SPATS1-403

LST TRIAL EVALUATION 2018-19

PROJECT NOTE E2: LST EMISSIONS SAVINGS

PN-E2-V4-1

SEPTEMBER 2018

PUBLIC

SPATS1-403

LST TRIAL EVALUATION 2018-19

PROJECT NOTE E2: LST EMISSIONS SAVINGS

TYPE OF DOCUMENT (VERSION) PUBLIC

PROJECT NO. 70038230

OUR REF. NO. PN-E2-V4-1 FINAL

DATE: SEPTEMBER 2018

SPATS1-403

LST TRIAL EVALUATION 2018-19

PROJECT NOTE E2: LST EMISSIONS SAVINGS

WSP

WSP House
70 Chancery Lane
London
WC2A 1AF

Phone: +44 20 7314 5000+44 20 7314 5000

Fax: +44 20 7314 5111+44 20 7314 5111

WSP.com

Quality control

Issue/revision	First issue	Revision 1	Revision 2	Revision 3
Remarks	Draft 1	Draft 2	Draft 3	V4-1
Date	22 Dec 2017	25 Feb 2018	6 July 2018	Sept 2018
Prepared by	Sioni Hole / Andy Talbot	Andy Talbot / Chris Squires	Paul Brand Andy Talbot	Paul Brand Andy Talbot
Signature				
Checked by	Eleanor Baker	Eleanor Baker	Helen Wilkinson	Helen Wilkinson
Signature				
Authorised by	Paul Brand (for Risk Solutions) Andy Talbot (For WSP)	Paul Brand (for Risk Solutions) Andy Talbot (For WSP)	Paul Brand (for Risk Solutions) Andy Talbot (For WSP)	Paul Brand (for Risk Solutions) Andy Talbot (For WSP)
Signature				
Project number	WSP: 70038230 Risk Solutions: J00005	WSP: 70038230 Risk Solutions: J00005	WSP: 70038230 Risk Solutions: J00005	WSP: 70038230 Risk Solutions: J00005
Report number				J00005 PN-E2-V4-1 FINAL
File reference				

Project Note Document Status and Confidentiality	
Status	This document is a Project Note as defined in the original proposal for the project. Project Notes are produced iteratively on work for which the scope and method are emergent. Each version describes the progress on the analysis to that point and proposes the direction and scope of the next step in the process. Where agreed by the client, that scope or direction may diverge from the thinking described in the original proposal. Project Notes, in their intermediate versions, are not formal deliverables under the contract. The final version of a Project Note may be a formal deliverable if the proposal states this.
Confidentiality	Project Notes are not normally for publication by any party, including DfT, as they contain discussion of work in progress during the development of an analysis. In this case, a final version of this project note (v4 only) has being ‘upgraded’ to publishable quality so that it can be issued with the main LST Trial 2017 Annual Report

CONTENTS

TABLES

FIGURES

Executive summary

The purpose of this workstream (Workstream E2) was to introduce a more refined analysis of the potential emissions savings from using LSTs in place of standard length trailers, particularly in terms of oxides of nitrogen (NO_x) and carbon dioxide equivalent (CO2e). This is the final issue of the project note describing this work and presenting the results which we anticipate carrying forward for inclusion in the LST Trial 2017 Annual Report.

We brought together a team of emissions modelling specialists and project experts from the main trial data collection and the routing work to develop the outline emissions model and agree how each of the input data elements could be generated. The decision was to model emissions savings at an individual ITN (OS Integrated Transport Network) 'link' level within each of the LST routes being generated by another part of the trial programme, and for each individual LST journey leg for a sample year, 2017.

After development and testing in Microsoft Excel, the model was ported to Microsoft Access so that it could be run directly inside queries being performed on the entire 2017 LST journey leg dataset, with reference tables derived from the LST route modelling (Workstream E1) for each ITN link used.

The final stage has been to extend the actual LST fleet statistics on number of trailers and distances covered to the end of 2017, into projected future years, under a selection of possible scenarios. The 2017 sample year of route and emissions performance results have then been applied to the fleet growth scenarios to give the emissions savings results and projections shown here. Two types of result are given:

1. **Savings as a percentage of the nominal 'Non-LST' emissions to carry the same goods** (based on the 2017 sample year) as the total for the year and then segmented by road class and air quality zones
2. **Total emissions savings for the trial in tonnes**
    a. Actual savings to end 2017
    b. Projected savings to end 2021 – the original 10-year trial period
    c. Projected savings to end 2026 – the notional end of the 2017 trial extension

The total emissions savings summary for each timeframe is shown below.

LST TRIAL EMISSIONS SAVINGS (ACTUAL/PROJECTED)

(All figures tonnes rounded)		To Date	10yr Trial	Extended Trial
		End 2017	*End 2021*	*End 2026*
Carbon Monoxide	CO	17	40	71
Carbon Dioxide equivalent	CO2e	28,180	67,030	120,066
Oxides of Nitrogen	NO_x	141	336	602
Particulate Matter (Exhaust)	PM Exhaust	2	4	6
Volatile Organic Compounds	VOC	3	8	14

Contacts:	WSP	Andy Talbot	020 7314 5198	andy.talbot@wsp.com
	Risk Solutions	Paul Brand	01925 413 984	paul.brand@risksol.co.uk

1 Introduction

Up to this point in the LST trial, emissions 'savings' arising from using the trailers have been expressed as a simple proxy metric of distance saved (compared to carrying the same goods on 13.6m standard trailers). This estimate has been subjected to a simple counterbalancing factor for additional fuel use, taken from the pre-trial estimates. On the trial from 2012 to the end of 2016, an estimated 125,000-150,000 trailer journeys had been saved, representing 15-18 million km of large HGV traffic removed from the road.

Section 2 of this note discusses the pre-trial modelling that was done to estimate the potential emissions savings from using LSTs and beyond, based on a number of possible, but as yet un-built, LST designs, operating over theoretical duty cycles.

The purpose of the current modelling was to generate a more refined analysis based on the actual LST designs that have emerged once the trial was launched and the actual operational patterns recorded in the trial data.

The aim is to produce projections of the potential emissions savings from using LSTs in place of standard length trailers when carrying the same set of cargo over the same duty cycle, particularly in terms of oxides of nitrogen (NO_x) and carbon dioxide (CO2e).

Section 3 and 4 of this note describe the modelling methodology and source data. After development and testing in Microsoft Excel, the model was ported to Microsoft Access so that it could be run directly inside queries being performed on the entire 2017 LST journey leg dataset, with reference tables derived from the LST route modelling (Workstream E1) for each ITN link used.

The final stage has been to extend the actual LST fleet statistics on number of trailers and distances covered to the end of 2017, into projected future years, under a selection of possible scenarios. The 2017 sample year of route and emissions performance results have then been applied to the fleet growth scenarios to give the emissions savings results/projections shown here.

Section 5 presents the main results that are carried forward for publication in the LST Trial 2017 Annual Report.

Two types of results have been produced:

1. **Savings as a percentage of the nominal 'Non-LST' emissions to carry the same goods** (based on 2017 sample year)
    a. Total
    b. Segmented by Road Class
    c. Segmented by areas of interest in terms of compliance with air quality objectives and limit values and Designated Sites with sensitive ecological features
2. **Total emissions savings for the trial in tonnes**
    a. Actual savings to end 2017
    b. Projected savings to end 2021 – the original 10-year trial period
    c. Projected savings to end 2026 – the notional end of the 2017 trial extension

This workstream has been undertaken by a combined team of experts from Risk Solutions, who are managing the overall LST trial evaluation and carrying out route modelling, and specialists from WSP Air Quality team. WSP provided the emissions model design and air quality expertise. Risk Solutions provided the integration of the emissions model with the LST routing model results and then constructed the projections of fleet growth, leading to the emissions savings projections.

2 Review of Pre-Trial Emissions Work

Previous estimates of emissions savings from the LST trial were made by TRL in 2010. Details are presented in TRL's Published Project Report PPR526 'The likely effects of permitting longer semi-trailers in the UK: vehicle specification performance and safety' Final Report, October 2010.

TRL used the Passenger car and Heavy-duty Emission Model (PHEM)[1] to generate emissions and fuel consumption data for 11 vehicle types comprising 5 standard articulated tractor and trailer (standard) configurations and 6 LST configurations (as per the extract in Figure 1 below).

FIGURE 1: VEHICLE SPECIFICATIONS USED IN PRE-TRIAL MODELLING

Table 6: Vehicle specifications used in the PHEM model.

		Existing Artic Single deck 16.5m (2+3)	Existing Artic Double deck 16.5m (2+3)	Existing Artic Single deck 16.5m (3+3)	Existing Artic Double deck 16.5m (3+3)	Existing Drawbar 18.75m (3+3)	Longer Artic Single deck 18.55m (3+3) Self Steer	Longer Artic Double deck 18.55m (3+3) Self Steer	Longer Artic Single deck 18.55m (3+3) Command Steer	Longer Artic Double deck 18.55m (3+3) Command Steer	Longer Artic Single deck 18.55m (3+3) Active Steer	Longer Artic Double deck 18.55m (3+3) Active Steer
Vehicle reference		*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
							Fully-laden					
Unladen weight	kg	13,543	19,035	14,533	20,025	15,000	15,307	20,918	16,072	21,683	16,177	21,788
Maximum payload	kg	26,457	20,965	29,467	23,975	29,000	28,693	23,083	27,928	22,318	27,823	22,213
Gross weight	kg	40,000	40,000	44,000	44,000	44,000	44,000	44,000	44,000	44,000	44,000	44,000
							Typical load					
Unladen weight	kg	13,543	19,035	14,533	20,025	15,000	15,307	20,918	16,072	21,683	16,177	21,788
Typical payload	kg	10,730	9,297	16,670	13,860	6,614	14,347	11,541	13,964	11,159	13,912	11,106
Gross weight	kg	24,273	28,332	31,203	33,885	21,614	29,654	32,459	30,036	32,841	30,089	32,894

Some account was taken of differences between vehicle types in terms of driving resistances that affect fuel consumption and emissions – in particular including drag, unladen weight, loading and friction. Only Euro V tractor units were considered.

The outputs of the modelling comprised emissions data in grams per kilometre (g/km) and g/km for each tonne of payload. The pollutants considered were carbon monoxide (CO), hydrocarbons (HC), NO_x, particulate matter (PM) and CO_2. Average speed emissions functions (g/km) were developed for typical and maximum laden standard and LST configurations.

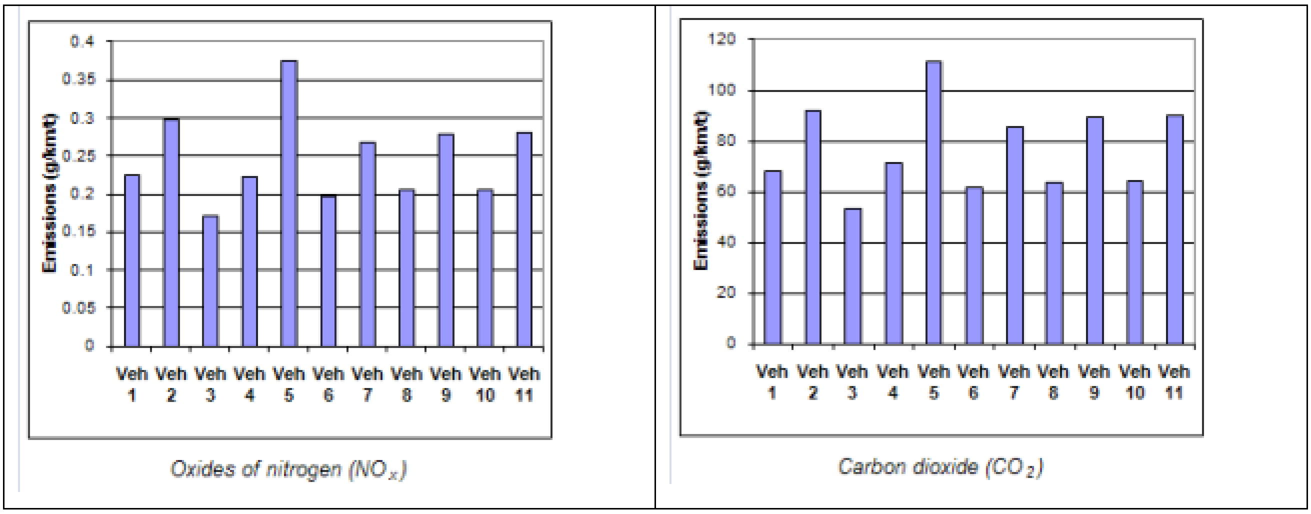
Modelling on the basis of an average speed of 86.9 km/hour indicated some modest potential for NO_x and CO_2 emissions savings (illustrated in the extracts in Figure 2 below). For example, there are potential savings if

[1] Developed by Graz University of Technology

vehicle reference type 6 (LST) replaces vehicle type 1 (standard) but not at all in the case of vehicle type 3 (standard) which appears to have the lowest g/km-tonne of payload emissions of NO_x and CO_2.

The remaining vehicle types all show similar or higher emissions compared to vehicle 1, as would be expected given the increased size and weight. This underlying increase in emissions per km slightly offsets the much larger gains predicted by the reduction in the number of journeys made to deliver the same goods.

FIGURE 2: EMISSION FIGURES BY VEHICLE TYPE FROM PRE-TRIAL ANALYSIS



Potential CO_2 emissions savings were reported by DfT in the document 'Impact Assessment of Longer Semi-Trailers (updated post-consultation)', September 2011. Modest savings were indicted for +2.05m LSTs but not for +1m LST options for which increased emissions were reported.

As part of the impact assessment work, an overall estimate of the potential savings in CO_2 was given as 3,000 tonnes, over the 10-year trial. Since the publication of the 2011 impact assessment, this figure has been commonly cited by DfT as the best estimate outcome.

In the intervening 7 years, many developments have emerged, including the industry settling on a particular set of LST designs, the widespread introduction of Euro VI engines and an increased focus on NO_x rather than just carbon emissions. In view of this, any direct comparison of our results to this headline '3,000 tonnes of CO_2' may be of less importance than the new estimates we produce.

However, it is important to note that the 3,000 tonnes figure was not a single result, but the average across a whole range of possible LST designs that were being considered in 2010, prior the trial. Most importantly, the results were all subject to an offsetting factor that predicted a large-scale movement of existing road-rail intermodal journeys back to road only, due to the additional carrying capacity of the LSTs.

An annex to the impact assessment, not often cited, showed that if the intermodal sector could design a 50' container that could operate on both LSTs and the rail freight network, then this offset from rail to road was replaced by a small shift from road to rail, with the resulting emissions savings being far greater than the 3,000 tonnes.

The actual effects of LSTs on intermodal traffic has now been studied in more depth in workstream E3 of this project, which has been presented to DfT separately. The conclusion from that work is that the availability of LSTs is a marginal issue in the decision to use or not use rail-freight. As a result, **the modelling here contains no consideration of an interplay between road and rail emissions**.

3 Methodology

Emissions Model Selection

The key parameters considered in the emissions calculations are:

- Euro category of the tractor unit pulling the trailer
- Unladen weight
- Vehicle loading from unladen to 44 tonnes gross vehicle weight (gvw)
- Vehicle speed

Without undertaking further modelling using PHEM to create emissions functions for Euro VI and pre-Euro V vehicle types, the most suitable emissions functions are provided by the European Monitoring and Evaluation Programme (EMEP) \ European Environment Agency (EEA) air pollutant emission inventory guidebook, chapter '1.A.3.b.i-iv Road transport', 2017. Average speed emissions functions are given for articulated HGV in gross vehicle weight ranges 14-20, 20-28, 28-34, 34-40 and 40-50 tonnes with loadings of 0, 50 and 100 percent. Emissions data within Defra's current Emissions Factors Toolkit (version 8.0.1) are based on these EMEP and EEA functions.

Model Suitability

We note that the functions used here do not include the full range of parameters that could be included if using PHEM – in particular aerodynamic resistance and rolling resistance. However, there is no known readily available source of data for these factors for an LST and an equivalent trailer of standard length, meaning it is not possible to model them. So, the question becomes whether there is any engineering reason to expect that these factors would be sufficiently different for LSTs as to influence the overall emissions results or any conclusions drawn from them.

Engineering judgement gives us reasonable confidence that not modelling these two factors will still provide results that are fit for the purpose intended here.

Aerodynamics: The only data source that is available is the work done by TRL in 2010, which concluded that there would be a very small increase in emissions due to a marginal increase in drag coefficient (c_d) due to the longer length, from c_d =0.55 (for a 3+3 tractor and standard trailer combination) to c_d =0.6 (for all 3+3 LST combinations, but it is unclear where they derived this increase from. For other factors affecting drag resistance (frontal area, construction materials) the LST is no different to the standard length equivalent.

Rolling Resistance: This is an issue in some longer/heavier vehicle designs which employ additional axles, but for an LST this is not the case. In terms of straight line resistance, the axles, tires and associated equipment are the same as an equivalent standard-length trailer. Rolling resistance will increase somewhat with higher loadings, however this may be compensated to an extent by lower rolling resistance during cornering for an LST due to the reduction in lateral 'scrub' because of the steering axle.

For all other factors available in PHEM (other driving resistances including inertia in wheels/gearbox, gearbox type, transmission gearing issues and gear-shift behaviour) we see no obvious argument to suggest that the LST would be materially different to its standard-length equivalent.

Whilst we recognise that the approach adopted is subject to certain limitations regarding real-world factors that affect emissions, there are no other suitable off-the-shelf emissions functions available to use and it is considered that the approach taken is in-keeping with the scope of the study.

This approach does not preclude DfT from commissioning an update of the pre-trial work using PHEM to generate emissions functions for LSTs specifically if it is believed that this would add further value or if further data were to be generated that would inform LST-specific function coefficients that were materially different to those for the equivalent 13.6m trailers.

Vehicle Weights

Unladen LSTs are by their nature heavier than unladen standard trailers due to their increased length as well as other design features that may add weight such as steering axles. In the earlier savings work reported on the trial a simple common factor was used to represent the estimated additional fuel consumption assumed used across all LST journeys to pull the additional weight.

The functions in the emissions model have been further developed to distinguish between conventional artic and LST vehicle types with an unladen load penalty for LST vehicles, and to calculate the emissions relative to an equivalent journey using a standard (13.6m) trailer. For the test modelling, the unladen load penalty was set at a nominal 1.5 tonnes to represent the additional weight of the extra trailer length and the steering axle. This nominal value was based on the pre-trial data in Figure 1, taking the relative unladen weight of a 3+3 combination with a 13.6m trailer (vehicle 3) and 15.65m (vehicle 6). This was a rather blunt simplification just used for the test modelling. The final results have been refined to take account of both linear load penalties associated with design features that will scale directly with trailer length, such as deck layout (single, dual) and body design (flatbed, box, skeletal etc) and design features that will add a fixed load penalty irrespective of trailer length such as number and type of steering axles. All trailers have a base weight assumed to be the weight of the equivalent 13.6m trailer of similar type (deck layout, body design and with a single, non-steering axle) and all trailers are assumed to be pulled by an identical tractor unit of fixed weight, taken from the original TRL work.

The overall unladen vehicle weight is obtained by adding the base trailer weight to the tractor weight, the steering axle weight and the additional length of the trailer greater than 13.6m multiplied by the factor for that design of trailer. For details of the values used see the tables in Annex B. The Gross Vehicle Weight, required for the emissions function, is then derived by adding the recorded goods weight as declared by the operator for each leg to the calculated unladen vehicle weight for the specific trailer operating that leg. Where this derived GVW exceeds the maximum permitted 44 tonnes it is capped at 44 tonnes, as we assume that operators have been operating legally on the roads, and any excess is likely to have been generated by our calculated assumptions.

Further work is planned during 2018 with SMMT to obtain the latest actual values for the marginal weights of individual LST designs, compared to their 13.6m equivalent. This will be used to update the results in the 2018 Annual Report (to be published in 2019).

At this stage, the modelling has been based on EURO V engines, although the actual fleet will have been mixed. Future work may be conducted to refine the results by using variable fleet engine mixes.

Emissions Model Development

The modelling is performed in two parts:

1. NO_x model at route link level; and
2. NO_x and CO2e model across all journey legs in the 2016-17 Trial Master Database (TMD).

These elements are 'nested' with the NO_x link level model being applied during the processing of every journey of the TMD for 2016 and 2017.

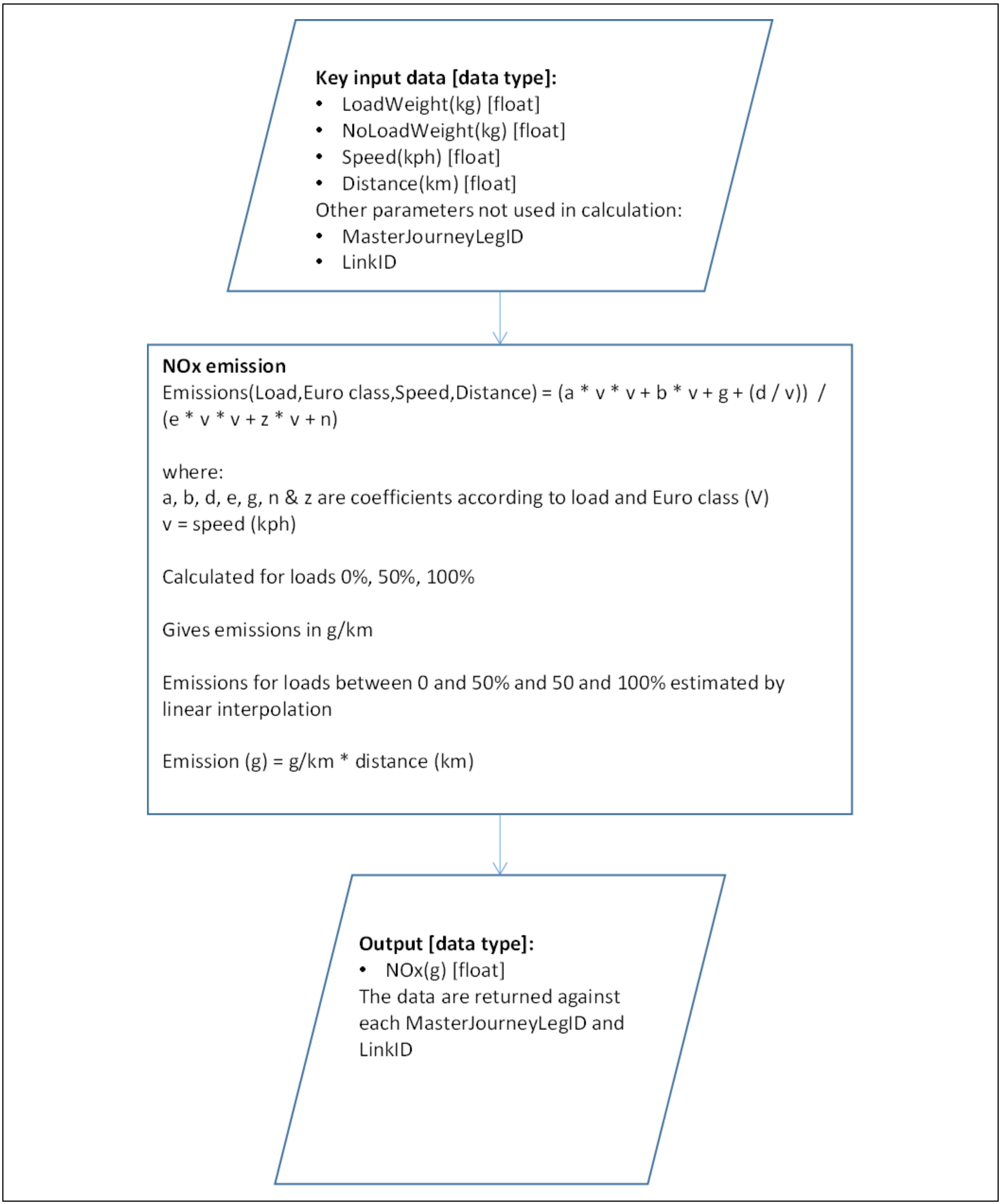
Link Level NO_x Model

The first part of the model uses data from the LST Routing Model (Workstream E3) for every ITN road link that the routing model has used in modelling the LST routes.

Figure 3 (below) illustrates the model process for the prototype NO_x model.

The calculation process has been implemented in a VBA module in Microsoft Excel as a set of functions to read in, error check and process the key input data.

FIGURE 3: (NO_x) EMISSIONS MODEL



NO_x calculation at Journey-Link Level

The process returns NO_x emissions in grams for the input data against any given journey and load on a specific route link. These link level results can, later, be totalled to generate emissions results at any level of aggregation (Link, Journey, All journeys on route, All journeys in dataset).

When handling the Load Weight, the EMEP/EEA emissions functions only give emissions for loads of 0, 50 and 100% of the maximum load of the vehicle, which for the purposes of this exercise is assumed to be the difference between 44 tonnes and the unladen mass of the vehicle (i.e. maximum load 100% = 44 tonnes – no load weight).

It is necessary to interpolate to determine emissions between these loadings. Polynomial and cosine functions have been considered for interpolation and rejected due to idiosyncratic uncertainties in favour of simple linear interpolation. No account has been taken of road gradient in the model at this stage; this has been assumed to be 0%.

The prototype model was successfully tested using a test dataset for LSTs provided by Risk Solutions. A sample of the model results from the testing is shown in Section 5, Table 1.

A notable feature is the option for Euro V to differentiate between emissions for a vehicle fitted with an exhaust gas re-circulation (EGR) or selective catalytic reduction (SCR) system to reduce NO_x emissions. The National Atmospheric Emissions Inventory (NAEI) assumes a Euro V split of 75% vehicles with SCR and 25% with EGR. SCR tends to be more effective at increased loads due to higher exhaust temperatures giving rise to a counter-intuitive reduction in NO_x emissions compared to other pollutants. EGR systems achieve reduction in NO_x but unlike SCR emissions tend to increase with load. There is no facility for Euro VI to differentiate between SCR and EGR systems and indeed SCR and EGR are often used in combination. (Note: Emissions data for pre-Euro V vehicles gives increasing NO_x emissions with increasing load weight.)

Integration into Trial Master Data – NO_x and CO2e Calculation

Figure 4 illustrates the integration with the TMD.

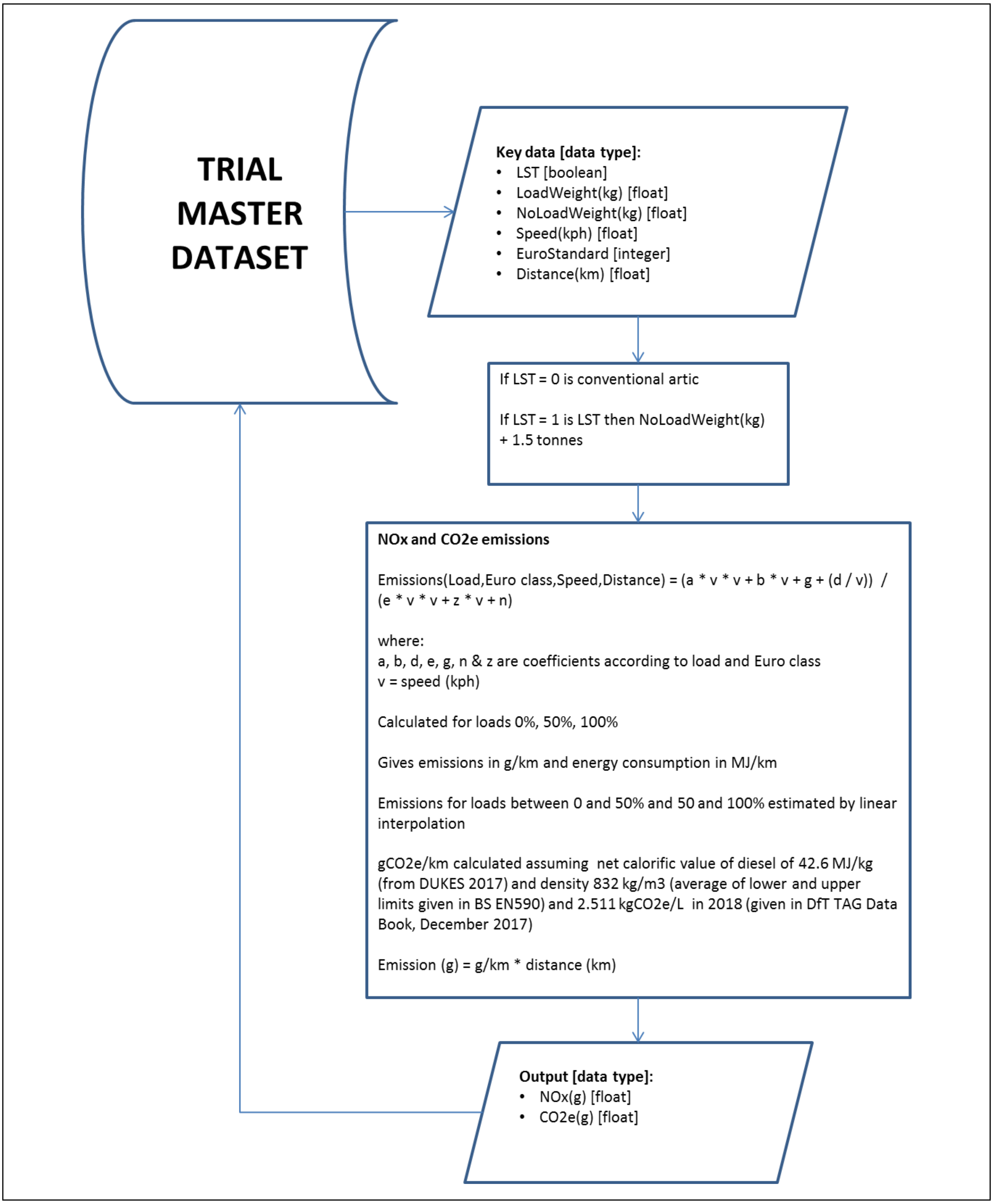
The EEA/EMEP emission functions provide NO_x emissions directly and also provide as an output to the function the energy consumption (MJ) associated with the given input data. CO2e mass emissions can be calculated using the energy consumption data in combination with information about the fuel used as follows:

$$M_{CO2e} = EC / (NCF * \rho_f / 1000) * E_f * 1000$$

Where:

- M_{CO2e} is mass of CO2e emission (g);
- EC is energy consumption (MJ) as calculated using EEA/EMEP function;
- NCF is the net calorific value of the fuel (42.6 MJ/kg for diesel from DUKES 2017);
- ρ_f is the density of the fuel (832 kg/m^3 for diesel, average of lower and upper limits given in BS EN590); and
- E_f is the mass emission of CO_2 per unit volume of fuel used (2.511 kgCO2e/L for diesel in 2018, given in DfT TAG data book, December 2017).

FIGURE 4: INTEGRATION OF THE EMISSIONS MODEL WITH THE TMD



Speed

The emissions model has speed as an input. Two sets of speed scenarios are available in the model.

The first is a simple reference table of average-speeds based on the road class. These are related to the average speeds used in the route modelling to influence route choice, but they need not be so.

These average speeds are not the speed limits (but are within them) so they do account for some normal speed variations and on minor roads are set quite low. These speeds have been set by experimentation with both the routing and emissions model with the intention of giving route journey times that are broadly representative of an 'uncongested flow scenario'.

The second is a variation on the first, where the reference speed for a link is moderated by any difference between the route modelled journey time and that declared by the operator for the specific journey leg. This is treated as a bounding case which is closer to the 'real-world scenario' but which we have reason to believe it more likely to overestimate the journey time than to underestimate it. We know that the journey time data provided to the trial is of variable quality for a number of reasons including:

- Where generated by telematics data, we know of cases where the two values available are not actually start departure and arrival times, but the start times of two sequential legs as in some cases these are the only times available. Such legs (we do not know how many there are) would always give an operator declared journey time significantly greater than the actual driving time. For these cases there is no balancing set of journeys where the declared time is too short.
- Where operators have highly repetitive operations, but no telematics, they will often know the departure time (which they control). For these cases there is no easy way to determine whether these journey times are 'generous' or 'optimistic'.

What we are able to say is that the real-world journey times are, largely, longer than the route modelled ones and so must represent a more congested flow scenario than the first one.

For our primary results, we have used the 'uncongested flow' scenario.

This might seem counter-intuitive but the reasoning is that for the specific purpose of this modelling, it is the prudent choice. The absolute emissions impact for a vehicle is higher in congested traffic, but here we are interested in the saving between the emissions from an operation running LSTs (with fewer journeys) than moving the same goods using 13.6m trailers. Since the dominant factor in the saving is the reduced journey count, the un-emitted emissions for each 'saved' journey is minimised by assuming uncongested flow, this will produce the most conservative estimate of emissions saved.

Model Test Results

The table below shows a set of results output from the model for a series of sample journey legs on samples of their links with operational data chosen at random from the TMD.

The cells shaded yellow represent the inputs to the emissions model from the TMD, while the outputs from the emissions model are in the cells shaded green. At present the tractor units are all assumed to be Euro V.

TABLE 1: MODEL RESULTS FOR A SAMPLE OF JOURNEYS FROM TEST DATA FOR NO_x AND CO2e EMISSIONS

Master Journey Leg ID	Link ID	Distance (km)	Load Weight (kg)	No Load Weight (kg)	Speeds (kph)	Load	NO_x (g)	Energy (MJ)	CO2e (g)
102089	osgb4000000019218181	0.10	14,750	16,763	48	54.2%	0.49	1.37	90.61
255596	osgb4000000007860264	0.02	11,393	16,763	96	41.8%	0.07	0.20	13.50
246900	osgb4000000010877926	0.77	6,000	16,763	96	22.0%	2.50	6.90	455.75
135428	osgb4000000007675196	0.02	13,680	16,763	48	50.2%	0.10	0.27	17.71
226141	osgb4000000006278611	0.78	26,640	16,763	96	97.8%	3.31	10.48	691.84
260715	osgb4000000013077307	0.01	3,000	16,763	64	11.0%	0.03	0.09	5.97
260743	osgb4000000013077307	0.01	16,380	16,763	64	60.1%	0.04	0.13	8.29

LST vs. Non-LST Emissions

The final step in the modelling is to create two estimates of the emissions for each journey, one for the actual LST legs and the other for a hypothetical set of non-LST legs moving the same goods. This is done by sending the information to the model twice for every link:

- LST leg using the calculated gross vehicle weight as noted above.
- Non-LST leg using:
  - a modified link-length representing the additional proportion of a leg, taken from the existing leg by leg distance saving factors already produced in the utilisation analysis in the main trial evaluation of utilisation levels (for which the method has been published in previous LST Trial Annual Reports);
  - a non-LST vehicle weight based on the LST trailer type but the standard 13.6m trailer length and axle configuration; and
  - a re-distribution of the weight carried on the LST leg across the hypothetical non-LST legs (see Annex B for a description of how this was calculated).

The result is that for every leg, on every link, the model returns emissions values for both the LST and non-LST cases. While these should not be taken as accurate emissions estimates for any individual leg (which would be influenced by other environmental factors), when aggregated up we believe this is a reasonable modelling approach.

Emissions Modelling – Spatial Analysis

By linking the emissions model to the routing model, we have been able to estimate not just the overall scale of emissions savings from the trial LSTs, but also:

- the proportion saved on each road type; and
- the proportion of the savings occurring in a number of spatial areas of interest.

The areas of interest for which we have produced results are show in Table 2 (overleaf).

The results for each area were produced by analysing every road link on each of the 56,000 unique LST routes and calculating the proportion of each link that falls into each of these spatial areas. The emissions analysis can then be segmented to show the savings that occurred within each area.

Sites with SAC, SSSI, Ramsar and SPA designations are commonly referred to as 'Designated Sites'. These sites may have cited features that are sensitive to changes in ambient NO_x, nitrogen deposition and acid deposition that can be brought about by changes in traffic emissions of NO_x – particularly from roads within 200m. We have also therefore calculated the emissions savings in any of the Designated Sites.

We calculated the proportion of each ITN road link that falls inside each area of interest by comparing every ITN road link shape with GIS shape files for the areas of interest. For Designated Sites we added a 200m buffer zone to each shape, to ensure we included road links that are on the boundary of an area. PCM areas are lines (roads), so we added a 100m buffer zone to each shape to allow for slight variations in road shapes. Air Quality Management Areas (AQMAs) contain a mixture of shapes and lines (roads), so we added the 200m buffer zone. Figure 5 shows examples of SSSI (red) and PCM (blue) areas with a 200m and 100m buffer zone near the M25. Roads used by LSTs are shown in black. Road links that have a proportion of their length inside sensitive areas are coloured.

FIGURE 5: SSSI (RED) AND PCM (BLUE) AREAS OF INTEREST WITH ROAD LINKS USED BY LSTS (BLACK)

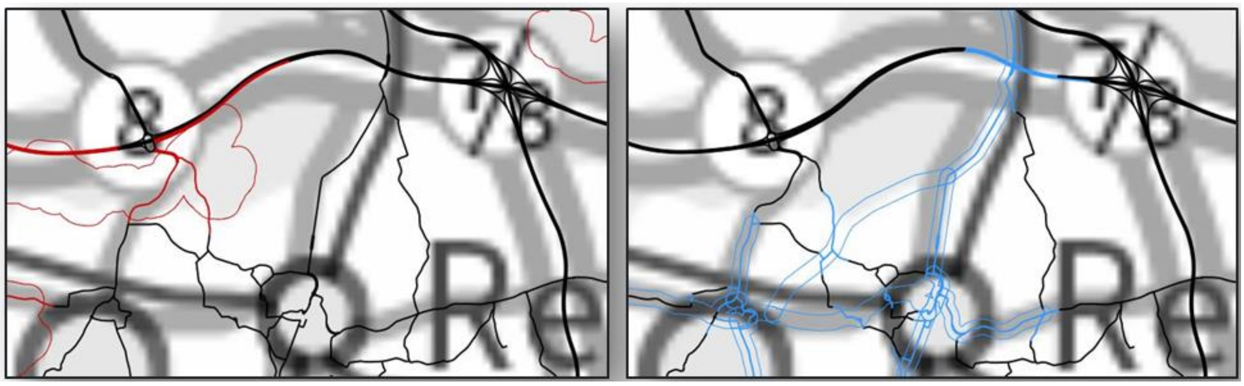


TABLE 2: EMISSIONS MODELLING SPATIAL AREAS OF INTEREST

Area of interest in emissions modelling	
AQMA	Air Quality Management Areas are areas where air pollutant concentrations exceed or are likely to exceed the relevant air quality objectives. AQMAs are declared for specific pollutants and objectives. [Definition: Defra LAQM.TG(16)] https://laqm.defra.gov.uk/technical-guidance/
PCM Links	The Pollution Climate Mapping model is a collection of models designed to fulfil part of the UK's EU Directive (2008/50/EC) requirements to report on the concentrations of particular pollutants in the atmosphere. These models are run by Ricardo Energy & Environment on behalf of Defra. There is one model per pollutant (including NO_x, NO_2, PM_{10}, $PM_{2.5}$ and other pollutants) each with two parts: a base year model and a projections model. The PCM provides outputs on a 1x1 km grid of background conditions plus representative roadside values for around 9,000 links. PCM is also used for scenario assessment and population exposure calculations to assist policy developments and also provides model runs to support the writing of Time Extension Notification (TEN) applications for PM_{10} and NO_x. [Definition: Defra] https://uk-air.defra.gov.uk/research/air-quality-modelling?view=modelling
SAC	Special Areas of Conservation are strictly protected sites designated under the EC Habitats Directive. Article 3 of the Habitats Directive requires the establishment of a European network of important high-quality conservation sites that will make a significant contribution to conserving the 189 habitat types and 788 species identified in Annexes I and II of the Directive (as amended). The listed habitat types and species are those considered to be most in need of conservation at a European level (excluding birds). [Definition: JNCC] http://jncc.defra.gov.uk/page-23
Ramsar	Ramsar sites are wetlands of international importance designated under the Ramsar Convention. [Definition: JNCC] http://jncc.defra.gov.uk/page-161
SSSI / ASSI	Sites of Special Scientific Interest (England, Scotland and Wales) and Areas of Special Scientific Interest (Northern Ireland). [Definition: JNCC] http://jncc.defra.gov.uk/page-1527
SPA	Special Protection Areas are strictly protected sites classified in accordance with Article 4 of the EC Birds Directive, which came into force in April 1979. They are classified for rare and vulnerable birds (as listed on Annex I of the Directive), and for regularly occurring migratory species. The European Commission's website hosts a full copy of the Directive 2009/147/EC on the conservation of wild birds (Birds Directive) (the codified version of Council Directive 79/409/EEC as amended), within which all the Articles and Annexes (including amendments) are given, along with useful interpretation information. [Definition: JNCC] http://jncc.defra.gov.uk/page-162

Emissions Model Application to Whole Trial Period

The modelling has been applied to the most recent year of data, 2017, as described above.

Data for previous years is derived for each previous year by:

- first calculating for each type of emissions an emission saving factor – which is the emissions saving per LST km derived from the 2017 results; and
- then calculating total emissions for each previous year as:

  Total Emissions = number of legs in year * average leg distances * emissions saving per LST km

This approach assumes that previous years have operational patterns that are not grossly different to 2017. Risk Solutions wider analysis of the trial data provides assurance that this is at least a reasonable assumption, based on the fact that key indicators such as the average journey leg length, loading percentages and calculated savings have been stable for all years, at least once the first 1-2 trial data periods were completed.

In this way emissions savings generated by using LSTs instead of standard length trailers have been estimated for all the years of the trial up to the end of 2017.

Fleet and Distance in Remaining Trial Years

In order to extend the modelling to future years, we need first to estimate the number of LSTs likely to be on the trial in each year, which is done by considering how many LSTs might join the trial in each period from 2018-P1 onwards. We have considered three LST trial fleet growth scenarios for the remainder of the trial, as described in Table 3.

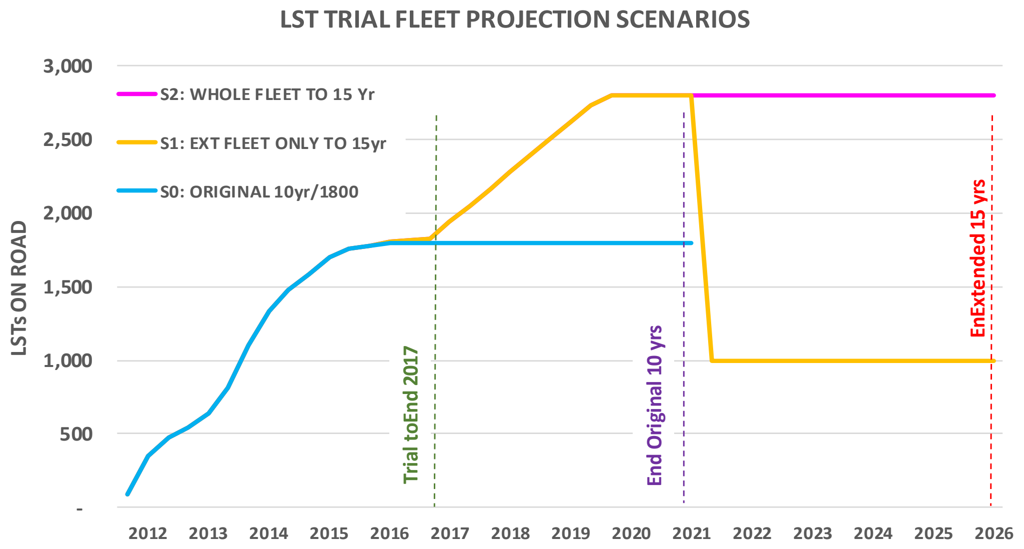
TABLE 3: LST TRIAL FLEET GROWTH SCENARIOS

Fleet Scenario	Description
S0: original 10-year trial with 1800 LSTs	The closest scenario to the original trial plan, where there would be only 1,800 LSTs and a duration of 10 years. The original trial plan and modelling assumed all 1,800 trailers were on the road by the end of the first year, whereas in fact this was only achieved at the year of 2016, year 5 of the trial.
S1: extension fleet only to 15 years	This may not be a real scenario, but at present, it is unclear whether, if the trial were to continue past year 10, the original 1,800 trailer allocations would be extended alongside the additional 1,000 trial places released in April 2017. This theoretical option models a scenario in which DfT decides NOT to adopt a policy allowing LSTs to be used beyond the trial, but fulfils its commitment to the 'new' 2017 allocations which appear to be valid for a further 5 years.
S2: whole fleet to 15 years	This is the more likely scenario, where if the use of LSTs were to remain a trial beyond the original 10 years, then the whole LST fleet would remain on the road until year 15. (In reality, this refers to the allocations remaining valid – many of the actual trailers being replaced when they reach end of life.)

The final variable to be considered is how fast the remaining trial trailer allocations are finalised (during 2018) and those trailers come onto the road. Our current modelling has assumed that 114 new trailers enter service in each 4-month period – the number we saw added in 2017-P3 and the average of the past 2-3 periods. By modelling with a fairly conservative assumption about fleet growth we are being prudent in that this will produce commensurately conservative emissions savings results.

The resulting fleet growth curves for each scenario are shown in Figure 6.

FIGURE 6: LST TRIAL FLEET GROWTH CURVES



EXTENDED FLEET GROWTH		
ASSUMED ADDITION RATE - TRAILERS PER PD	**114**	Actual trailers added in 2017-P3
RESULTING PROJECTION - PERIOD ALL ON ROAD	**2020-P2**	We may expect higher rates in 2018
		Rate for 1000 on road by 2019-P1 would be 225

For years up to 2017 we have data for the actual leg count and total distance covered by the LSTs. For 2018 onwards we have projected values based on the number of trailers in the fleet growth curve, combined with estimates for average numbers of legs and leg length per trailer, from 2017 (as the most recent year).

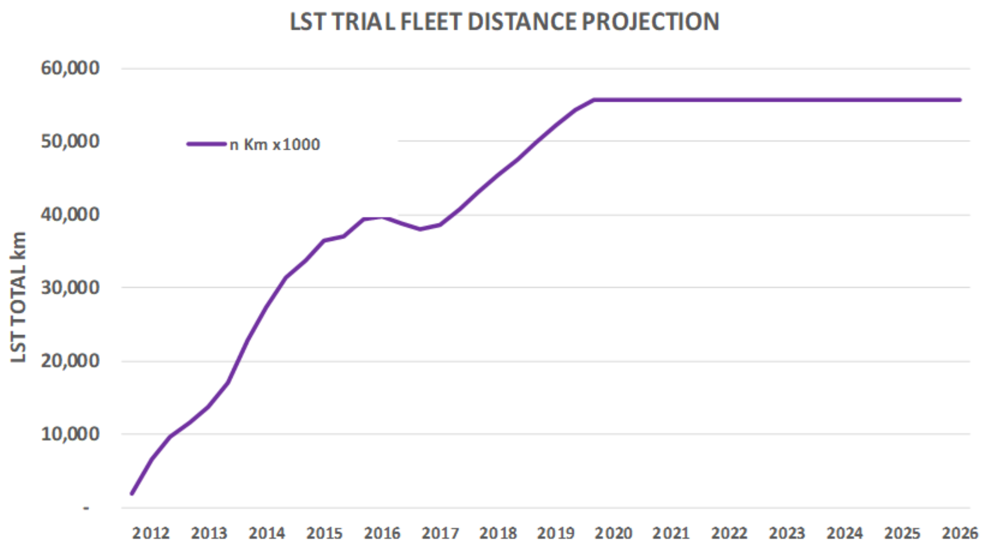
For the current report, we have used Scenario 2 (above) for these calculations, as it covers all the LSTs so far built or allocated by DfT. Alternative results for other scenarios can be produced if DfT requires.

The resulting fleet total distance curve for Scenario 2 is shown in Figure 7.

The slight ‘dip’ in the centre of the curve arises from an unusual set of data for a small number of operators who appear to have operated 10-20% fewer legs /km with their fleet of LSTs in 2017, compared to 2016.

We are in touch with the operators to see what caused this change as it does not appear to be the result of missing data legs, nor a reduction in their LST fleet size.

FIGURE 7: LST FLEET CUMULATIVE DISTANCE PROJECTION



EXTENDED FLEET GROWTH		
ASSUMED ADDITION RATE - TRAILERS PER PD	**114**	
RESULTING PROJECTION - PERIOD ALL ON ROAD	**2020-P2**	

S2: WHOLE FLEET TO 15 Yr
Actual trailers added in 2017-P3
We may expect higher rates in 2018
Rate for 1000 on road by 2019-P1 would be 225

4 Source Data

TABLE 4: DATA SOURCES

Input Data Field	Source	Level
LoadWeight	Weight of goods being carried given by the operator for each Journey Leg in the master trial data	Journey Leg
NoLoadWeight	Weight of unladen tractor and trailer, currently based on a single reference value of +1.5 tonnes (compared to a regular 13.6m trailer) from the pre-trial analysis. Work is underway to gather more up to date values from actual LST designs, in conjunction with the manufacturers via SMMT	Journey Leg
Speed	Based on relevant HGV speed limit for each link in a modelled LST journey route, adjusted by a ratio of modelled route time to the actual journey leg time provided by operators (this adjusts modelled route times based on speed limits to actual traffic conditions experienced on the day represented by reported journey times).	Route Link
Distance	Length of ITN link from the ITN data extracted in the LST routing model for every link used in every route that has been modelled. The routes themselves are derived from the start-end postcode data provided by operators for all journey legs in 2017	Route Link
LST Fleet Size and Distances Covered	Actual data on trailer numbers (and their designs) on the road from main LST dataset and the distances from the leg data.	Journey Leg and Individual Trailer Data
Engine Type	All modelling has been done assuming EURO V engines as the average.	

Terminology:

The LST trial has adopted the following terms:

- Journey leg – a single movement of a trailer from load pick up at A to load drop at B
    - The leg data is submitted by the operators for every LST movement
    - In 2016 and 2017, submissions were required to contain the postcode of A and B
- Route – defined as the start and end point of any leg from A to B
    - There will be many LEGS that run between the same A to B route
- Route link
    - when modelling the routes, each path followed by the model is converted into a series of ITN links (ITN is the base map used from OS)
    - once a route has been expressed as a series of links, the OS data for each link is available, such as road class, speed limit etc.

5 Results

The total emissions results for the reference year (2017) are shown in Table 5. Overall savings for all pollutants of approximately 7% are indicated for the trial.

TABLE 5: TOTAL SAVINGS ASSUMING UNCONGESTED FLOW (2017)

[tonnes emissions]	CO	CO2e	NO_x	PM Exhaust	VOC
LST	49.8	81,278	412	4.44	9.60
Non-LST	53.7	87,772	445	4.79	10.35
Saving	**3.9**	**6,494**	**32.6**	**0.038**	**0.744**
% Saving	*7.2%*	*7.4%*	*7.3%*	*7.3%*	*7.2%*
Saving per LST m km	***0.038***	***63.6***	***0.32***	***0.0034***	***0.0073***

The total mass emission saving for NO_x of 32.6 tonnes can be put in the context of total UK emissions for articulated HGVs in 2016 of approximately 16,000 tonnes (the latest available data) – or approximately 0.2% of total sector emissions. Likewise, the CO2e emissions saving of 6,494 tonnes compares to total UK emissions for articulated HGVs in 2016 of approximately 12,114,667 tonnes – or just less than 0.05% of total sector emissions. These figures are of course quite a small proportion of the total, since the number of trailers on the trial is only a small percentage of the total GB fleet. A more meaningful comparison will come with the scaling up work to be carried out in the coming year of the work on the trial

The bottom row of Table 5 gives the emissions savings expressed as a factor in tonnes per LST km, calculated from the 2017 data. This is used later to apply these reference year results to both actual LST distances covered in earlier trial years and the projected distances for future years.

The breakdowns that follow show the emissions results by road type (Table 6) and areas of specific interest regarding emissions (Table 7), with the further breakdown of emissions saved in ‘Designated Areas’ into the sub-areas (which overlap) in Table 8.

Note that the structure of the road type data is intentionally matched to the structure of DfT published road traffic data (TRA3105) so that the emissions (along with other data in the project) can be normalised by distances travelled on specific road types.

Emissions by Road Class

As shown in Table 6 below, when broken-down by road class, the percentage savings remain around 7% for all classes, the small variations reflecting minor variations in the savings of journeys with differing road class proportions.

The most substantial savings in total tonnes are with LSTs operating on motorways, with savings of 3,921.7 and 19.4 tonnes of CO2e and NO_x respectively, reflecting the high proportion of operations that take place on Motorways. However, these have a lower saving per km, due to the more efficient engine performance on these roads. The most notable savings in tonnes per LST million kilometre (mkm) for CO2e and NO_x are those for Trunk A and minor roads.

TABLE 6: EMISSIONS SAVINGS BY ROAD CLASS (UNCONGESTED FLOW - 2017)

By Road Type [tonnes]	CO	CO2e	NO_x	PM Exhaust	VOC
Motorway					
LST	28.7	48,961.7	245.0	2.6	5.6
Non-LST	31.0	52,883.4	264.5	2.8	6.0
LST SAVING	**2.2**	**3,921.7**	**19.4**	**0.2**	**0.4**
% Saving vs non-LST	*7.2%*	*7.4%*	*7.3%*	*7.3%*	*7.2%*
% of total 2017 saving	**58.2%**	**60.4%**	**59.7%**	**59.5%**	**58.5%**
Saving per LST mkm	*0.04*	*61.95*	*0.31*	*0.00*	*0.01*
Major (A Road)					
Trunk A Road					
LST	11.3	18,527.7	93.8	1.0	2.2
Non-LST	12.2	20,086.8	101.6	1.1	2.4
LST SAVING	**0.9**	**1,559.0**	**7.8**	**0.1**	**0.2**
% Saving vs non-LST	*7.5%*	*7.8%*	*7.7%*	*7.6%*	*7.6%*
% of total 2017 saving	**23.9%**	**24.0%**	**24.0%**	**24.1%**	**23.9%**
Saving per LST mkm	*0.07*	*120.87*	*0.61*	*0.01*	*0.01*
Principal A Road					
LST	6.9	10,697.2	55.1	0.6	1.3
Non-LST	7.4	11,478.4	59.1	0.6	1.4
LST SAVING	**0.5**	**781.2**	**4.0**	**0.0**	**0.1**
% Saving vs non-LST	*6.5%*	*6.8%*	*6.7%*	*6.6%*	*6.6%*
% of total 2017 saving	**12.6%**	**12.0%**	**12.2%**	**12.3%**	**12.5%**
Saving per LST mkm	*0.02*	*32.68*	*0.17*	*0.00*	*0.00*
Minor Roads					
LST	2.9	3,091.8	18.5	0.2	0.5
Non-LST	3.1	3,323.5	19.9	0.2	0.6
LST SAVING	**0.2**	**231.6**	**1.4**	**0.0**	**0.0**
% Saving vs non-LST	*6.7%*	*7.0%*	*6.8%*	*6.8%*	*6.7%*
% of total 2017 saving	**5.3%**	**3.6%**	**4.2%**	**4.1%**	**5.1%**
Saving per LST mkm	*0.10*	*112.46*	*0.66*	*0.01*	*0.02*

Emissions by Areas of Interest

In considering the emissions in 'areas of interest' the focus is on the impact of emissions on health, where the main emissions of interest are NO_x and particulates.

The results for areas of interest indicate potential benefits in-particular with savings in NO_x emissions which complements initiatives to reduce emissions in AQMAs, along PCM links and Designated Sites (Table 7 below).

15% of the emissions savings are in AQMAs where air pollutant concentrations already exceed or are likely to exceed relevant air quality objectives defined by Defra.

12% of the emissions savings are along PCM links including those where roadside concentrations are non-compliant with the limit value for annual mean NO_2.

Designated Sites may have cited features that are sensitive to changes in ambient NO_x, nitrogen deposition and acid deposition that can be brought about by changes in traffic emissions of NO_x – particularly from roads within 200m. In looking specifically at the Designated Sites, the only emission of interest is NO_x. The other emissions are still calculated by the model and so are included for completeness, but are de-emphasised in the remaining results tables.

A specific location can fall within the geo-spatial areas of more than one type of Designated Site, since their definitions allow them to overlap. The values given in Table 7 remove this duplication and show the results for emissions savings made on road links falling in any Designated Site. The values below in Table 8 note the savings for road links falling in each individual Designated Site, calculated separately, irrespective of whether those savings also appear under other sections of the table.

TABLE 7: EMISSIONS SAVINGS FOR AREAS OF INTEREST (UNCONGESTED FLOW - 2017)

[tonnes]	CO	CO2e	NO_x	PM Exhaust	VOC
AQMA					
LST	7.67	12,568	63.7	0.69	1.48
Non-LST	8.25	13,548	68.6	0.74	1.59
Saving	**0.58**	**979**	**4.9**	**0.052**	**0.112**
% Saving vs non-LST	*7.0%*	*7.2%*	*7.1%*	*7.1%*	*7.0%*
% of total 2017 saving	***15.0%***	***15.1%***	***15.0%***	***15.0%***	***15.0%***
Saving per LST m km	*0.036*	*61.8*	*0.31*	*0.003*	*0.007*
PCM Links					
LST	6.39	10,242	52.3	0.57	1.23
Non-LST	6.86	11,021	56.2	0.61	1.32
Saving	**0.47**	**780**	**3.9**	**0.042**	**0.090**
% Saving vs non-LST	*6.8%*	*7.1%*	*7.0%*	*6.9%*	*6.8%*
% of total 2017 saving	***12.2%***	***12.0%***	***12.0%***	***12.1%***	***12.1%***
Saving per LST m km	*0.04*	*61.2*	*0.31*	*0.003*	*0.007*
Designated Sites					
LST	3.27	5,340	27.1	0.29	0.63
Non-LST	3.51	5,742	29.1	0.31	0.68
Saving	**0.24**	**403**	**2.0**	**0.021**	**0.046**
% Saving vs non-LST	*6.8%*	*7.0%*	*6.9%*	*6.9%*	*6.8%*
% of total 2017 saving	***6.2%***	***6.2%***	***6.2%***	***6.2%***	***6.2%***
Saving per LST m km	*0.036*	*60.2*	*0.30*	*0.003*	*0.007*

TABLE 8: EMISSIONS SAVINGS FOR DESIGNATED SITES (UNCONGESTED FLOW - 2017)

[tonnes]	CO	CO2e	NO_x	PM Exhaust	VOC
Ramsar					
LST	0.28	440	2.27	0.02	0.05
Non-LST	0.30	472	2.43	0.03	0.06
Saving	**0.02**	**32**	**0.16**	**0.002**	**0.004**
% Saving	*6.4%*	*6.7%*	*6.6%*	*6.5%*	*6.5%*
Saving per LST m km	***0.04***	***58.0***	***0.29***	***0.003***	***0.007***
SAC					
LST	1.74	2,892	14.59	0.16	0.34
Non-LST	1.87	3,102	15.64	0.17	0.36
Saving	**0.12**	**211**	**1.05**	**0.011**	**0.024**
% Saving	*6.5%*	*6.8%*	*6.7%*	*6.6%*	*6.6%*
Saving per LST m km	***0.03***	***57.9***	***0.288***	***0.0031***	***0.0065***
SPA					
LST	0.75	1,164	6.01	0.06	0.14
Non-LST	0.80	1,250	6.45	0.07	0.15
Saving	**0.05**	**86**	**0.44**	**0.005**	**0.010**
% Saving	*6.7%*	*6.9%*	*6.8%*	*6.8%*	*6.7%*
Saving per LST m km	***0.04***	***61.0***	***0.311***	***0.0033***	***0.0073***
SSSI					
LST	2.10	3,448	17.45	0.19	0.40
Non-LST	2.26	3,721	18.81	0.20	0.44
Saving	**0.16**	**273**	**1.37**	**0.015**	**0.031**
% Saving	*7.1%*	*7.3%*	*7.3%*	*7.2%*	*7.1%*
Saving per LST m km	***0.04***	***62.8***	***0.314***	***0.0033***	***0.0071***

6-4 Emissions Results - Whole Trial

The final row of Table 5 gives the emissions savings expressed as a factor in tonnes per LST km, calculated from the 2017 data. The total emissions at three key time points in the trial are shown in Table 9, derived by applying the factors above, *pro-rata*, to the total LST distances covered in each year from the total fleet distance curve shown earlier in Figure 7. The emissions savings (cumulative tonnes) are also illustrated in Figures 8 to 12.

TABLE 9: TOTAL TRIAL EMISSION SAVINGS PROJECTION

LST TRIAL EMISSIONS SAVINGS SUMMARY				
FLEET SCENARIO:		S2: whole fleet to 15 years		
ASSUMED ADDITION RATE - TRAILERS PER PD:		114		
RESULTING PROJECTION - PERIOD ALL ON ROAD:		2020-P2		
(All figures rounded)	**Units**	**To Date**	**10yr Trial**	**Extended Trial**
		End 2017	**End 2021**	**End 2026**
Trial fleet stats (Actual/projected)				
LSTs on road		1,939	2,800	2,800
Total journey legs	million	4	8	15
Total distance covered	million km	443	1,055	1,889
SAVINGS	tonnes			
CO		17	40	71
CO2e		28,180	67,030	120,066
NO_x		141	336	602
PM Exhaust		2	4	6
VOC		3	8	14

These results related to the trial conditions, fleet and operational patterns. They will be segmented by operator type and used to scale up the results to forecast national impact, later in the trial

If we consider the key metrics of CO_2 and NO_x we estimate:

- A net reduction from the trial to date of around 28,000 tonnes of CO2e and 141 tonnes NO_x, as well as other emissions.
- A projected net reduction if the trial were to run to the original 10-year end point of around 67,000 tonnes of CO2e and 336 tonnes NO_x, as well as other emissions.

In terms of where the emissions have been reduced, the analysis shows that for the trial:

- 15% of the emissions savings noted above are being made in AQMAs where air pollutant concentrations already exceed or are likely to exceed relevant air quality objectives.
- 6.2% of the emissions savings noted above are being made within 200m of one or more Designated Sites (SAC, Ramsar, SSSI, SPA) – areas which have cited features that are sensitive to changes in ambient NO_x, nitrogen deposition and acid deposition that can be brought about by changes in traffic emissions of NO_x – particularly from roads within 200m.

These are all for LST fleet growth scenario 2 in Table 3, where both the original 1,800 LST allocations and the extended trial 1,000 trailers are permitted to continue on the road to year 15.

FIGURE 8: EMISSIONS SAVINGS - WHOLE TRIAL PROJECTION: CO

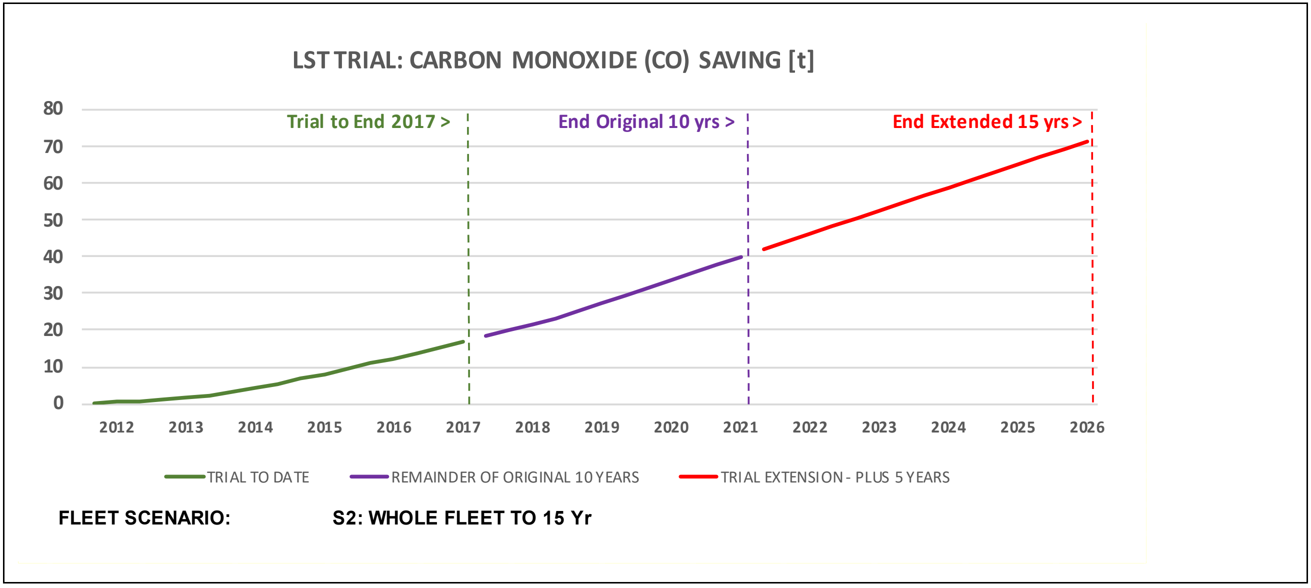


FIGURE 9: EMISSIONS SAVINGS - WHOLE TRIAL PROJECTION: CO2E

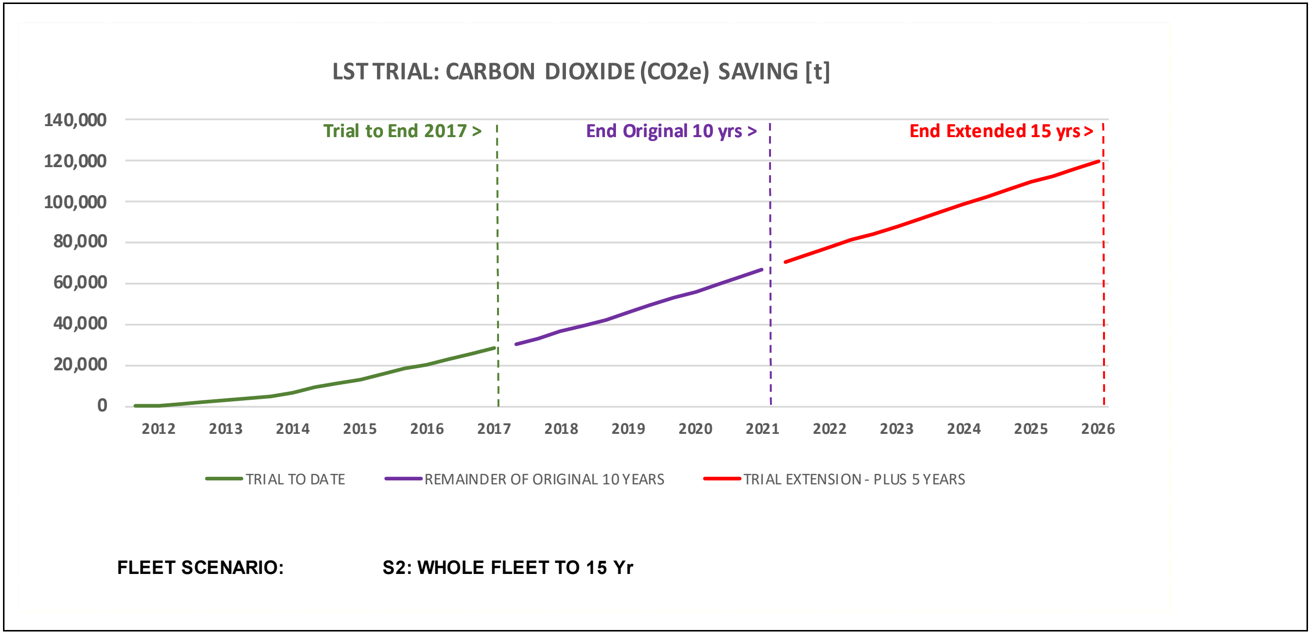


FIGURE 10: EMISSIONS SAVINGS - WHOLE TRIAL PROJECTION: NO_X

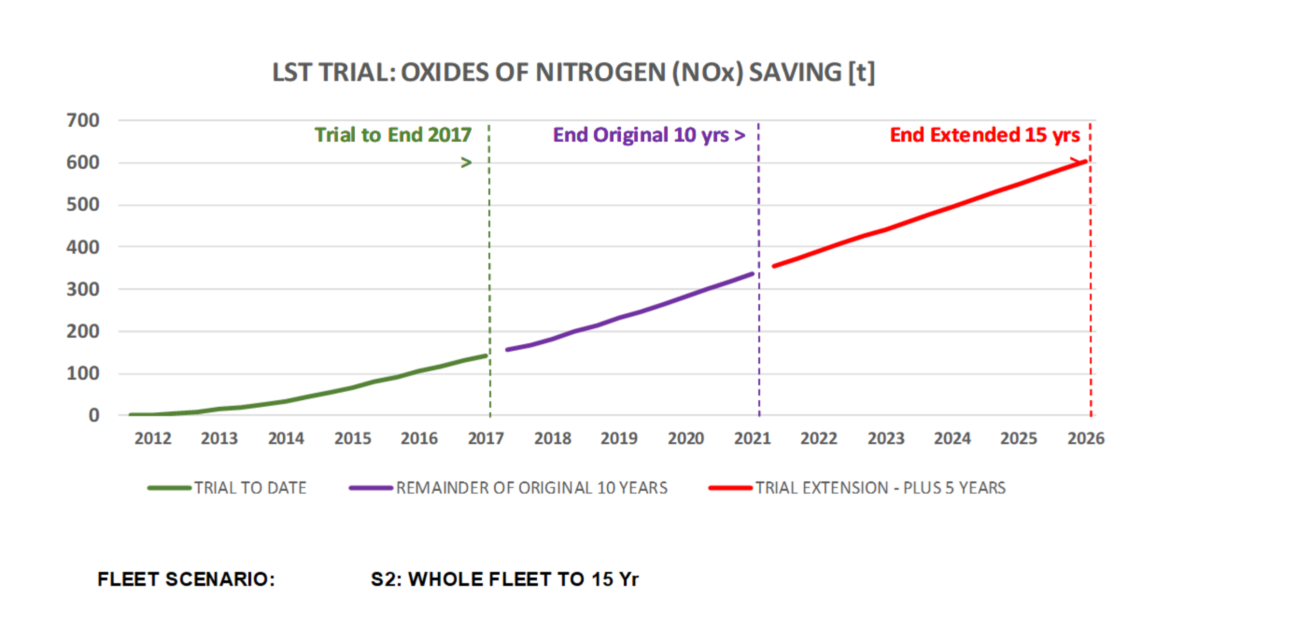


FIGURE 11: EMISSIONS SAVINGS - WHOLE TRIAL PROJECTION: PM (EXHAUST)

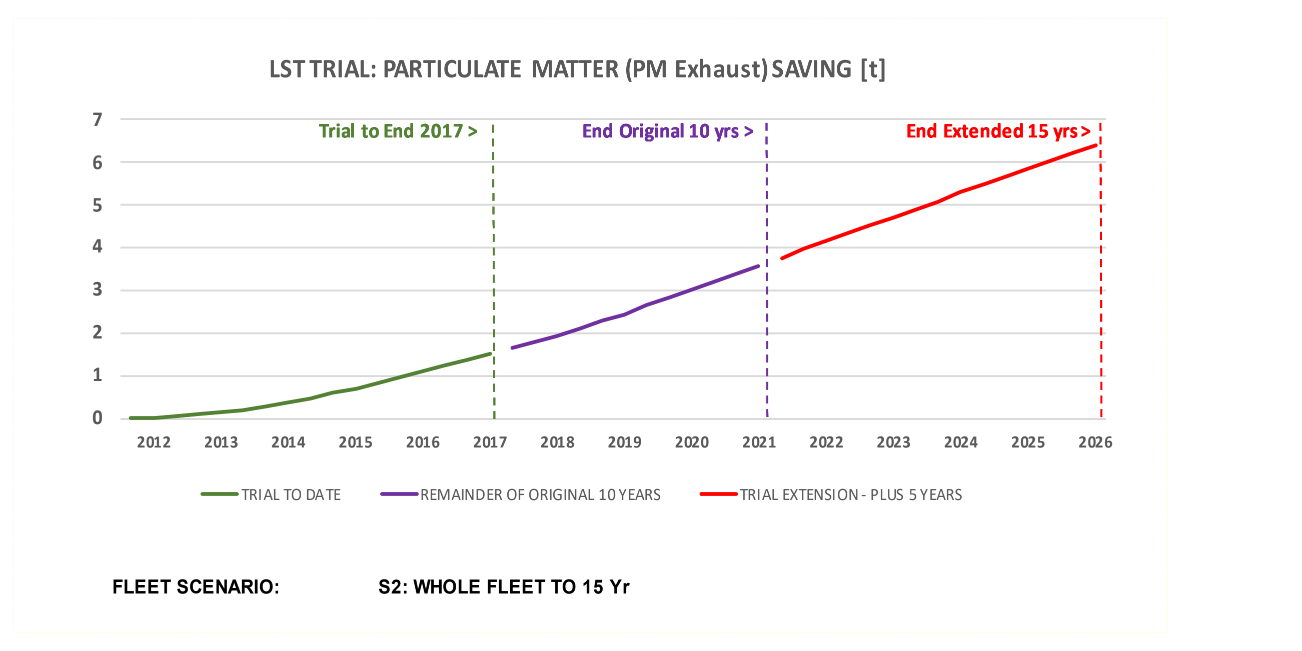
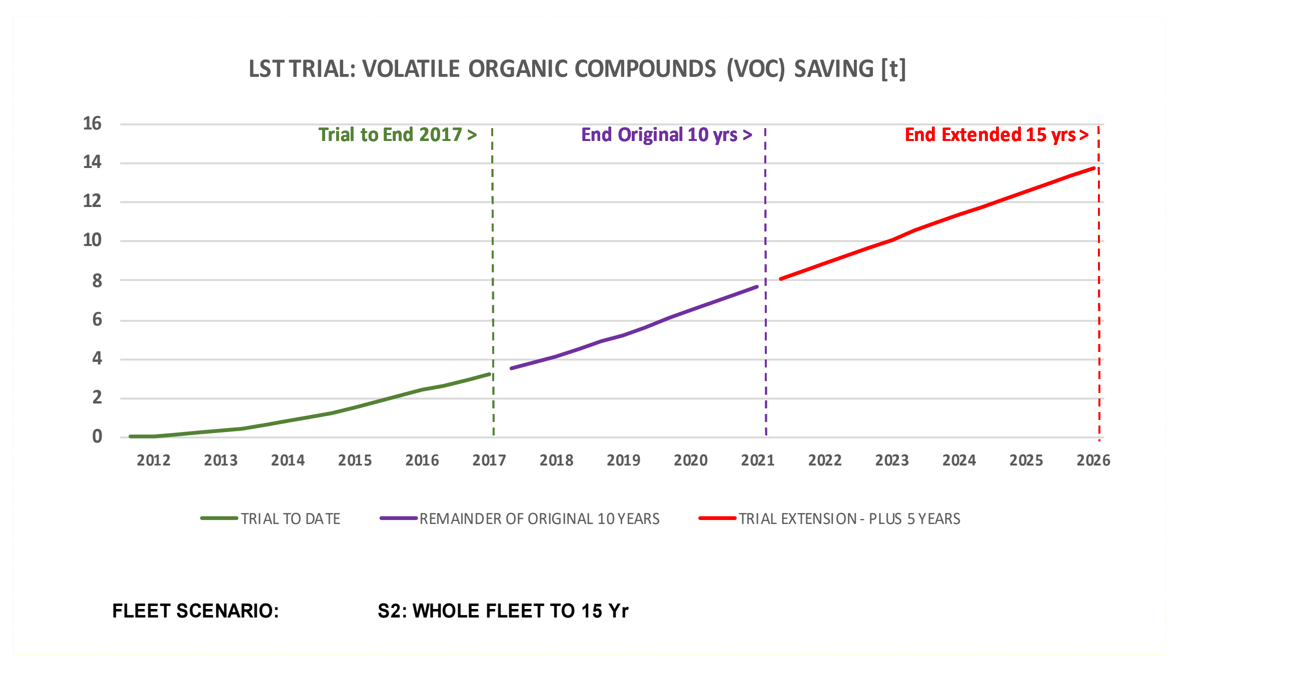


FIGURE 12: EMISSIONS SAVINGS - WHOLE TRIAL PROJECTION: VOC



ANNEX A EMEP/EEA REFERENCE VALUES SAMPLE

The EMEP/EEA emissions functions are provided as a set of functions split by vehicle type, vehicle load and pollutant. The vehicle type of most relevance to this project is Heavy Duty Trucks, Diesel Fuel, Articulated 40-50 tonnes, though emission functions are provided for a wide variety of vehicle types. Within each vehicle type, functions are provided for 0%, 50% and 100% vehicle load. To calculate emissions for other load values, the results of the given functions are interpolated to the appropriate load value. Functions are provided for CO, NO_x, VOCs and PM. Also provided are functions for EC which are then used to calculate CO2e emissions. Each function has an associate minimum and maximum speed within which the calculation is reliable. The arguments to each function includes the vehicle speed along with a series of empirically derived coefficients unique to each function. A relevant sample of the reference data as provided is shown in Table A1, and the complete data set can be found in Annex 3 to chapter '1.A.3.b.i-iv Road transport', of the EMEP/EEA air pollutant emission inventory guidebook 2016.

TABLE A1 – SAMPLE OF EMEP/EEA REFERENCE DATA FOR EMISSIONS FUNCTIONS

Category	Fuel	Segment	Euro Standard	Pollutant/Energy consumption	Road Slope	Load	Speed [km/h]	Speed [km/h]	Coefficients						
									Alpha	Beta	Gamma	Delta	Epsilon	Zita	Hta
Heavy Duty Trucks	Diesel	Articulated 40 - 50 t	Euro V	NOx	0	0	5	85	0.005756	0.192334	1.906235	10.05901	0.00283926	-0.00272	0.178175
Heavy Duty Trucks	Diesel	Articulated 40 - 50 t	Euro V	NOx	0	0.5	5	85	0.021413	1.220127	-4.0617	7.161994	0.00994936	-0.02835	0.06529
Heavy Duty Trucks	Diesel	Articulated 40 - 50 t	Euro V	NOx	0	1	5	85	0.053199	3.64661	-8.44857	8.187479	0.022358323	-0.00895	-7.1E-14
Heavy Duty Trucks	Diesel	Articulated 40 - 50 t	Euro V	EC	0	0	5	85	0.018086	0.426308	-0.40814	7.567281	0.003231756	-0.01683	0.105189
Heavy Duty Trucks	Diesel	Articulated 40 - 50 t	Euro V	EC	0	0.5	5	85	0.038027	1.544413	-5.37903	8.559451	0.005292502	-0.01128	0.040072
Heavy Duty Trucks	Diesel	Articulated 40 - 50 t	Euro V	EC	0	1	5	85	0.03946	2.365599	-7.49211	8.396204	0.00484256	0.003945	3.08E-15
Heavy Duty Trucks	Diesel	Articulated 40 - 50 t	Euro VI	NOx	0	0	5	85	-0.0007	0.091899	-0.68826	1.977669	0.002431602	-0.01714	0.040211
Heavy Duty Trucks	Diesel	Articulated 40 - 50 t	Euro VI	NOx	0	0.5	5	85	-0.00081	0.158957	-1.42673	5.08607	0.008160848	-0.05335	0.120912
Heavy Duty Trucks	Diesel	Articulated 40 - 50 t	Euro VI	NOx	0	1	5	85	-0.00024	0.069804	-0.67702	2.18231	0.00397621	-0.02536	0.053085
Heavy Duty Trucks	Diesel	Articulated 40 - 50 t	Euro VI	EC	0	0	5	85	0.027405	0.700596	-0.81122	11.92176	0.005114795	-0.02614	0.161395
Heavy Duty Trucks	Diesel	Articulated 40 - 50 t	Euro VI	EC	0	0.5	5	85	0.037337	1.560054	-5.40634	8.814655	0.005404254	-0.01206	0.043394
Heavy Duty Trucks	Diesel	Articulated 40 - 50 t	Euro VI	EC	0	1	5	85	0.065109	3.996901	-12.7891	14.33886	0.008319177	0.005735	-4.8E-14

.

ANNEX B VEHICLE WEIGHT CALCULATIONS

Unladen Vehicle Weight Assumptions

The weight assumptions used in the calculations of unladen trailer weights are given in the tables below. At this stage, these are based on the same core set of data used in the 2010 Impact Assessment for the theoretical LST design options that were being considered at that time. Here the weight elements have been re-configured to reflect the actual LST design variants that have appeared on the trial and hence can be used to derive a nominal weight for each trailer for which we have trial data.

In the longer term, we are looking at the option of an updated survey of manufacturers to give even more accurate weights for each component.

TABLE B1: DECK LAYOUT WEIGHT ASSUMPTIONS

Deck Layout	Base (13.6m) Trailer with 3 Fixed Axles Weight (kg)
Single	6,343
Fixed Dual – Partial	8,968
Fixed Dual - Full	9,843
Moving Dual - Partial	11,137
Moving Dual - Full	12,735

TABLE B2: TRACTOR UNIT WEIGHT ASSUMPTION

Tractor	Base Weight (kg)
Basic Tractor Unit	8,190

TABLE B3: STEERING AXLE WEIGHT ASSUMPTIONS

Steering Axel	Additional Weight (kg) vs. 13.6m with Fixed Axel
1 Self-Steer	190
2 Self-Steer	380
1 Command (Passive)	688
2 Command (Passive)	1,145
Active (Any More complex)	1,250
All Fixed / Other	190

TABLE B4: PER METRE IMPACT OF BODY DESIGNS FOR LONGER TRAILERS, AND FACTORS USED WHEN CALCULATING EQUIVALENT 13.6M TRAILER VEHICLE WEIGHTS

Deck Layout	Body Design	Additional Weight per Metre (kg)	13.6m Trailer 'Factor'
Single	BOX	192	1
Single	CURTAIN SIDED	192	1
Single	CURTAIN WITH CAGE RETENTION	192	1
Single	FLATBED	154	0.8
Single	SKELETAL	192	1
Single	TANKER / BULK	192	1
Moving Dual - Partial	BOX	248	1.3
Moving Dual - Partial	CURTAIN SIDED	248	1.3
Moving Dual - Partial	CURTAIN WITH CAGE RETENTION	248	1.3
Moving Dual - Partial	FLATBED	162	0.84
Moving Dual - Partial	OTHER	162	0.84
Moving Dual - Full	BOX	263	1.37
Moving Dual - Full	CURTAIN SIDED	263	1.37
Moving Dual - Full	CURTAIN WITH CAGE RETENTION	263	1.37
Fixed Dual - Partial	BOX	236	1.37
Fixed Dual - Partial	CURTAIN SIDED	263	1.37
Fixed Dual - Full	BOX	250	1.3
Fixed Dual - Full	CURTAIN SIDED	250	1.3
Fixed Dual - Full	CURTAIN WITH CAGE RETENTION	250	1.3

Recalculating Goods Weight for Non-LST Trailer Equivalent Calculation

When calculating the goods weight carried for the non-LST equivalent calculation we have made the following assumptions:

1. Savings are only made for those trailers that are making use of some or all of the additional length of the longer trailer i.e. where the load occupies any part of the trailer deck beyond the 13.6m length of a standard trailer. This is the assumption on which all savings calculations are based (see previous annual reports).
2. Irrespective of the weight of the goods carried, loads extending beyond the length of 13.6m, and therefore being carried in the additional part of the longer trailer, could not have been carried on a standard-length trailer. Low density, high volume goods would still need their weight to be redistributed if we are assuming the load would have to be carried by a standard-length trailer.
3. We assume that the 13.6m trailer carries a lower volume (and hence weight) of goods, over a longer distance, to ultimately deliver the same kg * km of goods.
4. To calculate the weight of goods assumed to be carried by the equivalent 13.6m trailer we define the additional length used in metres divided by 13.6 as X. The weight carried by the 13.6m trailer, $W_{13.6}$ is given by the following:

   $W_{13.6} = W_{LST} / (1 + X)$

WSP House
70 Chancery Lane
London
WC2A 1AF

wsp.com