STAIR (Screening Tool for Air Quality Impacts from Roads)

Technical Development Report

1. Introduction

AECOM Ltd was appointed by Natural England to develop an air quality screening tool to determine the number of additional vehicle movements above which there is a likelihood of Natural England's 1% criterion being exceeded for nitrogen oxides (NOx), ammonia (NH_3) and nitrogen deposition.

This criterion is a screening threshold used in air quality assessments for protected ecological sites (Special Area of Conservation (SAC), Special Protection Area (SPA), Ramsar sites and Sites of Special Scientific Interest (SSSI)). For any development or scheme that emits NOx (oxides of nitrogen) and / or NH_3 (ammonia), the contribution of the development (the Process Contribution; PC) is compared against the site's critical level, or critical load for nitrogen deposition.

The purpose of the Screening Tool for Air Quality Impacts from Roads (STAIR) is to enable local authorities, highways authorities and developers to screen road traffic impacts of proposed schemes to determine the appropriate level of assessment required in a consistent and transparent manner.

In line with National Highways DMRB LA 105[1] and Natural England advice[2], STAIR should only be used to screen impacts on ecological sites that are less than or equal to 200 metres from the road being assessed. At distances beyond 200 metres, the road source contribution is not typically discernible from fluctuations in background concentrations.

This report describes the development of STAIR and the underlying datasets and assumptions upon which the tool depends.

[1] DMRB LA105 available at https://www.standardsforhighways.co.uk/search/af7f4cda-08f7-4f16-a89f-e30da703f3f4
[2] Natural England guidance available at https://www.gov.uk/guidance/air-pollution-and-development-advice-for-local-authorities

2. Calculation Method

The basis of the calculation method for STAIR is the derivation of relationships between the road PC in terms of concentration (i.e. µg/m^3 in the air) and vehicle emissions (i.e. g/km/s emitted by vehicles using the road). The adopted approach enables the increase in pollutant concentration (NO_X, NO_2 (nitrogen dioxide), NH_3, nitrogen deposition) per vehicle movement to be estimated, from which the number of additional vehicle movements that would result in exceedance of the 1% criterion is determined.

To achieve this, the latest versions of tools were used to undertake the following steps:

- Calculation of road NO_X emissions using DEFRA's Emissions Factors Toolkit (EFT)[3].
- Calculation of road NH_3 emissions using Air Quality Consultants' Calculator for Road Emissions of Ammonia (CREAM)[4].
- Calculation of unitised road pollutant concentrations using ADMS-Roads[5].
- Development of simplified NO_X to NO_2 ratios using DEFRA's NO_X to NO_2 calculator[6].

NO_X and NH_3 emissions were calculated for all years from 2025 to 2050 across a range of speeds (5km/h to 110 km/h) and different road types, to capture the full range of traffic conditions, fleet mixes and years that users are likely to assess.

Each of the steps is described in detail in the following sub-sections.

2.1 Road NO_X Emissions

Road NO_X emissions were calculated using DEFRA's EFT Version 14.1.

Emissions were calculated for each year from 2025 to 2050 for road links representing the parameters in Table 1.

Table 1. Emissions Factors Toolkit Input Parameters

Road Type	Traffic Flow AADT	Heavy-Duty Vehicle (%)	Speed (km/h)	Years
England - Motorway (not London) England - Rural (not London) England - Urban (not London)	2,000	5	5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110	2025 to 2050

The 'Basic Split' traffic format in the EFT was used and 'Air Quality Modelling (g/km/s)' and 'Breakdown by vehicle' outputs selected.

The emission rates for light-duty vehicles (All LDVs) and heavy-duty vehicles (All HDV) were divided by the corresponding number of vehicles to obtain per-vehicle emission rates: for the inputted AADT of 2,000 and HDV percentage of 5% this equates to 1,900 LDVs and 100 HDVs.

The calculated NO_X emission rates and emissions per vehicle for each year were combined into a single table and embedded in STAIR to allow the emission rates for any year, road type and speed in the ranges given in Table 1 to be looked up.

2.2 Road NH_3 Emissions

Road NH_3 emissions were calculated using Air Quality Consultants' CREAM tool Version 2A. Emissions were calculated for each year from 2025 to 2050 for road links representing the parameters in Table 2.

[3] DEFRA (2026), Emissions Factors Toolkit Version 14.1.
[4] Air Quality Consultants (2025), Calculator for Road Emissions of Ammonia (CREAM) Version 2A.
[5] CERC (2026) ADMS-Roads: Atmospheric Dispersion Modelling System (Version 5.1) [Computer software]. Cambridge: Cambridge Environmental Research Consultants
[6] DEFRA (2024). NO_X to NO_2 Calculator Version 9.1.

Unlike the EFT, CREAM does not have the functionality to disaggregate outputs according to vehicle type. Therefore, in order to derive LDV and HDV NH_3 emission rates, calculations were carried out assuming 0% HDV (to obtain LDV emission rates) and 100% HDVs (to obtain HDV emission rates). The minimum speed supported by CREAM is 10 km/h. It was therefore assumed that emissions at 5 km/h were equal to emissions at 10 km/h.

Table 2. CREAM Input Parameters

Road Type	Traffic Flow	Heavy-Duty Vehicle (%)	Speed (km/h)	Years
England - Motorway (not London) England - Rural (not London) England - Urban (not London)	2,000	0, 100	10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110	2025 to 2050

The emission rates for LDVs and HDVs were divided by 2,000 to obtain per-vehicle emission rates. The calculated NH_3 emission rates and emissions per vehicle for each year were combined into a single table and embedded in STAIR to allow the emission rates for any year, road type and speed as per Table 2 to be looked up.

2.3 ADMS-Roads Modelling

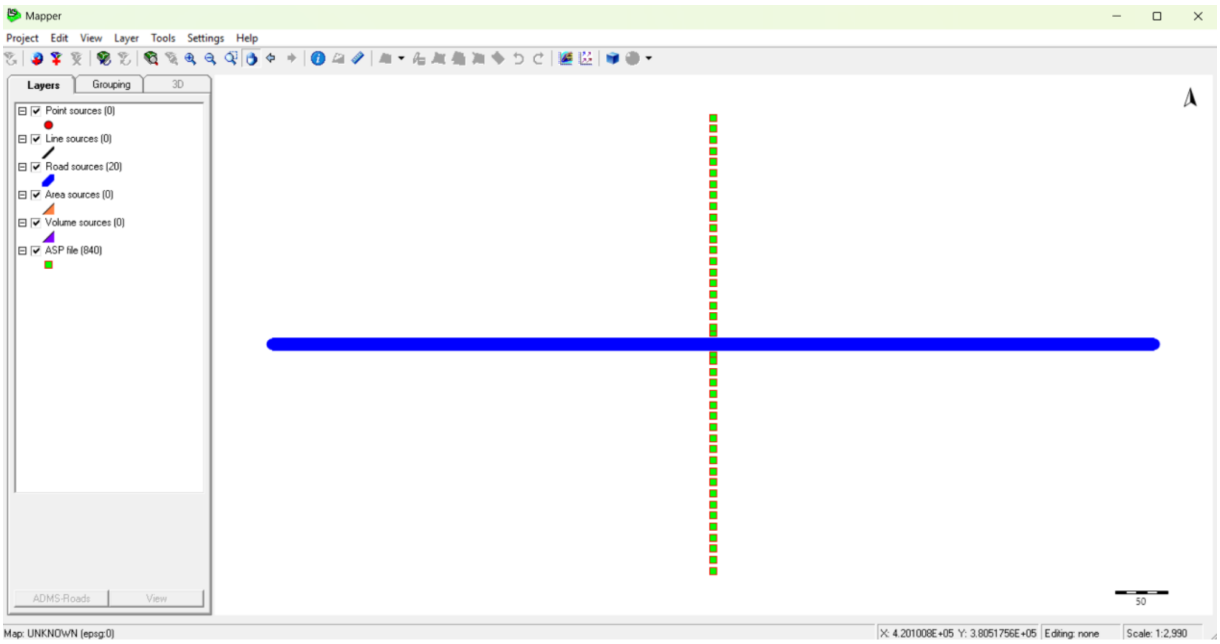
A series of ADMS-Roads models were run to determine the pollutant contribution of a single road source at receptor points at specified distances from the road edge.

Twenty straight-line road sources of length 800 m were modelled, with an assumed width of 10 m and a nominal emission rate of 0.002 g/km/s. Two transects (one either side of the road at the road's centre-point) were created perpendicular to each road link. Receptor points were created along these transects at the following distances from the road edge: 2 m, 5 m, 10 m and at 10 m intervals thereafter up to 200 m.

Models were set up and run assuming four different road orientations:

- East-West (transects oriented North-South)
- North-South (transects oriented East-West)
- Northwest-Southeast (transects oriented Northeast-Southwest)
- Northeast-Southwest (transects oriented Northwest-Southeast)

Figure 1. Example of ADMS-Roads Model Setup: East-West Road Orientation with North-South Receptor Transects



Annual mean road NO_X / NH_3 contributions (in µg/m³) were predicted at ground level (0 m height) at each receptor point. The road contribution was divided by the source emission rate (i.e. 0.002 g/km/s) to calculate the µg/m³ concentration per g/km/s emission.

To account for meteorological variability, all models were run with 17 different hourly meteorological datasets:

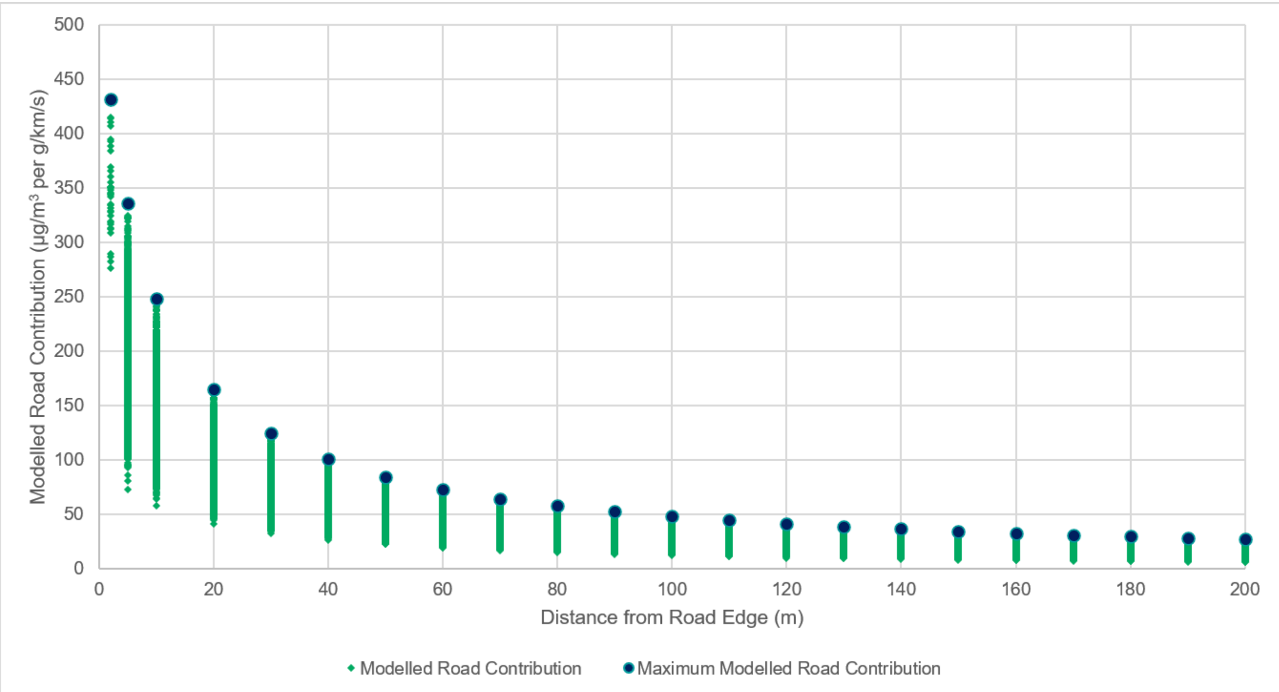
- Coningsby 2020 to 2024, inclusive
- Durham Tees Valley 2020, 2021 and 2022
- Gatwick 2020 and 2021
- Mildenhall 2020 and 2021
- Pershore 2020 and 2021
- Warcop 2020 and 2021

The meteorological station locations were chosen to capture conditions across different geographical regions of England and different years selected to investigate how meteorological variations affected modelled concentrations year-to-year. Preliminary sensitivity tests indicated that meteorological datasets for the year 2021 typically resulted in the highest predicted road contributions, followed by 2020. Therefore, all stations were run using 2020 and 2021 datasets. Model runs were also carried out using the Coningsby 2022, 2023 and 2024 datasets, and the Durham Tees Valley 2022 dataset.

The model outputs were combined into a single table and the maximum modelled road NO_X/NH_3 contribution at each distance from the road selected to provide a worst-case prediction of the road contribution at each distance.

Figure 2 shows the modelled road contributions plotted against receptor distance from the road edge. The green data points illustrate the range of modelled values, which vary according to road orientation, receptor position relative to the road (i.e. upwind or downwind), different meteorological datasets and other factors. The blue data points indicate the maximum modelled contribution at each receptor distance; these are the data points used in the tool calculations to provide a worst-case scenario.

Figure 2. Modelled Road Pollutant Contributions with Distance from Road Edge



It is common practice in dispersion modelling to derive and apply adjustment factors to modelled outputs to improve the agreement between modelled and measured concentrations. This process is known as model verification and is designed to reduce uncertainty in model predictions. STAIR allows the user to define model adjustment factors for NO_X and NH_3 to account for the discrepancy between modelled and measured concentrations. The default values are 1.5 for NO_X and 1 for NH_3; these values are derived from model adjustment factors for air quality assessments of ecological sites undertaken by AECOM.

2.4 NO_X to NO_2 Conversions

To calculate AADT thresholds for nitrogen deposition (NDep), road NO_X concentrations must first be converted to road NO_2. To achieve this, DEFRA's NO_X to NO_2 calculator was used to derive generic NO_X to NO_2 relationships.

NO_X to NO_2 calculations were performed for all local authority areas in England for a range of road NO_X concentrations (ranging from 5 µg/m³ to 10,000 µg/m³) and background NO_2 concentrations (ranging from 5 µg/m³ to 40 µg/m³) to completely cover the entire range of values likely to be encountered in a real-world scenario and to enable reliable relationships to be derived. Four different years were run (2025, 2030, 2035 and 2040) to account for variation in the NO_X to NO_2 relationship over time. The "All UK Traffic" mix was used in all calculations.

The outputted road NO_2 concentrations for each year were plotted against the corresponding inputted road NO_X and the maximum road NO_2 concentration selected for each road NO_X value. The resultant data points for road NO_X values up to 1,000 µg/m³ are shown in Figure 3. For each year, polynomial regression lines were fitted to the data points to enable the calculation of road NO_2 for any value of road NO_X. Three separate polynomial equations were defined to account for the change in the NO_X to NO_2 relationship with increasing NO_X: the first equation is applied to road NO_X values less than 181 µg/m³, the second to road NO_X values greater than or equal to 181 µg/m³ and less than 401 µg/m³ and the third to road NO_X values greater than or equal to 401 µg/m³.

Figure 3. Road NO_X Concentration Versus Road NO_2 Concentration

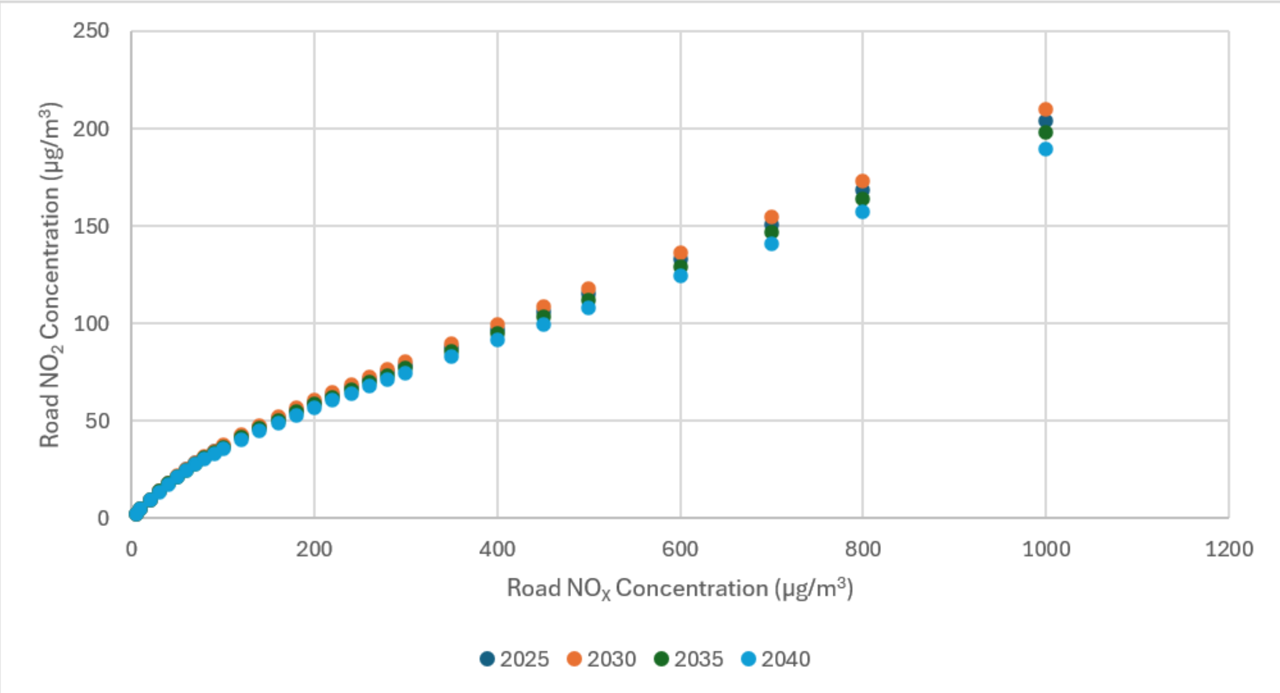


Table 3. Summary of Polynomial Coefficients used for NO_X to NO_2 Conversions

Year	Road NOx Range (µg/m³)	a	b	c	d
2025	< 181	3.27794E-06	-0.001691094	0.506503577	0.016657374
2025	181 < 401	1.69234E-07	-0.000195427	0.257139616	14.59448585
2025	>= 401	8.4089E-12	-1.41602E-07	0.177935702	26.16705923
2030	< 181	3.23142E-06	-0.001671637	0.509978777	0.008473271
2030	181 < 401	1.78011E-07	-0.000203727	0.265529409	14.27339241
2030	>= 401	8.56046E-12	-1.44347E-07	0.183698564	26.13145078

Year	Road NOx Range (µg/m^3)	a	b	c	d
2035	< 181	3.33144E-06	-0.001713126	0.503058313	0.01751089
2035	181 < 401	1.75506E-07	-0.000201015	0.252497244	14.54412553
2035	>= 401	8.41757E-12	-1.41458E-07	0.171788101	26.22000026
2040	< 181	3.40733E-06	-0.001742937	0.498236861	0.022676537
2040	181 < 401	1.75322E-07	-0.00019996	0.243463011	14.74967289
2040	>= 401	8.08088E-12	-1.36287E-07	0.163503342	26.27709062

Coefficients used in 3rd order polynomial ($y = ax^3 + bx^2 + cx + d$)

2.5 Calculation Steps

The calculation of AADT values predicted to result in an exceedance of the 1% criterion is summarised below. The steps describe the approach for NO_X; the same method is applied to NH_3 except for the NO_X to NO_2 conversion step.

1. The modelled road NO_X contribution from the ADMS-Roads modelling (Section 2.3) is looked up for the relevant distance from the road. This is multiplied by the model adjustment factor inputted by the user to give the adjusted road NO_X contribution per unit emission (i.e. µg/m^3 per g/km/s).
2. The reciprocal of the adjusted road NO_X contribution is calculated to give an emission rate of pollutant per unit concentration (i.e. g/km/s per µg/m^3).
3. The NO_X emission rate per unit concentration from Step 1 is divided by 1% of the relevant Critical Level (for NO_X this is 1% of 30 µg/m^3 or 0.3 µg/m^3) to determine the NO_X emission rate at which the 1% criterion is likely to be exceeded.
4. NO_X emission rates per LDV and per HDV are looked up from the table of road NO_X emissions (Section 2.1) for the year, road type and speed inputted by the user.
5. The number of LDVs and HDVs are calculated from the AADT and HDV percentage inputted by the user.
6. Total road LDV and total road HDV NO_X emission rates for the road link are calculated by multiplying the per LDV and per HDV emission rates (from Step 4) by the respective numbers of LDVs and HDVs (from Step 5). The total LDV emissions and HDV emissions are added together to get a total NO_X emission rate for the road link.
7. The total NO_X emission rate for the road link is divided by the AADT inputted by the user to obtain a NO_X emission rate per AADT.
8. The NO_X emission rate at which the 1% criterion is likely to be exceeded (from Step 3) is divided by the NO_X emission rate per AADT (from Step 7) to calculate the number of additional vehicles that would lead to the 1% criterion being exceeded (assuming speed and HDV percentage remains constant).
9. The above steps are repeated for NH_3. The NH_3 emission rate at which the 1% criterion is likely to be exceeded is calculated for two different critical levels:
   - 1% of 1 µg/m^3 = 0.01 µg/m^3 (for lichens and bryophytes)
   - 1% of 3 µg/m^3 = 0.03 µg/m^3 (for other vegetation)

For the calculation of AADT thresholds for nitrogen deposition, the following additional steps are required:

a. The total road NO_X emission rate (from Step 6) is divided by the emission rate of NO_X per unit concentration (Step 2) to calculate the road NO_X contribution (in µg/m^3) at the inputted AADT.

b. The road NO_X contribution (from Step a) is converted to a road NO_2 contribution by applying the polynomial equations described in Section 2.4.

c. The road NO_2 contribution is multiplied by the relevant NO_2 concentration to Ndep conversion rate to calculate the Ndep contribution due to road NO_2 (in kg.N/ha/year):

i. For moorland / grassland: 0.14 kg.N/ha/year

ii. For forest: 0.29 kg.N/ha/year

d. The total road NO_X emission rate (from Step 6) is divided by the calculated Ndep contribution due to road NO_2 (Step c) to calculate the NO_X emission rate per unit Ndep contribution from Road NO_2 (i.e. g/km/s per kg.N/ha/year).

e. As per Step c for road NO_2, the road NH_3 contribution is multiplied by the relevant NH_3 concentration to Ndep conversion rate to calculate the Ndep contribution due to road NH_3 (in kg.N/ha/year):

i. For moorland / grassland: 5.2 kg.N/ha/year

ii. For forest: 7.8 kg.N/ha/year

f. The total road NH_3 emission rate (referencing Step 6 and Step 9) is divided by the calculated Ndep contribution due to road NH_3 (Step e) to calculate the NH_3 emission rate per unit Ndep contribution from road NH_3 (i.e. g/km/s per kg.N/ha/year).

g. The Ndep contribution due to road NO_2 (kg.N/ha/year) and Ndep contribution due to road NH_3 (kg.N/ha/year) are summed to obtain the combined Ndep contribution due to road NO_2 and NH_3 (kg.N/ha/year).

h. The total NO_X emission rate and total NH_3 emission rate for the road link are summed to obtain the combined total NO_X and NH_3 emission rate (g/km/s) for the road link.

i. The combined NO_X and NH_3 emission rate per unit combined Ndep (g/km/s per kg.N/ha/year) is calculated by dividing the output from Step h by the output from Step g.

j. The combined NO_X and NH_3 emission rate per unit combined Ndep from Step i is multiplied by 1% of the relevant Critical Load (for Ndep this is normally 1% of between 5 kg.N/ha/year and 20 kg.N/ha/year, or 0.05 - 0.2 kg.N/ha/year) to determine the combined NO_X and NH_3 emission rate at which the 1% Ndep criterion is likely to be exceeded (g/km/s per kg.N/ha/year).

k. The combined total NO_X and NH_3 emission rate per unit AADT (g/km/s per AADT) is calculated as the combined total NO_X and NH_3 emission rate (g/km/s) for the road link divided by the total link AADT.

l. The combined Ndep rate at which the 1% criterion is likely to be exceeded (from Step j) is divided by the combined total NO_X and NH_3 emission rate per AADT (from Step k) to calculate the number of additional vehicles that would lead to the 1% criterion being exceeded (assuming speed and HDV percentage remains constant).

2.6 Worked Example – NH_3

This worked example follows the same Steps 1 – 8 given in the previous section to work through the calculations to determine an AADT change required to bring about a 1% change of the more stringent 1 µg/m^3 critical level of ammonia. The inputs to the tool for this example are as follows:

- AADT = 10,000;
- HDV% = 2%;
- Speed = 70 kph;
- Year = 2040;
- Distance from road = 2m;
- NH_3 model adjustment factor = 1.

1. For simplicity and ease of calculation, we will assume here that the modelled pollutant concentration (µg/m^3) per unit emission rate (g/km/s) is 400 µg/m^3 per g/km/s at 2 m from the road, which is similar to the maximum value used in the tool from the series of ADMS-Roads model runs conducted.
2. This gives a reciprocal adjusted road NH_3 contribution (emission rate of pollutant per unit concentration) of 0.0025 g/km/s per µg/m^3.

3. The NH_3 emission rate at which the 1% criterion is likely to be exceeded is 0.0025 multiplied by 1% of 1 $\mu g/m^3$ (0.01 $\mu g/m^3$), which is equal to 0.000025 g/km/s.
4. The looked-up NH_3 emission rates for the inputs given above are 2.14×10^{-7} g/km/s per LDV, and 7.91×10^{-7} g/km/s per HDV.
5. Based on 10,000 AADT and 2% HDV, this gives total LDVs of 9,800 and total HDVs of 200.
6. The total LDV NH_3 emission rate is 2.14×10^{-7} g/km/s per LDV multiplied by 9,800 LDV, which equals 0.002097 g/km/s. The total HDV NH_3 emission rate is 7.91×10^{-7} g/km/s per HDV multiplied by 200 HDV, which equals 0.000158 g/km/s. Combining these gives a total per link emission rate of 0.002255 g/km/s.
7. The NH_3 emission rate per AADT is then 0.002255 g/km/s divided by 10,000 AADT, giving 2.255×10^{-7} g/km/s per AADT.
8. Finally, the additional AADT required to generate an exceedance of the 1% criterion is the output from Step 3 (0.000025 g/km/s) divided by the NH_3 emission rate per AADT from Step 7 (2.255×10^{-7} g/km/s per AADT), which gives approximately 111 additional AADT on the road link needed to trigger the most stringent 1% criterion for NH_3.

3. Spreadsheet Tool Interface

The tool provides a compact user interface (Figure 4) for users to simultaneously select or change the inputs to the tool calculations and view the required outputs. Tabular and graphical outputs of the additional AADT change to bring about exceedance of the 1% criteria being shown directly below the input panels.

There are five primary inputs to the tool, in the top left corner, that are essential to obtaining the desired screening results, for which users are either able to select values from a dropdown menu or enter from a range of allowed values. These primary inputs consist of:

- Year (of assessment), selectable from 2025 to 2050;
- Existing AADT predicted in the assessment year for the road in question, allowed values range from 100 to 250,000;
- Percentage of HDVs predicted in the assessment year (allowed range from 0 to 100);
- Average vehicle speed (kph), selectable in 5kph or 10kph increments;
- Road type (select either rural, urban or motorway);

To allow for a variety of possible model verification scenarios that are reasonably possible in dispersion modelling assessments of ecological sites, the user is able to explicitly provide model adjustment factors for NOx and NH_3 – these are set by default to 1.5 for NOx and 1.0 for NH_3 and have allowable ranges of between 1.0 and 4.0.

The ecological inputs section allows the user to set the site-specific nitrogen deposition (Ndep) Critical Load (5, 10, 15 or 20 kg.N/ha/year), and the appropriate habitat type (forest/moorland). It is recommended that the user selects the Critical Load that corresponds most closely to the lower end of the Critical Load range of the site/feature being assessed. The user can then select the distance of the nearest point of the ecological site for assessment from the road edge.

The top-right panel sets out the constants used for calculating nitrogen deposition rate from the road contributions of NO_2 and NH_3 – these cannot be altered and are provided for information only.

The table in the bottom-left of the interface gives the additional AADT to breach the 1% criteria, with the selected distance of site from the road indicated by emboldened and red-bordered text. A graph on the bottom-right of the interface depicts the same information. These update automatically when any input values are changed.

Figure 4. Screenshot of the STAIR interface