	Euro standard	Urban			Rural			Motorway		
		2017 unweighted ANPR	2019 unweighted ANPR	2019 bvkm-weighted ANPR	2017 unweighted ANPR	2019 unweighted ANPR	2019 bvkm-weighted ANPR	2017 unweighted ANPR	2019 unweighted ANPR	2019 bvkm-weighted ANPR
	Euro 3	8%	5%	7%	8%	5%	7%	4%	3%	4%
	Euro 4	25%	19%	21%	24%	18%	19%	18%	12%	15%
	Euro 5	37%	35%	34%	37%	35%	34%	39%	34%	33%
	Euro 6_1	29%	22%	20%	30%	22%	20%	39%	27%	25%
	Euro 6_2	0%	19%	17%	0%	19%	18%	0%	25%	22%
	Euro 6_3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Rigid HGVs	Pre-Euro I	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Euro I	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Euro II	0%	1%	7%	1%	1%	6%	0%	0%	8%
	Euro III	8%	5%	9%	9%	7%	15%	7%	5%	5%
	Euro IV	9%	7%	17%	10%	7%	8%	9%	6%	8%
	Euro V	27%	20%	14%	27%	22%	20%	26%	22%	18%
	Euro VI	55%	68%	53%	53%	63%	51%	58%	67%	61%
Artic HGVs	Pre-Euro I	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Euro I	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Euro II	0%	0%	0%	0%	0%	0%	0%	0%	3%
	Euro III	1%	0%	1%	1%	1%	1%	1%	0%	1%
	Euro IV	3%	2%	9%	3%	1%	1%	2%	1%	2%
	Euro V	24%	15%	16%	22%	15%	28%	20%	14%	14%
	Euro VI	73%	83%	73%	74%	83%	70%	76%	84%	81%

8. FLEET COMPOSITION DERIVED FROM NEW FLEET TURNOVER MODEL

Having developed new survival rates, mileage rates and agreed assumptions (S4) on a 3-year averaging period on the most recent historic rates to apply to future years as well as new HGV and bus sales projections, UK average fleet compositions could be calculated in a fleet turnover model for the full historic time-series and projections to 2030 on a consistent basis. Fleet compositions calculated in this way can be compared and tested against on-road fleet compositional data shown by ANPR information, of the type demonstrated in Section 7. The data should be consistent ***if*** the ANPR data are sufficiently representative of activities on all UK roads. In reality, how truly representative a set of ANPR data is of the national fleet is not known and even if it was, thus appearing to make a fleet turnover model unnecessary, a model is still required to predict the fleet in future years where the main drivers available to make such predictions are usually forecasts in new vehicle sales and lifetime assumptions at a national level. A fleet turnover model is also necessary to fill the gap in years where there are no ANPR data available, including all the historical years prior to 2007. This is essential for enabling a consistent time-series in emission estimates to be made, a key requirement of inventory compilation. However, fleet compositions are not homogeneous around the country and ANPR has the additional benefit in that it can show the variation on different road types and potentially different local areas, a feature that cannot be derived from nationally averaged survival and mileage rates.

This section:

- Shows UK fleet composition defined by a new fleet turnover model using year-dependent survival rates and mileage with age rate indices from Sections 2 and 3 and assumptions from Section 4; compares the new fleet compositions with estimates for the current NAEI fleet turnover model, showing the effect of using the new survival and mileage rate assumptions
- Compares the fleet compositions calculated for 2019 with that implied by DfT’s ANPR data described in Section 7;
- Compares the fleet compositions calculated for 2017 with fleets derived from some local authority ANPR data that had been previously examined by Ricardo in a localisation workstream for Defra, exploring the use of such data provided for 5 different UK cities.

8.1 UK FLEET COMPOSITION RESULTS FROM THE TURNOVER MODEL

Table 8-1 to Table 8-6 show the UK fleet composition calculated from the turnover model for petrol cars, diesel cars, diesel LGVs, rigid HGVs, artic HGVs and buses for the years 2019, 2025 and 2030. These are expressed as the proportion of kilometres (vkm) travelled by each Euro category. Results are shown from the new fleet turnover model (Scenario S4) and from the current fleet turnover model used in the 2019 NAEI and projections (Baseline).

Table 8-1 Fleet composition for petrol cars expressed as the fraction of vehicle km travelled by each Euro category in 2019, 2025 and 2030. The Baseline refers to the fleet compositions from the current NAEI fleet turnover model. New fleet refers to the fleet composition from the revised fleet turnover model for 3 year averaging assumptions on mileage and survival rates for future years (S4, see text)

Vehicle Type	Year	Euro Standard	Baseline	New fleet
Petrol cars	2019	Pre-Euro 4	0.044	0.119
		Euro 4	0.140	0.209
		Euro 5	0.259	0.258
		Euro 6_1	0.158	0.131
		Euro 6_2	0.357	0.244
		HEV	0.033	0.030
		PHEV	0.010	0.009
		Total	**1.000**	**1.000**
	2025	Pre-Euro 4	0.001	0.002
		Euro 4	0.013	0.036
		Euro 5	0.087	0.151
		Euro 6_1	0.081	0.101
		Euro 6_2	0.201	0.212
		Euro 6_3	0.491	0.384
		HEV	0.073	0.067
		PHEV	0.053	0.047
		Total	**1.000**	**1.000**
	2030	Euro 4	0.000	0.001
		Euro 5	0.011	0.030
		Euro 6_1	0.018	0.042
		Euro 6_2	0.083	0.138
		Euro 6_3	0.698	0.615
		HEV	0.088	0.084
		PHEV	0.101	0.090
		Total	**1.000**	**1.000**

Table 8-2 Fleet composition for diesel cars expressed as the fraction of vehicle km travelled by each Euro category in 2019, 2025 and 2030. The Baseline refers to the fleet compositions from the current NAEI fleet turnover model. New fleet refers to the fleet composition from the revised fleet turnover model for 3 year averaging assumptions on mileage and survival rates for future years (S4, see text)

Vehicle Type	Year	Euro Standard	Baseline	New fleet
Diesel Cars	2019	Pre-Euro 4	0.026	0.058
		Euro 4	0.137	0.178
		Euro 5	0.357	0.343
		Euro 6_1	0.208	0.183
		Euro 6_2	0.265	0.231
		HEV	0.007	0.006
		Total	**1.000**	**1.000**
	2025	Pre-Euro 4	0.001	0.003
		Euro 4	0.022	0.048
		Euro 5	0.203	0.270
		Euro 6_1	0.180	0.181
		Euro 6_2	0.249	0.222
		Euro 6_3	0.320	0.255
		HEV	0.026	0.022
		Total	**1.000**	**1.000**
	2030	Euro 4	0.001	0.002
		Euro 5	0.039	0.084
		Euro 6_1	0.061	0.107
		Euro 6_2	0.149	0.194
		Euro 6_3	0.697	0.569
		HEV	0.053	0.045
		Total	**1.000**	**1.000**

Table 8-3 Fleet composition for diesel LGVs expressed as the fraction of vehicle km travelled by each Euro category in 2019, 2025 and 2030. The Baseline refers to the fleet compositions from the current NAEI fleet turnover model. New fleet refers to the fleet composition from the revised fleet turnover model for 3 year averaging assumptions on mileage and survival rates for future years (S4, see text)

Vehicle Type	Year	Euro Standard	Baseline	New fleet
Diesel LGVs	2019	Pre-Euro 4	0.028	0.054
		Euro 4	0.123	0.157
		Euro 5	0.294	0.317
		Euro 6_1	0.188	0.207
		Euro 6_2	0.366	0.265
		PHEV	0.001	0.000
		Total	**1.000**	**1.000**
	2025	Pre-Euro 4	0.001	0.002
		Euro 4	0.018	0.032
		Euro 5	0.105	0.133
		Euro 6_1	0.085	0.095
		Euro 6_2	0.193	0.207
		Euro 6_3	0.596	0.529
		PHEV	0.003	0.003
		Total	**1.000**	**1.000**
	2030	Euro 4	0.001	0.002
		Euro 5	0.020	0.036
		Euro 6_1	0.025	0.038
		Euro 6_2	0.083	0.102
		Euro 6_3	0.859	0.810
		PHEV	0.012	0.011
		Total	**1.000**	**1.000**

Table 8-4 Fleet composition for rigid HGVs expressed as the fraction of vehicle km travelled by each Euro category in 2019, 2025 and 2030. The Baseline refers to the fleet compositions from the current NAEI fleet turnover model. New fleet refers to the fleet composition from the revised fleet turnover model for 3 year averaging assumptions on mileage and survival rates for future years (S4, see text)

Vehicle Type	Year	Euro Standard	Baseline	New fleet
Rigid HGVs	2019	Euro I		0.006
		Euro II	0.005	0.026
		Euro III	0.043	0.078
		Euro IV	0.046	0.068
		Euro V	0.188	0.220
		Euro VI	0.718	0.603
		Total	**1.000**	**1.000**
	2025	Euro II		0.002
		Euro III	0.003	0.020
		Euro IV	0.005	0.012
		Euro V	0.034	0.059
		Euro VI	0.959	0.907
		Total	**1.000**	**1.000**
	2030	Euro III		0.002
		Euro IV		0.005
		Euro V	0.005	0.015
		Euro VI	0.995	0.978
		Total	**1.000**	**1.000**

Table 8-5 Fleet composition for artic HGVs expressed as the fraction of vehicle km travelled by each Euro category in 2019, 2025 and 2030. The Baseline refers to the fleet compositions from the current NAEI fleet turnover model. New fleet refers to the fleet composition from the revised fleet turnover model for 3 year averaging assumptions on mileage and survival rates for future years (S4, see text)

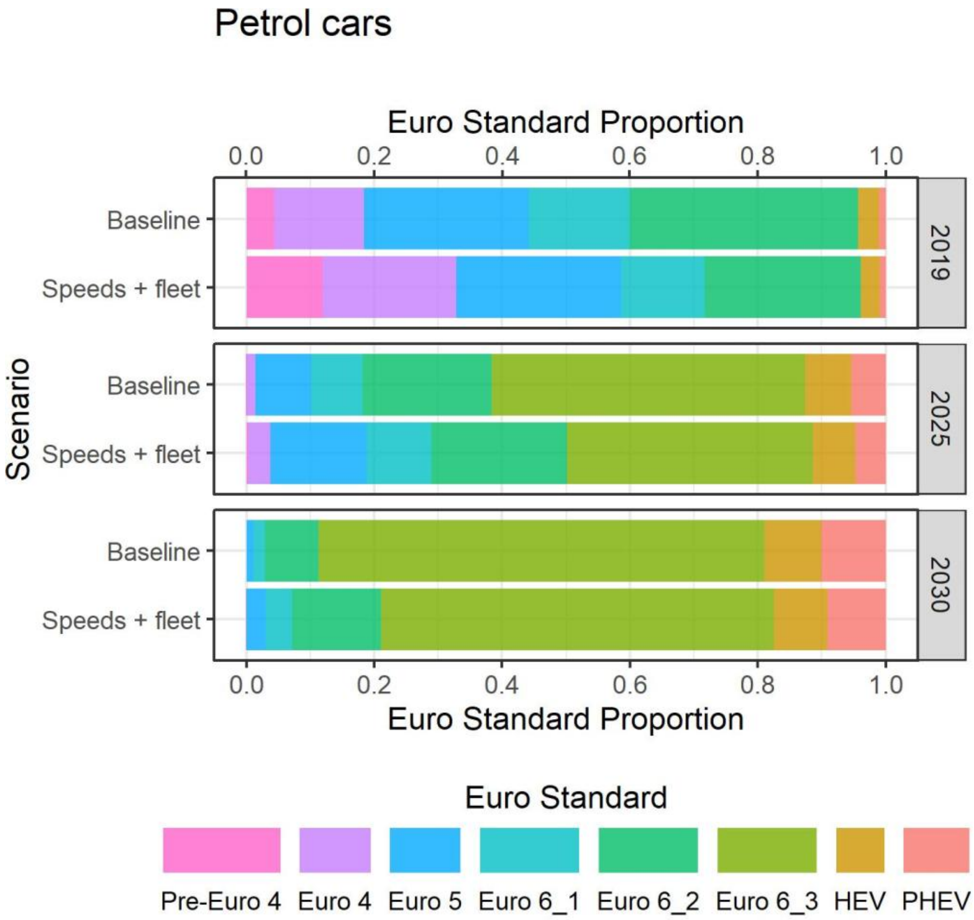
Vehicle Type	Year	Euro Standard	Baseline	New fleet
Artic HGVs	2019	Euro I		0.001
		Euro II	0.000	0.003
		Euro III	0.007	0.015
		Euro IV	0.011	0.019
		Euro V	0.129	0.134
		Euro VI	0.853	0.829
		Total	**1.000**	**1.000**
	2025	Euro II		0.000
		Euro III	0.000	0.003
		Euro IV	0.001	0.002
		Euro V	0.008	0.015
		Euro VI	0.992	0.981
		Total	**1.000**	**1.000**
	2030	Euro III		0.000
		Euro IV		0.001
		Euro V	0.001	0.002
		Euro VI	0.999	0.997
		Total	**1.000**	**1.000**

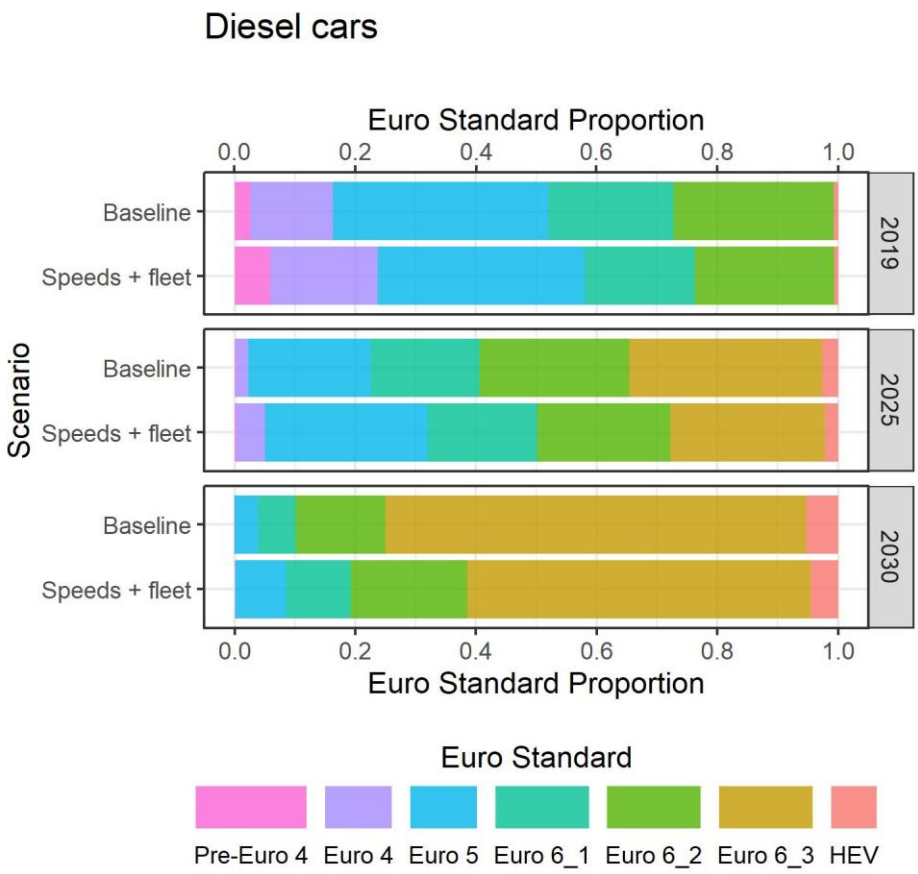
Table 8-6 Fleet composition for buses & coaches expressed as the fraction of vehicle km travelled by each Euro category in 2019, 2025 and 2030. The Baseline refers to the fleet compositions from the current NAEI fleet turnover model. New fleet refers to the fleet composition from the revised fleet turnover model for 3 year averaging assumptions on mileage and survival rates for future years (S4, see text)

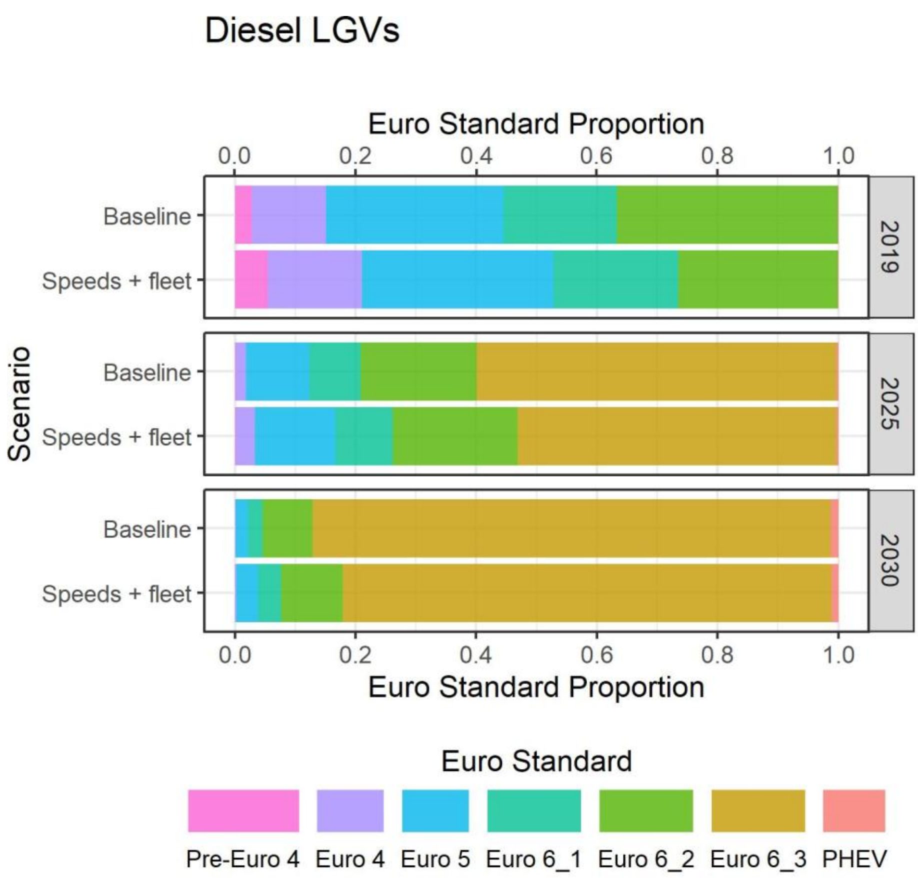
Vehicle Type	Year	Euro Standard	Baseline	New fleet
Buses & Coaches	2019	Euro I		0.001
		Euro II	0.014	0.012
		Euro III	0.067	0.094
		Euro IV	0.081	0.097
		Euro V	0.264	0.240
		Euro VI	0.575	0.551
		Electric	0.000	0.004
		Total	**1.000**	**1.000**
	2025	Euro II		0.001
		Euro III	0.010	0.012
		Euro IV	0.016	0.015
		Euro V	0.070	0.112
		Euro VI	0.903	0.752
		Electric	0.000	0.108
		Total	**1.000**	**1.000**
	2030	Euro III		0.001
		Euro IV		0.003
		Euro V	0.022	0.018
		Euro VI	0.978	0.675
		Electric	0.000	0.303
		Total	**1.000**	**1.000**

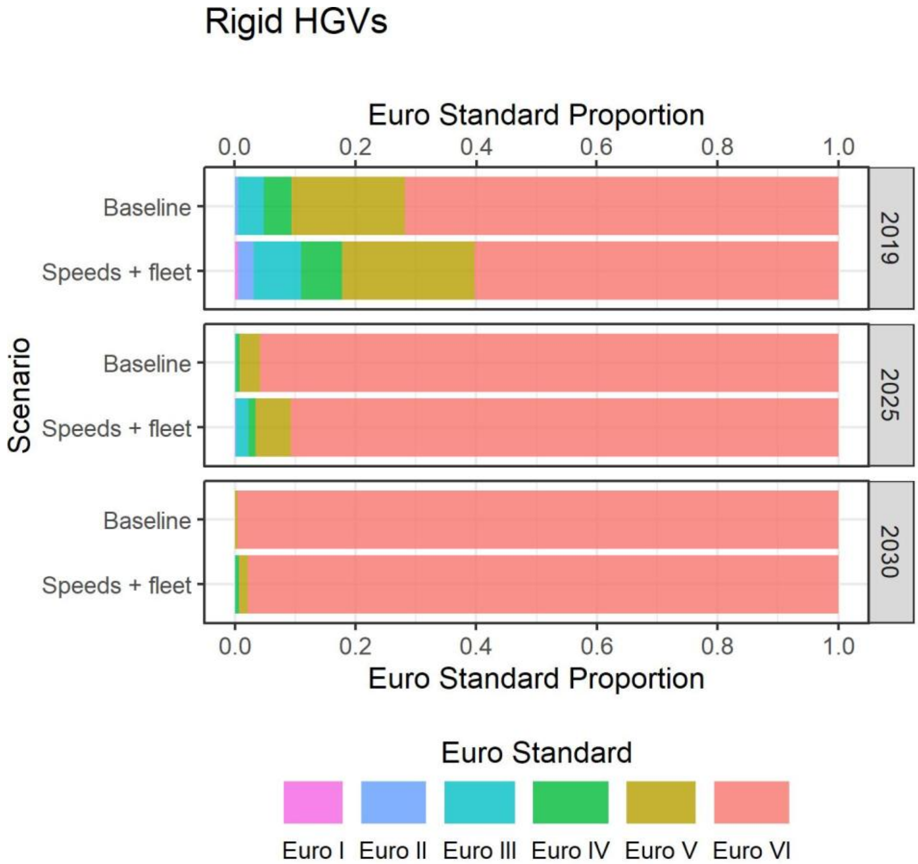
The comparisons between the different fleet composition versions are also seen schematically in Figure 8-1 for petrol cars, diesel cars, diesel LGVs and rigid HGVs.

Figure 8-1 Fleet composition of petrol cars, diesel cars, diesel LGVs and rigid HGVs in 2019, 2025 and 2030 derived using current approach (Baseline) and new fleet turnover model (referred to as “Speeds+fleet” in these charts)




Diesel cars
Euro Standard Proportion
0.0
0.2
0.4
0.6
0.8
1.0
Baseline
Speeds + fleet
Scenario
2019
2025
2030
Euro Standard
Pre-Euro 4
Euro 4
Euro 5
Euro 6_1
Euro 6_2
Euro 6_3
HEV


Diesel LGVs
Euro Standard Proportion
0.0
0.2
0.4
0.6
0.8
1.0
Baseline
Speeds + fleet
Scenario
2019
2025
2030
Euro Standard
Pre-Euro 4
Euro 4
Euro 5
Euro 6_1
Euro 6_2
Euro 6_3
PHEV



In comparison with the previous fleet compositions, the new turnover model is generally showing an older fleet than the current model for all vehicle types, most evident in current or recent years (2019); the differences become smaller in future years. This is due to the survival rates for recent years tending to show vehicles surviving longer than is currently assumed combined with their mileage tending to decrease with age at a slower rate than previously assumed. In future years (e.g. by 2030), the fleet composition becomes dominated by Euro 6/VI vehicles so it makes little difference what survival rates are used and hence the difference between the scenarios becomes smaller.

The differences between the current and new turnover model are more evident for petrol cars than other vehicle types. For example, in 2019, 18.4% of vkm were estimated to be done by pre-Euro 5 cars in the current model, but this has increased to 32.8% in the new model, with consequent decreases in the proportions for Euro 5 and 6 cars. This trend continues to 2025.

The changes in the fleet compositions for diesel cars and LGVs show a similar pattern to petrol cars, but the differences compared with the current fleet turnover model are smaller. Thus for diesel cars in 2019, 23.7% of vkm are now estimated to be done by pre-Euro 5 vehicles in 2019 compared with 16.3% derived from the current model. The trend continues but the differences become smaller in the projected years. For diesel LGVs in 2019, 21.1% of vkm are now estimated to be done by pre-Euro 5 vehicles in 2019 compared with 15.1% derived from the current model

In the case of rigid HGVs, in 2019, 17.7% of vkm are now estimated to be done by pre-Euro V vehicles in 2019 compared with 9.4% derived from the current model. For artic HGVs, the change has been to 3.7% of vkm done by pre-Euro V vehicles in 2019 compared with 1.8% derived from the current model. For buses and coaches, the change has been to 20.4% of vkm done by pre-Euro V vehicles in 2019 compared with 16.1% derived from the current model. Of course, when considering the composition of the fleet and the impact changes have on emissions, one has to consider the changes in all Euro standards including the relative differences in the Euro V and VI proportions.

8.2 COMPARING FLEET COMPOSITION DATA FOR 2019 WITH DFT ANPR DATA

Section 5 and Table 7-1 showed the proportions of Euro categories observed on urban, rural and motorway roads in the UK in 2019. These can be compared with the fleet composition data for the same year derived from the model.

Table 8-7 shows a comparison in the fleet compositions for petrol cars, diesel cars, diesel LGVs, rigid HGVs and artic HGVs from the current fleet turnover model (shown as Baseline), the new fleet model using the revised survival and mileage rates for 2019 and DfT's ANPR data for urban, rural and motorway roads. The weighted ANPR data from Table 7-1 are used as these are considered to be more representative of the national fleet. The data for the baseline and revised model in these tables are consistent with those shown in Table 8-1 to Table 8-6

The comparisons between the different fleet composition versions and ANPR data for 2019 are also seen schematically in Figure 8-2 to Figure 8-6 for petrol cars, diesel cars, diesel LGVs, rigid HGVs and artic HGVs, respectively.

Table 8-7 Fleet composition for petrol cars, diesel cars, diesel LGVs, rigid HGVs and artic HGVs expressed as the fraction of vehicle km travelled by each Euro category in 2019 compared with DfT's ANPR data for the same year. The Baseline refers to the fleet compositions from the current NAEI fleet turnover model. New model refer to the fleet composition from the revised fleet turnover model using survival and mileage rates at 2019 levels. The bvkm-weighted ANPR figures are used

		Year 2019				
		Baseline	**New model**	**DfT ANPR**		
Vehicle Type	Euro Standard	UK	UK	Urban	Rural	Motorway
Petrol Cars	Pre-Euro 4	0.044	0.119	0.159	0.152	0.118
	Euro 4	0.141	0.212	0.239	0.229	0.208
	Euro 5	0.265	0.265	0.269	0.263	0.258
	Euro 6_1	0.164	0.137	0.125	0.127	0.137
	Euro 6_2	0.386	0.268	0.208	0.229	0.280
	Euro 6_3	0.000	0.000	0.000	0.000	0.000
	Total	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**

		Year 2019				
		Baseline	**New model**	**DfT ANPR**		
Vehicle Type	Euro Standard	UK	UK	Urban	Rural	Motorway

		Year 2019				
Diesel Cars	Pre-Euro 4	0.026	0.058	0.075	0.080	0.051
	Euro 4	0.137	0.178	0.206	0.202	0.171
	Euro 5	0.357	0.344	0.366	0.357	0.344
	Euro 6_1	0.209	0.184	0.174	0.171	0.193
	Euro 6_2	0.271	0.236	0.179	0.191	0.242
	Euro 6_3	0.000	0.000	0.000	0.000	0.000
	Total	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**

		Year 2019				
		Baseline	**New model**	**DfT ANPR**		
Vehicle Type	Euro Standard	UK	UK	Urban	Rural	Motorway
Diesel LGVs	Pre-Euro 4	0.028	0.054	0.081	0.083	0.052
	Euro 4	0.123	0.157	0.206	0.192	0.145
	Euro 5	0.294	0.317	0.342	0.342	0.331
	Euro 6_1	0.188	0.207	0.198	0.205	0.248
	Euro 6_2	0.367	0.265	0.172	0.179	0.224
	Euro 6_3	0.000	0.000	0.000	0.000	0.000
	Total	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**

		Year 2019				
		Baseline	**New model**	**DfT ANPR**		
Vehicle Type	Euro Standard	UK	UK	Urban	Rural	Motorway
Rigid HGVs	Euro I	0.000	0.006	0.000	0.000	0.000
	Euro II	0.005	0.026	0.072	0.055	0.081
	Euro III	0.043	0.078	0.089	0.146	0.055
	Euro IV	0.046	0.068	0.165	0.083	0.076
	Euro V	0.188	0.220	0.143	0.205	0.182
	Euro VI	0.718	0.603	0.531	0.511	0.606
	Total	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**

		Year 2019		
		Baseline	**New model**	**DfT ANPR**

		Year 2019				
Vehicle Type	Euro Standard	UK	UK	Urban	Rural	Motorway
Artic HGVs	Euro I	0.000	0.001	0.000	0.000	0.000
	Euro II	0.000	0.003	0.000	0.001	0.026
	Euro III	0.007	0.015	0.011	0.007	0.007
	Euro IV	0.011	0.019	0.094	0.012	0.021
	Euro V	0.129	0.134	0.160	0.282	0.140
	Euro VI	0.853	0.829	0.735	0.698	0.806
	Total	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**

For all vehicle types there is a tendency for the ANPR to show a somewhat older fleet than is implied by the fleet turnover model, although the agreement is better with the model based on the new survival and mileage rates than the current model. Focusing on the ANPR data for diesel cars on just the urban roads, the ANPR data suggests around 35% of the fleet were Euro 6 vehicles compared with 42% indicated by the new model, the difference in the ANPR fleet being mainly distributed between the older Euro 4 and 5 vehicles to a roughly equal extent. The same pattern seems to be the case for petrol cars, although here a larger share in the ANPR data is among the pre-Euro 5 cars. The modelled fleets are not road-type specific, but differences between the modelled fleet and the ANPR data tends to be smaller on rural roads and motorways for petrol and diesel cars.

In the case of diesel LGVs, the differences between the ANPR data for urban roads and the model are larger than for passenger cars. For example, the ANPR data suggests 37% are Euro 6 vehicles compared with 47% in the model.

In the case of HGVs, again the differences between the ANPR data for urban roads and the model are larger than for passenger cars with there being more Euro IV and fewer Euro VI vehicles implied by the ANPR data than in the model. Again the differences are smaller for motorways.

The differences between the fleets according to the ANPR data and the fleet model could be due to a number of reasons. As stated earlier, the modelled data are based on national, statistical datasets which should capture the entire fleet but cannot be associated with a particular area. On the other hand the ANPR data represent a portion of the fleet and are specific to the locations where the observations were made, albeit data were sampled across a fairly large number of sites across the country.

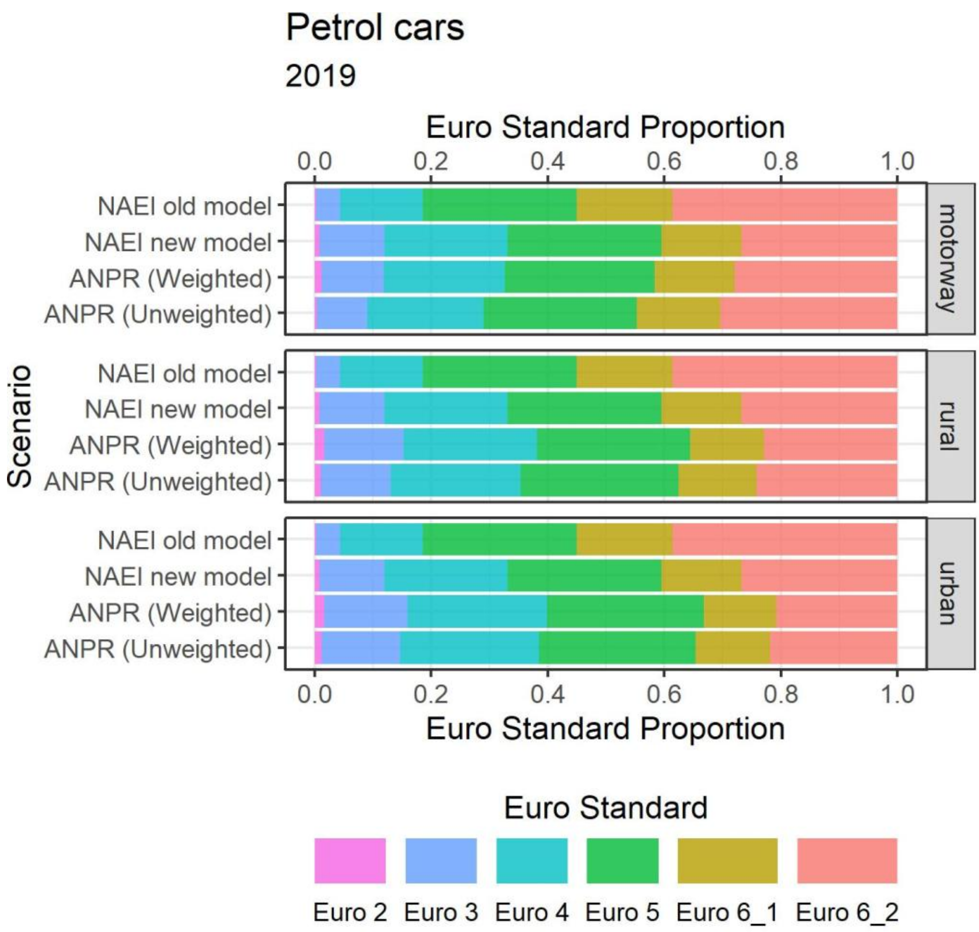


Figure 8-2 Fleet composition for petrol cars expressed as the fraction of vehicle km travelled by each Euro category in 2019 compared with DfT's ANPR data for the same year. NAEI old model is the Baseline referring to the fleet compositions from the current NAEI fleet turnover model. NAEI new model refers to the fleet composition from the revised fleet turnover model using survival and mileage rates at 2019 levels. The figure shows DfT ANPR fleets from the bvkm-weighted and unweighted data.

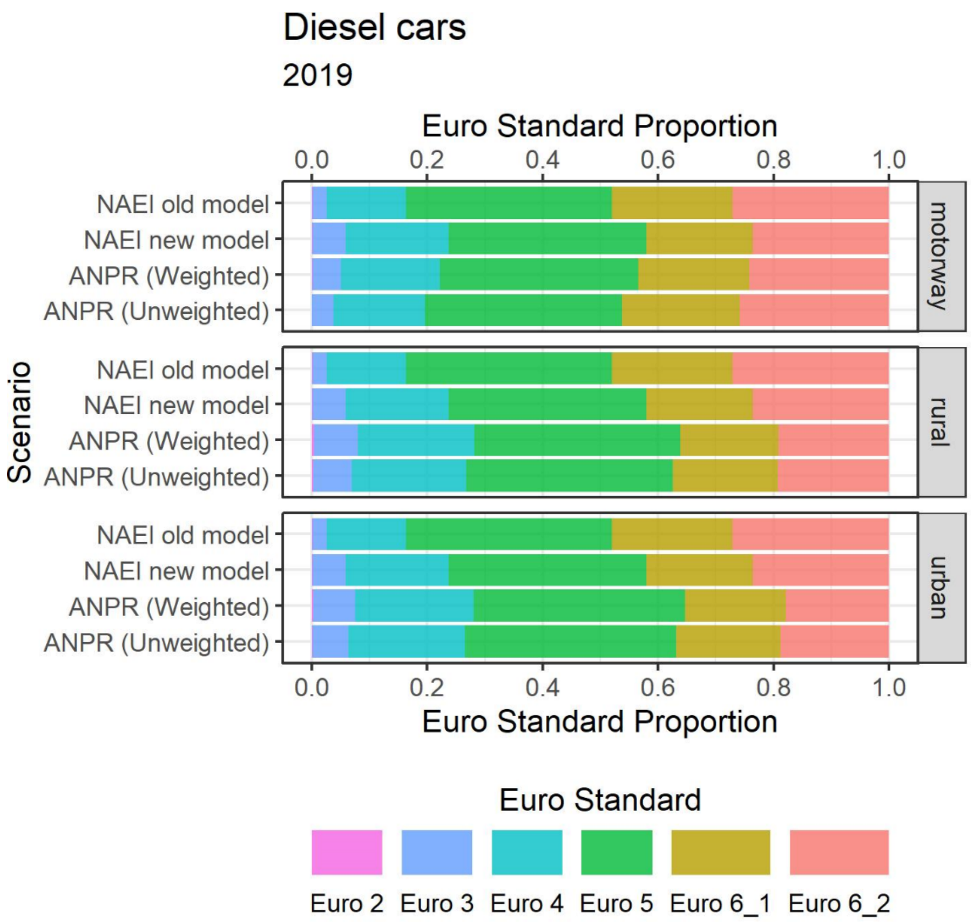


Figure 8-3 Fleet composition for diesel cars expressed as the fraction of vehicle km travelled by each Euro category in 2019 compared with DfT's ANPR data for the same year. NAEI old model is the Baseline referring to the fleet compositions from the current NAEI fleet turnover model. NAEI new model refers to the fleet composition from the revised fleet turnover model using survival and mileage rates at 2019 levels. The figure shows DfT ANPR fleets from the bvkm-weighted and unweighted data.

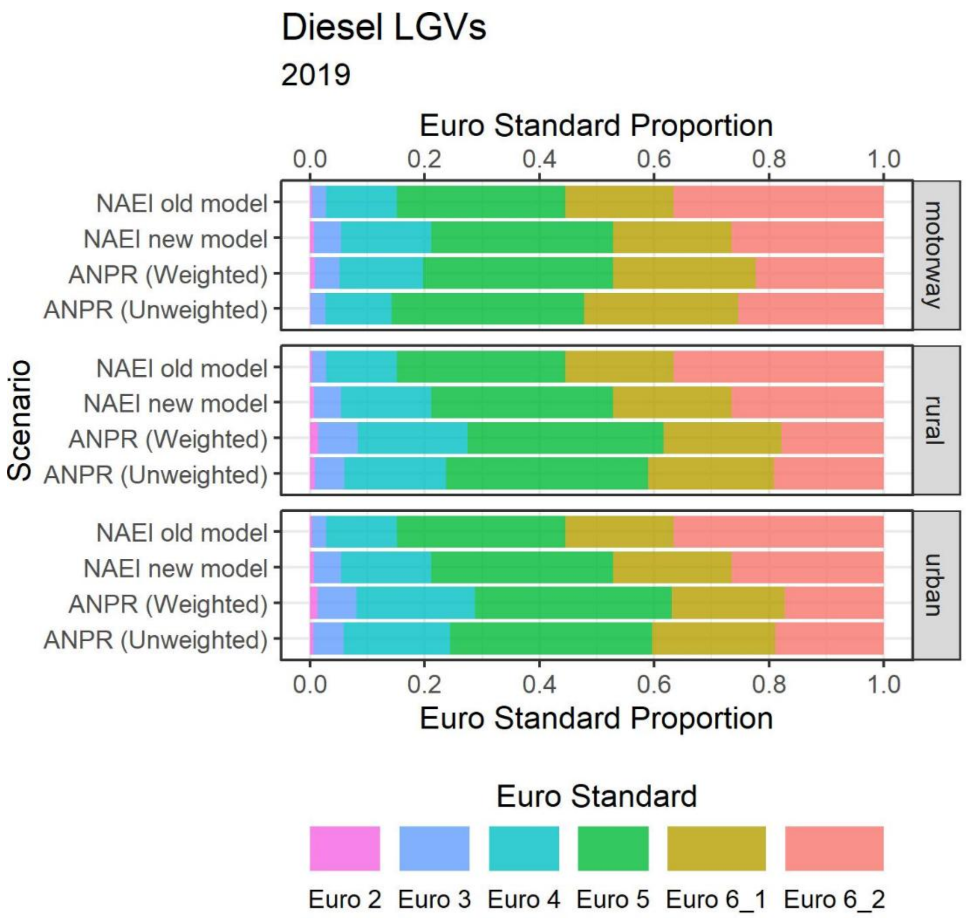


Figure 8-4 Fleet composition for diesel LGVs expressed as the fraction of vehicle km travelled by each Euro category in 2019 compared with DfT's ANPR data for the same year. NAEI old model is the Baseline referring to the fleet compositions from the current NAEI fleet turnover model. NAEI new model refers to the fleet composition from the revised fleet turnover model using survival and mileage rates at 2019 levels. The figure shows DfT ANPR fleets from the bvkm-weighted and unweighted data.

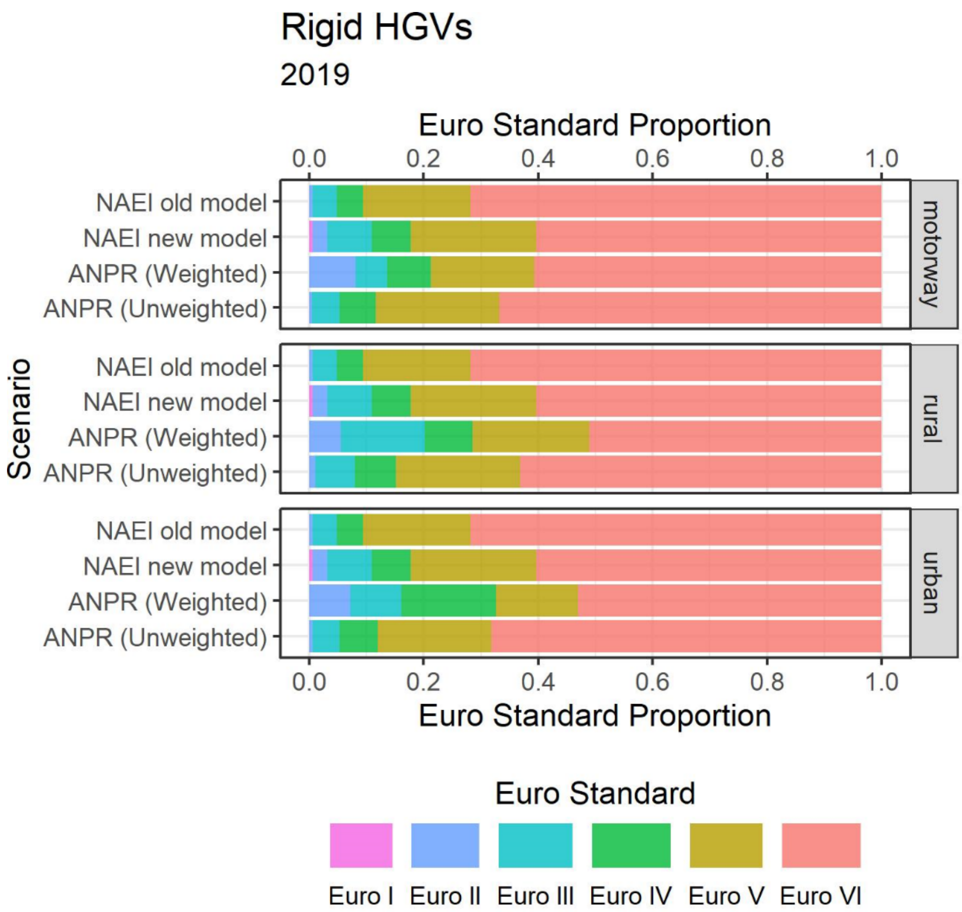


Figure 8-5 Fleet composition for rigid HGVs expressed as the fraction of vehicle km travelled by each Euro category in 2019 compared with DfT's ANPR data for the same year. NAEI old model is the Baseline referring to the fleet compositions from the current NAEI fleet turnover model. NAEI new model refers to the fleet composition from the revised fleet turnover model using survival and mileage rates at 2019 levels. The figure shows DfT ANPR fleets from the bvkm-weighted and unweighted data.

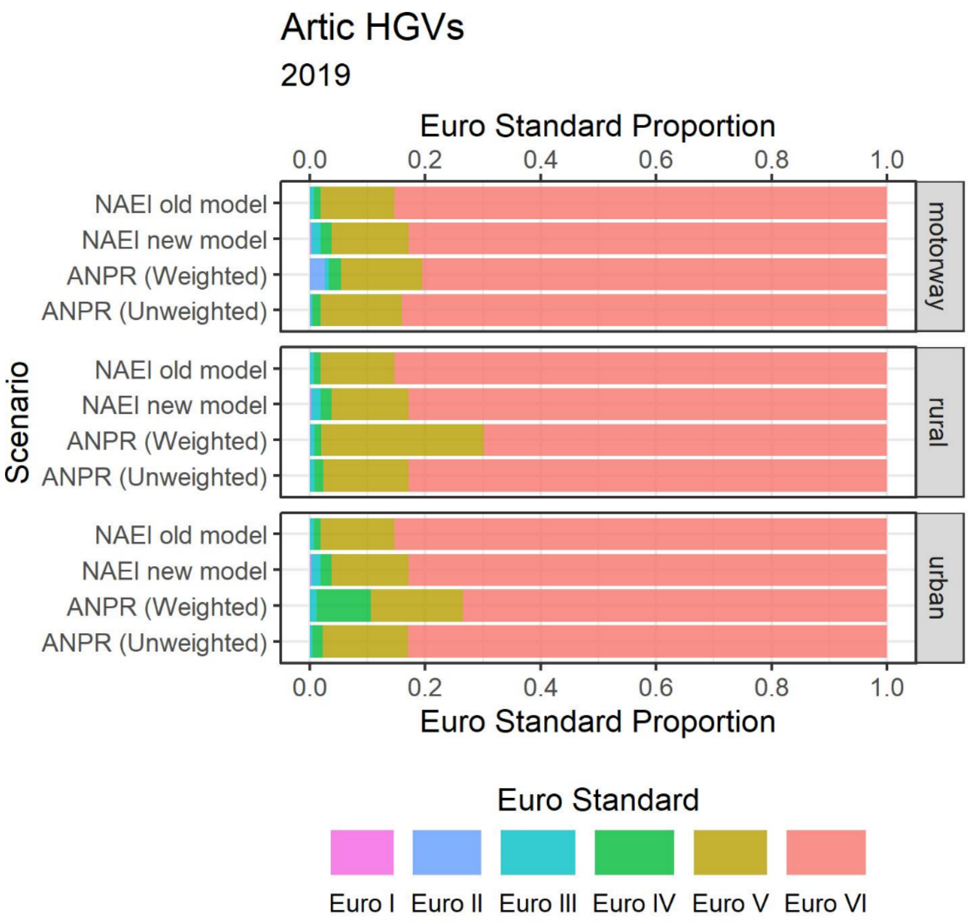


Figure 8-6 Fleet composition for artic HGVs expressed as the fraction of vehicle km travelled by each Euro category in 2019 compared with DfT's ANPR data for the same year. NAEI old model is the Baseline referring to the fleet compositions from the current NAEI fleet turnover model. NAEI new model refers to the fleet composition from the revised fleet turnover model using survival and mileage rates at 2019 levels. The figure shows DfT ANPR fleets from the bvkm-weighted and unweighted data.

8.3 COMPARING FLEET COMPOSITION DATA FOR 2017 WITH LOCAL AUTHORITY ANPR DATA

In 2019/2020, Ricardo conducted a study in the MAAQ programme to assess the potential use of localised fleet data provided by local authorities. This was part of a wider study into introducing further localised information in the Pollution Climate Mapping (PCM) model. ANPR data were received via Defra from 5 different local authority regions covering various observation periods in the calendar years 2016-2018 (Ricardo, 2020a)[15].

A key conclusion from this study was that local fleet composition from ANPR data in each of the five study areas showed that in all areas the fleet was older than the current NAEI fleet assumptions based on national datasets and that data for different sites within cities showed little variation in fleet

[15] Ricardo (2020a), "Future Evidence Programme: PCM model fleet and speed localisation scoping study" Draft report to Defra, 6th April 2020

composition within each city, but that fleets varied in composition between cities. Figure 2 from the Ricardo (2020a) report showed the variation in fleet composition for diesel cars. This is shown again in Figure 8-7 below.

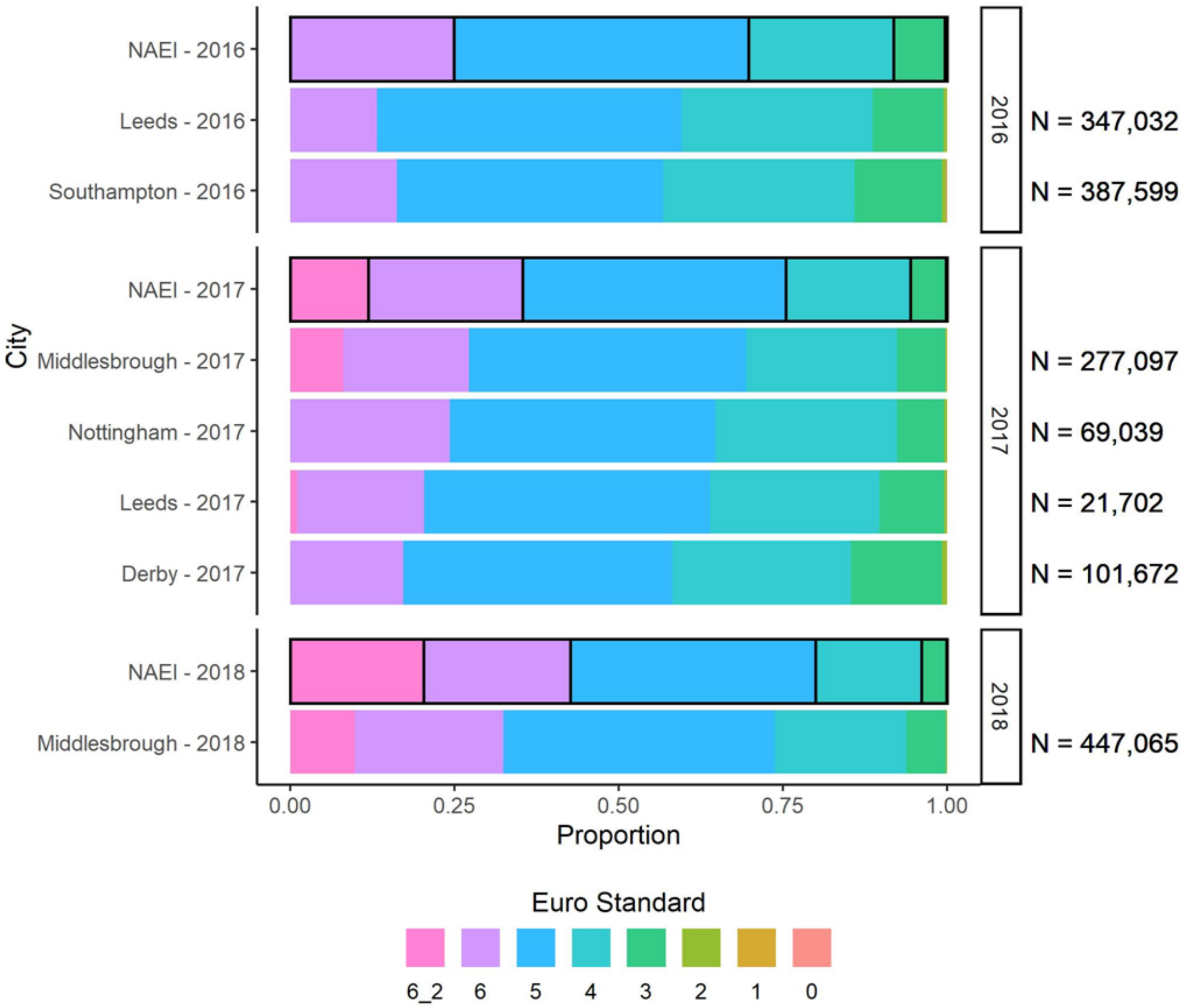


Figure 8-7 Comparison of the fleet composition for diesel cars between the current NAEI and the local city data for different calendar years (taken from Figure 2 in report by Ricardo (2020a) for Defra)

Table 8-8 show a comparison of fleets from the current NAEI fleet turnover model and the new turnover model for diesel cars using the revised survival and mileage rates for 2017 with ANPR data captured in three of the cities previously studied: Derby, Leeds and Middlesbrough in the same year. Table 8-9 shows the corresponding data for rigid HGVs.

The comparisons show that whilst the revised fleet model gives UK fleet compositions closer to the local fleet compositions than the current NAEI fleet model does, the local fleets still tend to be older. For example, the proportion of pre-Euro 5 diesel cars in the UK fleet in 2017 according to the current model is 25%, increasing to 31% for the new model, whereas values for these three cities are in the range 31-42% indicating a mostly older fleet operating in these areas. Similarly, the proportions of Euro 6 vehicles in the fleet is 35% according to the current fleet model, 31% according to the new model and in the range 17-27% in the local authority fleets. A similar situation is the case for HGVs.

There can be several explanations for these differences. Fleets can be genuinely older than the national average in these particular cities or it could be the case that it reflects the way vehicles are actually used in terms of mileage, e.g. that the decrease in mileage with increasing age of vehicle evident from the MOT data is not reflected in the way vehicles of different ages are used in local areas.

Table 8-8 Fleet composition for diesel cars expressed as the fraction of vehicle km travelled by each Euro category in 2017 compared with ANPR data observed by local authorities in the areas of Derby, Leeds and Middlesbrough for the same year. The Baseline refers to the fleet compositions from the current NAEI fleet turnover model. New model refer to the fleet composition from the revised fleet turnover model using survival and mileage rates at 2017 levels.

		2017				
		Baseline	New model	Local authority ANPR		
		UK	UK	Derby	Leeds	Middlesbrough
Diesel cars	Pre-Euro 4	0.056	0.097	0.147	0.103	0.076
	Euro 4	0.190	0.215	0.272	0.258	0.230
	Euro 5	0.400	0.374	0.410	0.435	0.422
	Euro 6_1	0.235	0.209	0.172	0.193	0.191
	Euro 6_2	0.119	0.104	0.000	0.011	0.081
	Euro 6_3	0.000	0.000	0.000	0.000	0.000
	Total	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**

Table 8-9 Fleet composition for rigid HGVs expressed as the fraction of vehicle km travelled by each Euro category in 2017 compared with ANPR data observed by local authorities in the areas of Derby, Leeds and Middlesbrough for the same year. The Baseline refers to the fleet compositions from the current NAEI fleet turnover model. New model refer to the fleet composition from the revised fleet turnover model using survival and mileage rates at 2017 levels.

		2017				
		Baseline	New model	Local authority ANPR		
		UK	UK	Derby	Leeds	Middlesbrough
Rigid HGVs	Pre-Euro IV	0.099	0.176	0.120	0.106	0.114
	Euro IV	0.080	0.106	0.182	0.268	0.176
	Euro V	0.258	0.296	0.384	0.323	0.309
	Euro VI	0.563	0.422	0.315	0.303	0.401
	Total	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**

The need in the future to model emissions and air quality nationally that take account of local differences in traffic and fleet compositions using data from ANPR observations presents a challenge when models are required to forecast future changes. Forecasting future emissions from road transport requires predictions of the future fleet composition using a fleet turnover model that accounts for changes in new vehicle sales and the gradual phasing out of older vehicles. Although local measures that introduce low emission zones restricting access to vehicles above a certain age or emission standard can be taken into account, predicting the future evolution of a baseline local fleet using national trends in new vehicle sales and activities is difficult when the local fleet appears different to the national fleet. One way around this may be to do as applied for gap filling mileage with age data for buses in Section 5.5 and use the local ANPR fleet information to fit a mileage with age profile to get a best match of the modelled fleet with the local ANPR fleet and then use this 'locally-calibrated' model to forecast the future evolution of the fleet.

9. UK EMISSIONS AND PROJECTIONS DERIVED FROM NEW FLEET TURNOVER MODEL

Using the new fleet turnover model with revised survival rates and mileage with age indices and new HGV and bus sales projections, and using the same emission factors and assumptions for current and future traffic growth and new vehicle sales (for cars and LGVs), UK road transport emissions of NO_x and PM were calculated in the NAEI emission models and the results compared with emissions calculated using current fleet turnover assumptions. In both cases (current and revised fleets), emissions were calculated using a model that incorporates the new speeds. The effect of using the new speeds relative to the old speeds (used in the 2019 NAEI submission) with the current fleet have already been shown for NO_x emissions in a separate report (Ricardo, 2021), but not for PM emissions.

This section will show the results of changing just the speeds (as previously shown for NO_x), relative to the current 2019 NAEI emission estimates, and then speeds plus revised fleet turnover model. The effect of just changing the fleet turnover model will be implied by the difference between the 'speeds plus new fleet' and 'speeds only' versions.

The changes made to fleet composition do not affect estimates of non-exhaust emissions of PM from tyre and brake wear and road abrasion. However, changes in speeds do affect the calculation of these emissions, so for completeness, this section will also show the effect of speeds on non-exhaust $PM_{2.5}$ emissions relative to current 2019 NAEI estimates using the old speeds.

All other data and assumptions used in all these comparison model runs are the same as used in the 2019 NAEI and projections. This means they are based on COPERT 5.3 emission factors, vehicle kilometre data from DfT up to 2019 and DfT's latest traffic forecasts provided in January 2021. Forecasts are all from a 2019 base year. The current methodology and assumptions made are described in the UK's latest Informative Inventory Report (IIR) for the 2019 NAEI reported in early 2021 (NAEI, 2021).

9.1 NO_X EMISSIONS

9.1.1 Changes in Emissions from the New Fleet Turnover Model

Table 9-1 shows the emission results for NO_x from the current baseline fleet model using old speeds (Base), current baseline fleet model using new speeds (Speeds) and using the new fleet turnover model and new speeds (Speeds+fleet) for 2005, 2010, 2015, 2019, 2025 and 2030.

Table 9-1. UK NO_x emissions in ktonnes from road transport for the current 2019 NAEI baseline fleet model using old speeds (Base), current baseline fleet model using new speeds (Speeds) and using the new fleet turnover model and new speeds (Speeds+fleet). All other assumptions and emission factors used in the emission calculations are the same for the three cases

ktonnes		2005	2010	2015	2019	2025	2030
Petrol cars	Base	189.5	62.7	24.6	17.1	15.4	16.3
	Speeds	174.2	59.8	24.5	17.3	15.8	16.7
	Speeds + fleet	201.0	69.1	27.9	18.2	15.9	16.8
Diesel cars	Base	87.4	104.7	129.0	128.1	74.1	38.8
	Speeds	83.5	98.1	122.3	122.4	72.0	37.9
	Speeds + fleet	84.8	100.0	124.7	121.5	77.8	43.6
Petrol LGVs	Base	7.5	1.8	0.5	0.2	0.2	0.2
	Speeds	7.0	1.7	0.5	0.2	0.2	0.2
	Speeds + fleet	7.1	2.2	0.5	0.2	0.2	0.2
Diesel LGVs	Base	64.4	60.3	94.4	99.3	41.7	21.7
	Speeds	59.9	56.1	81.8	84.5	35.0	18.3
	Speeds + fleet	61.3	57.0	80.5	78.1	39.9	21.8
Rigid HGVs	Base	78.2	54.3	30.5	14.0	3.3	2.4
	Speeds	81.1	57.4	34.0	16.5	4.2	3.0
	Speeds + fleet	91.8	66.7	41.9	21.2	6.4	3.7
Artic HGVs	Base	94.0	60.0	21.4	7.8	2.7	2.6
	Speeds	100.9	65.3	24.6	9.5	3.5	3.4
	Speeds + fleet	114.2	77.2	34.1	11.9	4.3	3.6
Buses	Base	43.0	34.9	20.4	8.9	3.1	1.7
	Speeds	43.7	35.8	21.3	9.3	3.2	1.7
	Speeds + fleet	44.5	36.7	23.2	11.6	3.8	1.3
Motorcycles	Base	1.6	1.0	0.8	0.5	0.2	0.1
	Speeds	1.4	0.9	0.7	0.4	0.2	0.1
	Speeds + fleet	1.4	0.9	0.7	0.4	0.1	0.1
All	**Base**	565.6	379.8	321.6	275.8	140.7	83.8
	Speeds	551.7	375.2	309.5	260.1	134.0	81.2
	Speeds + fleet	606.1	409.9	333.5	263.2	148.3	91.0

Figure 9-1 shows the difference in emissions between the “speeds” and “speeds + fleet” version illustrating the effect that the changes in fleet composition from the new fleet turnover model have on NO_x emissions for each vehicle type in 2005, 2019 and 2030.

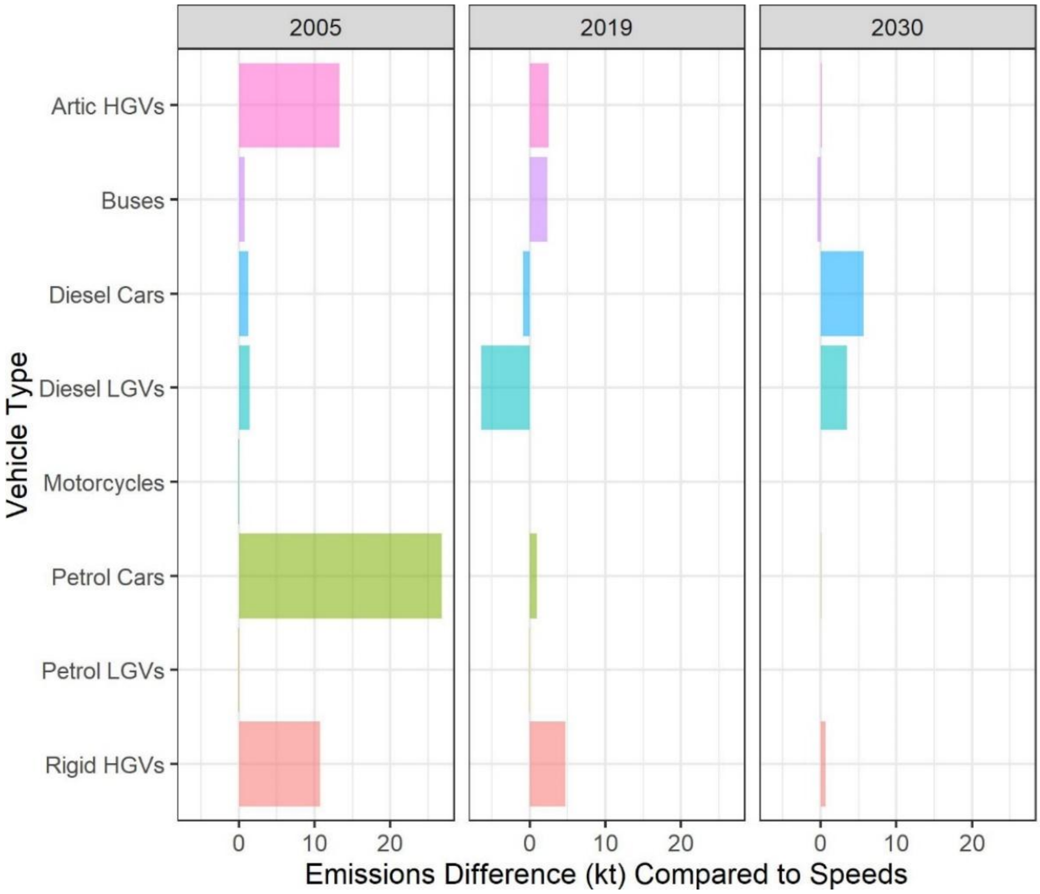


Figure 9-1 Difference in UK NO_x emissions (in ktonnes) calculated using the new speeds and fleet turnover model relative to the new speeds.

The fleet changes have led to an overall increase in emission estimates for all years in the historical inventory as can be seen from the difference between the “speeds” and “speeds + fleet” versions in Table 9-1. The differences are particularly large in the earlier part of the time-series, shown by the figures for 2005 and 2010 in Table 9-1 and more than offset the reductions shown by the new speeds relative to the current baseline (Base) in years up until 2017. However, the differences due to the fleet changes become smaller for the more recent years such that by 2018 and 2019 the increases due to the fleet changes are smaller than the reductions due to the speed changes. This means that overall, road transport emissions are higher than they were previously estimated in the 2019 NAEI up until 2017, but smaller than they were previously estimated in the 2019 NAEI for years 2018 and 2019.

One can also see that that different vehicle types make different contributions to these changes. In 2005, petrol cars and HGVs showed a particularly significant increase, but by 2019 these become much smaller and there is even a decrease in emissions from diesel LGVs to offset these increases.

In the projected years the new fleet turnover model leads to an increase in emissions compared with projections based on the current fleet turnover model. These increases exceed the reductions that are obtained by using the new speed data such that by 2030 emissions are predicted to be 7 ktonnes greater than predicted by current NAEI base projections using old speed data. All vehicle types except buses show an emission increase, but the vehicle type causing most of the change is diesel cars.

9.1.2 Understanding the Factors Causing Changes to Emission Estimates

There are several factors that are driving these changes. As shown in previous sections, there is a tendency for older vehicles to survive longer and do more mileage than previously estimated particularly in the more recent years, but the effect this has on emissions depends on the era being considered. In an era such as around 2005 the fleet was populated by vehicles meeting older emission standards which had higher emission factors than those populating the fleet in more recent years. The net effect on emissions of a change in fleet composition is influenced by the relative differences in emission factors between the Euro standards prevalent in the fleet at the time. So a relatively small change in the fleet in 2005 can have a larger impact on emissions in that year than a larger change in the fleet can have in 2019. This is quite an important factor for petrol cars.

As part of our QA/QC checks on the emission results from the detailed NAEI emissions model containing the new fleet turnover assumptions, a completely independent set of calculations was done in a more simplified form by a different member of the project team to check whether the change in NO_x emissions caused by changes in the fleet parameters was in the direction and magnitude expected. Tests were done for the years 2005 and 2019 by calculating the change in fleet-weighted emission factors for each vehicle type when the changes in fleet turnover parameters were applied, namely vehicle survival and mileage rates. Although simplified in its form, the results from these tests did confirm the changes in emissions seen from the full model and helped to explain the causes of the changes mentioned above.

The “slowdown” in vehicle turnover is responsible for the increase in emissions seen in the projected years when compared with current projections. This is a reflection of the decision made to apply a 3-year average in survival and mileage with age rates to predict the fleet going forward and is the main driver for change in emissions from diesel cars and LGVs which are now projected to decrease at a slower rate than before with the slower penetration of tighter Euro 6 standards. This is also the case for HGVs, although for these vehicles the changes in future new vehicle sales projections described in Section 6.3 also has an impact. Unlike other vehicle types, projected emissions from buses in 2030 are lower than previously predicted from the current fleet model, this being due to a greater share of buses being electrically powered than previously predicted.

Another very important factor to understand these changes in the historical inventory time-series is that the current NAEI uses a fleet which has been essentially “calibrated” against DfT’s ANPR data and the NO_x emissions shown Table 9-1 reflect this for the Baseline and “speeds” case. The new fleet turnover model has not been calibrated against ANPR data, but is based directly on the survival rates and mileage rates derived for different years in this study. A major problem with using the ANPR data in the NAEI is that data are not available for all years making it difficult to obtain a consistent historical time-series. Whilst such data is useful for a recent year, an extrapolated “ANPR correction” based on assumptions had to be used in the NAEI for earlier years to obtain as consistent a time-series as possible, but in doing so introduces greater uncertainty in estimates for earlier years in the historical time-series. In the absence of the comprehensive vehicle registration and, more particularly, mileage with age data now available from the MOT testing system, this approach was considered in the past a compromise to make best use of what evidence there was on fleet composition from the ANPR data which had been available to the NAEI.

However, the licensing and mileage data now available to us is considered far more robust and consistent across a longer time-series than has ever been the case before. We believe this makes its use preferential for the NAEI without any further ANPR calibration. Being based on a large number of records, these data do in our opinion provide a better reflection of vehicle usage by age suitable for the construction of an emissions inventory on a ***national scale*** over a consistent historical time-series and as the foundation of a fleet turnover model that can be used in predicting the composition of the fleet at national level for future projections.

It is therefore proposed not to make an 'ANPR calibration' to the fleet composition used in the NAEI in future. The differences in road transport emissions of NO_x shown in Table 9-1 reflect this decision as well as changes to the fleet turnover model used across the time-series and projections.

There is, however, still a place for using ANPR data to inform the emissions inventory. One of these is in determining variations in the percentage share of petrol and diesel cars on different road types. ANPR data has consistently shown that there is a higher share of diesel cars on motorways than on urban roads reflecting the proportionately higher mileage done by diesel cars on motorways compared with petrol cars. Such information cannot be gathered from the MOT records. Use of ANPR data from DfT for this purpose alone has been applied to split the vehicle kilometre data used in the latest emission estimates developed with the new fleet turnover model; the splits are unchanged from current values used.

Another area where ANPR can be used is in defining the composition of localised fleets in some very specific areas of interest rather than for a national roll-out. This will be an important consideration when understanding emissions and air quality in these areas and the impact of current and future measures, for example where Clean Air Zones are to be introduced. This area is currently being explored by Ricardo, in collaboration with the MAAQ project team and JAQU. The challenge here is, as alluded to previously, developing a consistent time-series in local fleet composition from a potentially different base to the national fleet determined from the fleet turnover modelling approach. A possible approach is to fit (or calibrate) a different mileage with age profile to get agreement between a modelled fleet composition and ANPR-based composition which is used to determine a time-series fleet composition trend specific to the area going forward, further modified to account for any local measures.

9.2 $PM_{2.5}$ EXHAUST EMISSIONS

Table 9-2 shows the exhaust emission results for $PM_{2.5}$ from the current baseline fleet model using old speeds (Base), current baseline fleet model using new speeds (Speeds) and using the new fleet turnover model and new speeds (Speeds+fleet) for 2005, 2010, 2015, 2019, 2025 and 2030.

Table 9-2. UK $PM_{2.5}$ exhaust emissions in ktonnes from road transport for the current 2019 NAEI baseline fleet model using old speeds (Base), current baseline fleet model using new speeds (Speeds) and using the new fleet turnover model and new speeds (Speeds+fleet). All other assumptions and emission factors used in the emission calculations are the same for the three cases

ktonnes		2005	2010	2015	2019	2025	2030
Petrol cars	Base	0.50	0.32	0.28	0.33	0.43	0.46
	Speeds	0.50	0.32	0.27	0.31	0.41	0.44
	Speeds + fleet	0.54	0.34	0.27	0.31	0.40	0.44
Diesel cars	Base	5.72	5.14	3.12	2.38	0.56	0.33
	Speeds	4.99	4.77	2.99	2.36	0.60	0.36
	Speeds + fleet	5.29	5.06	3.28	2.21	0.74	0.37
Petrol LGVs	Base	0.01	0.01	0.00	0.01	0.01	0.01
	Speeds	0.01	0.01	0.00	0.00	0.00	0.00
	Speeds + fleet	0.01	0.01	0.00	0.00	0.00	0.00
Diesel LGVs	Base	5.74	4.01	2.04	1.10	0.22	0.16
	Speeds	4.50	3.06	1.58	0.88	0.19	0.15
	Speeds + fleet	4.71	3.40	1.77	0.92	0.24	0.15
Rigid HGVs	Base	1.69	0.92	0.46	0.20	0.05	0.04
	Speeds	1.76	0.98	0.50	0.22	0.06	0.04
	Speeds + fleet	2.35	1.37	0.71	0.33	0.09	0.05

ktonnes		2005	2010	2015	2019	2025	2030
Artic HGVs	Base	1.94	0.95	0.37	0.15	0.07	0.07
	Speeds	1.96	1.00	0.40	0.17	0.08	0.08
	Speeds + fleet	2.50	1.31	0.55	0.21	0.09	0.08
Buses	Base	0.78	0.47	0.24	0.10	0.04	0.02
	Speeds	0.79	0.47	0.25	0.10	0.04	0.02
	Speeds + fleet	0.87	0.51	0.29	0.14	0.04	0.02
Motorcycles	Base	0.12	0.07	0.05	0.03	0.03	0.03
	Speeds	0.12	0.07	0.05	0.03	0.03	0.03
	Speeds + fleet	0.11	0.06	0.04	0.04	0.03	0.03
All	**Base**	16.50	11.87	6.57	4.30	1.39	1.10
	Speeds	14.63	10.65	6.03	4.07	1.40	1.12
	Speeds + fleet	16.38	12.06	6.92	4.17	1.63	1.14

Figure 9-2 shows the difference in emissions between the "speeds" and "speeds + fleet" version illustrating the effect that the changes in fleet composition from the new fleet turnover model have on $PM_{2.5}$ exhaust emissions for each vehicle type in 2005, 2019 and 2030.

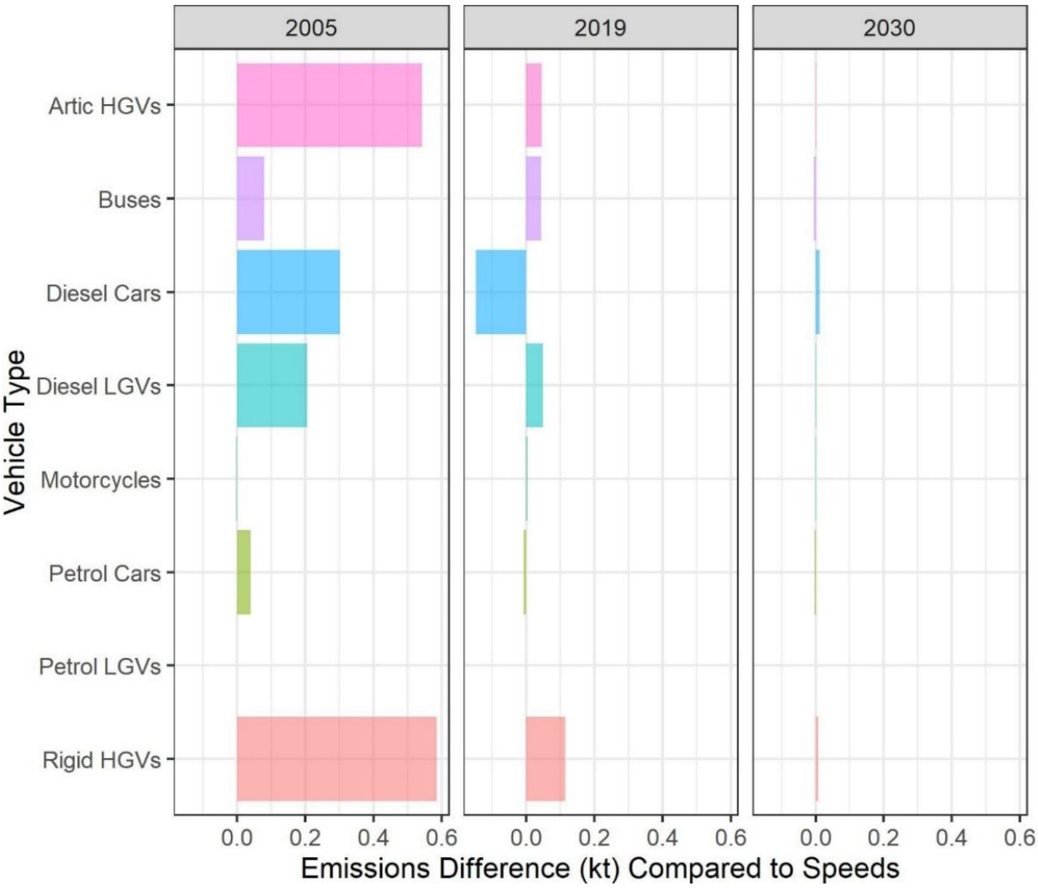


Figure 9-2 Difference in UK $PM_{2.5}$ exhaust emissions (in ktonnes) calculated using the new speeds and fleet turnover model relative to the new speeds.

As for NO_x the fleet changes have led to an overall increase in emission estimates for all years in the historical inventory as can be seen from the difference between the "speeds" and "speeds + fleet" versions in Table 9-2. The differences are largest in the earlier part of the time-series, shown by the figures for 2005 and 2010 in and Table 9-2 more than offset the reductions shown by the new speeds relative to the current baseline (Base) in years up until 2017. However, the differences due to the fleet changes become smaller for the more recent years such that by 2018 and 2019 the increases due to the fleet changes are smaller than the reductions due to the speed changes. This means that overall, road transport exhaust emissions are higher than they were previously estimated in the 2019 NAEI up until 2017, but smaller than they were previously estimated in the 2019 NAEI for years 2018 and 2019.

One can also see that that different vehicle types make different contributions to these changes. In 2005, diesel cars, LGVs, rigid and artic HGVs all showed a significant increase, but by 2019 these become much smaller and there is even a decrease in emissions from diesel cars to offset these increases.

In the projected years the new fleet turnover model leads to an initial increase in emissions compared with projections based on the current fleet turnover model, but by 2030 the increase is very small with hardly any change compared with current projections of exhaust emissions; the increase is 0.04 ktonnes.

The comments made previously for NO_x explain the changes seen in the $PM_{2.5}$ exhaust emissions.

9.3 $PM_{2.5}$ NON-EXHAUST EMISSIONS

Table 9-3 shows the non-exhaust emission results for $PM_{2.5}$ from tyre and brake wear and road abrasion combined from the current baseline fleet model using old speeds (Base) and current baseline fleet model using new speeds (Speeds) for 2005, 2010, 2015, 2019, 2025 and 2030. For this source, changing the fleet composition has no effect because the same emission factors apply to all Euro standards, technologies and fuel types for a given vehicle category, so only the effect of changing speeds is shown for completeness.

Table 9-3. UK $PM_{2.5}$ non-exhaust emissions in ktonnes from tyre and brake wear and road abrasion combined for the current 2019 NAEI baseline fleet model using old speeds (Base) and current baseline fleet model using new speeds (Speeds). All other assumptions and emission factors used in the emission calculations are the same for the two cases.

ktonnes		2005	2010	2015	2019	2025	2030
Cars	Base	4.96	4.91	5.23	5.64	6.06	6.39
	Speeds	5.22	5.17	5.50	5.94	6.38	6.74
LGVs	Base	1.04	1.12	1.31	1.48	1.60	1.73
	Speeds	1.13	1.21	1.42	1.61	1.74	1.88
Rigid HGVs	Base	0.69	0.61	0.58	0.56	0.54	0.55
	Speeds	0.76	0.67	0.65	0.62	0.61	0.62
Artic HGVs	Base	0.75	0.70	0.76	0.83	0.87	0.93
	Speeds	0.87	0.81	0.88	0.96	1.00	1.08

ktonnes		2005	2010	2015	2019	2025	2030
Buses	Base	0.26	0.26	0.23	0.20	0.20	0.20
	Speeds	0.32	0.32	0.28	0.24	0.24	0.24
Motorcycles	Base	0.03	0.03	0.03	0.027	0.028	0.028
	Speeds	0.03	0.03	0.03	0.029	0.029	0.030
All	**Base**	7.73	7.62	8.14	8.74	9.29	9.84
	Speeds	8.32	8.21	8.77	9.40	10.00	10.59

The change in speeds leads to an increase in non-exhaust emissions of PM from all vehicle types and by similar amounts across all years, though going forward in time to 2030, the increases get somewhat larger. The increase in non-exhaust emissions due to the new speeds increases from 0.66 ktonnes in 2019 to 0.75 ktonnes in 2030 compared with current NAEI estimates. It should be noted that the methodology for estimating non-exhaust emissions taken from the EMEP/EEA Emissions Inventory Guidebook, including the effect of speeds, is highly uncertain. Nevertheless, based on this approach, the effect of changing speeds on the non-exhaust emissions of $PM_{2.5}$ outweighs the effect of changes in speed and fleet combined on exhaust emissions since 2015.

9.4 SIGNIFICANCE OF FLEET COMPOSITION CHANGES TO THE NATIONAL TOTALS AND COMPLIANCE WITH EMISSION CEILINGS

It is important to consider the impact the changes to both the fleet turnover model and speeds have had on emissions in the context of the national totals and compliance with emission ceilings set under the UK National Emissions Ceilings Regulation 2018 (NECR) and the Gothenburg Protocol under the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (CLRTAP).

9.4.1 NO_x Emissions

Table 9-4 shows the current UK national totals for NO_x emissions covering all sources (NAEI 19 Base) and revised national totals using the new fleet turnover model and new speeds (Speeds+fleet).

Table 9-4 UK total emissions of NO_x from all sources in ktonnes for the current 2019 NAEI and projections based on the current fleet model using old speeds (NAEI19 Base) and using the new fleet turnover model and new speeds (speeds+fleet).

ktonnes	NAEI19 Base	NAEI19 with speeds+ fleet
2005	1731.3	1771.8
2010	1226.6	1256.7
2011	1152.0	1175.3
2012	1178.0	1197.9
2013	1119.0	1135.2
2014	1047.4	1062.0

ktonnes	NAEI19 Base	NAEI19 with speeds+ fleet
2015	1015.5	1027.4
2016	921.0	932.6
2017	891.7	902.2
2018	866.3	864.3
2019	839.1	826.5
2025	665.5	673.1
2030	580.8	588.0

The UK currently exceeds the NECR 2010 ceiling for NO_x of 1167 ktonnes in 2010 and 2012 and the Gothenburg Protocol ceiling of 1181 ktonnes in 2010. Under the 2012 amendment to the Gothenburg Protocol (and subsequently transposed under the NECR) a mechanism has been established that allows countries to apply for an “adjustment” to their national emission inventories incorporating the current best science emission estimates for the purpose of determining an emissions total which can be used for compliance checking against the set commitments. This is in recognition of the fact that inventories need to be based on “best science” and unforeseeable improvements can occur in the scientific understanding of the emission estimates for sources. This has been particularly the case for road transport with changes occurring in emission factors recommended for inventories in the EMEP/EEA Emissions Inventory Guidebook, for example. Significant changes have been made since the 2010 limits were set for NO_x emissions from diesel vehicles. The UK has therefore previously applied for adjustments to its NO_x emissions inventory for 2010 and 2012 under the Adjustment Mechanism on this basis. The UK’s adjustment application has been reviewed and accepted by the CLRTAP’s Executive Body for the purpose of compliance with the Gothenburg Protocol, and by the European Commission for the purpose of compliance with the NECD. In July 2018 the NECR transposed all NECD requirements, including 2010 emission ceilings and the adjustment mechanism, into UK law.

The changes to the road transport inventory as a consequence of the speed and fleet turnover model improvements have had the effect of increasing national total NO_x emissions in years 2010-2017 to an extent which it now means the UK exceeds the NECR ceiling in 2011 as well as 2010 and 2012. If implemented in the next version of the NAEI, it will therefore be necessary to apply for adjustments for 2010, 2011 and 2012, assuming changes to other sources in the inventory have no effect on estimates for these years. By following the normal Adjustment Mechanism permitted, this should not pose a problem. The changes that have occurred for other years have not led to exceedances of the 2010 ceilings.

The Gothenburg Protocol and NECR also set national emission reduction commitments to be achieved in 2020 and beyond and further, more stringent targets for 2030 and beyond. These are set as percent reduction on 2005 baseline emission: 55% reduction for 2020 and 73% for 2030 and beyond. Current NAEI projections suggest the 2020 targets should be met based on the 55% reduction target on the current inventory estimates for 2005. The changes to the road transport inventory as a consequence of the speed and fleet turnover model improvements will have the effect of increasing the 2005 baseline and will lead to increases in projected emissions for 2025. Overall, this does not change the prediction that the 2020 emission reduction targets for NO_x should be met. Other projected years have not yet been modelled and the inventory for the year 2020 itself is expected to have been influenced by COVID restrictions affecting emissions from a number of sources, including transport.

Current NAEI projections suggest the 2030 targets based on the 73% reduction target on the current inventory estimates for 2005 will not be met without further actions taken. The changes to the road transport inventory as a consequence of the speed and fleet turnover model improvements will have the effect of increasing the projected emissions for 2030, so this situation does not change.

9.4.2 $PM_{2.5}$ Emissions

Table 9-5 shows the current UK national totals for $PM_{2.5}$ emissions covering all sources (NAEI 19 Base) and revised national totals using the new fleet turnover model and new speeds (Speeds+fleet). This includes the impact of these changes on both exhaust and non-exhaust emissions.

Table 9-5 UK total emissions of $PM_{2.5}$ from all sources in ktonnes for the current 2019 NAEI and projections based on the current fleet model using old speeds (NAEI19 Base) and using the new fleet turnover model and new speeds (speeds+fleet).

ktonnes	NAEI19 Base	NAEI19 with speeds+ fleet
2005	129.2	129.6
2010	122.1	122.9
2011	110.1	111.0
2012	115.5	116.4
2013	118.2	119.3
2014	111.7	112.8
2015	111.4	112.3
2016	109.2	110.3
2017	109.7	110.8
2018	111.8	112.6
2019	108.7	109.2
2025	102.0	102.9
2030	101.1	101.9

The NECR and Gothenburg Protocol have not set ceilings on $PM_{2.5}$ emissions to be met from 2010. However, they do set national emission reduction commitments to be achieved in 2020 and beyond and further, more stringent targets for 2030 and beyond. These are set as percent reduction on 2005 baseline emission: 30% reduction for 2020 and 46% for 2030 and beyond. Current NAEI projections suggest neither the 2020 targets nor 2030 targets will be met without further actions being taken. The changes to the road transport inventory as a consequence of the speed and fleet turnover model improvements are relatively small and mainly due to the effect of the changes in speeds on the non-exhaust emissions. These will have the effect of increasing the 2005 baseline and will lead to increases in projected emissions for 2025 and 2030.

10. VALIDITY OF THE FLEET TURNOVER MODELLING APPROACH FOR THE INVENTORY

The development and application of the fleet turnover model described in this report is tailored to make the best use of data currently available in the UK for estimating and forecasting emissions from the road transport sector at a ***national*** level. It has the benefit of being consistent with transport statistics published and used by DfT for other purposes. It is also optimised for producing the necessary fleet composition and emission outputs for use in air quality models used for Defra's national policy development and assessments. A key question though can be asked as to whether the model and approach conform with current guidelines for reporting national emissions inventories under the requirements of the UNECE CLRTAP, NECR and UNFCCC and how they compare with methods used by other countries in Europe.

10.1 COMPLIANCE WITH EMISSION REPORTING GUIDELINES

The method used in the NAEI for road transport follows the most detailed Tier 3 approach in the EMEP/EEA Emissions Inventory Guidebook for reporting air pollutant and greenhouse gas emissions. A Tier 3 approach uses detailed vehicle activity data and emission factors in terms of vehicle category and sub-category and operational mode defined in terms of average speed or traffic situation. The Guidebook simply says emission [g] = emission factor [g/km] × number of vehicles [veh] × mileage per vehicle [km/veh) but without specifying where numbers of vehicles and mileage per vehicle data should come from, acknowledging that data availability varies across countries. The Guidebook states that vehicle statistics should be readily available from national statistical offices for all countries, but are often at an aggregated level with little information referring to the age and technology distribution as well as not always having vehicle activity data in a consistent form. The Guidebook permits inventory compilers to use whatever they consider the best data available according to national circumstances so long as it achieves the principles of Transparency, Completeness, Consistency, Comparability and Accuracy in the inventory. A key principle here is that of consistency in that any data used should enable a consistent time-series of emissions to be developed while using data from national statistical sources ensures these principles are followed.

The Guidebook states that the time series on fleet evolution and annual new vehicle registrations can be used to derive estimates of fleet composition in specific years and used in conjunction with "appropriate assumptions" for annual mileage of different vehicle categories. The UK has a wealth of statistical information on road transportation and in this respect, the fleet turnover model developed here meets these national inventory requirements by using a combination of detailed vehicle licensing data, MOT and other mileage data from surveys conducted by DfT and traffic data (vehicle kilometres) by vehicle and road type available over a consistent time-series. The improvements described here, particularly in terms of the annual mileage with age profiles and survival rates developed for different years, lead to a fleet turnover model that is far less dependent on assumptions. It also allows projections to be made on a basis consistent with historical years using assumptions on new vehicle registrations (sales) in future years.

10.2 DEVELOPMENT AND USE OF FLEET COMPOSITION FOR INVENTORIES IN OTHER COUNTRIES IN EUROPE

All countries in Europe have access to national vehicle registration records for use in their inventory compilation. However, our experience as Expert Reviewers for the NECD and UNECE CLRTAP on air pollutant emission inventory submissions by Member States has found that the level of detail available to countries is variable and not always as comprehensive as available in the UK. Some countries do have good sources of fleet and mileage data and this section reviews the methods used by six such countries in the EU, as explained in the countries' official Informative Inventory Reports (IIR) which are all available at https://www.ceip.at/status-of-reporting-and-review-results/2021-submission. The countries are Germany, France, Austria, the Netherlands, Denmark and Sweden. Each of these countries uses vehicle registration data directly in their emission models and all have access to annual mileage data from vehicle inspection programmes, similar to the MOT system in the UK. However, the data may be used in subtly different ways to suit national situations, although the IIRs do not always give great detail on how they are used.

The IIR for **Germany** states that vehicle registration data and data from "special surveys" are used. This includes data from a 2002 mileage survey and a 2005 "Road Transport Census", as well as data from a 2008 research report. The information is used in Germany's emissions model TREMOD. To find out further details it is necessary to access links to other reports some of which are written in German.

France uses its own model OPALE in conjunction with COPERT. The French IIR refers to the country's vehicle registration data and previous reports by INRETS on evolution and usage of the fleet. Statistics for light duty and heavy duty vehicles are used and reference is made to statistics from "Technical Inspections" for passenger vehicles; it is not clear what data these refer to, but it is likely to be annual mileage data. The variation in average annual mileage according to the age of the vehicles is taken into account, according to a report published in 2013. Mileage is distributed between urban, rural and motorway roads with reference speeds. Although not clear from the information in the IIR, it appears that initial calculations using mileage and fleet information are done in OPALE, then these parameters are optimised through an iterative process in COPERT to obtain an energy balance with fuel sales data.

Austria uses vehicle registration data split into detailed layers and takes annual mileage data from vehicle inspection programmes for cars, LGVs, buses and motorcycles. For HGVs, mileage data are taken from a traffic model informed by growth factors from traffic counts. Age dependent functions are used in a fleet turnover model. Emissions and fuel consumption are calculated from input of these data in their model NEMO and, like the inventory for France, further iteration steps are taken to align the detailed kilometres driven with national fuel sales data.

The Netherlands uses a set of detailed vehicle registrations data and mileage data taken from odometer readings at vehicle inspection programmes. A national model is used to distribute the vehicle kilometres travelled between urban, rural and motorway roads. A further, more detailed split of the vehicle kilometres between fuel type and vehicle age is done based on ANPR data on different road types. It is not clear for how many years the ANPR data are available for.

Denmark has a very clear description of the vehicle fleet composition in its IIR. It uses a detailed set of vehicle registration data which includes each vehicle's Euro emission standard identification. Again, vehicle inspection programmes are used as a source of annual mileage data for all years back to 1985. A more detailed mileage matrix from these records for the year 2008 is used to provide a further split by vintage to determine how mileage changes with vehicle age. Traffic monitoring data are used to split the mileage between urban, rural and motorway roads. The respective average speeds on these roads are taken from the Danish Road Directorate, with reference given to a report published in 1998, but it is not clear whether the speeds have been updated since then.

Sweden uses national fleet information from vehicle registrations datasets divided into vehicle segments and sub-segments. Vehicle inspection programmes are used to derive mileage as a function of vehicle age. The overall vehicle kilometres done on roads in Sweden are derived from traffic measurements in combination with a national mileage model using vehicle registrations and annual mileage data. The fleet and vehicle activity data are used in the HBEFA model to calculate emissions. This uses a traffic situation approach to define mode of vehicle operation so various statistics and trip information are used to distribute the vehicle kilometres travelled between the various traffic situations on Sweden's road network.

10.3 DIFFERENCES WITH THE UK APPROACH

Although all these countries use vehicle registration and mileage data mostly from vehicle inspection records in determining the vehicle fleet and its activities, what is different with the UK approach described in this report is how the mileage data are used. For the majority of cases, it seems that vehicle kilometres are obtained by multiplication of the number of vehicles (sub-divided by category) x annual mileage. This is different to the NAEI approach where annual vehicle kilometres travelled by vehicle and road type come directly from DfT's statistics derived from its annual traffic census with annual mileage data for each vehicle type from MOT records only used to distribute the vehicle kilometres by age using the profiles described in Section 5. Some countries do align their vehicle kilometre data with traffic measurements of some sort, so there may be equivalence with the UK approach in some cases. It is not always clear whether a full and detailed set of mileage data broken done by vehicle age are available in countries for every calendar year such as used here, for example that may not be the case for Denmark.

The advantages of the UK approach in using DfT's vehicle kilometre (vkm) data directly and then sub-dividing it into the different age categories are several fold:

- the vkm data from DfT is already split by road and area type which would not be possible just from MOT mileage records, although the Netherlands do use ANPR data to get a road type split.
- the emission trends produced from the vkm data will be harmonised with the vkm data used for other purposes in government
- the vkm data are consistent with the Annual Average Daily Flows (AADFs) provided by DfT for each road link on the national road network from the traffic census each year. These are also used by the NAEI for mapping the emissions
- the mileage with age and vehicle survival rates derived from historical trends can be used in a fleet turnover model to predict, with certain assumptions, the fleet in future years on a consistent basis. It is not clear how other countries make such fleet predictions, although the IIR for Austria does refer to use of survival rate functions.
- the vkm data provided by DfT for historic years are consistent with the format of data that DfT provides for future years used for the NAEI emission projections. These are from DfT's latest traffic forecasts and are given as vkm by vehicle, road and area type.

10.4 FUEL USED VS FUEL SOLD

A common theme in the approaches used in all these countries is that the activity data (vkm) used in calculating emissions and fuel consumption by detailed vehicle category, however that is done, are normalised to national fuel sales. This is a requirement for official reporting of national inventories and is essentially for accounting purposes and ensuring consistency across all countries and a net energy balance, particularly important in the calculation of greenhouse gas emissions. The issue also becomes important for smaller countries and those with much cross-border movement of traffic. However, the Guidelines for inventory reporting do permit countries to ***also*** (but not instead of) report emissions on a fuel used basis, i.e. according to vehicle activity without reconciling with fuel sales.

The UK submits both types of inventories, one based on fuel used, directly using vehicle km data, and one based on fuel sold where the fuel used inventory is further normalised to UK fuel sales. The fuel used version of the inventory is preferred for application in air quality modelling and assessments and for projections. This is for several reasons, as explained in the IIR.

Firstly, total national fuel sales of petrol and diesel (and other fuels used for road transport) in the UK are provided each year in the Digest of UK Energy Statistics (DUKES) published by BEIS, but these are not given by vehicle type. The NAEI calculates fuel consumption by vehicle, fuel and road type using the fleet information, vehicle kilometre data and fuel consumption factors and compares these ‘bottom-up’ estimates of total fuel consumed with the figures in DUKES. The agreement fluctuates between years but is between 1-10% across all years. It is not known which vehicle types may be causing the difference, probably all are to various extents reflecting uncertainty in the different parameters and approach used. However, when applying a normalisation factor equally to all vehicle types of the same fuel type to align with the totals given in DUKES, it can lead to trends on an individual vehicle type basis which do not align with trends expected from the vkm data alone. Our experience has been that this causes difficulties with parts of government using the vkm data for other purposes when there appears to be a lack of consistency.

Moreover, the normalisation step forces a break in the link between emissions and traffic flow data used for mapping purposes and other local scale assessments, whilst emission projections are also based on DfT’s traffic forecasts on a vehicle, area and road type basis.

Emissions shown in this report are taken straight from the emissions model using the fleet turnover approach described, combined with DfT’s vehicle kilometre data and COPERT speed-related emission factors, just as they have in the past. This will continue to form the basis of emissions data used in mapping, in modelling done by the PCM and for projections. However, we will continue to also produce an inventory version which will be normalised to fuel sales data in DUKES for reporting purposes.

10.5 CONCLUSION ON APPROACH VALIDITY

Our conclusion from this review is that the approach used to develop and utilise a fleet turnover model in the way described in previous sections of this report for the UK emissions inventory is valid and in compliance with international reporting guidelines. It is also consistent with and has certain advantages over the approaches used in other countries in that it makes full use of DfT’s traffic data, vehicle licensing statistics and MOT mileage records, enabling a consistent time-series of emission estimates to be made for the UK, both historically and for forward projections, and consistent spatially-resolved maps of emissions for air quality modelling purposes.

However, it should be emphasised, as is the case with inventories reported by other countries, that the approach is really tailored to provide an inventory of emissions from the road transport sector on a national scale through use of centralised, national statistics and datasets. It cannot, on its own, be expected to represent the fleets at local level, although local traffic levels are accounted for in the mapping of emissions by use of AADFs. Whilst local ANPR data can be used to indicate the variation in fleet compositions locally compared with the national average represented by the current fleet turnover model, such information is not available over a full time-series, i.e. it is normally only available for a recent year. However, as mentioned in Section 9.1.2 the NAEI is exploring this issue with Defra, aware of the increased importance of local differences in fleet compositions for modelling air quality and understanding the impacts of local measures.

11. SUMMARY AND CONCLUSIONS

A new and comprehensive set of vehicle licensing and MOT mileage data provided by DfT has been analysed, covering years between 2007 and 2019 (licensing data back to 1994 and MOT data also available for 2020). These have been used to develop revised vehicle survival rate and mileage with age profiles that vary by year and have been used to update the NAEI's fleet turnover model which currently uses a fixed profile based on data from 2010/11. Data from alternative sources were used to fill gaps in the mileage with age profiles, in particular for HGVs where mileage data from the Continuing Survey of Road Goods Transport (CSRGT) were provided by DfT, though only for the year 2019. Data from the National Travel Survey were used to fill mileage data gaps for passenger cars less than 4 years old, while anonymised ANPR were used to fill mileage with age gaps for diesel LGVs under 4 years old and for buses of all ages, all these data coming from sources at DfT.

Trends in these profiles could be extended out to vehicles up to 24 years in age, further than previously possible. The new profiles are similar in form from that currently used, showing a reduction in survival rate and annual mileage with increasing age of vehicle, but at rates that have slowed in recent years indicating that older vehicles of almost all types are surviving longer and doing greater mileage now than in the past. The exception is with HGVs where vehicle registrations suggest fewer older vehicles are surviving.

The survival rates and mileages for older vehicles are higher in recent years than currently assumed in the NAEI fleet turnover model. A new fleet turnover model has been constructed using the new year-dependent survival rates and mileage with age profiles developed from the DfT data to determine fleet composition in terms of the fraction of vehicle kilometres (vkm) in the UK done by vehicles complying with each Euro standard. The model now indicates that a larger share of the vehicle kilometres are done by older vehicles complying with earlier Euro emission standards than is currently estimated by the model. For example, in 2019, 18.4% of vkm done by petrol cars were estimated to be done by pre-Euro 5 cars in the current model, but this has increased to 32.8% in the new model, with consequent decreases in the proportions for Euro 5 and 6 cars. For diesel cars in 2019, 16.3% of vkm were estimated to be done by pre-Euro 5 cars in the current model, but this has increased to 23.7% in the new model.

The fleet turnover model has also been used to develop new fleet composition projections to 2030. To do this, the same new vehicle sales forecasts provided by DfT were used for passenger cars and LGVs but new forecasts were used for HGVs and buses previously unavailable to the NAEI. These came from analysis of a database of an industry market research organisation in the case of HGVs covering heavy duty engine production and from internet searches on industry sources in the case of buses which included the uptake of electric buses. Following our previous work and discussions with officials at DfT, an agreement was made to apply a 3-year average of the survival rates and mileage with age profiles for the years 2017-2019 to predict fleet turnover for future years; this assumption can be readily changed in the model. The new vehicle sales forecast assumptions and survival rates and mileage with age profiles were used to calculate fleet compositions for 2025 and 2030.

The fleet compositions derived from the fleet turnover model for 2019 have been compared with ANPR data for different vehicle and road types provided by DfT for the same year. For all vehicle types there is a tendency for the ANPR to show a somewhat older fleet than is implied by the fleet turnover model, although the agreement is better with the model based on the new survival and mileage rates than the current model. The differences between the ANPR fleets and the model fleets vary by road type; the model refers to the fleets across the whole of the UK and does not provide different fleets for different road types. The differences between the model and ANPR fleets on urban roads tends to be larger for diesel LGVs and HGVs than for passenger cars; the differences tend to be smaller on motorways. Similar conclusions were drawn by comparisons with fleets derived from local authority ANPR data in a previous study.

The revised fleet turnover model was used to estimate current and future NO_x and $PM_{2.5}$ emissions from UK road transport. The calculations were done in the NAEI road transport emissions model which also incorporated new speed data described in a previous report. Results of changing just the speeds (as previously shown for NO_x), relative to the current 2019 NAEI emission estimates, and then speeds plus revised fleet turnover model were shown.

The fleet changes have led to an overall increase in NO_x emission estimates for all years in the historical inventory compared with a version where only the speeds were changed. The differences are particularly large in the earlier part of the time-series mainly due to changes in petrol car and HGV emissions and more than offset the reductions shown by the new speeds relative to the current baseline (Base) in years up until 2017. By 2018 the differences due to the fleet changes become smaller such that overall road transport emissions are higher than they were previously estimated in the 2019 NAEI up until 2017, but smaller than they were previously estimated in the 2019 NAEI for years 2018 and 2019. In the projected years the new fleet turnover model leads to an increase in emissions compared with projections based on the current fleet turnover model. The slowdown in fleet turnover carried through to future years is responsible for the increase in emissions seen in the projected years when compared with current projections combined with the change in assumptions in new HGV and bus vehicle sales

The fact that the new fleet turnover model affects emissions to a different extent in different parts of the time-series is partly due to the magnitude of emission factors for the different Euro categories of vehicles prevalent in the fleet at different times. Another explanation for the differences is that the current inventory uses a fleet calibrated against ANPR data from DfT, but these are only available for certain years meaning it difficult to derive a consistent historical time-series in fleet evolution. The new fleet turnover model is not calibrated but is based directly on the survival rates and mileage rates derived for different years in this study. Being based on a large number of records, these data do in our opinion provide a better reflection of vehicle usage by age suitable for the construction of an emissions inventory on a ***national scale over a consistent historical time-series*** and as the foundation of a fleet turnover model that can be used in predicting the composition of the fleet at national level for future projections.

It is therefore proposed not to make an 'ANPR calibration' to the fleet composition used in the NAEI in future. However it is recommended that ANPR data are continued to be used for defining the share of petrol and diesel cars on different road types and in defining the composition of localised fleets in some very specific areas of interest rather than for a national roll-out. The use of ANPR data to determine a localised fleet composition is becoming a priority for local assessments and air quality modelling, but will need to be done alongside a fleet turnover model modified to capture differences between the local fleet and national fleet so it can be used to develop a consistent time-series in emissions from road transport within the local area. This does present a challenge, but an approach has been suggested to tackle this by calibrating a mileage with age profile in the fleet turnover model to fit the calculated fleet to the localised one which can then be used to calculate the local fleet going forward.

The fleet changes have led to an overall increase in exhaust emission estimates for $PM_{2.5}$ with the differences largest in the earlier part of the time-series. The increases become smaller in more recent years and are outweighed by reductions due to the speed changes. The new fleet turnover model leads to only a very small increase in exhaust emission estimates for 2030.

Non-exhaust emissions of $PM_{2.5}$ now make a larger contribution to total emissions from the road transport sector than exhaust emissions but are not affected by changes to fleet composition. **However,**

changes to speeds have led to an increase in non-exhaust emissions by about 0.6 to 0.8 ktonnes across all years.

The significance of these changes have been considered in the context of their impact on national totals and compliance with national emission ceilings under the UK National Emissions Ceilings Regulation 2018 (NECR) and the Gothenburg Protocol under the UNECE CLRTAP. The changes made to the fleet turnover model combined with changes to speeds have increased the national inventory to the extent that the UK will now exceed the NECR ceiling in 2011 as well as 2010 and 2012. The UK will be able to apply for an adjustment to these emission estimates for 2011 as permitted under the Adjustment Mechanism, and which it currently does for 2010 and 2012.

The fleet and speed changes have not changed the status of the UK with regard to its future predictions for compliance with 2020 and 2030 emission reduction targets for both NO_x and $PM_{2.5}$. Increases in overall $PM_{2.5}$ emissions from exhaust and non-exhaust processes predicted for 2025 and 2030 are 0.94 and 0.79 ktonnes, respectively, compared with current projections for these years.

The new fleet turnover modelling approach was also considered in terms of its compliance with current guidelines for reporting national emissions inventories under the requirements of the UNECE CLRTAP, NECR and UNFCCC and how it compares with methods used by other countries in Europe. Our review concludes that the approach is in accordance with guidelines. It is also consistent with and has certain advantages over the approaches used in other countries in that it makes full use of DfT's traffic data, vehicle licensing statistics and MOT mileage records, enabling a consistent time-series of emission estimates to be made for the UK, both historically and for forward projections.

In conclusion:

- **We recommend that the new vehicle survival and mileage rates, varying by year, are used in the NAEI's fleet turnover model and updated annually with new vehicle registration data and MOT mileage data provided by DfT.**

- **We recommend that the new NAEI fleet turnover model is also used in projecting future emissions with assumptions on new vehicle sales confirmed annually with DfT as well as confirmation or otherwise on use of survival rates and mileage with age rates carried forward to future years**

- **We conclude that fleets derived from local ANPR data are always likely to show differences with the national fleet derived from trends in national statistical sources. This should not prevent the fleet turnover approach described in this report being used for the NAEI and projections on a national scale, but will require further analysis and potential adjustment in certain parameters such as mileage where the evolution of a fleet needs to be modelled on a local scale**

12. REFERENCES

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- Statistician, Road Freight Statistics
- Statistician, Vehicles, Drivers and Access to Services Statistics, Travel and Environment Data and Statistics (TRENDS) Division

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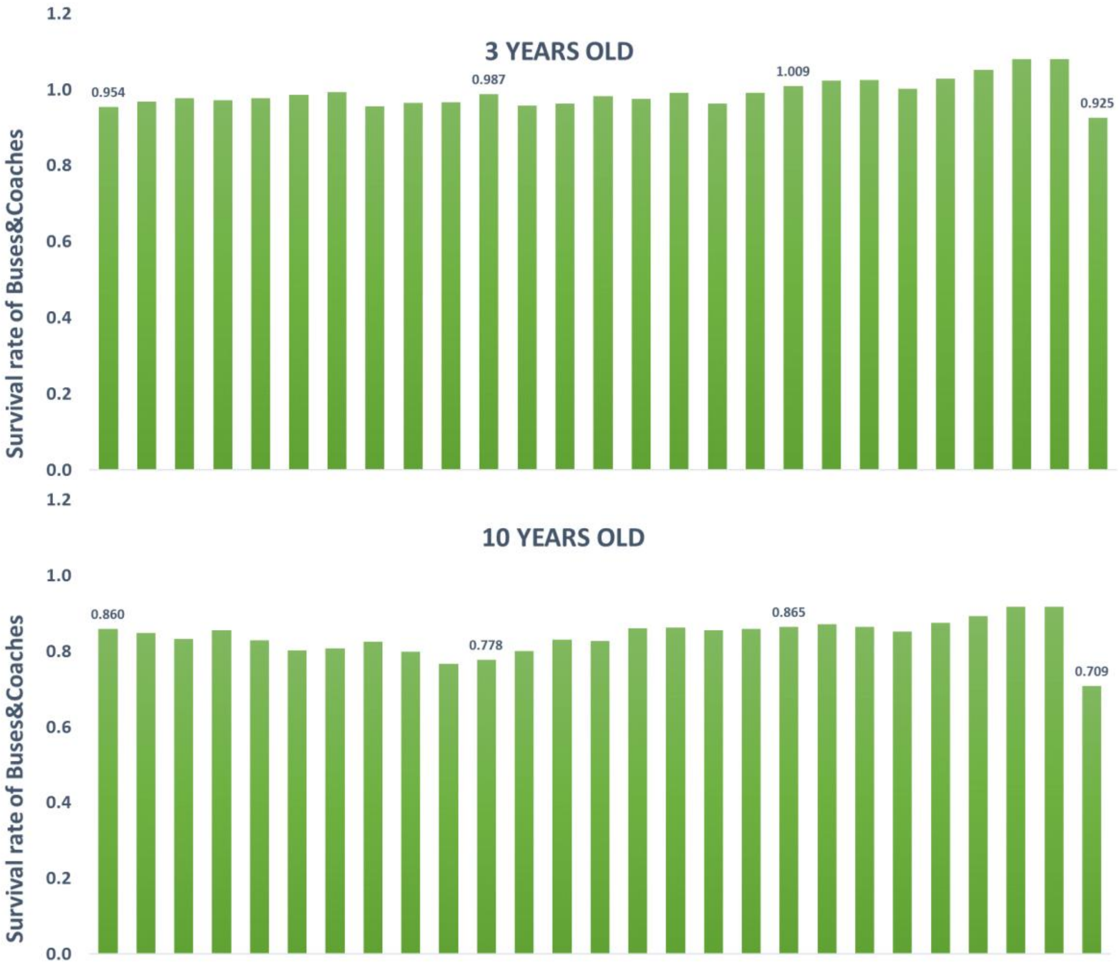
APPENDICES

APPENDIX 1 – ANALYSIS OF VEHICLE LICENSING DATA AND SURVIVAL RATES FOR BUSES AND COACHES, AND MOTORCYCLES

A.1 Analysis of Vehicle Licensing Data and Survival Rates for Buses & Coaches and Motorcycles

A.1.1 Buses & Coaches

Buses & coaches follow the same behaviour as cars and diesel LGVs, with older bus vehicles tending to survive more in recent years than they did in earlier years, as shown in Figure 13-1. The survival rates for older buses are tending to be higher than currently assumed in the NAEI.



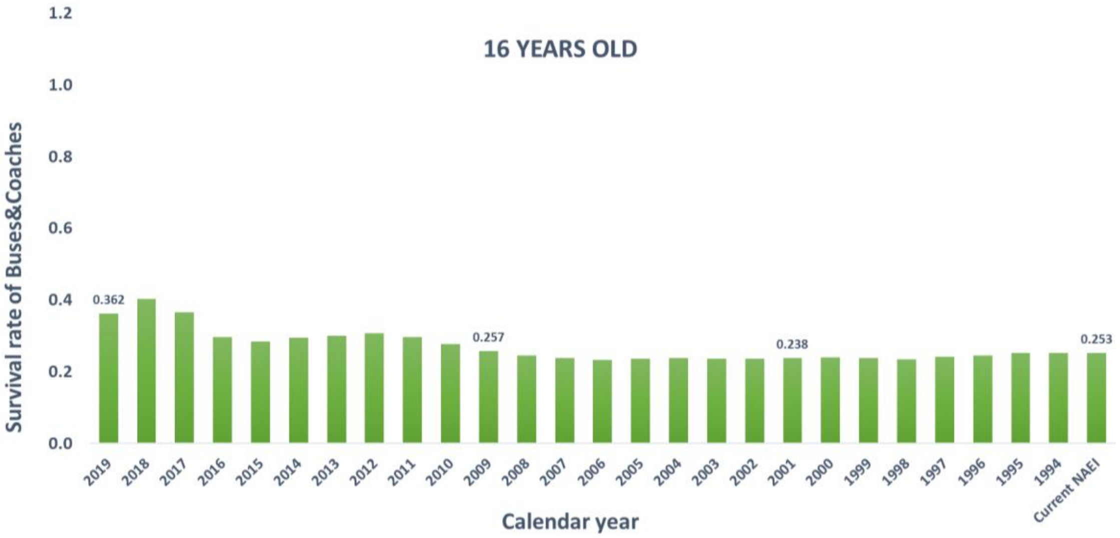


Figure 13-1 Year-dependant survival rates for 3, 10 and 16 years old buses & coaches for all calendar years compared against the current NAEI rate

A.1.2 Motorcycles

From Figure 13-2 to Figure 13-6, year-dependant survival rates for 3, 10 and 16 years old motorcycles per engine size are presented.

A.1.2.1 M/cycles <= 50cc

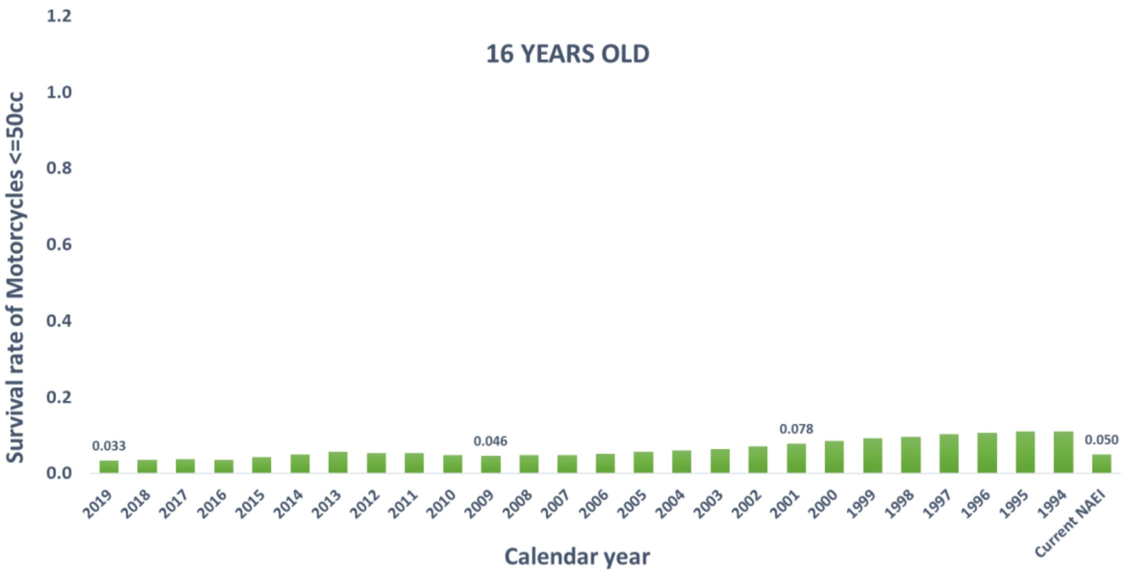
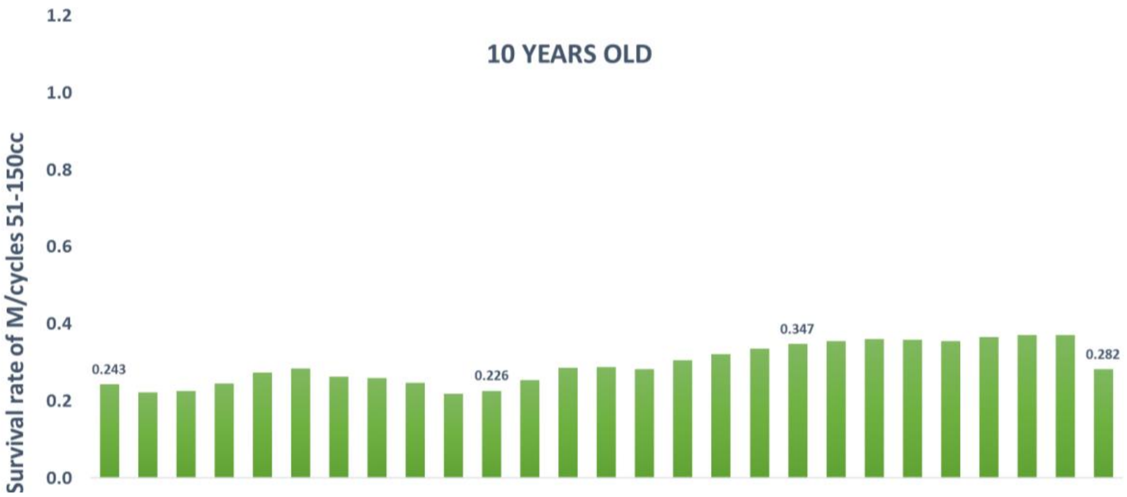


Figure 13-2 Year-dependant survival rates for 3, 10 and 16 years old m/cycles less than 50cc for all calendar years compared against the current NAEI rate

A.1.2.2 M/cycles 51-150cc



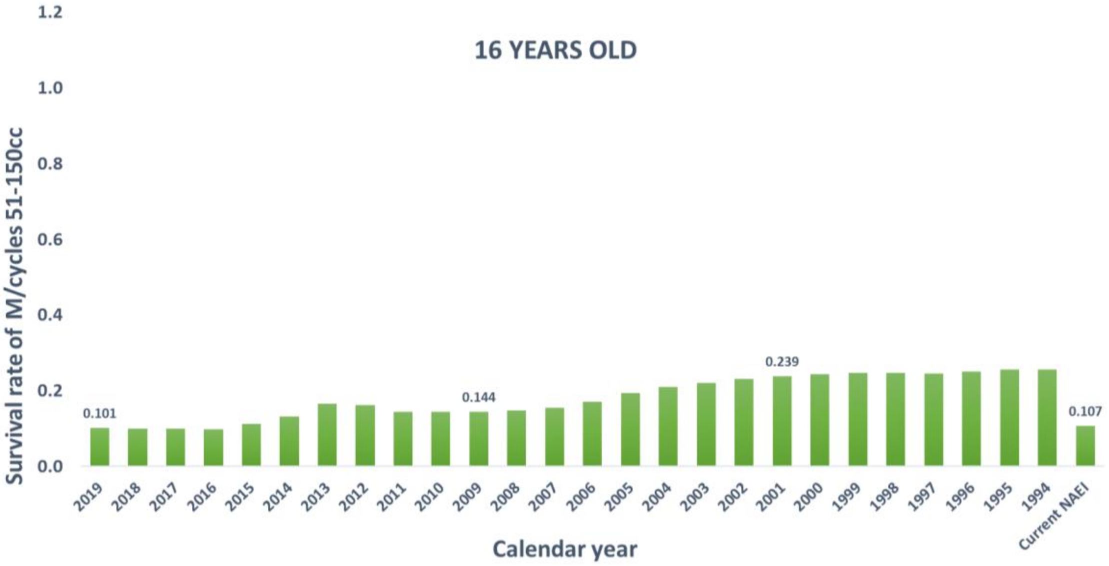


Figure 13-3 Year-dependant survival rates for 3, 10 and 16 years old m/cycles less between 51 and 150cc for all calendar years compared against the current NAEI rate

A.1.2.3 M/cycles 151-250cc

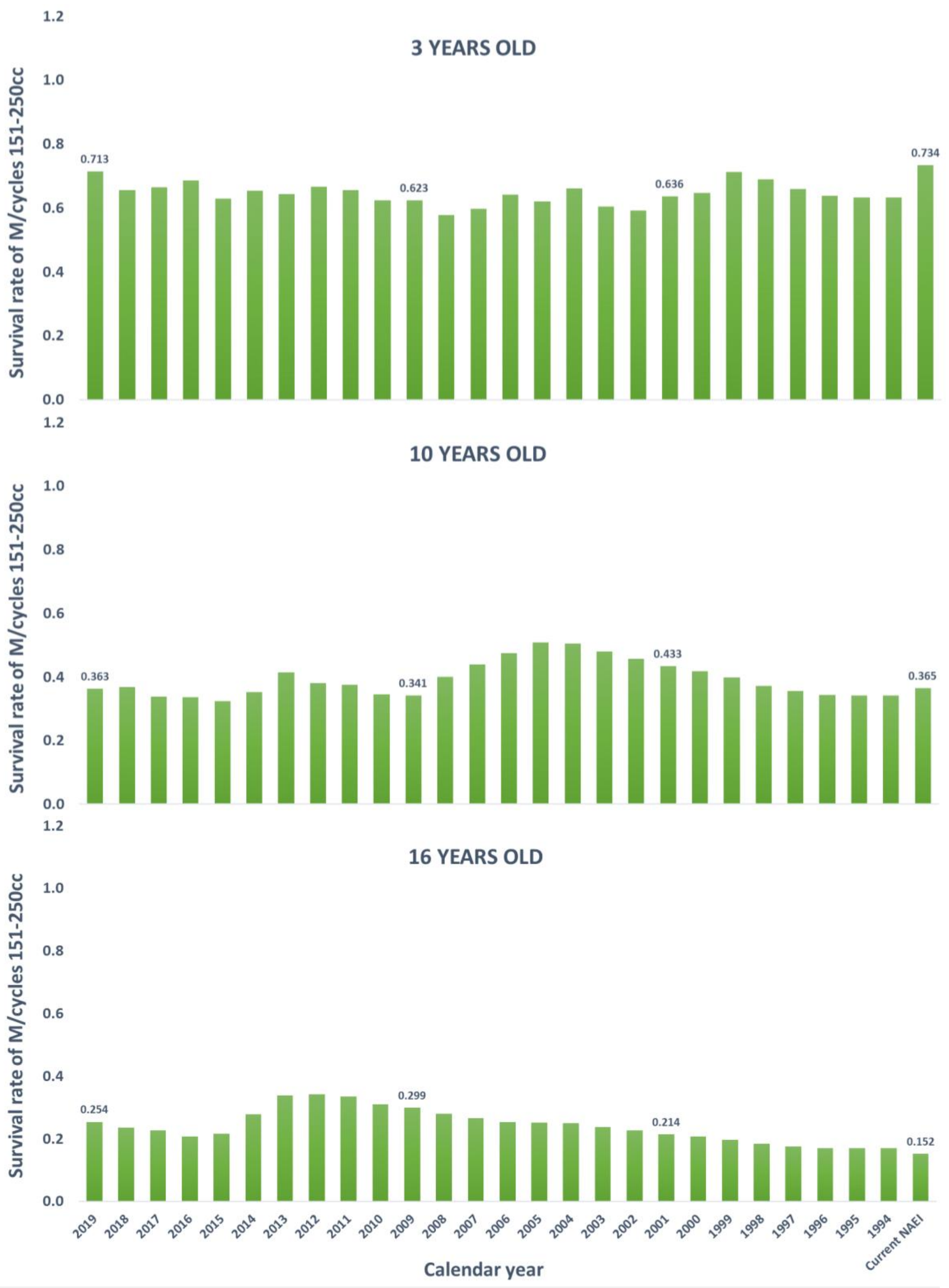


Figure 13-4 Year-dependant survival rates for 3, 10 and 16 years old m/cycles less between 151 and 250cc for all calendar years compared against the current NAEI rate

A.1.2.4 M/cycles 251-750cc

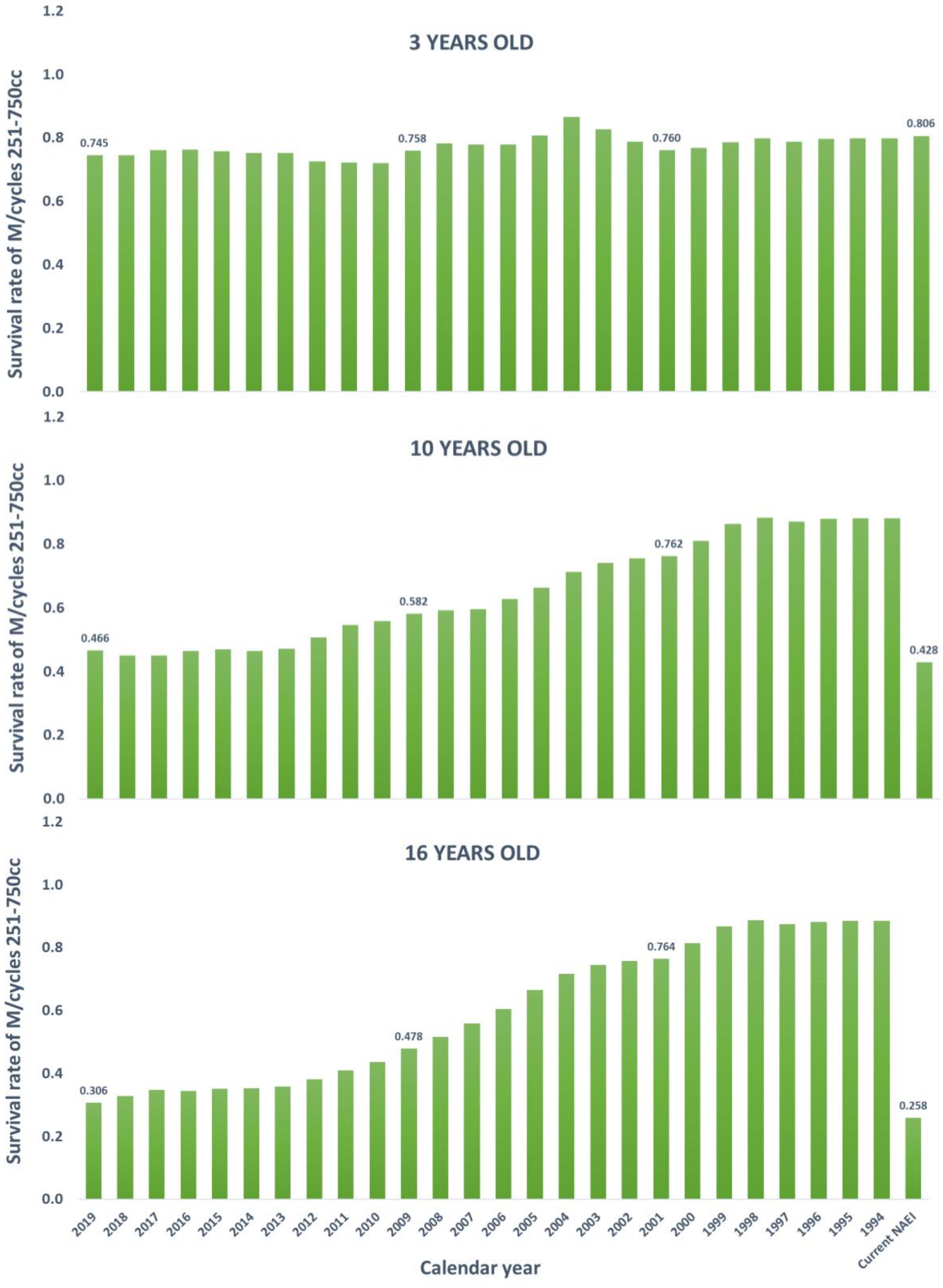


Figure 13-5 Year-dependant survival rates for 3, 10 and 16 years old m/cycles less between 251 and 750cc for all calendar years compared against the current NAEI rate

A.1.2.5 M/cycles >750cc

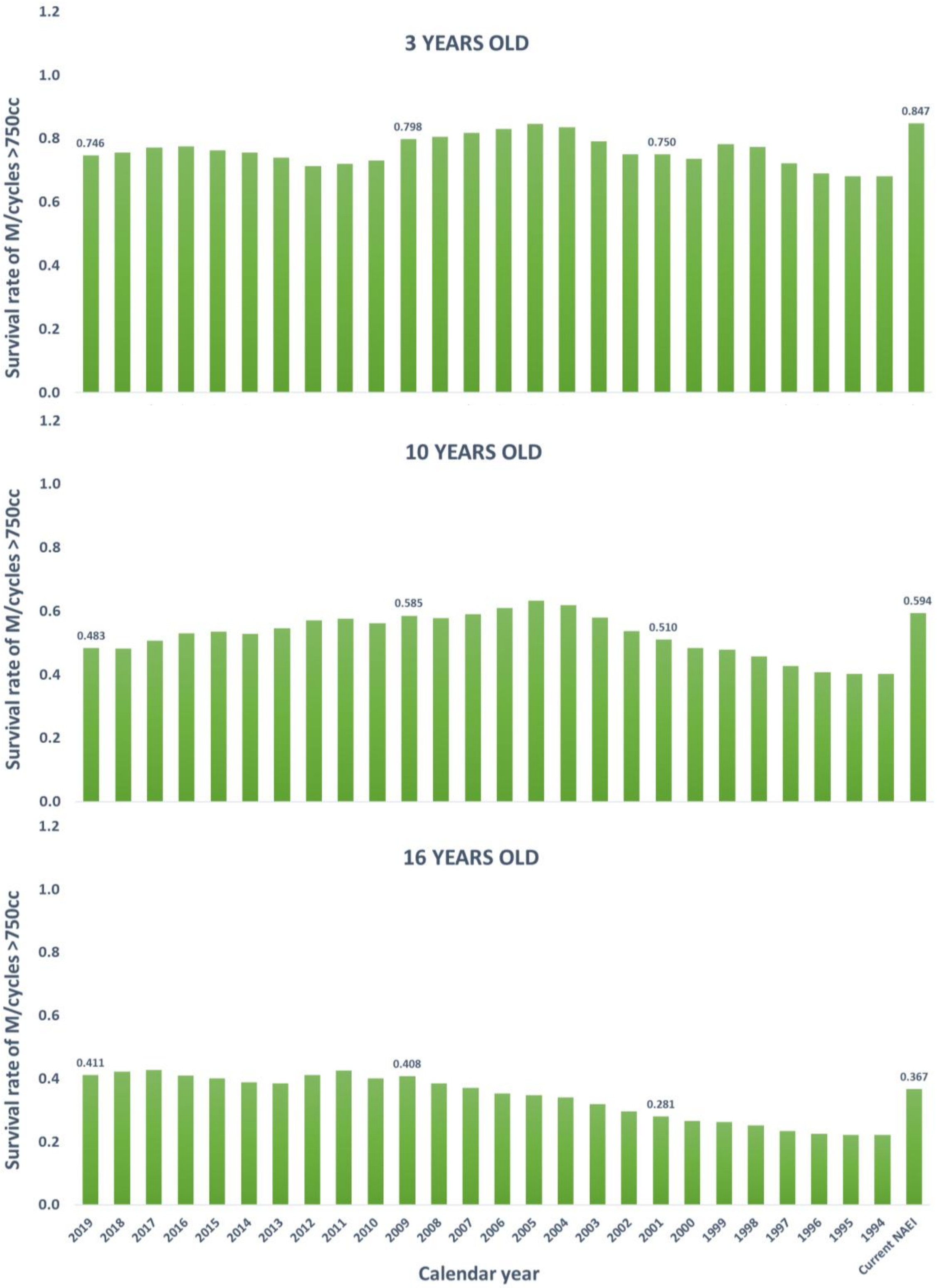


Figure 13-6 Year-dependant survival rates for 3, 10 and 16 years old m/cycles less above 750cc for all calendar years compared against the current NAEI rate

APPENDIX 2 – SURVIVAL RATES FOR ALL VEHICLE TYPES

Table 13-1 to Table 13-11 show the survival rates of all vehicle types in different years presented against the current survival rates used in the NAEI.

Table 13-1 Comparison of year-dependant survival rates against current NAEI rates for diesel cars

	Year									
Vehicle age	2019	2017	2015	2013	2011	2009	2007	2005	2003	Current NAEI
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.966
1	0.995	0.999	0.996	1.006	1.005	1.021	1.020	1.011	0.997	0.965
2	1.008	0.993	0.987	1.005	1.003	1.030	0.998	1.005	0.976	0.958
3	0.945	0.939	0.951	0.973	0.984	1.003	0.972	0.966	0.939	0.942
4	0.943	0.940	0.953	0.969	1.002	0.968	0.965	0.953	0.951	0.935
5	0.926	0.934	0.943	0.968	0.988	0.966	0.950	0.943	0.956	0.922
6	0.912	0.919	0.936	0.984	0.944	0.941	0.923	0.931	0.956	0.907
7	0.897	0.901	0.923	0.955	0.928	0.906	0.892	0.918	0.930	0.886
8	0.871	0.883	0.929	0.897	0.888	0.855	0.856	0.900	0.893	0.852
9	0.845	0.851	0.882	0.859	0.832	0.793	0.801	0.854	0.833	0.795
10	0.808	0.835	0.802	0.796	0.750	0.703	0.743	0.771	0.748	0.709
11	0.745	0.758	0.735	0.709	0.645	0.596	0.656	0.660	0.640	0.602
12	0.693	0.648	0.649	0.589	0.525	0.507	0.529	0.528	0.512	0.484
13	0.587	0.549	0.542	0.458	0.398	0.413	0.399	0.398	0.386	0.366
14	0.463	0.454	0.406	0.344	0.312	0.303	0.288	0.287	0.279	0.261
15	0.358	0.348	0.287	0.236	0.242	0.211	0.200	0.200	0.194	0.176
16	0.281	0.235	0.207	0.177	0.171	0.143	0.136	0.136	0.132	0.117
17	0.199	0.157	0.137	0.136	0.114	0.096	0.091	0.090	0.088	0.077
18	0.127	0.113	0.102	0.097	0.075	0.063	0.059	0.059	0.058	0.050
19	0.083	0.075	0.081	0.063	0.049	0.041	0.039	0.039	0.037	0.033
20	0.062	0.060	0.059	0.041	0.032	0.026	0.025	0.025	0.024	0.022

Table 13-2 Comparison of year-dependant survival rates against current NAEI rates for petrol cars

	Year									
Vehicle age	2019	2017	2015	2013	2011	2009	2007	2005	2003	Current NAEI
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.966

	Year								
1	1.001	1.000	0.995	1.001	1.007	1.015	1.026	1.027	1.006	0.965
2	1.002	0.994	0.985	1.009	1.007	1.049	1.016	1.023	0.996	0.958
3	0.979	0.973	0.972	1.004	1.009	1.031	1.010	1.003	0.980	0.942
4	0.989	0.981	0.996	1.001	1.037	1.009	1.003	0.997	0.995	0.935
5	0.979	0.978	0.992	1.005	1.023	1.005	0.987	0.988	1.009	0.922
6	0.966	0.979	0.979	1.021	0.987	0.983	0.967	0.979	0.995	0.907
7	0.958	0.968	0.974	1.000	0.975	0.956	0.943	0.976	0.975	0.886
8	0.952	0.949	0.980	0.954	0.939	0.915	0.912	0.940	0.951	0.852
9	0.931	0.927	0.945	0.921	0.889	0.862	0.864	0.884	0.898	0.795
10	0.901	0.913	0.875	0.857	0.810	0.768	0.781	0.809	0.815	0.709
11	0.848	0.850	0.808	0.768	0.711	0.649	0.666	0.697	0.702	0.602
12	0.798	0.737	0.708	0.641	0.576	0.536	0.545	0.562	0.565	0.484
13	0.700	0.631	0.586	0.508	0.424	0.409	0.413	0.426	0.429	0.366
14	0.558	0.508	0.442	0.374	0.318	0.305	0.298	0.307	0.309	0.261
15	0.442	0.383	0.319	0.247	0.224	0.212	0.207	0.214	0.215	0.176
16	0.332	0.264	0.220	0.173	0.158	0.143	0.140	0.144	0.145	0.117
17	0.233	0.179	0.141	0.117	0.105	0.095	0.093	0.096	0.097	0.077
18	0.152	0.121	0.097	0.082	0.071	0.064	0.063	0.064	0.065	0.050
19	0.102	0.079	0.065	0.056	0.048	0.043	0.042	0.043	0.044	0.033
20	0.070	0.055	0.047	0.038	0.033	0.030	0.029	0.030	0.030	0.022

Table 13-3 Comparison of year-dependant survival rates against current NAEI rates for diesel LGVs

	Year								
Vehicle age	2019	2017	2015	2013	2011	2009	2007	2005	2003	Current NAEI
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1	0.982	0.984	0.981	0.989	0.986	0.997	0.981	0.987	0.974	0.982
2	0.969	0.958	0.965	0.979	0.980	0.976	0.956	0.963	0.954	0.964
3	0.926	0.921	0.931	0.944	0.945	0.938	0.915	0.924	0.911	0.928
4	0.898	0.900	0.911	0.929	0.917	0.907	0.903	0.916	0.909	0.912
5	0.873	0.877	0.895	0.907	0.896	0.884	0.878	0.889	0.892	0.889
6	0.841	0.860	0.879	0.875	0.863	0.854	0.863	0.872	0.872	0.862
7	0.817	0.844	0.846	0.845	0.831	0.817	0.824	0.844	0.830	0.827
8	0.800	0.816	0.804	0.797	0.791	0.780	0.782	0.807	0.776	0.782
9	0.776	0.766	0.771	0.754	0.734	0.701	0.725	0.732	0.695	0.723
10	0.731	0.711	0.705	0.697	0.657	0.617	0.654	0.640	0.601	0.647

	Year									
11	0.658	0.665	0.645	0.611	0.528	0.524	0.541	0.519	0.487	0.555
12	0.592	0.580	0.576	0.496	0.422	0.438	0.414	0.390	0.366	0.452
13	0.533	0.505	0.472	0.352	0.332	0.329	0.293	0.276	0.259	0.349
14	0.439	0.431	0.354	0.264	0.264	0.229	0.200	0.188	0.177	0.260
15	0.361	0.334	0.239	0.201	0.193	0.156	0.137	0.129	0.121	0.191
16	0.296	0.238	0.178	0.161	0.132	0.108	0.095	0.089	0.084	0.143
17	0.225	0.161	0.138	0.121	0.095	0.078	0.068	0.064	0.060	0.109
18	0.161	0.123	0.113	0.088	0.071	0.058	0.051	0.048	0.045	0.086
19	0.114	0.100	0.091	0.068	0.055	0.045	0.039	0.037	0.035	0.069
20	0.091	0.084	0.069	0.053	0.043	0.035	0.031	0.029	0.027	0.057

Table 13-4 Comparison of year-dependant survival rates against current NAEI rates for artic HGVs

	Year									
Vehicle age	2019	2017	2015	2013	2011	2009	2007	2005	2003	Current NAEI
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1	0.976	0.990	0.987	0.978	0.970	0.994	0.989	0.984	0.979	0.987
2	0.944	0.939	0.988	0.947	0.969	0.959	0.972	0.974	0.946	0.958
3	0.864	0.898	0.894	0.847	0.900	0.860	0.896	0.835	0.846	0.857
4	0.819	0.880	0.801	0.799	0.845	0.771	0.764	0.731	0.799	0.775
5	0.720	0.643	0.674	0.675	0.660	0.635	0.621	0.632	0.618	0.643
6	0.544	0.548	0.557	0.602	0.515	0.465	0.492	0.509	0.579	0.519
7	0.369	0.448	0.487	0.410	0.425	0.378	0.404	0.386	0.453	0.415
8	0.320	0.365	0.421	0.318	0.297	0.274	0.326	0.344	0.376	0.317
9	0.219	0.301	0.266	0.233	0.226	0.215	0.223	0.254	0.301	0.230
10	0.187	0.244	0.194	0.162	0.160	0.161	0.179	0.190	0.236	0.166
11	0.147	0.150	0.137	0.117	0.116	0.107	0.128	0.157	0.195	0.116
12	0.121	0.110	0.092	0.082	0.089	0.088	0.098	0.130	0.161	0.081
13	0.086	0.081	0.070	0.063	0.063	0.062	0.083	0.110	0.137	0.058
14	0.064	0.055	0.050	0.050	0.055	0.050	0.071	0.095	0.118	0.038
15	0.051	0.047	0.040	0.038	0.041	0.045	0.065	0.086	0.106	0.026
16	0.035	0.035	0.031	0.032	0.033	0.039	0.056	0.074	0.092	0.019
17	0.031	0.027	0.026	0.027	0.029	0.034	0.049	0.065	0.081	0.013
18	0.024	0.021	0.023	0.022	0.026	0.030	0.043	0.057	0.071	0.009
19	0.019	0.019	0.020	0.021	0.024	0.028	0.040	0.053	0.066	0.007
20	0.015	0.017	0.017	0.018	0.021	0.025	0.036	0.047	0.059	0.005

Table 13-5 Comparison of year-dependant survival rates against current NAEI rates for rigid HGVs

	Year									
Vehicle age	2019	2017	2015	2013	2011	2009	2007	2005	2003	Current NAEI
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1	0.985	0.987	0.998	0.992	0.990	0.981	0.981	0.980	0.972	0.991
2	0.978	0.979	1.027	0.989	0.977	0.962	0.964	0.959	0.950	0.972
3	0.958	0.973	0.968	0.977	0.959	0.932	0.931	0.918	0.898	0.939
4	0.939	0.985	0.953	0.944	0.938	0.881	0.893	0.885	0.892	0.907
5	0.896	0.881	0.922	0.890	0.862	0.799	0.830	0.825	0.863	0.843
6	0.845	0.847	0.873	0.859	0.795	0.753	0.785	0.797	0.885	0.786
7	0.750	0.802	0.827	0.759	0.717	0.691	0.730	0.774	0.824	0.716
8	0.702	0.753	0.772	0.679	0.645	0.614	0.664	0.771	0.749	0.636
9	0.659	0.699	0.654	0.584	0.573	0.548	0.626	0.686	0.706	0.552
10	0.583	0.634	0.562	0.501	0.488	0.487	0.608	0.608	0.655	0.467
11	0.514	0.521	0.475	0.438	0.431	0.440	0.519	0.552	0.594	0.388
12	0.466	0.437	0.401	0.366	0.366	0.418	0.443	0.500	0.539	0.319
13	0.387	0.377	0.338	0.324	0.328	0.344	0.394	0.446	0.480	0.255
14	0.327	0.304	0.276	0.268	0.307	0.289	0.348	0.393	0.423	0.199
15	0.280	0.256	0.243	0.236	0.248	0.254	0.306	0.345	0.372	0.155
16	0.224	0.207	0.201	0.222	0.207	0.221	0.266	0.301	0.324	0.120
17	0.190	0.185	0.180	0.180	0.181	0.194	0.233	0.263	0.284	0.091
18	0.156	0.153	0.166	0.148	0.161	0.172	0.207	0.234	0.252	0.070
19	0.138	0.139	0.135	0.132	0.144	0.153	0.185	0.209	0.225	0.054
20	0.116	0.128	0.113	0.118	0.128	0.137	0.165	0.187	0.201	0.041

Table 13-6 Comparison of year-dependant survival rates against current NAEI rates for buses & coaches

	Year									
Vehicle age	2019	2017	2015	2013	2011	2009	2007	2005	2003	Current NAEI
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.966
1	0.986	0.986	1.005	0.998	1.018	0.994	0.984	0.977	0.986	0.946
2	0.985	0.978	0.992	1.002	0.967	0.989	0.961	0.979	0.967	0.928
3	0.954	0.977	0.978	0.994	0.965	0.987	0.962	0.975	0.962	0.925
4	0.957	0.952	0.982	0.952	0.964	0.962	0.971	0.999	0.997	0.920

	Year									
5	0.932	0.923	0.966	0.942	0.970	0.959	0.959	0.975	1.000	0.907
6	0.911	0.929	0.936	0.944	0.940	0.940	0.962	0.979	1.002	0.887
7	0.888	0.944	0.934	0.948	0.926	0.910	0.925	0.964	0.988	0.856
8	0.883	0.917	0.919	0.904	0.899	0.898	0.904	0.950	0.984	0.817
9	0.895	0.894	0.901	0.857	0.868	0.828	0.870	0.907	0.930	0.768
10	0.860	0.833	0.829	0.807	0.799	0.778	0.831	0.861	0.856	0.709
11	0.803	0.803	0.745	0.770	0.682	0.729	0.749	0.775	0.770	0.639
12	0.731	0.710	0.685	0.670	0.615	0.654	0.666	0.663	0.659	0.557
13	0.680	0.598	0.663	0.529	0.568	0.557	0.546	0.543	0.540	0.462
14	0.558	0.522	0.538	0.439	0.486	0.458	0.425	0.423	0.420	0.379
15	0.439	0.494	0.377	0.368	0.386	0.341	0.316	0.315	0.313	0.306
16	0.362	0.366	0.283	0.300	0.297	0.257	0.238	0.237	0.235	0.253
17	0.326	0.245	0.236	0.252	0.225	0.195	0.181	0.180	0.179	0.218
18	0.221	0.188	0.211	0.205	0.171	0.147	0.137	0.136	0.135	0.191
19	0.166	0.161	0.179	0.154	0.128	0.111	0.103	0.102	0.101	0.166
20	0.127	0.146	0.149	0.117	0.097	0.084	0.078	0.077	0.077	0.142

Table 13-7 Comparison of year-dependant survival rates against current NAEI rates for m/cycles <= 50cc

	Year									
Vehicle age	2019	2017	2015	2013	2011	2009	2007	2005	2003	Current NAEI
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
1	0.816	0.783	0.792	0.818	0.815	0.772	0.758	0.797	0.746	1.001
2	0.686	0.610	0.636	0.659	0.660	0.592	0.630	0.634	0.615	0.759
3	0.507	0.477	0.494	0.525	0.496	0.477	0.518	0.518	0.502	0.627
4	0.369	0.391	0.391	0.430	0.394	0.409	0.403	0.437	0.452	0.488
5	0.318	0.314	0.332	0.330	0.353	0.356	0.344	0.360	0.393	0.410
6	0.270	0.243	0.268	0.261	0.300	0.277	0.288	0.314	0.360	0.340
7	0.209	0.201	0.203	0.240	0.262	0.231	0.229	0.271	0.301	0.274
8	0.154	0.168	0.158	0.199	0.202	0.192	0.197	0.244	0.258	0.234
9	0.129	0.119	0.145	0.175	0.169	0.149	0.171	0.200	0.226	0.199
10	0.110	0.096	0.121	0.134	0.141	0.129	0.152	0.169	0.192	0.153
11	0.078	0.089	0.101	0.115	0.110	0.116	0.125	0.140	0.158	0.145
12	0.064	0.074	0.079	0.097	0.093	0.107	0.100	0.119	0.134	0.116
13	0.059	0.062	0.069	0.076	0.087	0.080	0.083	0.098	0.111	0.096
14	0.050	0.048	0.059	0.065	0.080	0.068	0.070	0.083	0.094	0.077

	Year									
15	0.039	0.043	0.045	0.064	0.061	0.056	0.057	0.068	0.077	0.063
16	0.033	0.036	0.042	0.057	0.052	0.046	0.047	0.056	0.063	0.050
17	0.028	0.028	0.040	0.045	0.040	0.035	0.036	0.043	0.048	0.042
18	0.025	0.027	0.035	0.037	0.033	0.029	0.030	0.035	0.040	0.032
19	0.019	0.027	0.031	0.032	0.028	0.025	0.025	0.030	0.034	0.026
20	0.020	0.026	0.026	0.024	0.021	0.019	0.019	0.023	0.026	

Table 13-8 Comparison of year-dependant survival rates against current NAEI rates for m/cycles 51-150cc

	Year									
Vehicle age	2019	2017	2015	2013	2011	2009	2007	2005	2003	Current NAEI
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
1	0.857	0.844	0.840	0.856	0.864	0.810	0.795	0.808	0.756	1.000
2	0.744	0.706	0.711	0.760	0.761	0.688	0.697	0.691	0.638	0.816
3	0.614	0.583	0.602	0.668	0.610	0.583	0.597	0.566	0.530	0.707
4	0.491	0.489	0.548	0.591	0.522	0.533	0.500	0.488	0.488	0.564
5	0.427	0.434	0.514	0.479	0.477	0.483	0.433	0.416	0.478	0.495
6	0.359	0.399	0.454	0.419	0.457	0.401	0.369	0.380	0.462	0.418
7	0.321	0.372	0.358	0.384	0.409	0.344	0.313	0.370	0.432	0.353
8	0.294	0.333	0.313	0.367	0.334	0.292	0.286	0.367	0.384	0.315
9	0.276	0.259	0.287	0.330	0.285	0.244	0.277	0.332	0.355	0.304
10	0.243	0.226	0.274	0.262	0.246	0.226	0.285	0.282	0.321	0.282
11	0.190	0.206	0.240	0.227	0.205	0.223	0.252	0.264	0.301	0.259
12	0.166	0.197	0.192	0.191	0.188	0.236	0.205	0.255	0.290	0.202
13	0.150	0.175	0.163	0.160	0.187	0.205	0.196	0.244	0.277	0.187
14	0.142	0.136	0.138	0.149	0.202	0.169	0.183	0.227	0.258	0.157
15	0.128	0.117	0.114	0.153	0.171	0.156	0.169	0.210	0.239	0.130
16	0.101	0.100	0.112	0.166	0.145	0.144	0.156	0.194	0.220	0.107
17	0.089	0.083	0.114	0.143	0.138	0.137	0.148	0.184	0.209	0.078
18	0.074	0.085	0.132	0.121	0.125	0.124	0.134	0.167	0.190	0.067
19	0.065	0.089	0.112	0.110	0.113	0.112	0.121	0.151	0.172	0.057
20	0.068	0.108	0.091	0.104	0.107	0.106	0.115	0.143	0.163	

Table 13-9 Comparison of year-dependant survival rates against current NAEI rates for m/cycles 151-250cc

	Year									
Vehicle age	2019	2017	2015	2013	2011	2009	2007	2005	2003	Current NAEI
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
1	0.836	0.866	0.813	0.823	0.792	0.822	0.789	0.780	0.757	1.000
2	0.783	0.759	0.745	0.756	0.742	0.731	0.659	0.747	0.716	0.822
3	0.713	0.665	0.629	0.644	0.655	0.623	0.597	0.620	0.605	0.734
4	0.591	0.628	0.594	0.622	0.567	0.520	0.594	0.589	0.554	0.652
5	0.558	0.531	0.536	0.576	0.533	0.512	0.512	0.512	0.579	0.584
6	0.525	0.506	0.529	0.501	0.449	0.523	0.492	0.481	0.567	0.536
7	0.451	0.463	0.474	0.464	0.445	0.445	0.421	0.519	0.597	0.439
8	0.426	0.438	0.404	0.385	0.473	0.428	0.391	0.511	0.573	0.407
9	0.385	0.403	0.379	0.394	0.392	0.367	0.436	0.525	0.528	0.386
10	0.363	0.337	0.323	0.414	0.375	0.341	0.438	0.508	0.480	0.365
11	0.340	0.319	0.329	0.345	0.327	0.384	0.436	0.454	0.429	0.330
12	0.282	0.263	0.346	0.330	0.301	0.401	0.424	0.400	0.378	0.268
13	0.256	0.270	0.290	0.282	0.350	0.397	0.375	0.354	0.335	0.216
14	0.224	0.299	0.273	0.265	0.380	0.368	0.328	0.310	0.293	0.210
15	0.222	0.248	0.225	0.309	0.362	0.327	0.291	0.275	0.260	0.177
16	0.254	0.227	0.215	0.338	0.335	0.299	0.266	0.251	0.238	0.152
17	0.224	0.197	0.264	0.325	0.292	0.260	0.232	0.219	0.207	0.132
18	0.194	0.180	0.290	0.301	0.253	0.225	0.201	0.190	0.179	0.126
19	0.171	0.221	0.283	0.259	0.217	0.193	0.172	0.163	0.154	0.114
20	0.157	0.254	0.254	0.222	0.186	0.166	0.148	0.140	0.132	

Table 13-10 Comparison of year-dependant survival rates against current NAEI rates for m/cycles 251-750cc

	Year									
Vehicle age	2019	2017	2015	2013	2011	2009	2007	2005	2003	Current NAEI
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
1	0.885	0.879	0.890	0.878	0.870	0.881	0.890	0.887	0.883	0.983
2	0.835	0.818	0.818	0.819	0.802	0.823	0.852	0.850	0.882	0.860
3	0.745	0.761	0.757	0.751	0.721	0.758	0.778	0.808	0.826	0.806
4	0.692	0.704	0.713	0.677	0.670	0.722	0.739	0.821	0.793	0.733
5	0.658	0.662	0.668	0.622	0.627	0.687	0.731	0.778	0.774	0.625
6	0.612	0.636	0.605	0.576	0.605	0.651	0.740	0.745	0.733	0.591

	Year									
7	0.572	0.585	0.555	0.547	0.579	0.642	0.699	0.722	0.728	0.554
8	0.547	0.535	0.513	0.525	0.554	0.650	0.665	0.683	0.723	0.526
9	0.508	0.483	0.487	0.503	0.549	0.612	0.637	0.667	0.732	0.473
10	0.466	0.449	0.469	0.471	0.546	0.582	0.596	0.662	0.741	0.428
11	0.418	0.428	0.442	0.472	0.511	0.558	0.586	0.660	0.739	0.380
12	0.386	0.411	0.418	0.463	0.486	0.520	0.558	0.663	0.743	0.350
13	0.367	0.380	0.412	0.430	0.466	0.510	0.558	0.663	0.742	0.325
14	0.348	0.361	0.407	0.405	0.439	0.483	0.565	0.671	0.751	0.301
15	0.322	0.357	0.371	0.383	0.424	0.481	0.562	0.668	0.747	0.276
16	0.306	0.347	0.351	0.357	0.409	0.478	0.559	0.665	0.744	0.258
17	0.299	0.314	0.332	0.350	0.404	0.473	0.553	0.657	0.735	0.229
18	0.293	0.295	0.309	0.334	0.400	0.468	0.548	0.651	0.728	0.208
19	0.260	0.274	0.301	0.331	0.397	0.464	0.543	0.645	0.722	0.184
20	0.245	0.257	0.283	0.335	0.401	0.469	0.549	0.652	0.730	

Table 13-11 Comparison of year-dependant survival rates against current NAEI rates for m/cycles >750cc

	Year									
Vehicle age	2019	2017	2015	2013	2011	2009	2007	2005	2003	Current NAEI
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
1	0.876	0.880	0.893	0.878	0.868	0.881	0.910	0.904	0.898	0.999
2	0.820	0.833	0.820	0.815	0.782	0.837	0.873	0.889	0.842	0.896
3	0.746	0.772	0.762	0.739	0.720	0.798	0.817	0.845	0.791	0.847
4	0.704	0.724	0.720	0.666	0.687	0.762	0.803	0.803	0.740	0.785
5	0.671	0.690	0.661	0.618	0.671	0.728	0.787	0.758	0.724	0.759
6	0.635	0.648	0.607	0.604	0.644	0.726	0.747	0.715	0.686	0.733
7	0.600	0.596	0.566	0.587	0.617	0.707	0.706	0.690	0.691	0.690
8	0.571	0.545	0.559	0.566	0.625	0.678	0.654	0.658	0.664	0.657
9	0.520	0.510	0.550	0.543	0.610	0.631	0.621	0.661	0.618	0.611
10	0.483	0.506	0.535	0.546	0.576	0.585	0.589	0.632	0.579	0.594
11	0.452	0.500	0.513	0.536	0.537	0.556	0.592	0.584	0.535	0.546
12	0.448	0.483	0.516	0.501	0.503	0.528	0.568	0.534	0.489	0.496
13	0.438	0.459	0.504	0.466	0.471	0.522	0.509	0.478	0.438	0.467
14	0.428	0.466	0.473	0.433	0.454	0.505	0.458	0.431	0.394	0.425
15	0.403	0.451	0.432	0.401	0.450	0.453	0.411	0.386	0.353	0.399
16	0.411	0.427	0.401	0.385	0.426	0.408	0.370	0.348	0.318	0.367

	Year									
17	0.396	0.381	0.378	0.386	0.382	0.366	0.332	0.312	0.285	0.315
18	0.375	0.355	0.360	0.365	0.344	0.330	0.299	0.281	0.257	0.288
19	0.328	0.328	0.358	0.326	0.308	0.295	0.267	0.251	0.230	0.272
0	0.304	0.313	0.338	0.286	0.270	0.258	0.234	0.220	0.202	

APPENDIX 3 – FLEET COMPOSITION VALUES FOR DIFFERENT FLEET TURNOVER ASSUMPTIONS

Fleet compositions for 2018, 2025 and 2030 showing sensitivity to assumptions made about survival rates and mileage with age rates in future years. See Ricardo (2020b) for details of scenarios (also Section 4.2 of this report):

- S1 – in which the rates for future years are maintained at the rates for 2019
- S2 – in which the rates for future years are maintained at the mean of the rates for the past 5 years (2015-2019)
- S3 – in which the rates for future years are maintained at the mean of the rates for the past 10 years (2010-2019)

Results shown refer to the fraction of vehicle km by each Euro standard. These results are based on the status of the fleet turnover model developed in an initial exploratory study and presented in our draft report submitted to Defra in October 2020, before further improvements presented in this report were made. The results are therefore not finalised ones from the current improvements and are only meant to show sensitivity to these assumptions.

Fleet Composition Proportions by Vehicle Type and Scenario for the Calendar Year 2018

Vehicle Type	Euro Standard	Baseline	S1	S2	S3
Petrol cars	Pre-Euro 4	0.07	0.17	0.17	0.17
	Euro 4	0.18	0.24	0.24	0.24
	Euro 5	0.29	0.27	0.27	0.27
	Euro 6_1	0.18	0.13	0.13	0.13
	Euro 6_2	0.24	0.16	0.16	0.16
	HEV	0.03	0.02	0.02	0.02
	PHEV	0.01	0.01	0.01	0.01
Diesel cars	Pre-Euro 4	0.04	0.08	0.08	0.08
	Euro 4	0.16	0.20	0.20	0.20
	Euro 5	0.37	0.35	0.35	0.35
	Euro 6_1	0.22	0.20	0.20	0.20
	Euro 6_2	0.20	0.17	0.17	0.17
	HEV	0.00	0.00	0.00	0.00
Diesel LGVs	Pre-Euro 4	0.04	0.07	0.07	0.07
	Euro 4	0.16	0.16	0.16	0.16
	Euro 5	0.34	0.33	0.33	0.33
	Euro 6_1	0.26	0.25	0.25	0.25
	Euro 6_2	0.20	0.19	0.19	0.19
	PHEV	0.00	0.00	0.00	0.00
Artic HGVs	Euro II	0.00	0.00	0.00	0.00
	Euro III	0.01	0.02	0.02	0.02

Vehicle Type	Euro Standard	Baseline	S1	S2	S3
	Euro IV	0.02	0.02	0.02	0.02
	Euro V	0.18	0.19	0.19	0.19
	Euro VI	0.79	0.77	0.77	0.77
Rigid HGVs	Euro II	0.01	0.02	0.02	0.02
	Euro III	0.06	0.09	0.09	0.09
	Euro IV	0.06	0.08	0.08	0.08
	Euro V	0.22	0.23	0.23	0.23
	Euro VI	0.64	0.59	0.59	0.59
Buses	Euro II	0.02	0.02	0.02	0.02
	Euro III	0.10	0.13	0.13	0.13
	Euro IV	0.09	0.10	0.10	0.10
	Euro V	0.31	0.30	0.30	0.30
	Euro VI	0.48	0.45	0.45	0.45
Motorcycles	Pre-Euro 4	0.73	0.67	0.67	0.67
	Euro 4	0.27	0.33	0.33	0.33

Fleet Composition Proportions by Vehicle Type and Scenario for the Calendar Year 2025

Vehicle Type	Euro Standard	Baseline	S1	S2	S3
Petrol cars	Pre-Euro 4	0.00	0.00	0.00	0.00
	Euro 4	0.01	0.04	0.03	0.03
	Euro 5	0.08	0.14	0.14	0.13
	Euro 6_1	0.08	0.09	0.10	0.10
	Euro 6_2	0.19	0.20	0.20	0.21
	HEV	0.07	0.07	0.07	0.07
	PHEV	0.06	0.05	0.05	0.05
	Euro 6_3	0.51	0.41	0.41	0.42
Diesel cars	Pre-Euro 4	0.00	0.00	0.00	0.00
	Euro 4	0.02	0.05	0.04	0.04
	Euro 5	0.17	0.24	0.23	0.21
	Euro 6_1	0.15	0.16	0.16	0.16
	Euro 6_2	0.21	0.19	0.20	0.20
	HEV	0.03	0.03	0.03	0.03
	Euro 6_3	0.41	0.34	0.34	0.36
Diesel LGVs	Pre-Euro 4	0.00	0.00	0.00	0.00
	Euro 4	0.02	0.03	0.03	0.02
	Euro 5	0.10	0.12	0.11	0.10
	Euro 6_1	0.08	0.08	0.08	0.08
	Euro 6_2	0.20	0.19	0.19	0.19
	PHEV	0.00	0.00	0.00	0.00
	Euro 6_3	0.60	0.58	0.59	0.60
Artic HGVs	Euro III	0.00	0.00	0.00	0.00
	Euro IV	0.00	0.00	0.00	0.00
	Euro V	0.01	0.01	0.01	0.01
	Euro VI	0.99	0.98	0.99	0.99
Rigid HGVs	Euro III	0.00	0.01	0.01	0.01
	Euro IV	0.01	0.01	0.01	0.01
	Euro V	0.04	0.05	0.05	0.05
	Euro VI	0.95	0.93	0.93	0.93
Buses	Euro III	0.01	0.01	0.01	0.01
	Euro IV	0.02	0.02	0.02	0.02
	Euro V	0.07	0.10	0.09	0.09
	Euro VI	0.89	0.87	0.88	0.88
Motorcycles	Pre-Euro 4	0.26	0.17	0.18	0.19

Vehicle Type	Euro Standard	Baseline	S1	S2	S3
	Euro 4	0.21	0.19	0.19	0.19
	Euro 5	0.53	0.64	0.63	0.62

Fleet Composition Proportions by Vehicle Type and Scenario for the Calendar Year 2030

Vehicle Type	Euro Standard	Baseline	S1	S2	S3
Petrol cars	Euro 4	0.00	0.00	0.00	0.00
	Euro 5	0.01	0.03	0.03	0.02
	Euro 6_1	0.02	0.04	0.04	0.03
	Euro 6_2	0.08	0.13	0.13	0.12
	HEV	0.09	0.08	0.09	0.09
	PHEV	0.10	0.09	0.10	0.10
	Euro 6_3	0.70	0.61	0.63	0.65
Diesel cars	Euro 4	0.00	0.00	0.00	0.00
	Euro 5	0.03	0.07	0.06	0.06
	Euro 6_1	0.05	0.08	0.08	0.07
	Euro 6_2	0.11	0.15	0.15	0.14
	HEV	0.06	0.05	0.05	0.05
	Euro 6_3	0.75	0.64	0.65	0.68
Diesel LGVs	Euro 4	0.00	0.00	0.00	0.00
	Euro 5	0.02	0.04	0.03	0.02
	Euro 6_1	0.02	0.03	0.03	0.03
	Euro 6_2	0.09	0.10	0.09	0.09
	PHEV	0.01	0.01	0.01	0.01
	Euro 6_3	0.86	0.82	0.83	0.85
Artic HGVs	Euro V	0.00	0.00	0.00	0.00
	Euro VI	1.00	1.00	1.00	1.00
Rigid HGVs	Euro V	0.01	0.01	0.01	0.01
	Euro VI	0.99	0.99	0.99	0.99
Buses	Euro V	0.02	0.02	0.02	0.02
	Euro VI	0.98	0.98	0.98	0.98
Motorcycles	Pre-Euro 4	0.08	0.06	0.06	0.06
	Euro 4	0.12	0.08	0.08	0.09
	Euro 5	0.80	0.86	0.86	0.85

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