



Údarás **Náisiúnta** Iompair

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1 Introduction

1.1 Background

Jacobs/SYSTRA were commissioned by the National Transport Authority to develop a set of Appraisal Modules linking to the outputs of its Regional Modelling System. Appraisal modules were developed for each of the following aspects of standard transport scheme assessment and appraisal:

- Safety Appraisal
- Economic Appraisal
- **Environmental Appraisal**
- Health Appraisal
- Accessibility and Social Inclusion Appraisal.

For the Environmental Appraisal module, it was agreed during the scoping and specification stage that ENEVAL would perform the relevant calculations. ENEVAL was developed by Systra Ltd and was completed in 2015 following changes to both the guidance around emissions calculations and fleet splits issued by the Department for Transport (UK), and related COPERT 5 guidance¹.

This note has been updated to include updates made to the Environment Module during the V3 RMS update.

¹ National Atmospheric Emissions Inventory 2013 (NAEI), TRL 2009 (It should be noted that the NAEI 2013 emissions rates are partly taken from COPERT 5 and also include emissions rates for new technology vehicles);



2 Implementation of the Environmental Module

2.1 Introduction

The Environmental Module calculates emissions based fleet make up and vehicle speed for each link in the model. Calculations are carried out by **ENEVAL** using COPERT 5 emission rates.

The Environmental Module outputs emissions by link, zone, sector or grid, which allows results to be mapped in GIS.

Detailed guidance on running through these steps is provided in *Environment_User_Guide_v3.3.1_Draft.docx* included with the Environment Module.

2.2 Process Overview

The Environment Module is a related set of processes that extract the relevant data from the regional model, process the data into the format required by ENEVAL and apply fleet make-up assumptions, run ENEVAL and then outputs the results in CSV tables and GIS shapefiles.

This section of the report describes each of the key stages in detail including the main assumptions

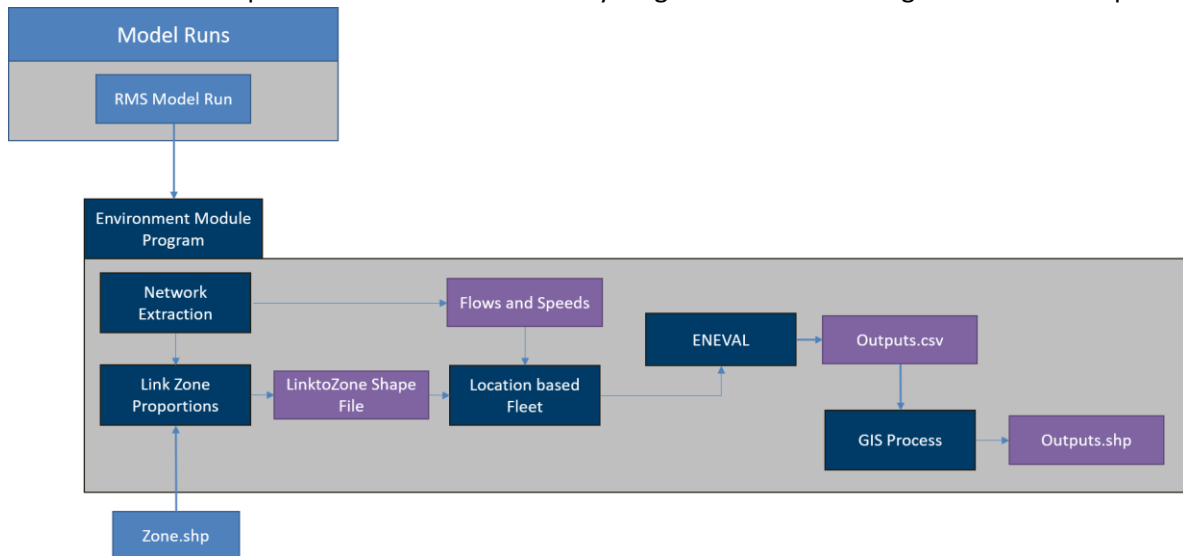


Figure 2.1 Environment Module Process Overview

used in the development of the Environmental Module.

2.3 ENEVAL

The current version of ENEVAL uses data from the following sources:

- Emission Rate calculation coefficients – National Atmospheric Emissions Inventory 2013 (NAEI), TRL 2009 (It should be noted that the NAEI 2013 emissions rates are partly taken from COPERT 5 and also include emissions rates for new technology vehicles)
- Fuel Scaling parameters - NAEI 2013
- Fleet split data – Based on work done in 2012 by SYSTRA on future fleet and pivoted off 2016 observed fleet data.
- Degradation Factors- NAEI 2013
- Catalytic Converter Failure rates - NAEI 2013



- Tyre, break and abrasion emissions rates

The latest ENEVAL model is built in the programming language C# and stores data in a SQL database, making use of Microsoft's SQL Server.

ENEVAL must be run from Cube, with processes included to run the ENEVAL executable and read and write data to SQL. This has several advantages

- The user doesn't have to worry about running code with appropriate arguments;
- It allows for additional pre- and post-run processes to be included; and
- It allows the user to make use of Cube's scenario management facility for tracking multiple runs.

The Environmental Module / ENEVAL are set up in such a way that interaction with the actual SQL databases should be minimal. It should only be required for removal of model runs and for any bespoke queries that are not provided for through the set of standard outputs produced as part of a run.

More information on the SQL database is provided in ANNEX A.

There are four sets of tables within the SQL database that contain parameters that may need to be changed, all of which can be done without editing the SQL database. These are:

- Annualisation Factors
- Link Type to Road Type Lookup
- Fleet and Road Type splits
- User Class to Vehicle Type

2.4 Emissions-related Indicators Produced by ENEVAL

The emissions estimated by the environmental appraisal process include the following;

- NO_x – Nitrogen Oxides, at low concentrations can lead to eyes, nose and respiratory irritation along with fatigue and nausea.²
- NO₂ – Nitrogen Dioxide, same effects as other Nitrogen Oxides but produces in higher amount.
- PM10 – Particulate Matter, can lead to respiratory complications including asthma and lung cancer.
- PM2.5 – Fine Particulate Matter, can lead to can lead to respiratory complications including asthma and lung cancer, as well as cardiopulmonary complications.
- HC – Hydro-Carbons, non-combusted fuel that is toxic in high concentrations.
- CO - Carbon Monoxide, odourless gas that cause respiratory problems at lower concentrations and asphyxiation at higher concentrations.

² <http://www.npi.gov.au/resource/oxides-nitrogen-0>



- CO₂ - Carbon Dioxide, a greenhouse gas with negligible health impacts but strong impact of global greenhouse effect.
- C₆H₆ – Benzene, can be damaging to aquatic life and water supply in sufficient concentrations.³
- CH₄ – Methane, a greenhouse gas that traps significantly more heat than CO₂ but decays at a faster rate.
- C₄H₆ - 1, 3 Butadiene, at low concentrations can irritate eyes, nose and throat and lead to heart and lung damage through prolonged exposure. High exposure can lead to central nervous system damage. Breaks down quickly in sunlight.⁴

The ENEVAL program calculates these emissions for 778 different fleet types for which there are distinct emissions factors. The emissions rate is given by either a single factor in (g/km) or by one of the formulae below (also in g/km).

$\text{Polynomial} = (((a*(x^3)))+(b*(x^2))+(c*x))+d)*(1-RF)$
$\text{Polynomial} = ((a*(b^x))*(x^c))*(1-RF)$
$\text{Polynomial} = ((a*(x^b)))+(c*(x^d)))*(1-RF)$
$\text{Polynomial} = ((a+(b*x))^{((-1)/c)})*(1-RF)$
$\text{Polynomial} = ((\text{Alpha}*x^2)+(\text{Beta}*x)+\text{Gamma}+(\text{Delta}*(\ln(x))+(\text{Epsilon}*\text{Exp}(\text{Zita}*x))+(\text{Ita}*(x^{\text{Thita}}))))*(1-RF)$
$\text{Polynomial} = ((\text{Alpha}+\text{Gamma}*x+\text{Epsilon}*x^2+\text{Zita}/x)/(\text{Ita}+\text{Beta}*x+\text{Delta}*x^2))*(1-RF)$
$\text{Polynomial} = ((\text{Alpha}*\text{Beta}^x)*(x^{\text{Gamma}}))*(1-RF)$
$\text{Polynomial} = (1/(((c*(x^2)))+(b*x))+a))*(1-RF)$
$\text{Polynomial} = (1/(a+(b*(x^c))))*(1-RF)$
$\text{Polynomial} = (a+(b/(1+\exp(((((-1)*c)+(d*\ln(x)))+(e*x))))))*(1-RF)$
$\text{Polynomial} = k*(a+bx+cx^2+dx^3+ex^4+fx^5+gx^6)/x$
$\text{Polynomial} = k*\exp((a+(b/x))+(c*\ln(x)))$
$\text{Polynomial} = k*(a+bx+cx^2+dx^3+ex^4+fx^5)$
$\text{Polynomial} = (((\text{epsilon}+(\text{alpha}*\exp(((((-1)*\text{beta})*x)))+(\text{gamma}*\exp(((((-1)*\text{delta})*x))))*(1-RF)$
$\text{Polynomial} = ((\text{alpha}-(\text{beta}*\text{EXP}(((((-1)*\text{gamma})*(x^{\text{delta}}))))))*(1-RF)$

Where:

x is the speed on a particular link; and

a, b, c, d, e, f, g, k, alpha, beta, gamma, delta, epsilon, zita, ita, thita are coefficients of the formula specific to each fleet type and emissions type.

³ <http://apps.sepa.org.uk/spria/Pages/SubstanceInformation.aspx?pid=21>

⁴ <http://www.npi.gov.au/resource/13-butadiene-vinyl-ethylene>



Emissions of all pollutants are output in the following formats:

- By link
- By Zone
- By grid - using a user defined grid along with a default national 1km² grid

When allocating link-based emissions to sectors or grid square, the proportion of the link contained within the relevant spatial area is used to calculate emissions. This reduces the incidence of 'reporting anomalies' which can occur if the centre point of links is used to allocate links to spatial areas (e.g. if a small change to a model link moves its centre point from one spatial area to a neighbouring one). These link-disaggregation proportions are calculated automatically from the relevant network files.

2.5 Emissions (pollutants and GHGs) Monetisation

Monetisation of emissions results is not carried out in the tool; however, it can be calculated using 2016 CAF figures were available. This includes costs for all emissions excluding Carbon Monoxide and Hydro-Carbons. The cost per kg are listed below:

- NOX - €5.85
- NO2 - €5.85
- PM10 - €19.14
- CO2 - €0.01
- (VOC) Benz - €1.44
- (VOC) Meth - €1.44
- (VOC) Butad - €1.44

PM 2.5 is excluded from the list as it is priced based on the location of emission. This is due to PM2.5 dispersal being greater in rural areas than urban and suburban areas. The price per kg of PM2.5 is defined as follows;

- Rural - €16.96
- Suburban - €48.78
- Urban - €200.24

2.6 ENEVAL Parameters of the Environmental Module

All the parameters defined below are stored in the Parameters folder but also in the Master Parameter sheet included with the Cube Program. This master parameter sheet should not be changed unless requested by the NTA.

The values in the Master Parameter sheet are the default values included in each of the input parameters discussed below, these CSVs are editable by the user where required.

2.6.1 Annualisation Factors

Annualisation factors are used in ENEVAL to provide results at an annual level. The annualisation factors are defined by the file;

{Catalog_Dir}\Parameters\Annualisation_Factors\{Region}_Annulisation_Factors.csv

The current annualisation factors included are from the 2012 model pending new factors being derived for the 2016 model, however a user may wish to apply figures derived for their current study.



2.6.2 Link Type to Road Types Lookups

ENEVAL Converts SATURN Link Types, using Capacity Indices, to ENEVAL Road Types. The current version of the ENEVAL database contains 11 Road types.

Table 2.1 Road Types

Road Type ID	Road Type Name
1	All (ROI)
2	ERM
3	Other Regions
4	Motorway (ROI)
5	Rural (ROI)
6	Dublin City Centre (ROI)
7	Cork City Centre (ROI)
8	Galway City Centre (ROI)
9	Limerick City Centre (ROI)
10	Waterford City Centre (ROI)
11	User Spec

By default, all link types from the SATURN network are assigned to Road Type 1. This can be varied through the file;

{Catalog_Dir}\Parameters\Link_Types\SFC_to_Link.csv

While the file;

{Catalog_Dir}\Parameters\Link_Types\SFC_Ref_Table.csv

Contains the definitions of each of the current Capacity Indices (Speed Flow Curves) used in the RMS.

The reason for having an All, ERM and Other Regions set is due to the addition of Non-Urban and Urban busses to the ENEVAL process. For the All split both Non-Urban and Urban busses are assigned to Vehicle Type 9 which contains the previous bus fleet definition.

For the Other Regions, the Urban and Non-Urban buses are assigned to two unique fleet profiles derived from data gathered from Bus Eireann on the respective fleets. As the Bus Eireann urban fleet is comprised of smaller vehicles with a different emissions profile to that of the Dublin Bus fleet an



additional fleet profile was added to represent the Dublin Bus fleet and as such Urban Buses are assigned to the Dublin Bus fleet split in the ERM road split. In both cases the Non-Urban split is represented by Bus Eireann's non-urban split, it is assumed that this is a reasonable proxy for private operators.

In all three of these fleet splits Car and Goods splits remain unchanged and follow the national profile. It may be possible to update this in the future with localised data, however current data would be better used to define City Centre fleet profiles.

Fleet Type / Vehicle Type

ENEVAL reads in the demand from the highway assignment model disaggregated by userclass. It then splits this demand down into Vehicle Types (e.g. electric car, petrol car, diesel car, etc.). This is done by Road Type (see above) – so Urban roads will have a higher proportion of electric cars and motorways a higher proportion of goods vehicles.

This is complicated slightly by the Vehicle Type to userclass lookup table, which allocates each input userclass to a set of Vehicle Types. For example, UC3 (CarCommute) is allocated to Vehicle Types 1, 2, 3 and 12 (electric, petrol, diesel and LPG cars). This allocation is taken into account when the split by Road and Vehicle type is undertaken.

These user class to vehicle definitions are defined by the file;

{Catalog_Dir}\Parameters\User_Classes\UC_to_Vehicle.csv

There is then a further level of splitting to get to the individual Fleet Type. The Fleet Type is made up of different engine sizes, vehicle sizes, Euroclass standards, standard or hybrid fuel types etc.

ENEVAL contains 16 Vehicle Types which are then disaggregated into 1249 Fleet Types. The emission calculations are then undertaken at this disaggregate level and aggregated up in the final outputs.

The detailed Fleet level outputs are not stored as standard as the database becomes very large (~40GB). However, selecting "Yes" for the **FullFleetSplitOutputs** catalog key with keep the full set of Fleet level emissions should analysis at that detail be required.

Fleet Type is the makeup of a vehicle fleet, for example the makeup of the Petrol Car fleet. This includes the proportion split of engine sizes and euro class. The built in fleet split is derived from 2010, 2014 and 2016 NCT and Vehicle Registration data. The future fleet trends are unchanged in V3 of the Environment Module.

Vehicle type is the split of the overall national fleet into individual vehicles classes; Car, LGV, HGV, PSV. These splits are applied to each of the different road types allowing the user to define a different split depending on road type or geographic area.

The Vehicle Type splits can be adjusted in the file;

{Catalog_Dir}\Parameters\Fleet_Profile\Fleet_to_Road_Type.csv



2.6.3 Emissions Rate Parameters

The version of ENEVAL used in the process was localised to Ireland based on the following assumptions, using DTTAS Guidance where applicable⁵.

- Emission Rate calculation coefficients – National Atmospheric Emissions Inventory 2013 (NAEI), TRL 2009 (It should be noted that the NAEI 2013 emissions rates are partly taken from COPERT 5 and also include emissions rates for new technology vehicles)
- The base year for the fleet split is 2016, this data was derived from values provided by DTTAS based on NCT and Vehicle Database data.
- Data provided to SYSTRA by DTTAS in January 2015 is used as the basis of the future Irish fleet size and vehicle split
- The age profile of each of the various sub-fleets (in terms of the proportions of new vehicles, 1-year-old, 2-year-old etc.) remain unchanged
- All Euro classes (including EURO 6/VI) continue to maintain their current emissions rates, as predicted by COPERT, as they age (NB ignoring this degradation as vehicles in each EURO class age **underestimates future emissions**)
- Effects from the Volkswagen emissions fixing scandal are not accounted for due to the lack of data available to understand the impact. This will result in an **underestimate in the short term**.
- No further improvement in vehicle emission technology (i.e. beyond EURO 6/VI) will be achieved – this assumption will **over-estimate future emissions**. However, updated EURO 6 vehicles are included from 2017 onwards. While EURO 7 is planned it is not expected data will be available from this classification for some time.
- The link-based output emissions incorporate the emissions from the traffic queuing at the end of the link (and will use estimates of average link-speeds which incorporate these junction delays⁶)
- Emissions are not adjusted to take account of link gradient⁷

2.6.4 Other Key Parameters

The following information will be needed by the software which will be used to appraise the emissions:

- The modelled year
- The annualisation factors which will be used to combine emissions from different time periods
- A flag denoting whether or not non-tail-pipe particulate emissions are to be included, this can be switched on or off using the key in Cube
- A flag denoting whether to include both link and junction-delay emissions or just link based emissions
- The relevant speed-based emission profiles by vehicle type and emission category

⁵ DTTAS provides many of the parameters for undertaking Common Appraisal Framework (CAF)-based appraisal of transport projects. This guidance and its supporting spreadsheets form the primary data sources for the various base-year emissions-related appraisal parameters.

⁶ SYSTRA's ENEVAL software provides the option of identifying emissions from traffic queueing at junctions separately from the link-based estimates – this option will not be used

⁷ SYSTRA's modelling of emissions in Sheffield city centre (based on an AIMSUN microsimulation model) suggests that adding the effect of steep gradients to uphill emissions results in a significantly greater increase than the decrease created in the downhill emissions.



- A flag denoting whether emissions should be calculated on a vehicle level or fleet level

2.6.5 Sector File Input / Creation

The Environmental Module can produce emissions at a sector level if a correspondence is provided between the links and sectors. The process can accept as an input an user-defined sector system which is created through a GIS process as part of the model run or manually. The sectors can be anything required by the user from Local Authorities or model zones to user defined cordons and sectoring systems.

An ArcPy Python library automatically creates the link-zone lookup. The location of this library is set via the PythonFolder catalog key.

The lookup creation process is done in six steps:

- Convert the *.NET file from the public transport model into a Shapefile
- Calculate the link distance
- Copy the sector shapefile from {CatalogFolder}\ModelFiles\Shapefiles
- Intersect the two shapefiles, producing a new link shapefile, split where each link crosses a sector boundary
- Calculate the new split link distances
- Calculate the proportion of each link in each sector.

The file created is then imported into the Model_SectorFile table in the SQL database. It should be noted that the format allows the same link to be included in different sectors with proportions, as long as the total adds up to one.

Alternatively, the user can provide the file, without running the above process. This option is selectable via the CalcLinkProps catalog key.



2.7 Regional Model Data Extraction

Regional Model data is extracted and formatted for input to ENEVAL using Cube Voyager applications / scripting. ENEVAL requires Link Data, and if desired Turn Data, to run⁸. The relevant data extracted by the Environmental Process are listed in Table 2.5.

The required link / turn data are read automatically by the Module from input Saturn UFS files and formatted to ENEVAL input requirements. The required format is provided below for reference. The Link Data CSV file will contain the information described in Table 2.6 below. The Turn Data CSV file is described in Table 2.7 below that.

Table 2.2 Model Outputs Required by ENEVAL

Model Output	Units
Link Flows (.ufs)	Vehicles per hour by vehicle type (or PCUS per hour and the relevant PCU factors)
Average Speed (by link and, if available, vehicle type) – these will incorporate the relevant junction delays (.ufs)	KPH
Link-length (.ufs)	Km
Cube Network (.net)	Converted to shp file for allocation of link-based emissions to sector and grid-square

⁸ The ENEVAL program can run without Turn Data being specified. This can be set using the IncludeTurns catalog key.



Table 2.3 Link Data Description

Column	Data	Units
1	Anode	Long Integer
2	Bnode	Long Integer
3	Assignment Type/Number	Integer
4	Link Type	Integer
5	Link Capacity	PCU per hour (Real)
6	Link Distance	Kilometres (Real)
7	Free Flow Time	Minutes (Real)
8	Congested Time	Minutes (Real)
9	Flow (a column for each User Class)	Vehicles or PCUs (Real)

Table 2.4 Turn Data Description

Column	Data	Units
1	Anode	Long Integer
2	Bnode	Long Integer
3	Cnode	Long integer
4	Assignment Type/Number	Integer
5	Turn Time	Minutes (Real)
6	Flow* (a column for each User Class)	Vehicles or PCUs (Real) <i>**must be the same units as the Link Flows</i>



3 Environment Process as Implemented in CUBE

3.1 Overview

The latest ENEVAL model is built in the programming language C# and stores data in a SQL database, making use of Microsoft's SQL Server Express, which is free for databases up to 10GB.

However, the model itself is run out of Cube, with processes included to run the ENEVAL executable and read and write data to SQL. This has a number of advantages

- The user doesn't have to worry about running code with appropriate arguments
- It allows for additional pre- and post-run processes to be included
- It allows the user to make use of Cube's scenario management facility for tracking multiple runs.

The model was set up in such a way that interaction with the actual SQL databases should be minimal. It should only be required for the backing up and removal of model runs and for any bespoke queries that are not provided for through the set of standard outputs produced as part of a run.

The model has four main steps, shown in 3. They are:

- Model Preparation
- Calculate Link-Sector proportions
- Running ENEVAL
- Produce Outputs

More detail on each of the steps is given below.



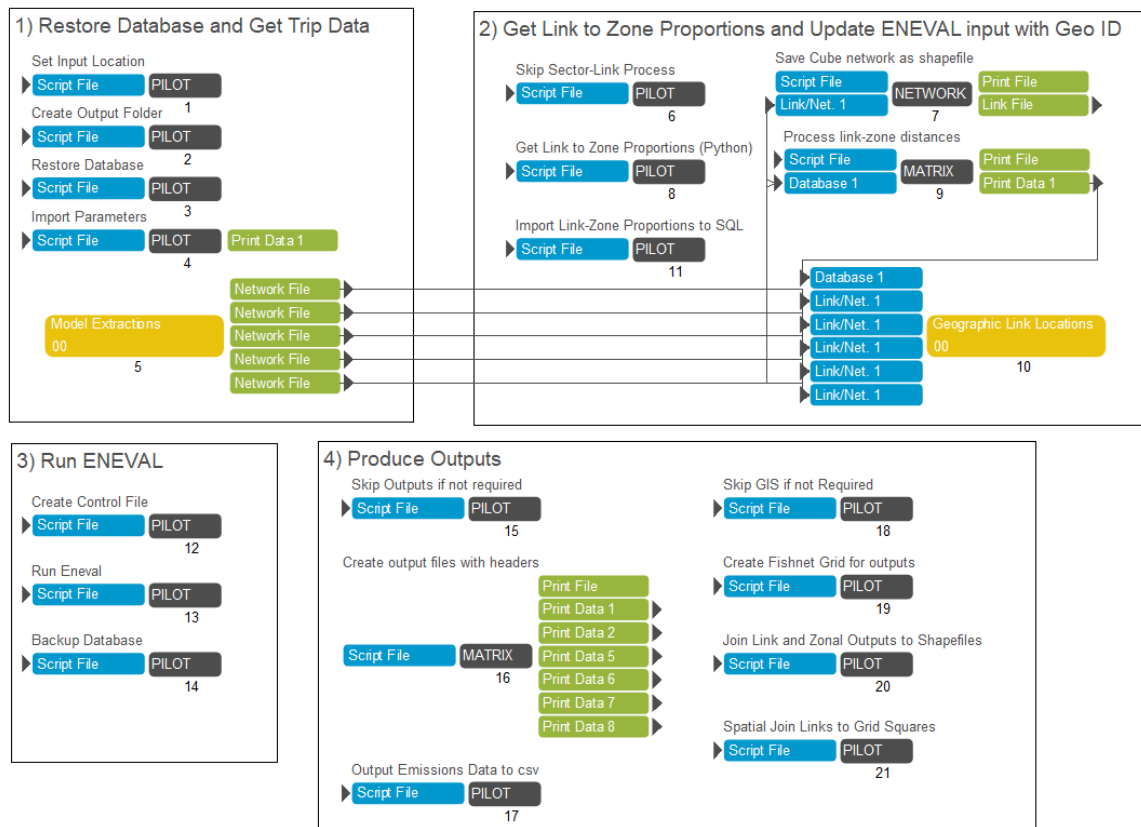


Figure 3.1 Model Processes

3.2 Model Preparation

The first step is to restore the SQL database template file (*.bak). This contains all the required tables and procedures for the run. The input model data will be read into this database and the full ENEVAL outputs will be stored here also.

This is followed by importing the parameters stored as CSVs into the SQL database. This step overwrites any data previously stored in the database.

The next step is to get the link information required for the model. This is done in two stages.

Firstly, the Saturn key files are created to run SATDB and output the required information. If a SATURN only run is being done this data is dumped in the correct format by SATDB, if a full run is being run however this data undergoes further processing.

Secondly, data is read from the On Offs output files from the model which contain PT speeds and flows. This data, and the road data, are combined into an input required for ENEVAL.

As the speed differs for general road users and public transport, additional lines are created in the input data for urban and non-urban bus. As ENEVAL cannot read in more than 1 set of data per link, the A Node is modified by adding 1,000,000 for Urban Busses and adding 2,000,000 for Non-Urban buses. This creates a unique line entry for general road users, urban bus and non-urban bus.



3.3 Calculate & Import Link-Sector Proportions

The ENEVAL model produces emissions at a link level. However, it is also possible to produce outputs at a zonal or sector level, by providing a lookup between each link and the desired zone/sector system.

The model process can create the required lookup file automatically utilising a Voyager network (*.NET) and the zonal shapefile. The Voyager Network is generated automatically using the input SATURN networks. Alternatively, the user can provide the Link to Zone lookup file, in the appropriate format. These options are selectable via the **CalcLinkProps** catalog key.

If no file is provided then ENEVAL will still run and produce link emissions, but not zonal/sector-based ones.

The Link-Zone proportion file is then used by the Geographic Link Locations process to determine what vehicle profile to apply based on zone location. This is done by updating the attributed capacity index on the link, unless the user specifies it to be excluded in the keys, to match that assigned to the zone.

The definition for these areas are defined by a column Geo_ID in the zone shapefile and can be defined with values correlating to the desired vehicle split profile.

3.4 Run ENEVAL

This is the main part of the model. Firstly, a control file is created which contains all the model variables to pass to the main ENEVAL program. These include the run name, model year, number of time periods, location of input files, etc.

This process creates a file called **ENEVAL.ctf** and is stored in the main model run folder **{CATALOG_DIR}\Runs\{Region}\{Model Year}\{Run ID}\4_Outputs_{Region}_{Model Year}_{Growth}_{Run ID}_Input_v{Input Version}\Appraisal_Tools\ENEVAL**

The variables in the control file are as follows;

Variable	Description	Default Value
0	Run ID	{Run ID}{Growth}{Model Year}
1	Model Year	2000 + {Model Year}
2	Region	{Region}
3	Server	{Server}
4	Database Name	{Region}_ENEVAL_{Run ID}{Growth}{Model Year}
5	Username	Catalog Key
6	Password	Catalog Key
7	Number of Time Periods	{NoOfTimePeriods}
8	Assignment Types	1
9	File Chunk Size	{FileChunkSize}



10	Input Folder	{CATALOG_DIR}\Runs\{Region}\{Model Year}\{Run ID}\4_Outputs_{Region}_{Model Year}_{Growth}_{Run ID}_Input_v{Input Version}\Appraisal_Tools\ENEVAL'
11	Output Folder	{CATALOG_DIR}\Runs\{Region}\{Model Year}\{Run ID}\4_Outputs_{Region}_{Model Year}_{Growth}_{Run ID}_Input_v{Input Version}\Appraisal_Tools\ENEVAL'
12	Include Turns	False – Removed from v3 as not compatible with PT
13	PT Networks	False
14	Report Zone results	True
15	Report Network Stats	True
16	Report Emissions Stats	True
17	Run Stored Procedures	True
18	Create Full Fleet Outputs	{FullFleetSplitOutputs}
19	ENVR File	False
20	Tyre and Breaks	{TandB}

The main ENEVAL process is then run using a command line and the control file. This reads in all the link data from the files listed in the control file and then calculates the emissions.

The emissions calculation is done in “chunks” to avoid exceeding the memory capacity of the computer. The chunk size can be set via a catalog key. Generally, it appears the model can process up to 30,000 links at a time – the default was set to 10,000. There doesn’t seem to be any time differences between running a few large chunks or a larger number of small chunks. However, if too large a chunk size is chosen then the model may fall over.

On completion of the ENEVAL process a stored procedure in SQL removes the added values denoting urban and non-urban busses, restoring their original link values and combines records before reporting.

3.5 Produce Outputs

The model creates a selection of standard outputs as part of the main ENEVAL run. These are stored within the SQL database. The model also outputs a number of standard outputs, such as emissions by link, zone etc. to text file.

In addition, the model can produce ArcGIS shapefiles containing link and zonal/sector emission information. It also produces grid plots of emissions, summing the links crossing each grid square. More details on the outputs available are given in the Model Outputs section below.



4 Testing

This section covers a series of test undertaken to assess the changes to the Environment Module in the V3 Update.

4.1 Comparison of Environment Module v2 to v3

The new V3 Environment module includes an updated from ENEVAL 10 to ENEVAL 11 as well as the inclusion of an updated fleet. This test was conducted to understand the impact that the new Environment Module has on the same input road networks.

New base networks from all five regional models were compared, with the inputs applied to the V2 Environment Module and the V3 Environment Module. The results are shown in Table 4.1 and Table 4.2 for V2 and V3 respectively and the difference in Table 4.3.

Table 4.1 Environment Module v2 Emissions

Region	NOX	NO2	PM10	PM25	HC	CO	CO2	Benz	Meth	Butad
Units	Kiloton	Ton	Ton	Ton	Ton	Ton	Megaton	Ton	Ton	Ton
ERM	5.06	1225.43	664.35	387.43	283.05	6.91	4.02	4.93	36.28	5.39
SWRM	1.60	406.11	19.73	18.74	74.75	2.38	1.37	1.42	11.84	1.51
WRM	1.83	402.04	265.21	152.60	86.06	2.65	1.54	1.74	13.60	1.76
MWRM	1.57	328.18	204.41	118.74	26.70	2.28	1.23	1.38	10.17	1.36
SERM	1.45	340.07	199.55	116.27	75.51	1.96	1.17	1.16	8.93	1.40

Table 4.2 Environment Module v3 Emissions

Region	NOX	NO2	PM10	PM25	HC	CO	CO2	Benz	Meth	Butad
Units	Kiloton	Ton	Ton	Ton	Ton	Ton	Megaton	Ton	Ton	Ton
ERM	11.09	3364.76	235.74	223.96	440.84	8.33	4.00	9.85	46.15	6.27
SWRM	3.63	1149.26	80.65	76.61	145.00	2.92	1.38	2.92	14.96	1.82
WRM	4.07	1268.54	85.62	81.34	161.96	3.23	1.56	3.57	17.56	2.14
MWRM	3.23	980.95	255.86	167.70	122.89	2.83	1.24	2.75	13.00	1.60
SERM	3.10	926.79	67.28	63.91	116.42	2.41	1.18	2.33	11.41	1.64



Table 4.3 Difference in Emissions

Region	NOX	NO ₂	PM ₁₀	PM ₂₅	HC	CO	CO ₂	Benz	Meth	Butad
Units	Kiloton	Ton	Ton	Ton	Ton	Ton	Megaton	Ton	Ton	Ton
ERM	6.03	2139.34	-428.61	-163.47	157.79	1.42	-0.03	4.92	9.87	0.89
SWRM	2.03	743.15	60.91	57.87	70.25	0.54	0.01	1.50	3.12	0.31
WRM	2.24	866.50	-179.60	-71.27	75.91	0.58	0.01	1.83	3.96	0.37
MWRM	1.66	652.77	51.45	48.96	96.18	0.55	0.01	1.36	2.83	0.24
SERM	1.65	586.72	-132.27	-52.36	40.91	0.45	0.01	1.17	2.47	0.24

The most notable difference is in the NO_x and NO₂ levels between the two versions of the Environment Module. These can be explained by several factors.

Firstly, the predicted 2016 fleet used in V2 of the Environment Module has a substantially higher proportion of the fleet consisting of Diesel EURO 6 vehicles, however with 2016 observed data now available it shows 7% less EURO 6 Diesel Vehicles and 10% more EURO 5 than predicted. EURO 5 emissions standard for NO_x are 0.18g/km while EURO 6 is 0.08g/km.

In addition to this, ENEVAL 11 includes new variations of EURO 6 classifications based on year of production.

5 Comparison against reported CO₂

CO₂ emissions related to transport in 2016 equated to **12.3 Megatons** as reported by the CSO⁹. This was calculated from their data using the following;

Proportion of Emissions related to Transport 2016 – 20.1%

Total CO₂ Emissions in 2016 – 61.3 Megatons

To get the total national emissions produced by the Environment Module the sum of zonal levels was calculated, with an average taken where zones overlapped.

This gave a total national level of CO₂ as shown in Table 5.1 below.

Table 5.1 CO₂ by Regional Model

	ERM	SWRM	WRM	MWRM	SERM	Total
Megatons of CO₂	3.97	1.04	1.54	1.23	1.16	8.95

⁹ <https://www.cso.ie/en/releasesandpublications/ep/p-eii/eii19/greenhousegasesandclimatechange/>



This is lower than the reported figure for several reasons;

- This figure does not account for Rail Emissions.
- The Environment Module does not account for Intrazonal trips, this will exclude a sizable proportion of short distance trips in the lower detail areas of the model. However, in the more detailed areas of the model this proportion will be negligible.
- Some links are excluded as they do not align with a zone, this is common where links are in close proximity to coast lines or rivers.

6 Comparison against EPA Report

In 2019 the EPA published a report into Air Quality Levels in Dublin, the technical report¹⁰ prepared by Cambridge Environmental Research Consultants to support this study provided emissions of NO₂, NO_x and Particulates by tons produced as shown Table 6.1 below.

Table 6.1 EPA reported Emissions

Emissions in Tons	NO ₂	NO _x	PM ₁₀	PM _{2.5}
Modelled Roads >2500 AADT	1,036	4,149	223	140
Modelled Road < 2500 AADT	121	394	23	15
Total	1,157	4,543	246	155

This data covers the study area shown in Figure 6.1, also shown is the equivalent selection of links from the ERM. This was used to find a comparative level of emissions shown in Table 6.2.

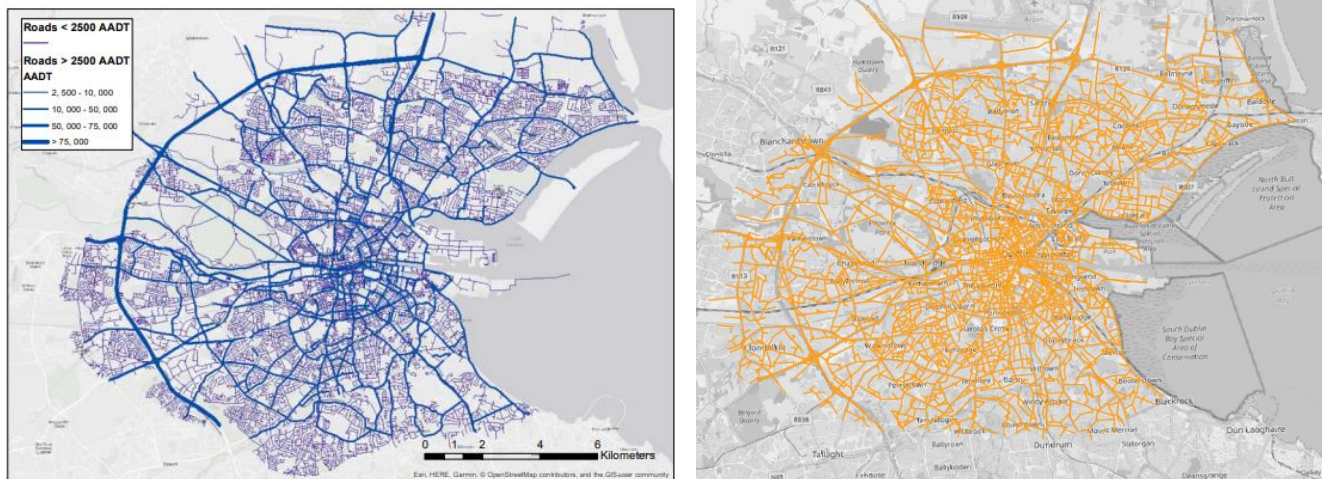


Figure 6.1 Assessment area for EPA and ERM

Table 6.2 Environment Module Reported Emissions

Emissions in Tons	NO ₂	NO _x	PM ₁₀	PM _{2.5}
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¹⁰ https://www.epa.ie/pubs/reports/air/quality/Technical_report_NO2_modelling_Dublin.pdf

Environment Module	674	2,325	46	43
Difference	-483	-2,218	-200	-112

While the difference seems quite high several factors need to be considered;

- The ERM network is lower detail than that used by the EPA report so has less links to calculated emissions data for.
- The EPA report represents 2019 while the ERM represents 2016, traffic levels will have increased in the 3 years separating the tests.
- The EPA report used AADTs and an assumed speed of half the posted speed limit, by contrast the Environment Module uses the modelled speeds which are link specific. While many links in Dublin are congested during the peak they are less so during the inter-peak and off-peak. This will result in a higher speed in the ERM than the EPA's prediction lowering NO₂ and NO_x.
- The Environment Module results do not include tyre and brake abrasion in the results shown above.



7 Conclusion and Recommendations

7.1 Conclusion

An environmental appraisal tool for the NTA Regional Modelling System was developed based on ENEVAL, in combination to the assumptions listed in this note.

To conclude the development of the module, the following sense checks were performed as part of its sign-off:

- Runs for all 5 regional models were completed and the results reported in the testing section.
- The results of all five runs were checked against the reported emissions from the previous version of ENEVAL, this is covered in section 4.
- The results were checked against the national levels of CO₂ as reported by the CSO, the results are reported in section 4.
- The results for the ERM were used to compare Air Quality Emissions to those reported by the EPA in their 2019 report, this is covered in Section 4.

7.2 Recommendations

The NTA may wish to liaise with DTTAS over potential development of a future fleet profile. The current profile included with the Environment Module uses previously provided future profiles that may not be representative of the Department's vision of a future fleet.

With the introduction of EURO7 during this decade the NTA may wish to revisit their future assumptions to include the adoption of EURO7 standards.

In addition to nationwide updates to the fleet the latest version of the Environment Module includes functions to allow for regions specific fleet profiles, this would need to be informed through data gathered from an ANPR survey but would allow for more accurate modelling of City Centres or towns.

It is expected that new versions of ENEVAL will become available as new fleet data is made available, the NTA may wish to incorporate these new versions in the Environment Module as they become available.



Annex 1

Database

The model stores all the inputs it reads in, the outputs it creates and parameters in SQL database files. A template database was created, containing all the required tables and stored procedures, and the model restores this backup as the first step in the process.

The templates are stored in the location below (where {CatalogFolder} represents the name of the main program folder).

{CatalogFolder}\ModelFiles\DbfTemplates

Different template versions can be selected through the **DatabaseTemplateVersion** catalog key.

The process restores the template to a database with a name in the format **{ModelName}_{RunID}{Growth}{ModelYear}** and stores the actual database and log files in C:\Microsoft SQL Server\DataFiles and C:\Microsoft SQL Server\LogFiles respectively. Note: These files shouldn't be modified or deleted here, but through SQL Management Studio.

The various tables can be viewed from within SQL Server Management studio. 0 shows an example database, showing the tables. These can be aggregated into six groupings;

- **ID tables** – containing model dimensions and descriptions of key variables (e.g. vehicle types, emission types, fleet types, etc.). These are useful for checking the actual description for a given ID – e.g. ID_VehType 1 is Electric Car;
- **Lookup tables** – containing correspondences between pairs of variables (e.g. between ENEVAL vehicles types and the Userclasses input from the model);
- **Input tables** – tables that the model reads data into (e.g. Model_LinkData, Model_SectorFile);
- **Output tables** – containing output emissions data from ENEVAL (e.g. Output_Link/TurnData);
- **Parameter tables** – containing the parameters, splits and coefficients required by ENEVAL (e.g. PRM_FleetSplit, PRM_Emissions_Coeff); and
- **Reporting tables** – containing summarised emissions information (e.g. Report_Emissions_By_Sector, Report_EmissionsByLink).



Example of a database in SQL Server Management Studio

SQLQuery12.sql - CR5933\SQLEXPRESS.master (sa (52)) - Microsoft SQL Server Management Studio (Administrator)

Object Explorer: CR5933\SQLEXPRESS (SQL Server 11.0.5058 - sa)

- Databases
 - System Databases
 - CensusMatrixCreator
 - ENEVAL_10
 - ERM_ENEVAL_BY05A512
 - ERM_ENEVAL_BY05A524
 - Database Diagrams
 - Tables
 - System Tables
 - FileTables
 - dbo.CONV_Fleet2VehType
 - dbo.CONV_LinkType2RoadType
 - dbo.CONV_VehType2UC
 - dbo.ID_AnnualisationFactors
 - dbo.ID_AnnualisationFactors_12hrs
 - dbo.ID_AnnualisationFactors_Yearly
 - dbo.ID_Emissions
 - dbo.ID_Flag
 - dbo.ID_Fleet
 - dbo.ID_Formula
 - dbo.ID_Fuel
 - dbo.ID_LinkType
 - dbo.ID_RoadType
 - dbo.ID_Standard
 - dbo.ID_TimePeriod
 - dbo.ID_UserClass
 - dbo.ID_VehType
 - dbo.Model_LinkData
 - dbo.Model_SectorFile
 - dbo.Model_TurnData
 - dbo.Output_LinkData
 - dbo.Output_TurnData
 - dbo.PRIM_CatFail
 - dbo.PRIM_CatFail_Lookup
 - dbo.PRIM_Emissions_Coeff
 - dbo.PRIM_FleetRoadType
 - dbo.PRIM_FleetSplit
 - dbo.PRIM_FuelScaling
 - dbo.PRIM_Mileage
 - dbo.PRIM_MileageFunction
 - dbo.PRIM_Tyres_and_Breaks
 - dbo.RAIL_ID_FLAG
 - dbo.RAIL_ID_FLAG_TEMP
 - dbo.RAIL_Input_LinkData
 - dbo.RAIL_Lookup_DefaultFactors
 - dbo.RAIL_Lookup_DefaultFactors_TEMP

SQLQuery12.sql - CR5933.master (sa (52))

```

/***** Script for SelectTopNRows command from SSMS *****/
SELECT TOP 1000 [ID_VehType]
, [Description]
FROM [ERM_ENEVAL_BY05A524].[dbo].[ID_VehType]
  
```

Results

ID_VehType	Description
1	Electric Car
2	Petrol Car
3	Diesel Car
4	Electric LGV
5	Petrol LGV
6	Diesel LGV
7	Rigid HGV
8	Articulated HGV
9	PSV
10	Motorcycle
11	Taxi
12	LPG Car
13	LPG LGV

Query executed successfully. CR5933\SQLEXPRESS (11.0 SP2) sa (52) master 00:00:00 13 rows



Annex 2 User Comments

The table below outlines comments received and how they have been addressed.

Comment	
Would be useful to have results by link by user class.	Results by link by Vehicle Class added as an output, userclass was not possible due to size.
The fleet will vary between city centres and rural areas. ANPR data may be available in the future to inform alternate fleet.	GEO_ID option added to allow changing of fleet based on location.
The default grid doesn't cover the area for my study.	Custom grid can be imported for used during the analysis process.
The fleet profile needs to be changed to reflect project specific profiles.	Parameters folder added with option to change fleet.

