Documentation of a Calculation Tool for Maritime Emissions

Annex 1.3.2 to the Final Report

April 2007

IVL Swedish Environmental Research Institute
PREFACE

This documentation and manual has been written as part of the SUTRANET project (Work Package 1: Transport Research and Development Network). SUTRANET (‘Sustainable Transport Research & Development Network in the North Sea Region’) is a project within the framework of the European Commission’s (EC’s) Interreg IIIB North Sea Programme.

The present document describes step-by-step the content of a tool in MS Excel – also developed as part of the SUTRANET project – for the calculation of air emissions from ships on a route-to-route basis, and how to use this tool.

The document has been prepared by the Swedish Environmental Research Institute (Gothenburg branch), with Åke Sjödin, Emma Henningsson and Eje Flodström as the authors. Aalborg University’s Department of Development and Planning has added a few editorial amendments to the final version.

April/June 2007

Jorgen Kristiansen
Aalborg University, Department of Development and planning
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1 Introduction

As part of achieving the objective of Work Package 1 of the SUTRANET-project - “to establish a sustainable research and development network and improve the decision-making basis by elaborating the first step of a transport information system for the NSR” - a simple and user-friendly, yet complete, updated and versatile tool for calculating maritime emissions was developed. The present document describes step-by-step the content of this tool and how to use it.

The main constituents of the tool are derived from functions established in the EC DG TREN project ARTEMIS [1]. Some emission factors have been upgraded using recent research and commissions undertaken by IVL [2, 3] and ENTEC [4].

The tool is designed to enable emissions calculations from a limited amount of data for ship movements while at the same time allowing a more detailed breakdown of input data when such is available.

Ships are very heterogeneous in character and any generalised data should be treated with caution, as the actual spread in impact is quite large. Furthermore, when looking at local environmental effects, it is quite possible that individual ships or classes of ships have a very significant impact. Detailed data for individual ships are therefore always preferred.

As most ships have a ships register entry it is often possible to extract some technical details from ships registers, especially main engine size and type and design speed. In some cases though no detailed ships data are available, such as projected traffic or when traffic has to be derived from cargo flow.

The minimum amounts of information for the calculations are the type of ship and the size expressed in either Gross Tonnage or Deadweight. This takes care of the larger variation in average ship’s performance. Another factor that is very important is the operating speed of the vehicle and it’s relationship to the speed towards which the ship is optimised.

Emissions are calculated either from known fuel consumption or from power output via an estimate of the power loading applied to the installed machinery.
2 Estimating Maritime Emissions

2.1 General

Quantification of emissions from ships can today be considered to be manageable as concerns the majority of ship types and in general terms. It can be stated that for individual ships it is possible to reasonably calculate the energy consumption, emission factors and emissions per produced freight, as the information required to do this usually is available for the known ship.

In order to do a complete calculation, the information should cover the actual fuel consumption for the ship including the “normal” changes of speed ‘en route’. It should include the consumption of fuel during the port stay.

The complete information should incorporate:

- Recorded fuel consumption at cruising speed
- Recorded fuel consumption during passages and manoeuvring
- Recorded fuel consumption during ships stay in port
- Fuel quality and sulphur content, main engines and auxiliary engines
- Measured emission data for the engines
- Latest port call and route.

For existing traffic, most of the information needed may be obtained if the request can be addressed to the ship. The information is in most cases related to the ship and needs only to be changed if major changes are done in the operational routine or of ships’ equipment.

The full approach calls for the identification of the installed power, engine type and design speed of each vessel by combining port data with ships’ register data. The ships’ particulars are used together with power and speed models for normal operation to yield fuel consumption and emissions.

One ready example is ferry traffic where a few ships calling at high frequency constitute a large traffic load. Other ships have a very high freight capacity meaning that the transport demand on a particular route can be filled with very few ship movements per year.

The particulars registered for the ships vary between ports and administrations. However, in general the Gross Tonnage (GT) is registered. The GT is an internationally ratified measurement that gives a fair value of the ship’s size. Most of the ships’ duties are based on the GT.

By knowing the GT of a ship and the type of vessel it is possible to build an empirical function that gives the ship’s fuel consumption and/or installed power. It should be stated that this is an approximate method, but it is built on the available information and based on a fairly large number of ships.
2.2 Available Data

For open sea traffic the actual route can only be estimated approximately. It should be noted that diversions from the actual length of the route by the vessel will give an error in the result of emissions and energy as these factors are given as linear loads. However, at present there seems to be no other practical way of handling the modelling as in reality each ship is free to move over the water according to the local conditions and the traffic situation. A “true” result would only be possible if each individual ship could be geographically traced and recorded during the voyage. New technologies may make this possible in the future.

2.3 Spatial Topics

Open sea traffic takes place over large areas where the locations of the individual ships are not known and cannot be derived from any available data source. Some routes are naturally more well-defined than others, as for example ferry routes. For sea transportation, urban areas are of interest mainly at the location of busy ports and where inland waterways pass population centres. To this can be added a few narrow sea passages with very high traffic intensity like for example the English Channel, and Öresund.

A large part of sea transportation takes place in international waters outside national territories. Furthermore, there is no requirement for merchant ships to report when passing in or out of territorial borders at sea.

Some types of waterborne transport, especially passenger ships, have a large seasonal variation in the traffic intensity. This may also be important in an assessment if the peak load is more interesting than the yearly average.

In northern Europe large sea areas are ice covered in the winter. This increases the energy consumption and emissions from ships operating under these conditions. A complete model of waterborne transport emissions has to take this into account. Seasonal storms also add to the energy consumption in the sea areas that have such climatic conditions. At the moment there is very little input data on how large the increases are, especially as this varies very much from year to year.

2.4 Traffic Data

The ports keep data on all ship calls on an individual basis. Some particulars are registered for the traffic as they are the base for different fees and port duties. However, these particulars are not related to the environmental details of the sea transportation. The reporting to the national authorities does normally not include any other data on the ships than the size, measured as Gross Tonnage. Record is usually kept of previous and next port but these data are rarely assembled into traffic figures on a network.

Other than the ports and some national authorities, Lloyd’s Fairplay keep a commercial database on ships’ movements. This is based on information from representatives in ports and covers a large part of the total traffic. Ferries and some other ships running on a fixed schedule are not included.
It is possible to collect ship movement data from the ports. The ports record the previous and next destinations of the ships which gives the possibility to assemble port to port relations. These have to be converted into movements along virtual sea lanes approximating the normal routes between the ports. For the whole of Europe this amounts to approximately 600 - 2,000 individual ports.

One complication is that the authorities responsible for statistics can not report data that reveal commercial information about individual companies. Sea transportation often consists of few units with large capacities and some ports are operated by single companies. This means that the reporting cannot be too detailed in order not to reveal the market of the operators to their competitors. One option is to report not from individual ports but from coastal segments.

All methods for calculating the energy consumption and emissions that are based on ship movements need more traffic data than what is presently reported.

### 2.5 Fleet Composition

It is not possible to define any generalised fleet compositions for waterborne transportation due to the individual variations of the ships and the large impact of these variations. This means that the fleet composition has to be separately defined for each system to be evaluated.

An emission model based only on the number of ship movements makes no sense as the variation in ships' sizes is too large between ports or sea areas. To achieve a satisfactory accuracy, the minimum demand is a size breakdown of the fleet.

However, there are also large technical differences between different ship types that result in very different engine power vs. size relationships. This stands out in particular for ferries and Ro/Ro ships as they are volume optimised and also faster on average than other ships. Passenger ferries normally can, and should, be treated separately but RoRo ferries are mostly mixed with other cargo ships in the traffic figures.

For the part of traffic that is possible to generalise, the best compromise between traffic data workload and accuracy appears to be the categorisation of the ships by Size and Ship Type. This enables the model to handle the differences between ships while still being within the grasp of normal port statistics reporting.

This approach is also very suitable when looking at predicted traffic in scenarios or prognoses.

The emissions are calculated both for ships en route and during stay in port and include auxiliary machinery. This is because emissions in port contribute significantly to urban pollution in several cities.
2.6 Emission Data

The majority of today’s ships are equipped with diesel engines. Steam piston engines are only used by a few historic ships and steam turbines became uneconomical with the fuel price increases in the seventies, so those ships are mostly phased out. A few large tankers still exist with steam turbines and a few ships also have auxiliary machinery of this type.

Gas turbines were previously only used in military vessels and a few small high-speed passenger ships. The expanding market for high-speed ferries has meant that gas turbines are becoming more interesting and quite a few vessels are built or planned with this alternative. Future emission requirements might also lead to a shift in preferences between engine types. At present though nearly all ships are covered by diesel and gas turbine emission data.

2.7 Fuel Data

Waterborne transport uses a large number of different fuel qualities such as Heavy Fuel Oil, Gasoil, Marine Diesel, etc. The specifications of the different types are often indistinct and the spread in properties is substantial.

Sulphur emissions are not engine related but depend only on fuel sulphur content and fuel consumption. This presents a problem when modelling emissions from ships’ data as the ship types have to be connected to fuel composition. The method used so far for this is empirical judgement.

The operators have tended to use as heavy fuels as practical due to the economics but other factors than pure fuel cost are taken into account. Heavier fuels give increased demand for maintenance and risk for malfunctions. On a generalised level slow-speed engines are easier to adapt to heavy fuel usage meaning that the sulphur content is higher on these ships and as an average follows ship’s size. However, more recently environmental demands have come into play that has resulted in a trend towards low sulphur fuels in certain regions especially in ferries and high-frequent operations.

When using Heavy Fuel Oil as main fuel, the auxiliary engines are usually run on lighter fuels like Marine Diesel or Gasoil. These are also used for starting of the main engine. In port, most of the emissions stem from the auxiliary engines and thus usually consist of emissions from lighter fuel qualities. This mainly affects sulphur oxide emissions and particulates.

From a life cycle point of view the most important issue is whether the fuel is distillate or residue/straight run type as this affects the energy consumption for fuel production. Other treatments of the fuels also affect this but it is virtually impossible to separate all the different qualities on the market. In general the life cycle additions are very small for marine fuels; typically 1-5 percent as concerns energy consumption. The marine diesel fuels can then be separated into two categories:

- Distillate Marine Fuel (MDO, Gasoil, VRD etc.).
- Heavy Fuel Oil (HFO, IFO180 etc.).

Further categories might be needed if, in the future, environmental pressure leads to the need for desulphuring of residue oil. However, in the foreseeable future the need for low sulphur marine fuels will be met by distillate fuel and residue fuels from low sulphur crude.
Even if a model is designed to connect fuel type or sulphur content to ship size and type, this relationship can change very quickly with the market demands.

2.8 Environmental Assessment Based on Statistics

Generalised environmental information from statistics will vary in complexity depending of available information. Statistics are generally collected for economical purposes and the collected data seldom relates to environmental information. This is especially apparent in ship transport.

For ship transport a special size dimension of the vessels has been created as a base for charging dues and fees in ports and fairways. This dimension is known as the GT or Gross Tonnage of the vessels. The GT is a mathematical formula based on the enclosed volume of the vessel.

As there is a certain relation to the physical vessel it is possible to use the GT as a basis for environmental quantifications in a general way as long as the information also can be combined with basic information regarding ships’ categories. Using a larger source of statistics from where generalisations may be drawn may refine these methods.

It should, however, be stressed that this will always be generalised from populations with large spreads and should not be used for individual services or transports. Neither is it advisable to project ship transport statistics from one population to another.

As the available statistics usually derive from fee and tax systems that vary between nations, there may also be variations in the dimensions for which information is available. GT may not always be the most suitable basis for these types of statistics, and knowledge is currently lacking on how available this type of information is in a total European perspective.

What may be done is, however, to refine the available information material by using a wider database and many sources, build on a more firm structure of categorisation of vessels and test the result on known transport systems.

2.9 Environmental Assessment Related to Freight/Passenger Traffic

The available freight statistics are normally based on sources that have little relation to the transport mode. The freight flows are usually drawn from customs declarations or trade information collected by national statistics institutes. Today it is not possible to draw statistical information from this on a detailed level as collection of this type of information is largely prohibited in EU.

At present no models or data exists that allows freight flows to be transferred and projected on ship transport with the exception of commodities that are typical for ship transport, petrol and oil products, bulk, etc.
3 Existing Models/Tools for Maritime Emissions versus the SUTRANET Tool

There are already a few emission and fuel consumption models/calculation tools for sea transportation as well as other transport modes available "on the market". The most well-known and widely spread and used are:

**NTMCalc:**

The Network for Transport and Environment, NTM (www.ntm.a.se) is a non-profit organisation, initiated in 1993, and aiming at establishing a common base of values on how to calculate the environmental performance for various modes of transport. NTM offers a free web-based emission calculation tool for calculating emissions and energy for all transport modes.

Regarding maritime emissions, NTMCalc provides 5 types of ships, with no further differentiation into engine type, fuel type (except S-content), and abatement equipment type. There is a need of update as regards emission factors for most transport modes.

**EcoTransIT:**

EcoTransIT is a web-based (www.ecotransit.org) free to use emission and energy consumption calculation tool for all transport modes, jointly hosted by a number of rail operators in Europe. For shipping it provides 5 types of ships differentiated into sea and inland waterway transport, with no further differentiation into engine type, fuel type, and abatement equipment type. There is a need of update as regards emission factors particularly for shipping.

**Swedish Shipowners Association:**

The Swedish Shipowners Association (www.sweship.se) has developed a web-based ship database associated with a tool for calculating emissions and energy for shipping. The calculation tool is fairly detailed and updated as regards emission factors, but it is only available for ship owners.

The relatively poor degree of detail, flexibility and emission factor update of existing maritime emission calculation tools, particularly as regards maritime emissions, justify the tool developed within the SUTRANET-project. In short, its features are:

- differentiates into 14 types of ships, 9 types of engines (for the most common engine types further differentiation into engine power ranges), 3 types of fuels, and 6 types of abatement equipments;

- operates on both default data and on more detailed optional data;

- updated with the most recent research from the EU ARTEMIS-project and IVL/ENTEC-data.
4 Description of the SUTRANET Tool - Users Manual

The following chapter describes the functions and operations of a MS Excel calculation tool for modelling maritime emissions, developed within the SUTRANET project. Its primary goal is to quantify emissions to air from a single ship or a fleet of ships on specified transport routes. Emissions in port are also modelled.

4.1 Overview

Besides a short instruction sheet, the tool consists altogether of seven MS Excel sheets, of which four are used for data input:

- **Ship Input**: Defines the ships to be modelled. The input form accommodates detailed data; however where data is not available, default values for ship type are applied.
- **Route Input**: Defines the routes to be modelled.
- **Traffic Input**: Defines the traffic on each route, i.e. here defined ships and defined routes are combined.
- **Port Input**: Defines the port time per ship and port.

Cells for entering input data and input information are marked in yellow:

The main output sheet is:

- **Results**: Displays the calculated emissions and fuel consumption per route and per port.

In addition there is a ship database sheet:

- **Ships Table**: Stores and displays all entered ships along with intermediate data for the calculations, as well as the calculated emission and fuel consumption factors for routes and ports, expressed as kg/km and kg/hr, respectively.

The final sheet - **Ship Defaults** - contains all the default values that the model uses for the calculations of emission and fuel consumption factors (cf. **Ships Table**). This is just a presentation, information and "look-up" sheet.
4.2 Ship Input Sheet

The Ship Input sheet, cf. Figure 1, is the spreadsheet where all crucial and available information and data regarding the ship is entered by the user. Based on the entered information, and the default values presented in the Ships Defaults sheet, the model calculates emission and fuel consumption factors for each ship, which are then stored in the Ship Table sheet.

![Ship Input Sheet](image)

**Ship Input**

<table>
<thead>
<tr>
<th>Common register and ID</th>
<th>Optional data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of ship</td>
<td>Operating Speed (Knots)</td>
</tr>
<tr>
<td>Flag</td>
<td>ME Abatement equipment</td>
</tr>
<tr>
<td>Signal letter</td>
<td>ME SFC (g/kWh)</td>
</tr>
<tr>
<td>IMO number</td>
<td>ME FC cruise (kg/h)</td>
</tr>
<tr>
<td>MMSI number</td>
<td>ME Fuel Type</td>
</tr>
<tr>
<td>Type of Ship</td>
<td>ME Fuel Sulphur (%)</td>
</tr>
<tr>
<td>Build year</td>
<td>ME Fuel Carbon (%)</td>
</tr>
<tr>
<td>Gross Tonnage (GT)</td>
<td>ME Emission fact NOx (g/kWh)</td>
</tr>
<tr>
<td>Dead Weight (Dwt)</td>
<td>ME Emission fact THC (g/kWh)</td>
</tr>
<tr>
<td>Design Speed (Knots)</td>
<td>ME Emission fact CO (g/kWh)</td>
</tr>
<tr>
<td>Number of main engines (ME)</td>
<td>ME Emission fact TP (g/kWh)</td>
</tr>
<tr>
<td>Main Engine type</td>
<td>AE Number</td>
</tr>
<tr>
<td>Main Engine Power (kW)</td>
<td>AE Type</td>
</tr>
<tr>
<td>AE Power (kW)</td>
<td>AE Abatement equip</td>
</tr>
<tr>
<td>AE Load Cruise (%)</td>
<td>AE Load Cruise (%)</td>
</tr>
<tr>
<td>AE FC cruise (kg/h)</td>
<td>AE Load in port (%)</td>
</tr>
<tr>
<td>AE Load in port (%)</td>
<td>AE FC in port (kg/h)</td>
</tr>
<tr>
<td>AE Fuel Type</td>
<td>AE Fuel Sulphur (%)</td>
</tr>
<tr>
<td>AE Fuel Carbon (%)</td>
<td>AE Emission fact NOx (g/kWh)</td>
</tr>
<tr>
<td>AE Emission fact THC (g/kWh)</td>
<td>AE Emission fact CO (g/kWh)</td>
</tr>
<tr>
<td>AE Emission fact TP (g/kWh)</td>
<td>Notes: Compulsory fields are marked in blue.</td>
</tr>
</tbody>
</table>

Emission factor in kg/h? Convert here:
- BF (g/kg fuel)
- FC (kg/h)
- Cruise power (kW)
- EF (g/kWh)

| AE Abatement equip | AE Load Cruise (%) |
| AE Power (kW) | AE Abatement equipment |
| AE Fuel Type | AE Fuel Sulphur (%) |
| AE Fuel Carbon (%) | AE Emission fact NOx (g/kWh) |
| AE Emission fact THC (g/kWh) | AE Emission fact CO (g/kg)
| AE Emission fact TP (g/kg)

Figure 1. Ship Input sheet in the SUTRANET emission calculation tool.

The ship input is divided into Common Register and ID Data and Optional Data, cf. Figure 1. In the Common Register and ID Data there are five (5) cells that are required to be filled in by the user in order to have the model running. These are marked in blue. All other inputs are optional for the user. The mandatory inputs are:

**Name of ship**
Enters the (unique) name of the ship. Used as ship identity in Traffic Input sheet.

**Type of ship**
From a scroll-down menu in the cell where the information shall be entered, the user can choose from 14 different types of ships: Bulk ship, Container ship, RoRo ship, Vehicle carrier, General cargo ship, Reefer,
Oil tanker (Tanker), LNG tanker, LPG tanker, Cargo ferry, High speed ferry, Passenger ferry, Cruise ship, and Other. Once a ship type is selected, the model specifies gross tonnage, operating speed, number of main and auxiliary engines, etc., according to the Ships Defaults sheet, unless specific information for these parameters is entered by the user in the Ship Input sheet.

**Gross Tonnage**
Enters the gross tonnage of the ship in tonnes.

**Main engine type**
From a scroll-down menu in the cell where the information shall be entered, the user can choose from four (4) different types of main engines: High Speed Diesel, Medium Speed Diesel, Slow Speed Diesel, Gas Fuelled Piston, and Gas Turbine. Once a main engine type is selected, the model specifies the fuel type that the main engine operates on according to the Ships Defaults sheet, unless specific information for fuel type is entered by the user in the Ship Input sheet (Optional Data).

**Main engine power**
Enters the overall main engine (rated) power for the ship in kW.

Remaining Common Register and ID Data optional for the user to enter are Flag, Signal Letter, IMO Number, MMSI Number, Build Year, Dead Weight, Design Speed, and Number of Main Engines. Of these, only the last two are used by the model for the calculations.

**Optional Data:**

**Operating Speed**
Enters the normal operating speed of the ship.

**ME Abatement Equipment**
From a scroll-down menu in the cell where the information shall be entered, the user can choose from six (6) different types of abatement equipment to reduce main engine-out emissions: DWI (Direct Water Injection), HAM (Humid Air Motor), SCR (Selective Catalytic Reduction), SCR + oxi cat (oxidation catalyst), Scrubber (to reduce emissions of mainly sulphur dioxide), IMO (International Maritime Organisation legislation on air emissions from ships - not yet in force), and None (no abatement equipment). Once an abatement equipment is selected, the model specifies the emission reduction rates for each pollutant according to the Ships Defaults sheet.

**ME Load Cruise**
Enter the normal operating power level of the ship's main engines in % of rated (full) power.

**ME SFC**
Enter main engine specific fuel consumption in g/kWh.

**ME FC Cruise**
Enter main engines fuel consumption in kg/hour at cruise.

**ME Fuel Type**
From a scroll-down menu in the cell where the information shall be entered, the user can choose from five (5) different types of fuels that the main engine operates on: Distillate Fuel Oil, LPG/LNG, Marine Diesel, Residual Oil and Road Quality Diesel (extremely low sulphur). Once a fuel type is selected, the model specifies sulphur content and the carbon content (unless specific information on fuel sulphur and/or carbon content is entered by the user in the adjacent cells) of the fuel.
according to the Ships Defaults sheet, which is used by the model for the calculation of SO₂ and CO₂ emissions, respectively.

**ME Fuel Sulphur**
Enters main engine fuel sulphur content in percent (%) by weight.

**ME Fuel Carbon**
Enters main engine fuel carbon content in percent (%) by weight.

**ME Emission fact X**
Enters main engine emission factor for pollutant X (NOₓ -nitrogen oxides, THC - total hydrocarbons, CO - carbon monoxide or TP - total particulate matter) and replaces default factor according to the Ships Defaults sheet.

**AE Number**
Enter the number of auxiliary engines.

**AE Type**
From a scroll-down menu in the cell where the information shall be entered, the user can choose from four (4) different types of auxiliary engines: High Speed Diesel, Medium Speed Diesel, Slow Speed Diesel, Gas Fuelled Piston, and Gas Turbine. Once an auxiliary engine type is selected, the model specifies the fuel type that the auxiliary engine operates on according to the Ships Defaults sheet, unless specific information for fuel type is entered by the user.

**AE Power**
Enter total (rated) power of auxiliary engines in kW.

**AE Abatement Equipment**
Same as for **ME Abatement Equipment**, see above.

**AE Load Cruise**
Enter normal operating power level in % of rated (full) power of auxiliary engines during cruise.

**AE FC Cruise**
Enter auxiliary engines fuel consumption in kg/hour at cruise.

**AE Load in Port**
Enter normal operating power level in % of rated (full) power of auxiliary engines during port stay.

**AE Fuel Type**
Same as for **ME Fuel Type**, see above.

**AE Fuel Sulphur**
Enter auxiliary engine fuel sulphur content in percent (%) by weight.

**AE Fuel Carbon**
Enter auxiliary engine fuel carbon content in percent (%) by weight.

**AE Emission fact X**
Enter auxiliary engine emission factor for pollutant X (NOₓ -nitrogen oxides, THC - total hydrocarbons, CO - carbon monoxide or TP - total particulate matter), and replaces default factor according to the Ships Defaults sheet.

Once all the compulsory and available information has been entered into the **Ship Input** sheet, the user has to right mouse-click on the "Save to database"-button to save the entered information, before proceeding to the next step - the **Route Input** sheet.

By right mouse-clicking on the "View the ships"-button the **Ship Table** sheet appears, with the ships and associated information/data entered, to be checked by the user.
There is also a built-in calculator in the *Ship Input* sheet for converting emission factors expressed in g/kg fuel into g/kWh.

### 4.3 Route Input Sheet

The *Route Input* sheet, cf. Figure 2, is the spreadsheet where all routes or route segments that should be analysed are entered by the user. The maximum number of route segments that can be entered is 245. The user enters the route number (compulsory), the name (optional), the location (optional), and the length (compulsory) in nautical miles of the route segment.

#### Route Segment input

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Location</th>
<th>Length (naut. mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Example route 1</td>
<td>Kattegatt</td>
<td>150</td>
</tr>
<tr>
<td>2</td>
<td>Example route 2</td>
<td>North Sea NE</td>
<td>350</td>
</tr>
<tr>
<td>3</td>
<td>Example route 3</td>
<td>North Sea SW</td>
<td>250</td>
</tr>
</tbody>
</table>

*Notes*

Create a new row for each shipping route segment that you want to analyse.

*Figure 2.* *Route Input* sheet in the SUTRANET emission calculation tool.

To clear this sheet, mark up the cells you want to clear and press the delete-button or the clear content button.
4.4 Traffic Input sheet

The Traffic Input sheet, cf. Figure 3, is the spreadsheet in which each ship entered in the Ship Input sheet is assigned to one or several routes or route segments specified in the Route Input sheet. One ship can be assigned to several routes, just as well as one route can contain several ships, as long as the number of route and ship combinations is limited to 245. In the Route and Ship columns, each route and ship are selected from a scroll-down menu that contains all the routes and ships entered in the Ship Input sheet and the Route Input sheet, respectively. For each route and ship combination, the user also has to enter the number of passages that each ship conducts on each route per time unit, e.g. per year, week, etc., or whatever time unit the user wants his/her analysis to be based on.

After completion, and if the user does not want to include any port emissions in the analysis, upon left mouse-clicking on the "Save and recalculate"-button, the Results sheet appears, presenting the results of the calculations (see Section 4.6). If the user wants to include also port emissions in the analysis, proceed to the Port Input sheet, simply by left mouse-clicking on the Port Input sheet tag.

Traffic data input

<table>
<thead>
<tr>
<th>Route</th>
<th>Ship</th>
<th>Passages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Example route 1</td>
<td>1 Example ship 1</td>
<td>50</td>
</tr>
<tr>
<td>2 Example route 2</td>
<td>2 Example ship 2</td>
<td>100</td>
</tr>
<tr>
<td>1 Example route 1</td>
<td>3 Example ship 3</td>
<td>25</td>
</tr>
<tr>
<td>3 Example route 3</td>
<td>4 Example ship 4</td>
<td>40</td>
</tr>
</tbody>
</table>

Figure 3. Traffic Input sheet in the SUTRANET emission calculation tool.

To clear this sheet, mark up the cells you want to clear and press the delete-button or the clear content button.
4.5 Port Input sheet

The Port Input sheet, cf. Figure 4, is the spreadsheet in which ships entered in the Ship Input sheet can be assigned to one or several all ports. One ship can be assigned to several ports, just as well as one port can contain several ships. Just as for routes, the number of port and ship combinations is limited to 245. The user has to enter the port name, select the ship(s) calling on this port from a scroll-down menu that contains all the ships entered in the Ship Input sheet, the number of calls of the ship(s) to the port per a defined time unit (the same as used for the number of passages in the Traffic Input sheet), and one of the following:

- total port time (in hours), if load/unload time and lay time are not known
- load/unload time and lay time (in hours)

If no time data is given, default values will be used in the calculations.

After completion of the Port Input sheet, upon left mouse-clicking on the "Save and recalculate"-button, the Results sheet appears, presenting the results of the calculations (see Section 4.6).

### Port traffic data input

<table>
<thead>
<tr>
<th>Port name</th>
<th>Ship</th>
<th>Calls</th>
<th>Total port time (hrs)</th>
<th>Load/unload time (hrs)</th>
<th>Lay time (hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example port 1</td>
<td>Example ship 1</td>
<td>50</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Example port 2</td>
<td>Example ship 2</td>
<td>100</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Example port 3</td>
<td>Example ship 3</td>
<td>20</td>
<td></td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Example port 4</td>
<td>Example ship 4</td>
<td>40</td>
<td>16</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 4. Port Input sheet in the SUTRANET emission calculation tool.

To clear this sheet, mark up the cells you want to clear and press the delete-button or the clear content button.
4.6 Results Sheet

The Results sheet presents the results of the calculations based on the input in the Traffic Input and Port Input sheets, respectively. The results are divided into two tables, one for the route emissions and one for the emissions in port, cf. Figure 5 and 6.

The fuel consumption and emissions of NOX, THC, CO, TP, CO2 and SOX are presented in kilogram per time unit applied for the number of passages and calls, respectively, given in the Traffic Input and Port Input sheets, respectively (e.g. if the number of passages on a given route in the Traffic Input sheet is per year, then the results for the route emissions in the Results sheet will be in kg/year). Results are presented for individual routes and ports as well as the overall (Grand Total) fuel consumption and emissions for all routes and all ports combined.

Results - route emissions

<table>
<thead>
<tr>
<th>Data</th>
<th>Route no.</th>
<th>1</th>
<th>2</th>
<th>3 (blank)</th>
<th>Grand Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum of Fuel consumption kg</td>
<td>741916.7488</td>
<td>1051376.667</td>
<td>1188477.366</td>
<td>2981770.782</td>
<td></td>
</tr>
<tr>
<td>Sum of NOx kg</td>
<td>63593.7674</td>
<td>3163.351852</td>
<td>113955.5556</td>
<td>180712.6749</td>
<td></td>
</tr>
<tr>
<td>Sum of THC kg</td>
<td>1556.950411</td>
<td>602</td>
<td>3002.469136</td>
<td>5161.419546</td>
<td></td>
</tr>
<tr>
<td>Sum of CO kg</td>
<td>3709.825944</td>
<td>1532.222222</td>
<td>5435.390947</td>
<td>10677.43911</td>
<td></td>
</tr>
<tr>
<td>Sum of TP kg</td>
<td>1634.004598</td>
<td>862.8148148</td>
<td>3358.024691</td>
<td>5854.844104</td>
<td></td>
</tr>
<tr>
<td>Sum of CO2 kg</td>
<td>2366714.429</td>
<td>3353891.567</td>
<td>3791242.798</td>
<td>9511848.794</td>
<td></td>
</tr>
<tr>
<td>Sum of SOx kg</td>
<td>50312.14943</td>
<td>31541.3</td>
<td>83193.41564</td>
<td>165046.8651</td>
<td></td>
</tr>
</tbody>
</table>

Figure 5. Results table for route emissions in the Results sheet in the SUTRANET emission calculation tool.

Results - port emissions

<table>
<thead>
<tr>
<th>Data</th>
<th>Port name</th>
<th>Example port 1</th>
<th>Example port 2</th>
<th>Example port 3</th>
<th>Grand Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum of Fuel consumption kg</td>
<td>164220</td>
<td>68040</td>
<td>137760</td>
<td>370020</td>
<td></td>
</tr>
<tr>
<td>Sum of NOx kg</td>
<td>9337.08</td>
<td>3868.56</td>
<td>7832.64</td>
<td>21038.28</td>
<td></td>
</tr>
<tr>
<td>Sum of THC kg</td>
<td>250.24</td>
<td>103.68</td>
<td>209.92</td>
<td>563.84</td>
<td></td>
</tr>
<tr>
<td>Sum of CO kg</td>
<td>398.62</td>
<td>165.24</td>
<td>334.56</td>
<td>898.62</td>
<td></td>
</tr>
<tr>
<td>Sum of TP kg</td>
<td>156.4</td>
<td>64.8</td>
<td>131.2</td>
<td>352.4</td>
<td></td>
</tr>
<tr>
<td>Sum of CO2 kg</td>
<td>523861.8</td>
<td>217047.6</td>
<td>439454.4</td>
<td>1180363.8</td>
<td></td>
</tr>
<tr>
<td>Sum of SOx kg</td>
<td>11495.4</td>
<td>4762.8</td>
<td>9643.2</td>
<td>25901.4</td>
<td></td>
</tr>
</tbody>
</table>

Figure 6. Results table for port emissions in the Results sheet in the SUTRANET emission calculation tool.
4.7  Ship Table Sheet

The Ship Table sheet serves also as a database for all the ships entered by the user via the Ship Input sheet. It stores all the Common Register/ID and Optional Data entered by the user via the Ship Input sheet, and displays all intermediate as well as final results for the calculations of fuel and emission factors, for both routes and ports. The division of the Ship Table sheet columns is as follows:

- **Common Register and ID Data**: Columns B - O
- **Optional Data**: Columns P - AR
- **Intermediate data for calculation**: Columns AS - CN
- **En Route Emissions (kg/km)**: Columns CO - DD
- **Port Emissions (kg/h)**: Columns DE - DR

Thus, the Ship Table sheet can be used as an emission factor and/or specific fuel consumption database/model, independently of all the other components (e.g. Route Input and Traffic Input sheets) of the SUTRANET emission calculation tool (except for, of course, the Ship Input sheet).

4.8  Ship Defaults Sheet

The Ship Defaults sheet contains all the default values applied by the model for all the different parameters that are involved in the calculations of route and port emissions. As can be seen there is a large number of parameters that default values are applied for, when optional data are not provided by the user (which may often be the case). For instance, gross tonnage, design speed, auxiliary engine relative power, port load/unload and lay time, and the number of main and auxiliary engines, depending on the type of ship, fuel type used depending on the engine type, and specific fuel consumption and emission factors, depending on the engine power. Also, typical default values for sulphur content depending on the type of fuel and emission reduction rates depending on type of abatement equipment are listed here.
5 References


