Transport strategy
Carbon assessment

Final report
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1 Introduction

Background to this project

1.1 Central government policy commits the UK to a 'net zero carbon' position by 2050. In order to align Transport for the South East's (TfSE) Transport Strategy and subsequent Area Study plans to this commitment, it is necessary to baseline the region's transport carbon dioxide emissions. Along with informing each Area Study from inception, this will also inform the need for intervention, scale of challenge/opportunity, and option generation.

1.2 Transport for the South East engaged Steer to adapt the South East Economy and Land Use Model (SEELUM – a Land Use and Transport Interaction model) to interface with Department for Environment, Food and Rural Affairs' Emissions Factors Toolkit. This was to enable the calculation of carbon emissions from transport ("at tailpipe") in order to allow testing and comparison of strategy scenarios for carbon reduction, as well as the impacts of schemes identified as part of the Area Studies.

Emissions Factors Toolkit

1.3 The Emissions Factors Toolkit is published by the Department for Environment Food & Rural Affairs (DEFRA) to assist local authorities in carrying out Review and Assessment of local air quality as part of their duties under the Environmental Act 1995.

1.4 The Emissions Factors Toolkit has been designed to allow users to calculate road vehicle pollutant emission rates for oxides of nitrogen (NOx) and Particulate Matter (PM10 and PM2.5), for a specified year, road type, vehicle speed and vehicle fleet composition. Carbon dioxide (CO_2) emission rates can also be calculated for petrol, diesel and alternative fuelled vehicles. For the purposes of this study, carbon dioxide equivalent (CO_2e – which in addition to carbon dioxide includes a conversion of methane and other "greenhouse gases" in carbon dioxide equivalents in terms of impact) was the pollutant category of focus when calculating the level of emissions and potential impacts relating to the introduction of various schemes compared to estimated baseline values.

SEELUM model

1.5 As part of the project to develop its Transport Strategy, Steer was commissioned to develop a model that would determine the impact of economic growth scenarios on employment, population and travel in the South East. This model was the South East Economy and Land Use Model (SEELUM).

1.6 SEELUM is a transport and land use model that simulates the interaction of transport, people, employers and land-use over periods of time. SEELUM is a simulation, which means that it attempts to replicate events in the real world using simplified representations of how people perceive their circumstances and decide how to react. It is also dynamic, which means it is concerned with how events unfold through time: as its internal clock rolls forward it calculates, step by step, how conditions change and how people respond. It does this for everything encompassed by the model, at every time step, simultaneously.

1.7 SEELUM's primary use is to test how investment in transport, sometimes coupled with changes to land-use policy, affect the economic performance of a region, city or urban area. It does this principally by simulating how changes in patterns of connectivity and access affect how attractive different locations are for employers and/or households to locate in, how they respond, and what the consequences are. For example, if travel costs rise in a particular area (say, due to an exogenous input), depending on the other options available, people may change their mode of travel, change where they live or change where they work. In the extreme, if there are no other viable options to access work, people can become unemployed. Similarly, businesses can relocate to an area if transport costs reduce, increasing their accessibility to the potential workforce.

1.8 Figure 1.1 shows a high-level view of the linkages in the model. Figure 1.2 shows a high-level view of the key inputs and outputs when testing scenarios.

Figure 1.1: High level overview of the linkages in the model

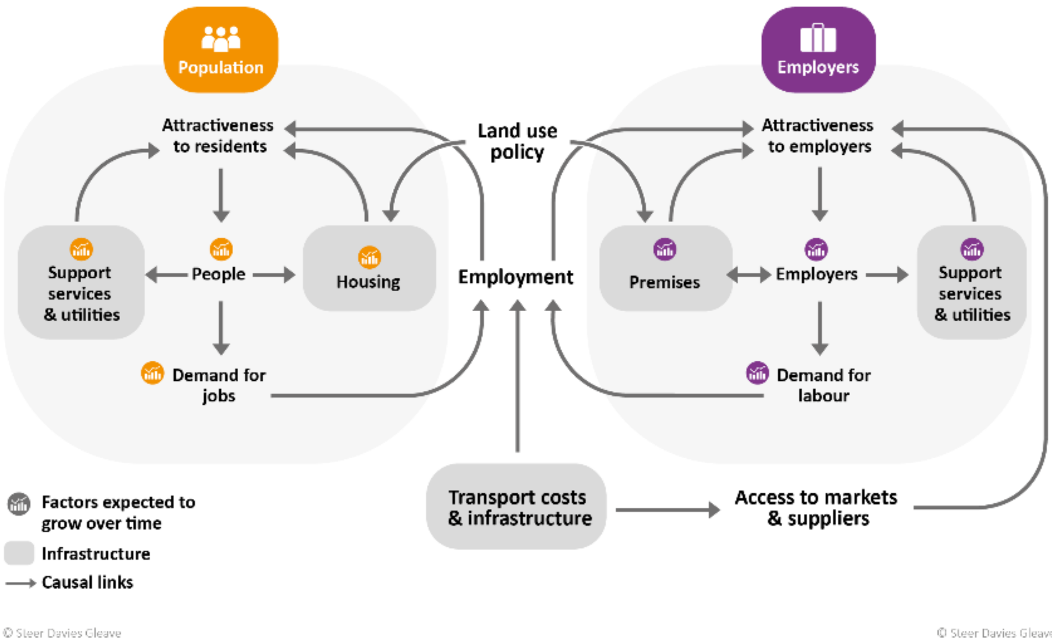
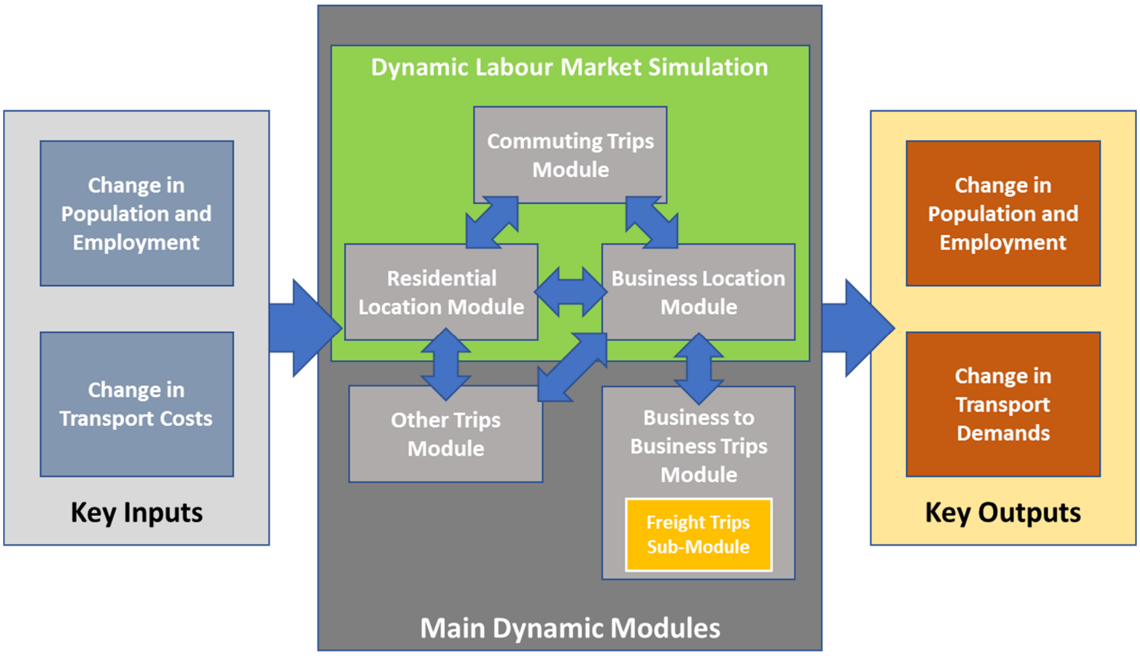


Figure 1.2: High level overview of scenario testing inputs and outputs



Project scope

1.9 This project was initially segmented into the five tasks outlined below:

i. Update SEELUM's handling of highway vehicle operating costs so that a behavioural response to new fuel technology can be captured.
ii. Create an interface for transferring highways data from SEELUM into the Emissions Factors Toolkit.
iii. Calculate emissions calculations for rail travel.
iv. Test the current scenarios that were used to develop the transport strategy with the new SEELUM/Emissions Factors Toolkit model.
v. Develop and test new scenarios that would enable net zero emissions to be achieved by 2050.

1.10 As the work progressed, it was identified that certain key assumptions in DEFRA's Emissions Factors Toolkit were not aligned with the Department for Transport's Transport Analysis Guidance. The assumptions in the Emissions Factors Toolkit, which lead to a lower conversion rate that would otherwise be expected, reduced the possibility of achieving a net zero outcome. Due to this, task 5 was re-scoped to focus on identifying high-level assumptions that would lead to differing levels of overall emissions reduction.

2 Calculating highway emissions

Introduction

2.1 In order to provide more detailed analysis of CO_2 emissions, and how they vary in response to the policy initiatives being tested by TfSE, it was necessary to make changes to some of SEELUM's calculations, as well as create new outputs to allow for the reporting of transport emissions and for the model to interface with the Emissions Factors Toolkit. This consisted of:

- Updating SEELUM's handling of vehicle operating costs, so that a behavioural response to new fuel technology can be captured in model runs.
- Enabling the SEELUM outputs to be transferred to the Emissions Factors Toolkit via a spreadsheet-based interface file.
- Developing internal Road as well as Rail emission calculations within SEELUM itself.

2.2 This chapter covers the highway elements in the above list. Rail is described in chapter 3.

Changes made to SEELUM highway calculations

2.3 Changes were made to the assumptions that had been used in SEELUM for vehicle operating costs in the original scenario testing work. This was so that changes could be better captured in behaviour in response to changes in vehicle operating costs over time due to the adoption of new fuel technology.

2.4 In the pre-updated version of the model, the model inputs included a vehicle operating cost for all journey purposes of 8 pence per kilometre for 2018 and an annual growth rate in that cost of 0.07%. The 2018 vehicle operating cost was derived from an assumption of vehicle fuel efficiency being approximately 15 kilometres per litre, and an average fuel price of 120 pence per litre. The growth rate was calculated using Table A1.3.12 of the November 2018 version of the Transport Analysis Guidance Databook. This table provides lists of annual parameter values to be used in an equation to calculate vehicle operating cost in pence per kilometre based on an assumed average speed. An average speed of 60km/h (37mph) was assumed.

2.5 Rather than applying the same compound annual growth rate every year to the vehicle operating costs, the model now uses a value for each year based on the changing fleet mix (i.e. electric vehicles becoming a greater percentage of the total number of vehicles). This means that the cost of travel by road will change in each year due to the changes in fleet mix and trips in the model may change mode and/or destination based on those cost changes.

2.6 Vehicle operating cost were calculated for each year from 2018 to 2050 using 'Average Car' values in Table A1.3.12 of the latest version of the Transport Analysis Guidance Databook (May 2019)[1]. 'Average Car' values were used as these reflect the changes in fleet mix over time.

2.7 As the value of 8 pence per kilometre is used in the model's setup and calibration, it is better that the model run still starts from this value, else changes in the first years of the run will be a response to the model's change of starting position. Therefore, an average speed was calculated that would result in a 2018 vehicle operating cost of 8 pence per kilometre using the latest parameters from the Databook. This speed was just under 25km/h[2]. This average speed is held constant over time for the vehicle operating cost calculation. As scenarios can result in average speeds rising or falling, a potential future improvement could be to investigate ways of allowing the speed input to this calculation to change over time. It should however be noted that these constant speed assumptions, regarding the internal Vehicle Operating Costs calculation within SEELUM, were not utilised as inputs to the Emissions Factor Toolkit as the speed values for each link were varied based on the level of congestion. **Error! Reference source not found.** shows how the vehicle operating cost for car varies over time for the two methods.

2.8 Table A1.3.12 also allowed for calculation of vehicle operating costs for different types of vehicles, the full list of types being:

- Car: private vehicles,
- LGV: Light Goods Vehicles (under 3.5 tonnes),
- OGV1 and OGV2: Other Goods Vehicles (with OGV1 referencing non-articulated vehicles and OGV2 referencing articulated vehicles – both often referred to as Heavy Goods Vehicles), and
- PSV: Passenger Service Vehicles (such as buses and coaches).

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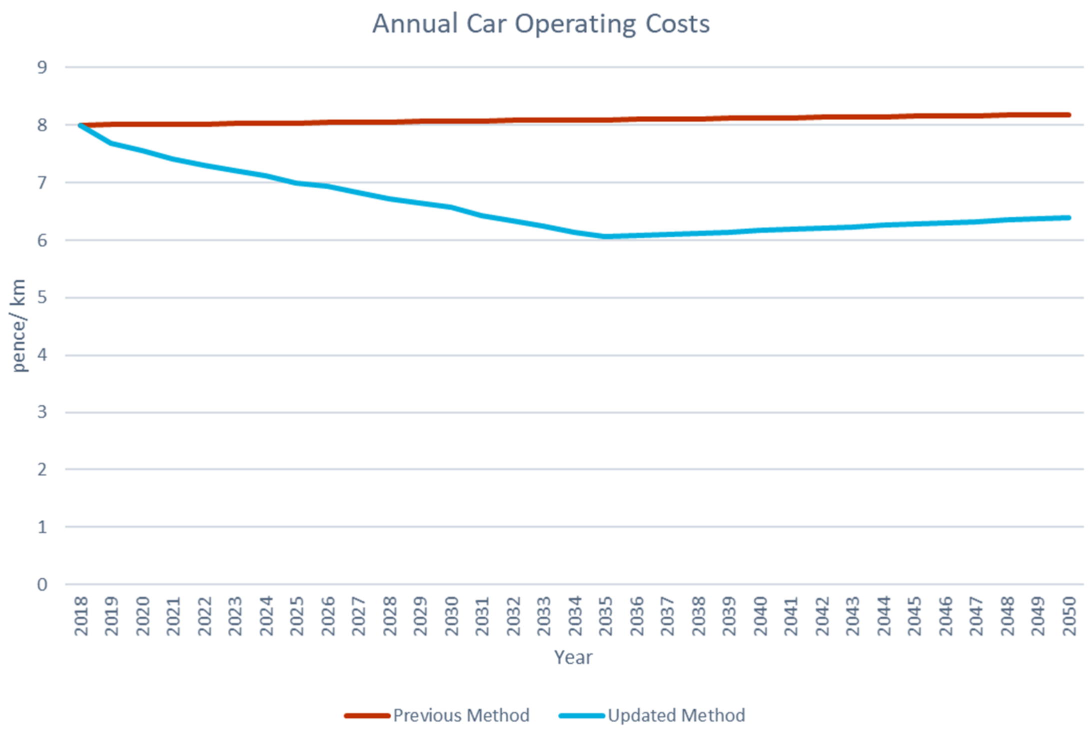
[1] Note that the parameter values had changed between the November 2018 and May 2019 versions of the Databook, so using the same speed with each version of the Databook will provide a different result.

[2] In considering this speed, we reflected that the 60km/h assumption used previously may have been high.

Figure 2.1: Comparison of car vehicle operating costs for the previous method and the updated method



2.9 It was assumed that the main vehicle type to be used for commute and other home-based journey purposes would be car and so the car vehicle operating costs were used for those journey purposes. Although cars were assumed to be the main mode of travel for these trip types when investigating vehicle operating cost assumptions, the environmental impact of modal shift due to scenario testing was still taken into consideration. More on this can be found under the Calculating Road Emissions Within SEELUM section toward the end of Chapter 2.

2.10 For business trips it was assumed that different fleet mixes of car, 'Light Goods Vehicles' and 'Other Goods Vehicles' based on the type of business categories within SEELUM. Businesses in the model are grouped into nine categories derived from the Standard Industrial Classification of Economic Activities (SIC) 2007 codes. In lieu of readily available data of the split in vehicle types for *business trips only*, high level estimations were made of the split of vehicle types that would be expected, given the business type. These can be seen in

2.11 Table 2.1. This is an area for potential further refinement should SEELUM itself become a primary method of calculating emissions in addition to the Emissions Factors Toolkit.

2.12 For Other Goods Vehicles, an average speed of 45km/h was assumed. This is higher than the average speed for cars, but it was reasoned that these vehicles are more likely to be travelling on motorways. For Light Goods Vehicles, the same speed as cars was assumed due to their more likely being used in urban areas. As previously highlighted, potential future improvements to SEELUM could include the investigation of ways to allow the speed input to this calculation to change over time

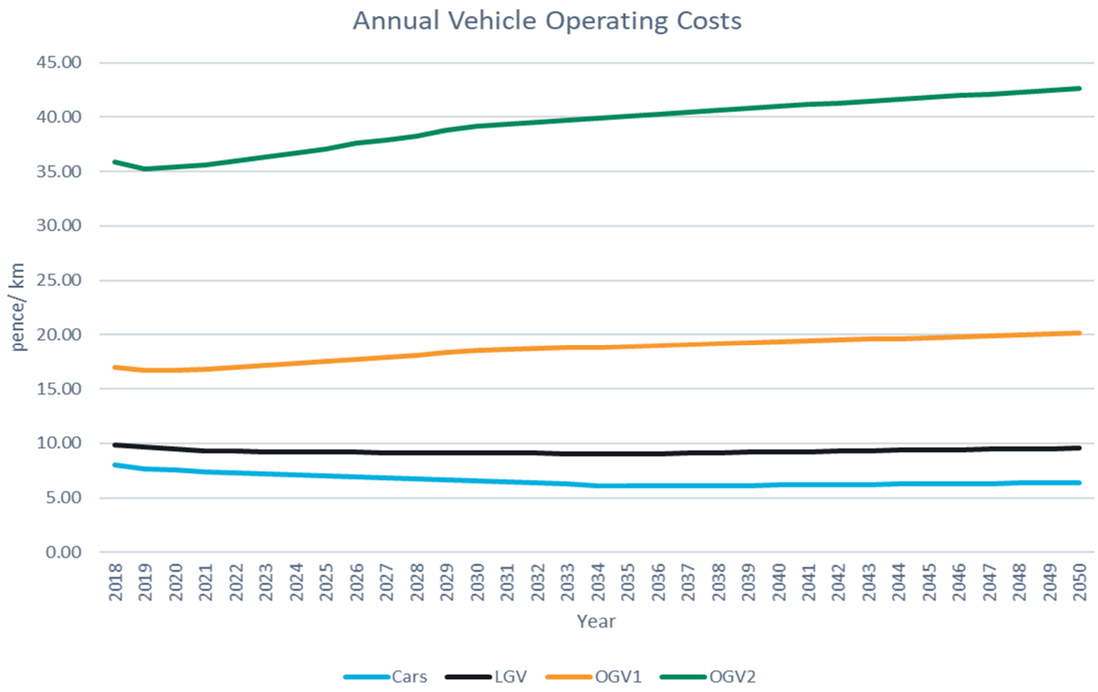
2.13

2.14 Figure 2.2 shows how the operating cost of different vehicle types changes over time.

Table 2.1: Vehicle fleet mix by business type

Business type	Car	LGV	OGV1	OGV2	Total
Advanced Manufacturing	10%	10%	50%	30%	100%
Knowledge Service Sectors	100%	0%	0%	0%	100%
Primary	5%	5%	45%	45%	100%
Finance and Business	100%	0%	0%	0%	100%
Education	90%	5%	5%	0%	100%
Retail and Catering	5%	45%	30%	20%	100%
Other Industry & Manufacturing	5%	5%	45%	45%	100%
Other Services	10%	10%	50%	30%	100%
Port Freight Handler	0%	20%	30%	50%	100%

Figure 2.2: Vehicle operating costs over time using updated method



Adaptation of SEELUM outputs to interface with the Emissions Factors Toolkit

2.25 To provide the Emissions Factors Toolkit with the data it requires, some adjustments to SEELUM outputs were needed. The Emissions Factors Toolkit requires the following inputs:

- link name (for link identification purposes);
- link lengths (in kilometres);
- link road type assignment (rural, urban or motorway);
- average link speed (in kilometres per hour);
- traffic flow on each link (number of vehicles per hour); and
- the number of Heavy Goods Vehicles per link (as a percentage of traffic flow).

2.26 Within SEELUM, highway vehicle kilometres between each zone pair is a combination of two components:

- The 'on-network' leg of the journey, and
- The 'off-network' leg (also known as the access network).

2.27 Together they represent the Strategic and Major Road Network in Figure 2.3. Trips where one of the origin or destination was outside of the TfSE area also needed special consideration

2.28 All road journeys in SEELUM contain an off-network component, however due to the on-network component representing the Strategic and Major Road Network, not all trips will be assigned to use it. (A detailed discussion on the approaches used for these network types can be found in our technical report on the building of SEELUM[3]).

2.29 For each zone pair, the on-network links can be identified that will be used during the journey. Each of these links has a distance attribute and using this attribute and an existing model input that provides the total distances between zone pairs, the respective on-network and off-network journey distances travelled can be calculated.

2.30 All on-network trips are within the TfSE area and the model can produce outputs for these trips (e.g. link ID, traffic flows, link distances, average link speeds, and percentage of OGVs per link) that can be used directly by the Emissions Factors Toolkit with some minor adjustments. Inputs to the Emissions Factors Toolkit need to be classified as "motorway", "rural" or "urban" road types. As the on-network links within the model are used to represent the Strategic and Major Road Network within the South East, these links were categorised as motorway journeys under road type.

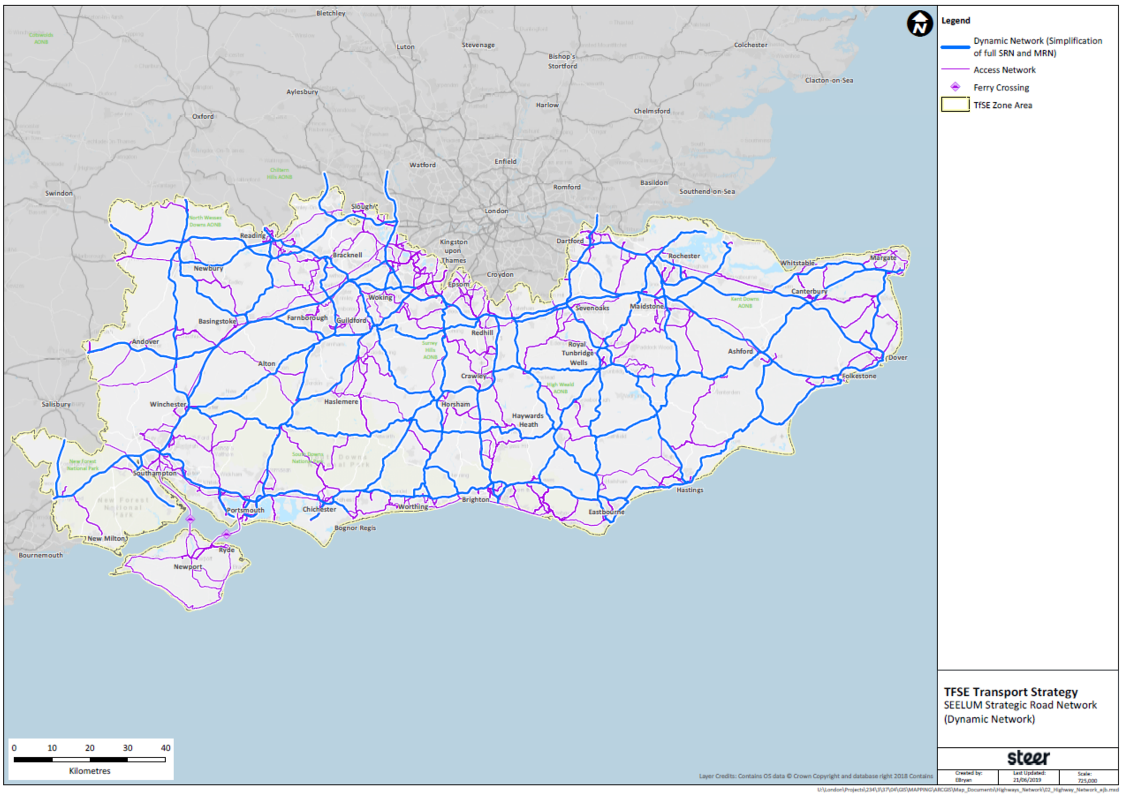
2.31 For off-network trips three 'pseudo-links' were created. These links were segregated to represent the different road types (motorway, rural and urban) that are not explicitly represented by the network. SEELUM generates the total number of off network trips for these links. The distances

[3] Transport Strategy for the South East – Scenario Forecasting Technical Report, Chapter 3.

for off-network trips was factored by the proportion of network kilometres assumed to be within the TfSE area. The proportions used can be found in

2.32 Table 2.2 below.

Figure 2.3: The Strategic and Major Road Networks and access network in the study area



Source: Steer

2.33 Off-network distances were segregated into rural, urban and motorway using data from the Department of Transports Transport Analysis Guidance (Table a 5.4.1) and referring to the assumed 2020 proportion of total traffic for the three-road types for regions outside of London. Using this assumption, an off-network road type split was calculated of:

- 0.37 for urban roads;
- 0.38 for rural roads; and
- 0.25 for motorway roads.

2.34 As SEELUM includes trips that are external to the TfSE area, a trip adjustment factor was introduced so as to only include trips that would use the TfSE road network. To achieve this, a matrix of factors was applied to all trips so as to only include trips where at least one of the origin or destination zones was within the TfSE area.

2.35 Following these adjustments, each of the average pseudo link distances (to be used as an input for the Emissions Factors Toolkit) was derived by dividing the total number of off-network vehicle kilometres modelled, by the total number of off network trips modelled. SEELUM was able to provide the remaining metrics (i.e. average off-network speeds link, and percentage of OGVs) with minimal further adjustment.

2.36 As the model has both a peak and off-peak period, adjustments were also made to ensure that the right proportion of peak and off-peak trips on each link – in terms of a vehicle flow for an average hour – were provided to the Emissions Factors Toolkit. In order to derive these flows the following assumptions were used as shown in Table 2.2. Using these assumptions, SEELUM outputs could be provided in the format and units required by the Emissions Factors Toolkit.

Table 2.2: SEELUM assumptions used to generate Emissions Factors Toolkit outputs

Assumption	Value	Source
Number of SEELUM Peak periods in average weekday	2	Steer
Number of SEELUM Off-peak periods in average weekday	2	Steer
Average Weekday to average weekday hour factor	0.0417 (i.e. 1/24)	Number of trips per day divided by 24 hours.
Annual Average Weekday traffic to Average Annual Daily Traffic factor	0.951	Analysis of weekday traffic compared to average day traffic profile (Highways England data)
On network road type assumed	Motorway	Steer
Percentage of Off-network distance apportioned to motorway road type	0.25	Transport Analysis Guidance (Table A 5.4.1) – 2020 road split
Percentage of Off-network distance apportioned to rural road type	0.38	Transport Analysis Guidance (Table A 5.4.1) – 2020 road split
Percentage of Off-network distance apportioned to urban road type	0.37	Transport Analysis Guidance (Table A 5.4.1) – 2020 road split
Off network distances multiplier for TfSE to TfSE trips	100%	Steer
Off network distances multiplier for External to TfSE trips (short distance	50%	Steer
Off network distances multiplier for External to TfSE trips (mid distance	20%	Steer
Off network distances multiplier for External to TfSE trips (long distance	10%	Steer
Off network distances multiplier for External to External trips	0%	Steer
Off network trip multiplier for TfSE to TfSE trips	100%	Steer
Off network distances multiplier for External to TfSE trips	100%	Steer
Off network distances multiplier for External to External trips	0%	Steer

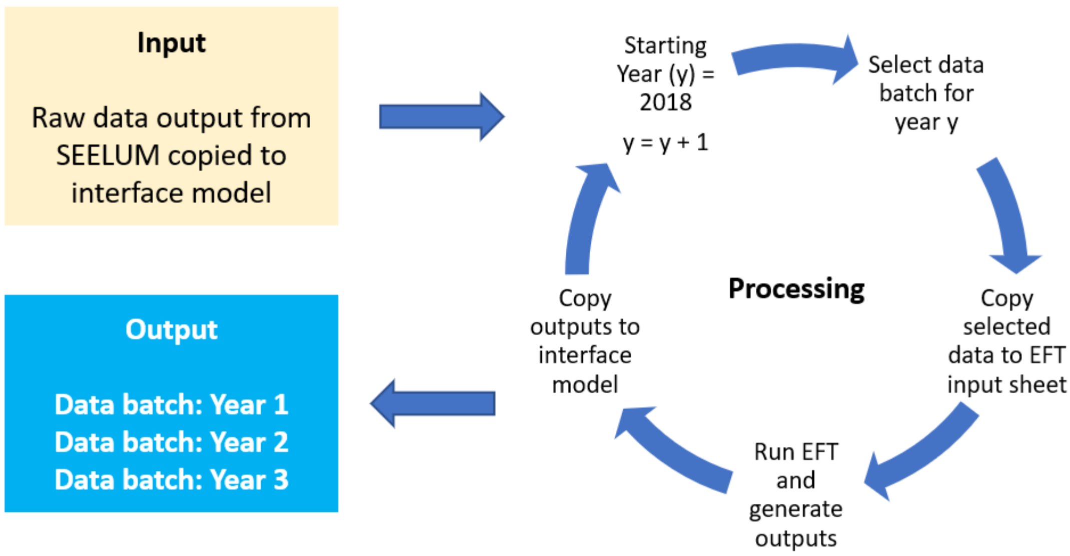
Interface with the Emissions Factors Toolkit

2.37 The interface with the Emissions Factors Toolkit was required due to the following reasons:

- Outputs generated through SEELUM were required to be made compatible with the input formats of the Emissions Factors Toolkit and;
- The Emissions Factors Toolkit can only run data in batches of a single year at a time.

2.38 An Excel tool based on VBA macros was developed that enabled automated batch-processing of SEELUM outputs. Figure 2.4 shows the process diagrammatically.

Figure 2.4: Interface with the Emissions Factors Toolkit



Source: Steer

2.39 A typical scenario run through the interface tool does the following:

i. Data dump for a given scenario is extracted from SEELUM as a raw excel file.
ii. First macro processes and transforms this dump into formats supported by the Emissions Factors Toolkit Input sheet.
iii. Through a second macro, the interface model cycles through each year in the processed data as a separate Emissions Factors Toolkit run.
iv. Outputs from the Emissions Factors Toolkit after each run are copied to the output sheet of the interface model and presented in a summary table, providing the calculated emissions produced for each link and year, ready for further analysis.

Calculating Road Emissions Within SEELUM

2.40 To allow “sense checking” of the outputs of the Emissions Factors Toolkit, functionality was added to SEELUM to also allow it to calculate highway emissions using the same data and assumptions as the Emissions Factor Toolkit (where they could be accessed).

2.41 Highway emissions are calculated as a function of emissions rates and vehicle kilometres. SEELUM is able to provide the vehicle kilometres and so the Emissions Factors Toolkit was used as a common source of data and assumptions regarding future fleet mixes and emissions rates for highway vehicles.

2.42 Average emissions rates, differing by road type (rural, urban and motorway), were calculated using the 2018 Emissions Factors Toolkit emissions rates for each vehicle type, (see Appendix D), and applying the vehicle fleet mixes provided within the Emissions Factors Toolkit, (see Appendix A).

2.43 Although the Emissions Factors Toolkit only calculates emissions till 2030, the fleet mix assumptions by road type were presented up to 2035. However, this still falls short of the horizon year of the Transport Strategy scenarios, which are modelled until 2050. Therefore, in order to not have a constant fleet mix assumption post 2035, the rate of change for each vehicle type was taken between 2034 to 2035 and applied it to each year up to 2050. It should be noted that assumed changes in fleet mix post 2035 should be treated as hypothetical and were made in the absence of guidance from the Department for Transport. These high-level assumptions are therefore not intended to be used as forecasts but rather a proxy for scenario testing.

2.44 The emissions rates for 2018 were taken directly from the Emissions Factors Toolkit. Emission rates between 2018 and 2030 were assumed to improve by 1% per year. This assumption was calculated by comparing Emissions Factors Toolkit outputs between 2018 and 2030 and adjusting for the change in vehicle kilometres travelled as well as the change of emissions rate that could be attributed to the changing fleet mix.

2.45 This rate of change between 2018 and2030 is an area for potential future improvement if the detailed data within the Emissions Factors Toolkit could be made available.

2.46 As the Emissions Factors Toolkit only produces outputs up to 2030, the post 2030 rate of efficiency improvement is based on guidance produced by Highways England in a document [4] highlighting areas of future development of the Emissions Toolkits Factor. These assumptions can be found in Appendix B. By applying these adjusted vehicle type emissions factors to the estimated vehicle fleet mixes by road type, the assumed average rate of emissions by road type was calculated. These emissions can be found in Appendix A.

2.47 By multiplying the number of trips calculated by SEELUM by the trip distances, segregated by on-network and off-network, the vehicle kilometres travelled were derived, segregated by road type (urban, rural and motorway). These values were then multiplied by the emissions rates for each road type to generate the total emissions produced for the model's periods.

2.48 Seeing as the Emissions Factors Toolkit estimates for vehicle fleet mix and vehicle emission rates were static tables, assumptions were required to adjust the impact of modal shift as a result of scenario testing on road-based emissions. To incorporate impacts relating to modal shift (e.g. from car to bus) we have adjusted the emissions assumed to be generated by Passenger Service Vehicles (bus, coach and taxi/private hire) to scale in

[4] "Highways England Carbon appraisal methodology – Greenhouse gas calculations and the emissions factors toolkit"

proportion to the relative increase in mode trips when compared to the Business as Usual scenario.

2.49 This has allowed for a more accurate estimate of carbon emissions generated in various scenario tests. It should be noted that this adjustment does not currently consider spare capacity on the bus network, which would translate to an increased impact when adjusting emissions rates. Due to the relatively low proportion of emissions generated by PSVs when compared to total Road emissions, this assumption appears sensible. However, the adjustment assumption has been identified as a potential area for future improvement.

2.50 SEELUM models two periods during the average weekday: “peak” and “off-peak”. In order to scale these emissions up into an annual total level, additional assumptions were applied:

- An average weekday contained two model peak periods and two model off-peak periods.
- These were factored by the average weekday total by 0.951 in order to convert the total emissions to an annual average day value.
- This factor was derived from *weekday* traffic levels across multiple sites within the South East compared to that of an *average day* for the same sites using Highways England data[5].
- Finally, the total emissions calculated for an average annual day was multiplied by 365 (assumed number of days per year) to produce the total annual emissions for road travel within SEELUM.

2.51 The emissions rate within SEELUM does not consider an adjustment relating to average speed across the network. This is applied and adjusted for within the Emissions Factors Toolkit. As such, the incorporation of an average network speed and its impact on vehicle emissions has been identified as a potential future improvement. This incorporation would provide further refinement to the internal calculations within the model.

[5] http://webtris.highwaysengland.co.uk/

3 Calculating rail emissions

Introduction

3.1 In contrast to road emissions, where a model to calculate these has been developed (the Emissions Factors Toolkit) no such standard tool exists for rail emissions. This is likely due the shifting base assumptions and the large number of different data sources needed, for example: fleet mix of each operator, rolling stock consumption rates and the assumed service timetable.

3.2 An approach has been taken that we consider reasonable, given the current constraints, for estimating the contribution of rail to overall emissions. It has been developed to be integrated within the SEELUM model and based on a combination of publicly available data and Steer industry knowledge.

3.3 To validate the approach, a comparison has been carried out with an alternative method that calculated emissions outside of SEELUM. This is described at the end of this section alongside possible future areas of development.

Method

Calculating greenhouse gas emissions for a rail service

3.4 Focus is initially on the calculation of CO_2e emitted by a train service. This, measured in units of $KgCO_2e$ (kilograms of carbon-dioxide equivalent) which is a function of:

- the distance travelled by the service;
- the fuel used by the service. Depending on rolling stock type this is either:
  - diesel measured in litres (L); and
  - electricity measured in kilowatt-hours (kWh);
- the consumption rate (i.e. how much fuel is used per distance travelled) which is a function of:
  - the rolling stock type;
  - the number of vehicles in the train;
  - the timetable / service pattern, which impacts:
    - the speed the train runs at; and
    - how frequently a service stops - more stops mean more time waiting at stations and then accelerating to get up to speed afterwards; and
- the assumed greenhouse gas emissions per unit of fuel used.

3.5 For any given service, it’s total emissions can be therefore be calculated as the following product:

Rail service emissions	=	kilometres travelled	x	vehicles in service	x	consumption rate per kilometre per vehicle	x	greenhouse gas emissions per unit of fuel used

3.6 Future changes in emissions for a service would be driven by forecasts for each of these contributing factors. While it is stated later how changes to ‘kilometres travelled’ and ‘vehicles in service’ are dealt with, it is worth noting that the assumptions for changes for the other two factors are sourced from the Transport Appraisal Guidance Databoook, May 2019.

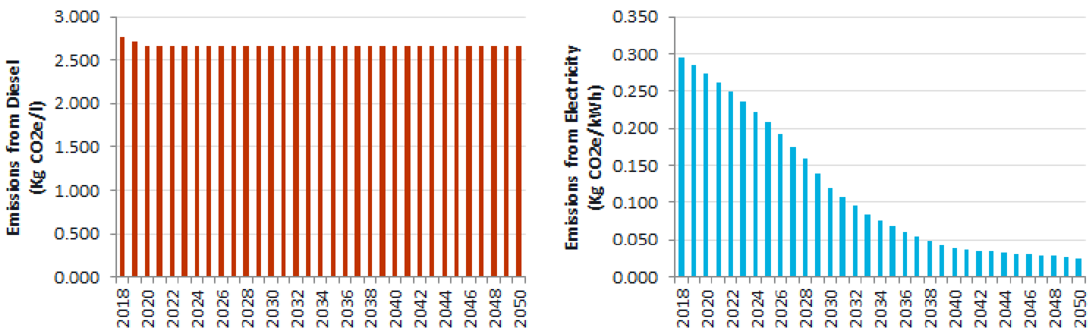
3.7 Consumption rates are from *‘Table A 1.3.10: Forecast Assumed Vehicle Fuel Efficiency Improvements to 2050’*. Note that the Guidance assumptions forecast no change in consumption rates for diesel powered stock from 2020, and no change at all for electric powered stock. This is likely an underestimate of the future improvements to fuel efficiency but has been used in the absence of any other readily available data source.

3.8 Greenhouse gas emissions per unit of fuel are from *‘Table A 3.3: Carbon dioxide emissions per litre of fuel burnt / kWh used’*. For diesel-based greenhouse gas emissions, the Guidance assumes a 3% decrease in rate from 2028 to 2020 and a 0% change from 2020 to 2050. For electric-based greenhouse gas emissions, the Guidance assumes a 7% decrease from 2018 to 2020, and a further 91% decrease from 2020 to 2050, resulting in a total 91% decrease.

3.9 Transport Appraisal Guidance explains the approach to estimating emissions and these indicators in *‘TAG Unit A3 Environmental Impact Appraisal’*.

3.10 With the majority of services in the TfSE region being electric, the forecast 91% drop in greenhouse gas emissions per kWh electricity is expected to drive the results of the overall forecast emissions attributed to rail services – see Figure 3.1.

Figure 3.1: Assumed forecast Rail Emissions from Diesel (left) and Electricity (right) – Note different axis



Source: Transport Analysis Guidance Databook, May 2019, Table A 3.3

3.11 A full list of sources is found in Appendix E.

Services in the TfSE area

3.12 The TfSE area is served by a number of different operators - see Figure 3.2. It contains:

- The majority, if not all, of the South Western Railway, Southern and Southeastern operators, which cover a broad region;
- Thameslink services operated south of London;
- Specialist services such as Gatwick Express and HS1, the latter run by Southeastern; and
- A proportion of services at the boundaries run by Great Western Railway and CrossCountry.

Figure 3.2: Excerpt of National Rail Train Operator Route Map showing the range of different train operators in the London and TfSE region.

Source: www.nationalrail.co.uk – Train Operator Route Map

3.13 Each of these operators run a range of service pattern using a range different rolling stock. The majority of the region is electrified but there are sections which still run diesel services. Rather than assign rolling stock to every service and explicitly modelling them, a high-level approach was undertaken. This started with deriving an assumed consumption rate per mile for each Train Operating Company (TOC).

3.14 The fleet for each TOC was reviewed and a data gathering exercise took place in which the following information was obtained:

- Vehicle types operated by each TOC,
- Whether the vehicle runs on Diesel or Electric power,
- The consumption rate per vehicle, and
- The following information to aid aggregation:
  - Number of each vehicle in the service of each TOC,
  - Seating capacities per vehicle,
  - Assumed vehicles per service,

3.15 The current consumption rates for the majority of electric stock was selectively sourced from Network Rail's 'Traction Electricity Modelled Consumption Rates List' for Control Period 6. For diesel stock, and electric stock not listed in the previous file, the rates were estimated based on Steer industry knowledge.

3.16 Once a fuel consumption rate per vehicle for each type of rolling stock was estimated, these were then aggregated into 12 TOC categories based on TOC areas of operation and fuel type. The average consumption rate was weighted by the number of vehicles for each stock type in service by the TOC.

3.17 Table 3.1 shows the 12 TOC categories and the estimated consumption rates. Note most electric stock consumes between 3-5 kWh per vehicle mile. The Thameslink value of 2 kWh per mile is a Steer judgement based how recent the stock was built and the inclusion of regenerative braking which aids fuel efficiency by approximately 20%.

Table 3.1: Consumption rates per vehicle mile

TOC category	Consumption rate per vehicle mile	
CrossCountry – Diesel	1.00	litre
Gatwick Express – Electric	3.50	kWh
Great Western, South Coast – Diesel	0.70	litre
Great Western, Inland – Diesel	0.70	litre
Great Western – Electric	3.50	kWh
Southeastern, HS1 only – Electric	3.60	kWh
Southeastern, not HS1 – Electric	4.33	kWh
Southern – Diesel	0.70	litre
Southern – Electric	3.46	kWh
Southern, Inland – Electric	3.32	kWh
South Western Railway – Electric	3.88	kWh
Thameslink – Electric	2.00	kWh

Note: Each figure presented is an aggregation of high-level estimates. The figures should be used only for the purpose they were created for and should not be presented as evidence of the level of one TOCs consumption over another.

3.18 The Transport Analysis Guidance tables mentioned earlier are then used to create a forecast set of greenhouse gas emissions per vehicle kilometre from 2018 to 2050 for each TOC Category.

Estimating rail emissions across the TfSE area within SEELUM

3.19 Rather than base the emissions calculation on the entire rail network in the TfSE region, emissions have been estimated using the simplified version of the rail network contained within SEELUM and extrapolating it to cover the full network. The SEELUM rail network is shown in Rail emissions for the TfSE area are estimated by:

- Estimating the emissions for each rail network link.
- Extrapolating to cover the entire TfSE area.
- Applying an annualisation factor.

3.20 The emissions for each rail network link are calculated by:

- Assigning a TOC Category 'emission rate per vehicle kilometre' to the link, blending between TOC Categories where appropriate.
- Converting this to 'emission rate per seat kilometre' using researched fleet mix and seats per vehicle.
- Multiplying by seats on the rail link (already contained within SEELUM for Peak and Off-Peak) and link length.

3.21 This is extrapolated to cover the entire TfSE area by:

- Calculating the average greenhouse gas emissions rate per passenger minute based on the number of passengers travelling on each rail link and their journey time on each rail link.
- Then multiplying this by the time rail passengers spend travelling not on rail links, nor on access / egress modes, to get the total 'off-network' emissions.
- The off-network emissions are added to the link emissions to get total emissions.

3.22 Figure 3.3 overleaf with SEELUM's zone to zone rail journeys assigned to use the links most appropriate for each zone pair. The SEELUM rail network was constructed in order to simulate the impact of capacity constraints on rail demand and as such the rail links included reflect the busiest rail corridors over the breadth of the TfSE region.

3.23 Rail emissions for the TfSE area are estimated by:

- Estimating the emissions for each rail network link.
- Extrapolating to cover the entire TfSE area.
- Applying an annualisation factor.

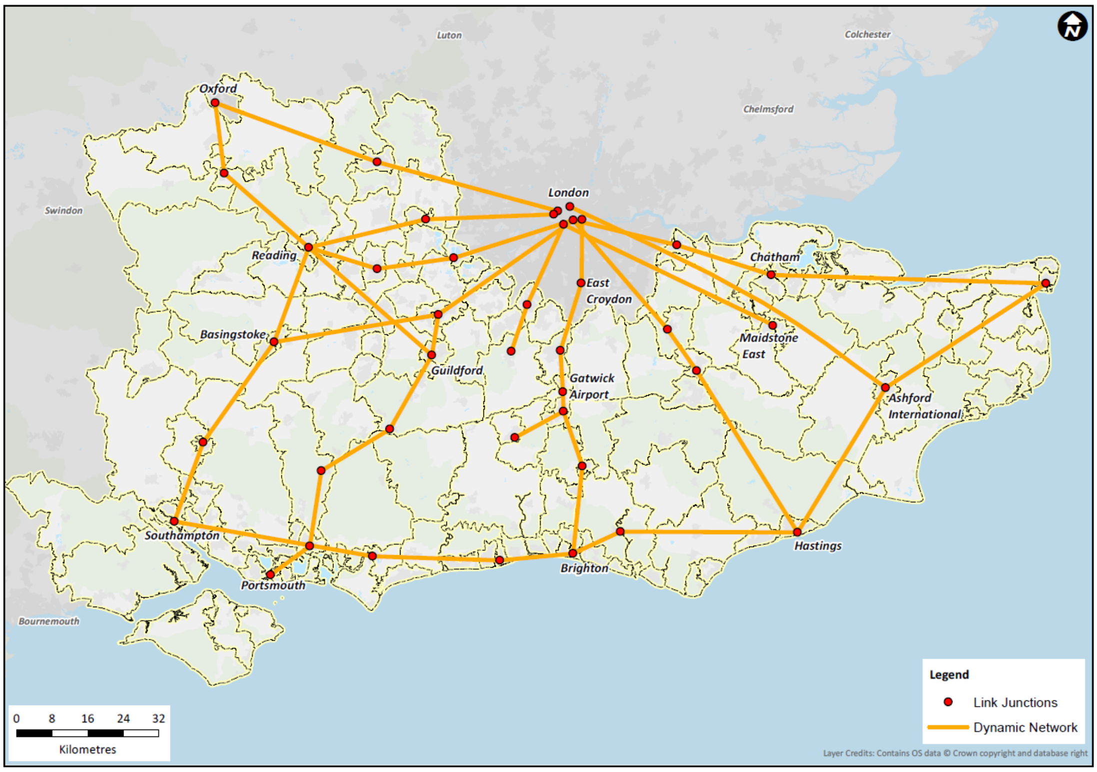
3.24 The emissions for each rail network link are calculated by:

- Assigning a TOC Category 'emission rate per vehicle kilometre' to the link, blending between TOC Categories where appropriate.
- Converting this to 'emission rate per seat kilometre' using researched fleet mix and seats per vehicle.
- Multiplying by seats on the rail link (already contained within SEELUM for Peak and Off-Peak) and link length.

3.25 This is extrapolated to cover the entire TfSE area by:

- Calculating the average greenhouse gas emissions rate per passenger minute based on the number of passengers travelling on each rail link and their journey time on each rail link.
- Then multiplying this by the time rail passengers spend travelling not on rail links, nor on access / egress modes, to get the total 'off-network' emissions.
- The off-network emissions are added to the link emissions to get total emissions.

Figure 3.3: SEELUM Rail Network



Source: Steer

3.26 Note that only demand between zone pairs (and rail links) within the London and TfSE areas are considered in the above method as it is assumed that all rail services in the TfSE region will carry at least one passenger from this area. In other words, zone-to-zone rail demand and generalised journey time has been used to estimate the coverage of rail services in the TfSE region relative to the SEELUM rail network.

3.27 This method is calculated for peak and off-peak hours and summed to get a daily rail emissions level. An annualisation factor of 332 is applied to get an annual figure. The annualisation factor is calculated by:

- comparing the number of Southeastern and South Western Railway services in a weekday timetable against the number in a Saturday and Sunday timetable,
- then extrapolating based on the number of each days in the year, and
- considering reduced services on bank holidays.

Review of results

3.28 Table ENV0201 from the 2019 Transport Statistics Great Britain report estimates that in 2017 rail accounted for 2% of domestic transport (road and rail) greenhouse gas emissions. From SEELUM, it is estimated as 3% in 2018. Considering the approach taken, we assess this to be a sensible approximation.

3.29 As a further sense check, rail emissions have been calculated outside of SEELUM based on the kilometres run by services in the TfSE area and applying a single average emissions factor by train kilometre. While also a high-level method sensitive to the assumed emissions factor, it is a useful comparison as it takes a very different approach to the one used in SEELUM. A variation of around 60% in emissions in 2018 is observed, which would increase rail's contribution to total emissions by approximately two percentage points.

3.30 These sense checks have served to add validity to our estimate while also showing that there remains scope for improvement.

Limitations and possible future areas for improvement

3.31 Looking back at the original calculation for rail service emissions:

Equation 3.1: Rail service emissions calculation

Rail service emissions	=	kilometres travelled	x	vehicles in service	x	consumption rate per kilometre per vehicle	x	greenhouse gas emissions per unit of fuel used

3.32 For option testing within SEELUM, changes were reflected to kilometres travelled by capacity changes in the rail network which are present in the existing options.

3.33 There are three areas where we believe there is scope for improvement:

- The assumed change in *'consumption rate per km per vehicle'* is static from 2020 in Transport Analysis Guidance Databook. In reality this will change as the fleet mix of different operators changes, either due to electrification schemes reducing the need for diesel powered stock, or simply certain stock types reaching the end of their usable life and needing to be replaced. Several operators in the TfSE region will be replacing stock within the next 5 years. New rolling stock tend to be more fuel efficient and include functions such as regenerative braking, where energy created by braking is re-used, and can reduce consumption by around 20%.
- Our method focuses on calculating emissions on a subset of the rail network and extrapolating based on passenger journey time. It may be more robust to base it on distance travelled from services derived from the timetable. However, to this would require a significant exercise to estimate the stock type and train length for each service.
- An update of input data sources as and when newer and/or more detailed sources become available.

4 Scenario results

Introduction

4.1 This section presents the model outputs and discusses results. These results and accompanying commentary have been separated into two sub-sections, with the focus of each being:

- the impacts resulting from updating SEELUM's Vehicle Operating Cost assumptions; and
- the emerging results relating to calculated Transport Emissions.

4.2 The following naming conventions are used for the scenarios:

- **Business as Usual (BAU)**: This scenario assumes NTEM growth and only do minimum transport interventions.
- **Sustainable Route to Growth (SRtG)**: A "do something" scenario aimed to increased mode shift to public transportation while encouraging economic growth within the study area. This scenario is supported by increased road pricing, public transport fare subsidisation, no policy constraints on CAV/MAAS, road space reallocation, improved bus/high quality urban transit and pedestrianised urban centres. This scenario is also the "preferred scenario" informing TfSE's Transport Strategy.

4.3 Further details regarding the scenarios, naming conversions and description regarding output metrics can be found within our full report[6].

Impact of vehicle operating cost assumption update

4.4 This section provides the updated key metric as well as transport-based impacts of the tested scenarios as a result of updating our vehicle operating cost (VOC) assumptions.

4.5 The tables below show the impacts of the updated vehicle operating cost calculation by comparing our final year (2050) model results. Table 4.1 highlights the impact between a version of the Business as Usual scenario, run in the model which assumed the previous vehicle operating cost calculation, and compares the outputs with a version of the Business as Usual scenario run in the model that utilises the new vehicle operating cost assumption.

[6] Report Title: Transport Strategy for the South East – Scenario Forecasting Technical Report

Table 4.1: BAU model output comparison (prior and post vehicle operating cost update)

Model	Population	Employment	Gross Value Added (GVA)	Total Trips
BAU (pre VOC update)	8.84m	3.68m	400b	24.2m
BAU (post VOC update)	8.84m	3.69m	401b	24.3m
% impact of VOC update	**-0.04%**	**+0.3%**	**+0.3%**	**+1%**

4.6 The results from Table 4.1 illustrate that the overall impact of implementing these more refined vehicle operating costs assumptions was rather marginal across the key metrics. The resulting impact is driven by the relative change in vehicle operating costs experienced for the most dominant road transport mode, which is car. Where previously the operating costs were assumed to rise gradually throughout the modelling period, the costs for car journeys are now expected to reduce over time, which increases the propensity to travel, thereby generating marginally more trips throughout the study area.

4.7 Table 4.2 illustrates the implied impact between the Business as Usual scenario and the Sustainable Route to Growth (preferred option) scenario. This table also shows the difference derived between the two scenarios compared to what has previously been reported (prior to VOC calculation update) found in the final row.

Table 4.2: BAU vs. SRtG (post vehicle operating cost update)

Model	Population	Employment	Gross Value Added (GVA)	Total Trips
BAU (post VOC)	8.84m	3.69m	401b	24.3m
SRtG (post VOC)	8.93	4.19m	464b	25.5m
% impact scenario	+1%	+14%	+16%	+5%
Difference from impact previously reported	**0%**	**+1%**	**+1%**	**+1%**

4.8 The change in vehicle operating cost assumptions has improved the model's robustness and had minimal impacts on key metrics. Therefore, the updating of this assumption does not alter the preferred scenario commentary.

SEELUM emissions results

Introduction

4.9 This section provides the results relating to emissions calculations for the two scenarios identified above. As the work progressed throughout this study, it became clear that certain key underlying assumptions in the Emissions Factors Toolkit did not align with Transport Analysis Guidance. These assumptions inhibited the possibility of achieving a net zero outcome without further adjustment and have been identified as limitations below.

Limitations of the Emissions Factors Toolkit

4.10 The current version of the Emissions Factors Toolkit (version 9.0), released in May 2019, has limitations identified by the Department for Transport. A recent Highways England review of the underlying data also found that whilst the Emissions Factors Toolkit is methodologically more robust than TUBA for estimating emissions, underlying issues are likely to lead to a significant over estimation of emissions in the long term.

4.11 Steer's review of the Emissions Factors Toolkit has similarly highlighted some limitations regarding the tool and its underlying assumptions. The main areas identified as recommendations for future development and updating of assumptions include:

- The lack of assumed electric vehicles within the vehicle fleet mix for various road types. Currently the Emissions Factors Toolkit assumes no electric vehicles to be present on road types defined as "rural" or "motorway", and only 7.3% of total vehicles to be electric on "urban" roads by 2035. We view this assumption as an under-estimate. This point has similarly been raised by Highways England, who stated that fleet proportions should be aligned with Transport Analysis Guidance[7].
- Non-alignment with Transport Analysis Guidance emissions factors and the assumed adjustment in efficiency growth have also been highlighted as potential limitations by Highways England and have been confirmed by the Department for Transport as areas to be addressed in future updates to the tool.
- The Emissions Factors Toolkit currently only projects emissions to 2030, which is short of Transport for the South East's forecast horizon of 2050. Therefore, we were required to extrapolate certain assumptions to enable calculations of emissions to 2050. Where possible, this extrapolation has been performed applying recommendations as per Highways England guidelines.
- As the Emissions Factors Toolkit does not include calculation of rail emission Steer has developed its own calculation within SEELUM.

4.12 While awaiting an updated version of the Emissions Factors Toolkit, anticipated shortly in 2020, the outputs derived from the Emissions Factors Toolkit have been primarily used as benchmark figures until a revised update is made available. As these misaligned assumptions are shared in both emissions' calculation methods, we assess the absolute values generated from calculations will be subject to further adjustments in the future. As such the emissions rates calculated by the both models have been presented by indexing expected emissions to a 2018 level. This has allowed inference of similarities regarding expected trend impacts where possible in an attempt to validate results.

Results

4.13 The charts and tables below show the level of emissions from 2018 to 2050, associated with road and rail transport. All charts have been indexed on 2018

[7] "Highways England Carbon appraisal methodology – Greenhouse gas calculations and the emissions factors toolkit"

values and therefore present the expected change in emissions throughout the modelling period based on 2018 emissions.

4.14

4.15 Figure 4.1 and Figure 4.2 below present calculated indexed emissions factors for road and rail from 2018 till 2050. Both charts compare outputs generated by the Emissions Factors Toolkit and internal SEELUM calculations for road. Due to the lack of a standardised rail emissions toolkit, only rail emissions generated within SEELUM have been presented. As mentioned within the rail calculations section of this report, the rail emissions have been validated by comparison with an alternative method which was calculated outside of SEELUM.

Figure 4.1: SEELUM vs Emissions Factors Toolkit output comparison (BAU)

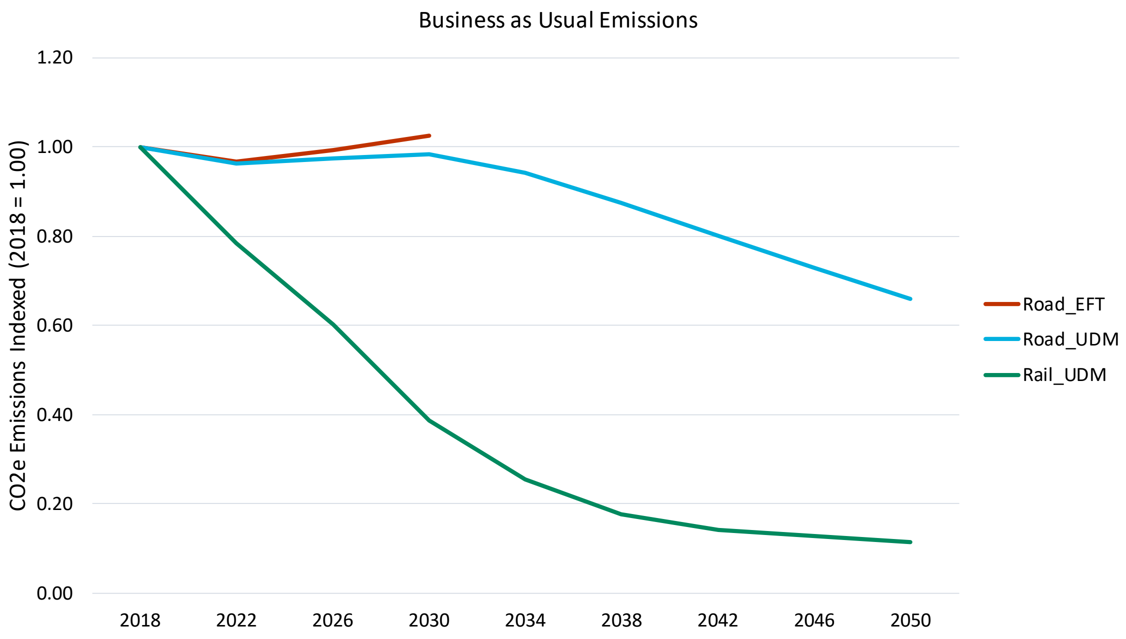
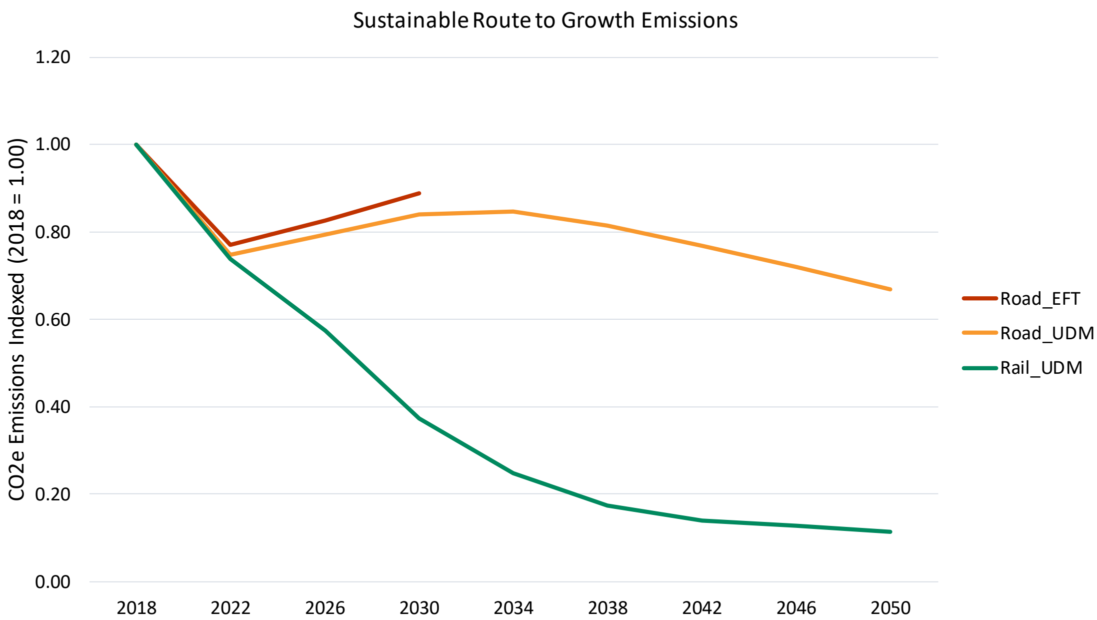


Figure 4.2: SEELUM vs Emissions Factors Toolkit output comparison (SRtG)

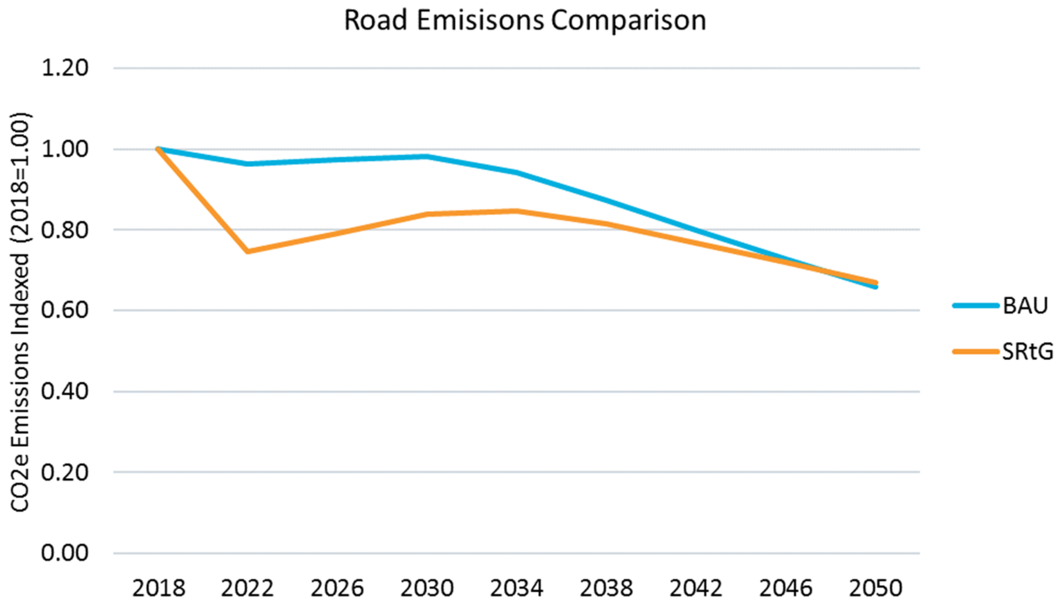


4.16 Both figures above achieve the same reduction in rail emissions over the modelled period. This is because rail emissions in the model are driven by changes in the number of rail vehicles (and hence carrying capacity). The scenario assumes improvements to fares and generalised journey time with an implicit assumption that it is delivered with the same rail vehicle fleet. In both scenarios, rail emissions reduce to around 11% of 2018 emissions by 2050. It should be highlighted that that future improvement to assumptions relating to rail capacity could be made in order to satisfy levels of service required for the increased levels of rail demand found in do-something scenarios.

4.17 Both estimates follow a similar profile in the short term, with a slight divergence for the Emissions Factors Toolkit values, which increase at a slightly steeper rate by 2030. This divergence is understood to be due to the Emissions Factors Toolkit's taking account of speed variations, which is not included in SEELUMs internal calculation. The similarity between emission estimates for road between both methods provides validation that the impact of scenarios is expected to be similar, satisfying that the long-term results generate by SEELUM appear to be sensible.

4.18 Figure 4.3 below illustrates the difference between the road emissions generated by SEELUM for our two scenarios.

Figure 4.3: SEELUM BAU vs. SRtG Road emissions comparison



4.19 The outputs show emissions for road reducing to around 66% of 2018 levels by 2050 for both scenarios. Even though the SRtG scenario is expected to have fewer trips by 2050 than BAU, the similarity of end point emissions is due to longer average journey distances under the SRtG scenario, this can be explained by the scenario encouraging individuals to travel further to places of work as a result of the scenario interventions implemented. This results in similar total vehicle kilometres being travelled throughout the network for both scenarios.

4.20 Note that though the end point of both scenarios reaches a similar reduction of emissions, the cumulative effect of implementing the SRtG scenario is a substantially lower in terms of total volume of emissions produced throughout the modelled period (i.e. the area under the curve).

4.21 A noticeable differentiating factor between model outputs is the rapid short-term decline in emissions experienced by SRtG when compared to BAU. This rapid decline is a result of the do something scenario schemes being implemented at the beginning of the modelling period. This is an area which could potentially be refined in the future to accommodate the phased application of schemes over time. It should be noted however that the benefits associated with these schemes are modelled dynamically and therefore realised on an annual basis. Phasing the do something schemes would reduce the difference between the two road emissions scenario outputs.

4.22 This indexed level of emissions resulting from road transport illustrates that the target of achieving net zero carbon by 2050 would not be possible. This is a result of the current assumptions regarding vehicle type emissions and fleet mixes for road types obtained from the Emissions Factors Toolkit. As stated previously these assumptions should be reviewed and updated.

4.23 Due to these assumptions inhibiting the possibility of achieving a net zero outcome by 2050 the method was adjusted to that of identifying high-level assumptions which would allow for differing levels of emissions reduction. The aim of this was to provide further information regarding the adjustments needed to hypothetical future scenarios, thereby enabling a 2050 Net Zero outcome.

Hypothetical scenario creation

4.24 After reviewing the assumptions within the Emissions Factors Toolkit, the factor limiting the expected rate of emissions reduction over time was found to be, in Steers view, the relatively low conversion rate of vehicle fleet to electric vehicles (zero emission vehicles). The Emissions Factors Toolkit currently assumes only 7.3% of the urban fleet mix will be electrified by 2035, with 0% assumed for rural and motorway fleets. Extrapolating this rate of change to 2050 leads to an assumed electrified fleet level of 20.8% for the urban fleet, and 0% for rural and motorway fleet mixes. Furthermore, this 20.8% would only apply to 37%[8] of off-network journeys. Therefore, our understanding is that using these current assumptions, the relative number of electric vehicles across the network by 2050 has been underestimated, and, in absence of updated assumptions, requires the development of high-level scenarios to better project the future emissions generated within the South East.

4.25 With the aim of creating scenarios, which could realistically lead to a net zero carbon outcome by 2050, three varying levels of assumed electric fleet mix by 2050 have been developed as a proxy. The three hypothetical scenarios created were:

- "Conservative" electric vehicle fleet mix where by 2050:
  - 75% of cars
  - 50% of Light Goods Vehicles
  - 25% of Other Goods Vehicles/Heavy Goods Vehicles, and
  - 50% of Passenger Service Vehicles are assumed to be electric
- "Intermediate" electric vehicle fleet mix where by 2050:
  - 80% of cars
  - 60% of Light Goods Vehicles
  - 40% of Other Goods Vehicles/Heavy Goods Vehicles, and
  - 80% of Passenger Service Vehicles are assumed to be electric
- "Express" electric vehicle fleet mix where by 2050:
  - 100% of cars
  - 80% of Light Goods Vehicles
  - 60% of Other Goods Vehicles/Heavy Goods Vehicles, and
  - 100% of Passenger Service Vehicles are assumed to be electric

4.26 In other words, an assumption has been made that the electric fleet is assumed to grow linearly from 2018, till the fleet mix of electric vehicles for each scenario has been reached by 2050. The expected impacts on emissions generated by these three hypothetical scenarios have been profiled over time in

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[8] The assumed proportion of urban road splits for off-network journeys. Sourced from Transport Analysis Guidance (Table A 5.4.1).

4.28 Figure 4.4, Figure 4.5 and Figure 4.6 below.

Figure 4.4: Change in emissions – Conservative fleet change

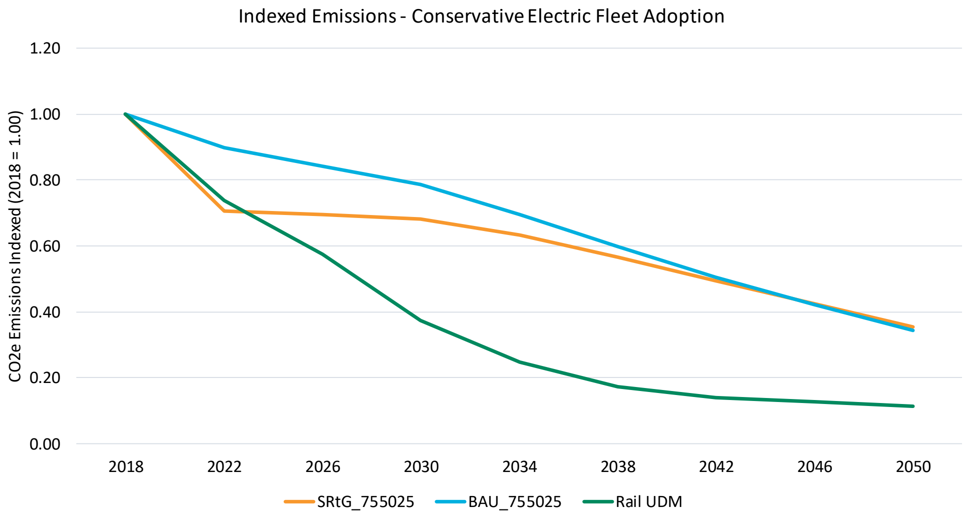


Figure 4.5: Change in emissions – Intermediate fleet change

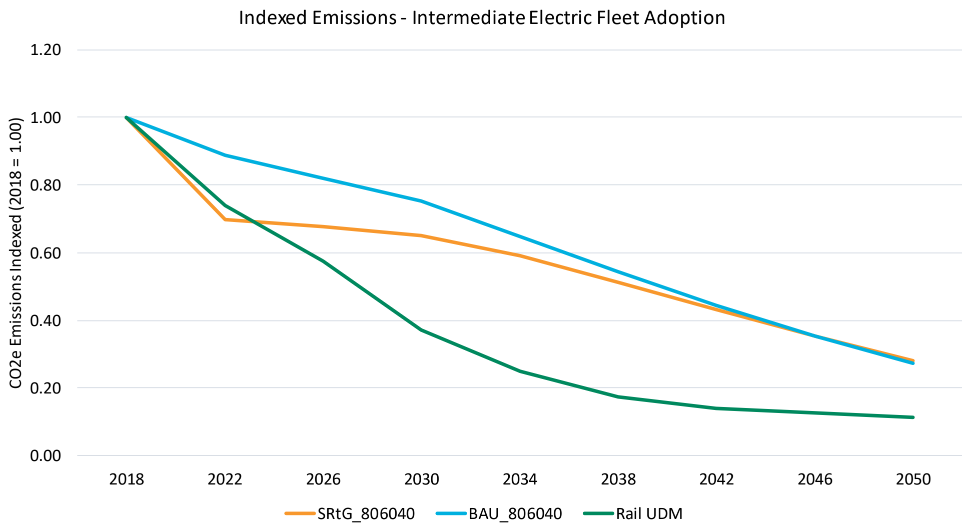
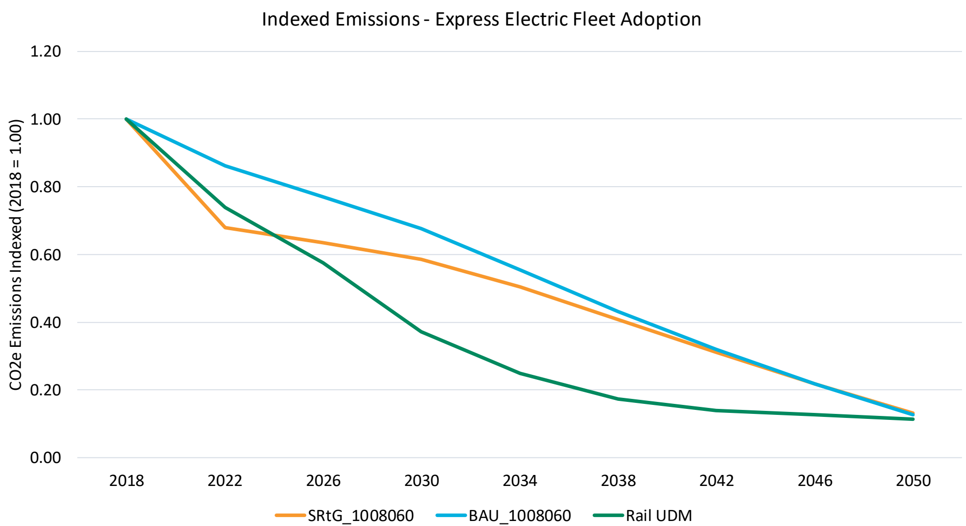


Figure 4.6: Change in emissions – Express fleet change



4.29 As can be seen from the charts above, increasing the rate assumed for electric fleet adoption reduces the resulting generation of road emissions. Table 4.3 below summaries the indexed road emissions generated by 2050 across the three scenarios.

Table 4.3: 2050 road emissions (indexed on 2018 values)

Scenario	Current Assumption	Conservative	Intermediate	Express
Business as Usual	0.66	0.34	0.27	0.13
Sustainable Route to Growth	0.67	0.36	0.28	0.13

4.30 From the table above, it can be seen that to achieve net zero carbon, even allowing for up to 5% of residual emissions to be off-set or captured, by 2050, further interventions would be required for all scenarios. To illustrate the level of impact required by these interventions, the level of non-electric vehicle trips has been quantified that will need to be reduced, either by encouraging fewer trips be taken or shifting the trips to other modes.

4.31 For this illustration, it has been assumed motorway vehicle fleet mix proportions for all road trips. This is appropriate due to the motorway kilometres being the highest number of vehicle kilometres travelled throughout the model.

4.32 In Table 4.4 below, the total number of road trips for both the "Business as Usual" and "Sustainable Route to Growth" scenarios have been provided. Additionally, the number of road trips have been split proportionately to represent the assumed number of Car, LGV, HGV (or OGV) and PSV journeys to take place in 2050. It should be noted that the number of trips in the table below are not directly proportional to the emissions produced by each vehicle category due to the characteristics attributed to each category.

Table 4.4: High-level assumed number of trips by vehicle category by 2050 (in million trips)

Model	Total Road Trips (2050)	Car Trips	LGV Trips	OGV/HGV Trips	PSV Trips
BAU	19.367m	12.836m	3.272m	1.899m	1.360m
SRtG	19.491m	11.877m	3.027m	1.757m	2.831m

4.33 By utilising the above number of vehicle trips, in conjunction with the assumed adoption relating to electric vehicles, the number of non-electric vehicles modelled can be identified which generate CO_2e emissions. The number of non-electric vehicles for each scenario has been provided in the table below.

Table 4.5: Number of non-electric vehicle trips by type in 2050 (in millions of trips)

Scenario Vehicle Type	Conservative		Intermediate		Express	
	BAU	SRtG	BAU	SRtG	BAU	SRtG
Car	3.2	3.0	2.6	2.4	-	-
LGV	1.6	1.5	1.3	1.2	0.7	0.6
OGV/HGV	1.4	1.3	1.1	1.1	0.8	0.7
PSV	0.7	1.4	0.3	0.6	-	-

4.34 Using the SEELUM outputs of road emissions, it is also possible to determine the total emissions produced by each vehicle type. These emissions, broken down by vehicle type for each scenario, has been provided in the table below:

Table 4.6: Emissions generated by non-electric vehicle trips by type in 2050 (in million kg of CO_2e emissions)

Scenario Vehicle Type	Conservative		Intermediate		Express	
	BAU	SRtG	BAU	SRtG	BAU	SRtG
Car	2,946	2,894	2,357	2,316	-	-
LGV	2,199	2,242	1,759	1,794	880	897
OGV/HGV	6,877	7,184	5,502	5,747	3,668	3,831
PSV	208	403	83	161	-	-
Total	**12,229**	**12,723**	**9,700**	**10,017**	**4,547**	**4,728**

4.35 From our estimates, in order to achieve a level of residual emissions of 5% of 2018 emissions, total road emissions for Car, LGV, OGV/HGV and PSV combined need to reach a target value of 1,776 million kilograms of CO_2e by 2050.

4.36 To achieve these levels of emissions by 2050, the remaining percentage of emissions generated by non-electric vehicles would need to be reduced by the following amounts respective to each scenario:

Table 4.7: Further reduction in remaining non-electric vehicles required to achieve 5% of 2018 emissions

Scenario	Conservative		Intermediate		Express	
	BAU	SRtG	BAU	SRtG	BAU	SRtG
Reduction %	-85%	-86%	-82%	-82%	-61%	-62%

4.37 Applying this blanket reduction rate to the scenario values would lead to absolute reduction of non-electric vehicles being required as follows:

Table 4.8: Absolute reduction in non-electric vehicles needed to achieve 5% of 2018 emissions (millions of trips)

Scenario	Conservative		Intermediate		Express	
Vehicle Type	**BAU**	**SRtG**	**BAU**	**SRtG**	**BAU**	**SRtG**
Car	-2.743	-2.555	-2.097	-1.954	-	-
LGV	-1.398	-1.302	-1.069	-0.996	-0.399	-0.378
OGV/HGV	-1.217	-1.134	-0.931	-0.867	-0.463	-0.439
PSV	-0.581	-1.218	-0.222	-0.466	-	-
Total	**-5.940**	**-6.209**	**-4.319**	**-4.283**	**-0.862**	**-0.817**

4.38 It should be noted that the above table applies the blanket reduction rate required across all vehicle types in order to reduce the total emissions generated to the targeted level. Due to the nature of vehicle emissions by vehicle type, it is possible that other combinations of vehicle trip reductions could achieve the same targeted emissions value. This combination may produce a varying reduction in total trip numbers needed.

Conversion scenario

4.39 A workshop session was held with the Transport Strategy Working Group on the 23 June 2020 and with the Transport Forum on 30 June 2020. During session, the results of the three hypothetical scenarios presented above were discussed and the outputs were used as proxies to assist in the development of a fleet conversion scenario.

4.40 The purpose of the 'Conversion' scenario was to consider varying electric vehicle fleet conversion rates (as a proxy for all zero emission vehicle types) to be achieved at different timescales, all while ensuring that the measures were suitable for the scale of challenge in order to reach the desired time frame. Using the workshops' findings, this scenario was created by applying a phased targeted approach regarding zero-emissions vehicles on the road network. The electric vehicle fleet targets by year for this scenario can be found outlined below:

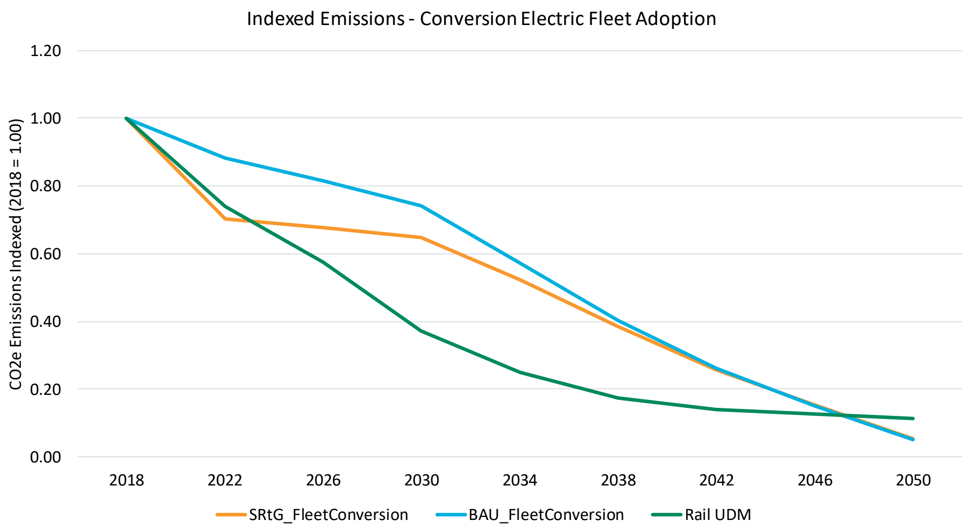
- The 'Conversion Scenario' electric vehicle fleet mix (and vehicle kilometres) targeted by **2030**:
  - 40% of cars
  - 30% of Light Goods Vehicles
  - 0% of Other Goods Vehicles/Heavy Goods Vehicles, and
  - 40% of Passenger Service Vehicles are assumed to be electric
- The 'Conversion Scenario' electric vehicle fleet mix (and vehicle kilometres) targeted by **2040**:
  - 80% of cars
  - 60% of Light Goods Vehicles
  - 40% of Other Goods Vehicles/Heavy Goods Vehicles, and
  - 80% of Passenger Service Vehicles are assumed to be electric
- The 'Conversion Scenario' electric vehicle fleet mix (and vehicle kilometres) targeted by **2050**:
  - 100% of cars

- 100% of Light Goods Vehicles
- 80% of Other Goods Vehicles/Heavy Goods Vehicles, and
- 100% of Passenger Service Vehicles are assumed to be electric

4.41 In the above scenario, the electric vehicle fleet mix has been assumed to grow linearly between milestone target years (2030, 2040 and 2050). The result is a rapidly expanding fleet mix of electric vehicles which achieves a higher penetration of electric vehicles by 2050 than the 'Express' hypothetical scenario previously covered. The expected impacts on emissions generated by the 'Conversion' scenario has been profiled over time in Figure 4.7 below.

4.42 In the 'Conversion' scenario, residual road emissions for 2050 achieve 5.4% for the Business as Usual and 5.8% for the Sustainable Route to Growth scenario when compared to 2018 levels. This is much nearer the 5% target of 2018 emissions than the three hypothetical electric fleet scenarios previously covered, assuming the emissions associated with energy production (Scope 2 emission) and supply chain for manufacture of the vehicles (Scope 3) are also zero carbon. All discussions below will refer to 'updated' tables which now include the outputs relating to the 'Conversion' scenario.

Figure 4.7: Change in emissions – Conversion fleet change



4.43 The number of non-electric vehicles for each scenario has been provided in the table below.

Table 4.9: Updated number of non-electric vehicle trips by type in 2050 (in millions of trips)

Scenario	Conservative		Intermediate		Express		Conversion	
Vehicle type	BAU	SRtG	BAU	SRtG	BAU	SRtG	BAU	SRtG
Car	3.2	3.0	2.6	2.4	-	-	-	-
LGV	1.6	1.5	1.3	1.2	0.7	0.6	-	-
OGV/HGV	1.4	1.3	1.1	1.1	0.8	0.7	0.4	0.4
PSV	0.7	1.4	0.3	0.6	-	-	-	-

4.44 Similarly, to the section above, utilising the SEELUM outputs of road emissions, it is also possible to determine the total emissions produced by each vehicle type. These emissions, broken down by vehicle type for each scenario, has been provided in the table below:

Table 4.10: Updated emissions generated by non-electric vehicle trips in 2050 (in million kg of CO_2e emissions)

Scenario	Conservative		Intermediate		Express		Conversion	
Vehicle	BAU	SRtG	BAU	SRtG	BAU	SRtG	BAU	SRtG
Car	2,946	2,894	2,357	2,316	-	-	-	-
LGV	2,199	2,242	1,759	1,794	880	897	-	-
OGV/HGV	6,877	7,184	5,502	5,747	3,668	3,831	1,834	1,916
PSV	208	403	83	161	-	-	-	-
Total	12,229	12,723	9,700	10,017	4,547	4,728	1,834	1,916

4.45 To achieve the 5% of 2018 residual emissions by 2050, which equates to 1,745 million kilograms of CO_2e by 2050. The remaining percentage of emissions generated by non-electric vehicles would need to be reduced by the following amounts respective to each scenario:

Table 4.11: Updated Reduction in non-electric vehicles required to achieve 5% of 2018 emission

Scenario	Conservative		Intermediate		Express		Conversion	
	BAU	SRtG	BAU	SRtG	BAU	SRtG	BAU	SRtG
Reduction %	-85%	-86%	-82%	-82%	-61%	-62%	-3%	-7%

4.46 Applying this blanket reduction rate to the scenario values would lead to absolute reduction of non-electric vehicles being required as follows:

Table 4.12: Updated reduction in non-electric vehicles needed to achieve 5% of 2018 emissions (millions of trips)

Scenario	Conservative		Intermediate		Express		Conversion	
Vehicle	BAU	SRtG	BAU	SRtG	BAU	SRtG	BAU	SRtG
Car	-2.743	-2.555	-2.097	-1.954	-	-	-	-
LGV	-1.398	-1.302	-1.069	-0.996	-0.399	-0.378	-	-
OGV/HGV	-1.217	-1.134	-0.931	-0.867	-0.463	-0.439	-0.012	-0.026
PSV	-0.581	-1.218	-0.222	-0.466	-	-	-	-
Total	**-5.940**	**-6.209**	**-4.319**	**-4.283**	**-0.862**	**-0.817**	**-0.012**	**-0.026**

4.47 As mentioned in the concluding remarks regarding the hypothetical scenarios, it should be noted that the above table applies the blanket reduction rate required across all vehicle types in order to reduce the total emissions generated to the targeted level. Due to the nature of vehicle emissions by vehicle type, it is possible that other combinations of vehicle trip reductions could achieve the same targeted emissions value. This combination may produce a varying reduction in total trip numbers needed. This comment is still relevant for the 'Conversion' scenario as even within the OGV/HGV vehicle type category, varying levels of emissions are produced depending on the type of OGV/HGV being studied.

5 Concluding remarks

General

5.1 The South East Economy and Land Use Model has been successfully modified to enable it to interface with Department for Environment, Food and Rural Affairs' Emissions Factors Toolkit. This enables the calculation of carbon emissions from transport ("at tailpipe") to be undertaken. These enhancements will allow the impacts of schemes identified as part of the Area Studies to be assessed as well as testing and comparison of strategy scenarios for carbon reduction.

The transport strategy's preferred scenario – *A Sustainable Route to Growth*

5.2 The "preferred scenario" informing the Transport Strategy assumes[9]:

- **Private vehicles:** Implementation of a national Road User Charging scheme and wider intervention, such as reallocation of road space) to double the generalised journey cost of private vehicle use. This, in part, results in a 10% reduction in trips made by private vehicle by 2050 compared to the *Business as Usual* scenario.
- **Public transport:** fare subsidisation, improved rail connectivity and capacity, and improved bus/high quality urban transit to half generalised journey costs of public transport. This, in part, results in over 100% increase in trips made by public transport by 2050 compared to the *Business as Usual* scenario.
- **Active travel:** Pedestrianised urban centres and other measures to reduce the generalised journey cost of active modes. This, in part, results in a minor 2% increase in trips made by active mode by 2050 compared to the *Business as Usual* scenario.
- Assumptions have also been made for:
  - **Digital technology:** removal of policy constraints on Connected and Autonomous Mobility (including more efficient use of the highway network) and Mobility as a Service having a corresponding effect on generalised journey times for different modes, and increased levels of home working and a reduction in the number of shopping trips made per person

[9] The assumptions included in the "preferred scenario" have been developed for the purposes of scenario testing and are owned by Transport for the South East. They have therefore not been agreed with the Department for Transport.

- **Spatial planning:** Focused growth of jobs in priority industrial sectors, as identified in Transport for the south East's Economic Connectivity Review, in the largest major economic hubs and coastal communities.

5.3 The *Sustainable Route to Growth* "preferred scenario" results in lower carbon emissions, emitted from surface travel, than the *Business as Usual* scenario between now and 2050.

5.4 Efforts to decarbonise rail, bus and coach, and taxi and private hire vehicles are supported by TfSE through its Transport Strategy. Emissions from rail are forecast to reduce heavily between now and 2050, however, these emissions comprise a relatively small percentage of all transport emissions from travel in the TfSE area.

5.5 Road transport is the greater challenge both in terms of percentage reduction still required and as a proportion of total emissions.

5.6 Based on Department for Transport forecasts of the conversion of vehicle fleets to electric vehicles, still results in:

- 67% of 2018 emission levels for road travel by 2050; and
- 11% of 2018 emission levels for rail travel by 2050.

5.7 Three key observations are:

- While there is a reduction in transport emissions per person in the South East, population increases partially off-setting efficiencies in fuel technology and conversion to zero emission fleets.
- While spatial planning assumptions locate employment in better connected and more accessible larger major economic hubs and in coastal communities that might have higher levels of unemployment and more labour available to fill new jobs, the increase in the number of jobs and value of the jobs results in people willing to travel further to access these jobs, resulting in a larger number of trips that cannot be conveniently made by more sustainable modes. Thus, partially off-setting efficiencies in fuel technology and conversion to zero emission fleets.
- Central government forecasts for the conversion of vehicle fleet are very low and do not appear to align with central government policy, changing political narrative, or other industry forecasts regarding, for example, the sale of electric and other zero emission vehicles. Highways England have provided constructive feedback to the Department for Transport and Department for the Environment, Food and Rural Affairs to this effect.

Zero emission vehicles – vehicle fleet conversion options

5.8 Given the issues identified with central government sources for the conversion of vehicle fleets to zero emission vehicles, three alternative and more "optimistic" options were identified for 2050.

- "Conservative" electric vehicle fleet mix where by 2050:
  - 75% of cars;
  - 50% of Light Goods Vehicles; and
  - 25% of Other Goods Vehicles/Heavy Goods Vehicles, and
  - 50% of Passenger Service Vehicles are assumed to be electric.

- “Intermediate” electric vehicle fleet mix where by 2050:
  - 80% of cars;
  - 60% of Light Goods Vehicles; and
  - 40% of Other Goods Vehicles/Heavy Goods Vehicles, and
  - 80% of Passenger Service Vehicles are assumed to be electric.
- “Express” electric vehicle fleet mix where by 2050:
  - 100% of cars;
  - 80% of Light Goods Vehicles; and
  - 60% of Other Goods Vehicles/Heavy Goods Vehicles, and
  - 100% of Passenger Service Vehicles are assumed to be electric.

5.9 The three options resulted in 36%, 28% and 13% residual emission by 2050 on 2018 levels, respectively. Through a workshop held with the Transport Strategy Working Group and Transport Forum, a phased targeted approach regarding zero-emissions vehicles on the road network was created and achieved a residual emission of slightly more than 5% by 2050 on 2018 levels from assumptions of 100% of car vehicle kilometres, 100% of LGV vehicle kilometres, 80% of all OGV/HGV vehicle kilometres, and 100% of all PSV vehicle kilometers are made using zero emission vehicles.

5.10 Even with considerably higher estimates for conversion of private car, LGV, HGV/OGV and PSV fleets to electric (a proxy for all zero emission technologies), “electrification” is insufficient in itself to achieve net zero carbon by 2050. It is unlikely that road freight will have removed its dependency on the internal combustion engine. It is also assumed the energy production will also be net zero carbon, from the use of renewable energy sources and implementation of carbon capture and storage measures.

Next steps

5.11 If we are to achieve net zero carbon emissions from transport by 2050, and especially so if we are to achieve net zero carbon sooner than 2050, the greater the shift to sustainable modes is required, including a reduction in the total number of trips we make or generate, particularly by private vehicles.

5.12 Given the already large increases in generalised journey cost to car and reduction in cost for public transport modes (and corresponding increase in trips) that are a feature of the sustainable route to growth scenario, areas of enquiry might be better focussed on:

- policy and wider intervention to accelerate the conversion of private car fleet to zero emission;
- policy and wider intervention to accelerate the conversion of road freight to zero emission vehicles and more sustainable modes;
- policy and wider intervention to increase active travel mode share considerably; and
- policy and implementation of:
  - localised demand management interventions;

- investment and roll out of enhanced digital technology to facilitate home working and online access to services and amenities;
- more wholesale review of local planning and its impacts on carbon emissions, including from transport and travel; and
- the operation of other generators of travel demand (e.g. education, healthcare).

5.13 In addition, assumptions made assume energy production and manufacturing (and other supply chain activity) are also net zero carbon. Government and related policy and action should be encouraged to enable this.

5.14 Transport for the South East will have to continue to work with partners and stakeholders through the development of the area studies to identify the interventions needed to further enhance the detail of the Transport Strategy to meet net zero carbon goals for transport and travel.

5.15 Steer have made a number of other technical recommendations for enhancing the assessment of carbon assessment in transport, and Steer would be delighted to continue working with Transport for the South East; Department for Transport; Department for the Environment, Food and Rural Affairs; and other partners to improve the analytical framework available for assessment in the important area.

A Vehicle fleet mix by road type

		2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Urban																			
	1Petrol car	41.9%	40.7%	39.7%	38.9%	38.1%	37.3%	36.7%	35.9%	35.2%	34.5%	33.7%	32.9%	32.1%	31.2%	30.4%	29.7%	28.9%	28.2%
	2Diesel car	36.7%	37.0%	36.9%	36.7%	36.4%	36.0%	35.3%	34.5%	33.5%	32.5%	31.5%	30.5%	29.5%	28.5%	27.6%	26.8%	26.0%	25.3%
	3Taxi (black cab)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	4Petrol LGV	0.4%	0.4%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
	5Diesel LGV	14.7%	14.9%	15.1%	15.2%	15.3%	15.4%	15.5%	15.5%	15.5%	15.5%	15.4%	15.3%	15.1%	14.9%	14.7%	14.5%	14.2%	13.9%
	6Rigid	1.1%	1.1%	1.2%	1.1%	1.1%	1.1%	1.1%	1.1%	1.1%	1.1%	1.1%	1.1%	1.1%	1.1%	1.1%	1.0%	1.0%	1.0%
	7Artic	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
	8Bus and coach	1.0%	1.1%	1.1%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%
	9Motorcycle	1.1%	1.1%	1.1%	1.1%	1.1%	1.1%	1.1%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
	10HybridCarPetrol	1.6%	2.0%	2.3%	2.7%	3.0%	3.2%	3.5%	3.7%	3.9%	4.0%	4.1%	4.1%	4.2%	4.1%	4.1%	4.0%	4.0%	3.9%
	11PlugInHybridCarPetrol	0.6%	0.8%	1.0%	1.4%	1.9%	2.4%	3.1%	4.1%	5.2%	6.4%	7.7%	8.9%	10.2%	11.5%	12.8%	14.0%	15.0%	16.0%
	12HybridCarDiesel	0.2%	0.4%	0.6%	0.8%	1.0%	1.1%	1.3%	1.4%	1.6%	1.7%	1.8%	1.9%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
	13ElectricCar	0.2%	0.2%	0.3%	0.3%	0.4%	0.4%	0.5%	0.7%	0.8%	1.0%	1.2%	1.4%	1.7%	2.0%	2.4%	2.8%	3.3%	3.8%
	14ElectricLGV	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.3%	0.4%	0.6%	0.8%	1.0%	1.3%	1.7%	2.0%	2.3%	2.7%	3.1%	3.5%
Rural																			
	1Petrol car	35.0%	34.0%	33.2%	32.5%	31.9%	31.5%	31.0%	30.6%	30.2%	29.8%	29.3%	28.8%	28.3%	27.8%	27.3%	26.8%	26.3%	25.8%
	2Diesel car	40.5%	40.8%	40.7%	40.6%	40.2%	39.7%	39.1%	38.2%	37.2%	36.2%	35.1%	34.1%	33.1%	32.2%	31.4%	30.6%	30.0%	29.4%
	3Taxi (black cab)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	4Petrol LGV	0.4%	0.4%	0.4%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
	5Diesel LGV	15.6%	15.8%	15.9%	16.0%	16.2%	16.3%	16.4%	16.5%	16.7%	16.9%	17.1%	17.2%	17.4%	17.5%	17.7%	17.8%	17.9%	18.1%
	6Rigid	2.6%	2.6%	2.6%	2.5%	2.5%	2.5%	2.4%	2.4%	2.4%	2.4%	2.4%	2.3%	2.3%	2.3%	2.3%	2.3%	2.3%	2.3%
	7Artic	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.5%
	8Bus and coach	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
	9Motorcycle	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%	0.8%	0.8%	0.8%	0.8%
	10HybridCarPetrol	1.3%	1.6%	2.0%	2.2%	2.5%	2.7%	3.0%	3.1%	3.3%	3.4%	3.5%	3.6%	3.7%	3.7%	3.7%	3.6%	3.6%	3.6%
	11PlugInHybridCarPetrol	0.5%	0.7%	0.9%	1.1%	1.6%	2.0%	2.6%	3.5%	4.5%	5.5%	6.7%	7.8%	9.0%	10.3%	11.5%	12.6%	13.7%	14.7%
	12HybridCarDiesel	0.2%	0.4%	0.6%	0.8%	1.0%	1.2%	1.4%	1.6%	1.8%	1.9%	2.0%	2.1%	2.2%	2.3%	2.3%	2.3%	2.3%	2.3%
	13ElectricCar	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	14ElectricLGV	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Motorway																			
	1Petrol car	25.4%	24.5%	23.9%	23.4%	23.1%	22.9%	22.8%	22.7%	22.7%	22.7%	22.6%	22.5%	22.4%	22.2%	21.9%	21.7%	21.4%	21.1%
	2Diesel car	46.1%	46.6%	46.6%	46.4%	46.0%	45.5%	44.7%	43.7%	42.5%	41.3%	40.0%	38.8%	37.7%	36.6%	35.7%	34.9%	34.1%	33.5%
	3Taxi (black cab)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	4Petrol LGV	0.4%	0.4%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
	5Diesel LGV	14.4%	14.5%	14.6%	14.7%	14.8%	14.9%	15.0%	15.1%	15.3%	15.4%	15.6%	15.7%	15.9%	16.0%	16.1%	16.2%	16.3%	16.4%
	6Rigid	3.5%	3.4%	3.4%	3.4%	3.3%	3.3%	3.3%	3.2%	3.2%	3.2%	3.2%	3.2%	3.1%	3.1%	3.1%	3.1%	3.1%	3.0%
	7Artic	7.8%	7.8%	7.8%	7.7%	7.7%	7.6%	7.6%	7.5%	7.5%	7.5%	7.5%	7.5%	7.5%	7.5%	7.5%	7.5%	7.6%	7.6%
	8Bus and coach	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%	0.2%
	9Motorcycle	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
	10HybridCarPetrol	1.0%	1.2%	1.4%	1.6%	1.8%	2.0%	2.2%	2.3%	2.5%	2.6%	2.7%	2.8%	2.9%	2.9%	3.0%	3.0%	2.9%	2.9%
	11PlugInHybridCarPetrol	0.4%	0.5%	0.6%	0.8%	1.1%	1.5%	1.9%	2.6%	3.4%	4.2%	5.1%	6.1%	7.1%	8.2%	9.2%	10.2%	11.1%	12.0%
	12HybridCarDiesel	0.3%	0.5%	0.7%	1.0%	1.2%	1.4%	1.6%	1.8%	2.0%	2.2%	2.3%	2.4%	2.5%	2.6%	2.6%	2.6%	2.6%	2.6%
	13ElectricCar	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	14ElectricLGV	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Fleet mix for 2018-2035 extracted from Emissions Factors Toolkit.

B Estimated fuel efficiency improvements post 2030

Year	% adjustment for fuel efficiency from a 2030 base
2030	-
2031	-0.78%
2032	-1.12%
2033	-1.34%
2034	-1.78%
2035	-1.84%
2036	-1.85%
2037	-2.12%
2038	-2.07%
2039	-2.01%
2040	-2.22%
2041	-2.14%
2042	-2.06%
2043	-2.25%
2044	-2.16%
2045	-2.08%
2046	-2.26%
2047	-2.18%
2048	-2.10%
2049	-2.27%
2050	-2.29%

Source: Highways England

C Emissions rate by road type

Road Type	Emission units	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Urban	CO2e g/km	146.5	144.7	143.0	141.0	139.0	137.4	135.7	133.7	131.6	129.6	127.6	125.4	123.1
Rural	CO2e g/km	168.1	166.0	164.0	161.9	159.9	158.4	156.8	155.2	153.7	152.4	151.1	149.7	148.4
Motorway	CO2e g/km	215.8	212.9	210.1	207.3	204.6	202.7	200.7	198.8	197.2	195.9	194.7	193.3	192.0

		2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Urban	CO2e g/km	120.0	116.6	113.1	109.1	105.1	103.2	101.0	98.9	96.9	94.8
Rural	CO2e g/km	146.3	143.7	140.9	137.7	134.5	131.3	127.9	124.6	121.4	118.1
Motorway	CO2e g/km	189.7	186.8	183.5	179.6	175.7	171.8	167.6	163.6	159.7	155.6

		2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Urban	CO2e g/km	92.7	90.8	88.8	86.9	85.0	83.1	81.3	79.6	77.8	76.0
Rural	CO2e g/km	115.0	112.0	108.9	106.0	103.3	100.4	97.7	95.1	92.4	89.8
Motorway	CO2e g/km	151.8	148.1	144.3	140.7	137.2	133.7	130.3	127.1	123.7	120.5

D Emissions rate by vehicle type

Vehicle type	Units	2018 CO2e
1 Petrol car	(g/km)	130.22
2 Diesel car	(g/km)	120.64
3 Taxi (black cab)	(g/km)	194.55
4 Petrol LGV	(g/km)	191.58
5 Diesel LGV	(g/km)	182.81
6 Rigid	(g/km)	608.59
7 Artic	(g/km)	961.43
8 Bus and coach	(g/km)	657.38
9 Motorcycle	(g/km)	90.45
10 Hybrid Car Petrol	(g/km)	80.31
11 PlugIn Hybrid Car Petrol	(g/km)	34.20
12 Hybrid Car Diesel	(g/km)	81.38
13 Electric Car	(g/km)	0.00
14 Electric LGV	(g/km)	0.00

E Rail emission assumption sources

Assumption	Source
Rolling Stock Types in use by each TOC	Steer research and industry experience
Number of Vehicles for each Stock Type	
Seating capacity per Vehicle	
Vehicles per service	
TOC Category definition and rolling stock contained within	
Current consumption rate for each Rolling Stock Type	Majority of electric stock sourced from Network Rail's 'Traction Electricity Modelled Consumption Rates List' for Control Period 6. For diesel stock, and electric stock not listed in the previous file, the rates estimated based on Steer industry knowledge.
Change in consumption rates	Transport Analysis Guidance Databoook, May 2019, 'Table A 1.3.10: Forecast Assumed Vehicle Fuel Efficiency Improvements to 2050'
Change in emissions per litre fuel / kWh Used	Transport Analysis Guidance Databoook, May 2019, 'Table A 3.3: Carbon dioxide emissions per litre of fuel burnt / kWh used'
Proportion of each SEELUM rail link served by each TOC category	Combination of Steer judgement and examining MOIRA SW09 May 2016 Weekday Timetable
Mileage of each rail link	Taken from MOIRA SW09 May 2016 where available, when not possible the walking distance from Google Maps was used as an approximate.
Capacity per SEELUM rail link, demand and journey time	Pre-exisiting within SEELUM model. Note these are dynamic variables.
Weekday to Weekend service numbers for Annualisation factor	Examining SWR and SE services in MOIRA SW09 May 2016 Weekday, Saturday and Sunday timetables.

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