Update of navigation chapter
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Summary

The work consists in the revision of the Emission Factors and Methodologies of the Navigation chapter with:

- Literature review of the emissions estimates methodology (EMs) and emission factors (EFs) for navigation sector

- Statistical analysis of Lloyd’s database (years 1997 and 2010) for world fleet characterization regarding fuel consumption (FC) and others parameters (the 1997 database was purchased in the frame of MEET project while the 2010 in the frame of an ongoing national project in Italy)
Activities

◆ Revision of Tier 1 activity/fuel split for EFs
◆ Revision of main pollutants, heavy metals, PAHs and PCB, HCB, PCCD/F Tier 1 EFs
◆ Revision of Tier 2 and Tier 3 EFs for NO$_x$ and NMVOC for different engine types/fuel combinations (medium and large ships)
◆ Inclusion of Tier 2 and Tier 3 EFs for PM
◆ Revisions of Tier 2 and Tier 3 activity data evaluation methodology
◆ Revision of Tier 3 emissions estimates methodology
Tier 1 – Methodology

1  Obtain national statistical FC by fuel
2  Estimate national emissions with Tier 1 EFs

Tier 1 generally introduces the only split between fuels and no one between technologies

GB old chapter introduce technology specific Tier 1 EFs
Tier 1 - Revision of the split of the Efs

- In the actual GB it’s inconsistent a Tier 1 for small diesel boats; consequently the reference to “medium to large” is removed from Table 3-1 and Table 3-2, while EFs for MDO/MGO recreational ships in Table 3-3 are moved in Tier 2

- Similarly for gasoline is inconsistent, in Tier 1, the split between 2 and 4-stroke; a unique set of average EFs (on a share of 75% for 2 and 25% for 4-stroke, roughly the ratio of 2001 Danish inventory) is proposed in Table 3-3
Tier 1 - Revision of the emission factors

- \( \text{NO}_{\chi} \), PM ad NMVOC EFs for BFO and MDO/MGO are updated using the average of the Tier 2 values (Entec 2002) in cruise for medium speed and low speed engines (for NOx the 2000 values are used).

- Following Entec, 2007, for BFO and MDO/MGO EFs, \( \text{PM}_{10} \) is assumed as equivalent to TSP and \( \text{PM}_{2.5} \) is assumed equivalent to 90% of TSP (some slightly different figure of 92% is proposed by US EPA new methodology for port in U.S. Environmental Protection Agency, 2009).
Tier 1 - Revision of the emission factors

- Heavy Metals EFs contained a lot of errors in the units for BFO (Table 3-1) and MDO/MGO (Table 3-2); data revised from original Lloyd’s 1995 document and new informations (Cooper D.A., Gustafsson T., 2004) has been used to compute average new emissions factors

- EFs for PCB, HCB, PCCD/F have been inserted in Table 3-1 for BFO and Table 3-2 for MDO/MGO (in actual tables only lower/upper interval was defined) using the data from Cooper, 2005 (also wrong unit for PCDD/F have been corrected)
Tier 1 - Revision of the emission factors

- Actual PAHs EFs are computed on the basis of Table 3-16; the procedure is unclear as the table reports percentage of single compounds on total of PAHs; the total PAHs emissions are not reported in the original work by Lloyds: the proposal is to delete PAHs data from Guidebook and indicated as not estimated.

- Heavy metals and POPs EFs for gasoline in Table 3-2 are of uncertain origin (for example no EF is proposed for heavy metals in the chapter "Non-road mobile sources and machinery"), so it is better to use Not Available for these pollutants.
Tier 2 – methodology

1. Obtain national statistical FC by fuel and national statistical port arrivals data by type of vessel

2. Compute total power installed by type of vessel using data elaborated from Lloyds DB (Table 3-6)

3. Split total power installed for type of vessel by engine speed/fuel class (ES/FC) using Table 3-7

4. Compute total power installed by ES/FC as sum of figures derived in step 3.

5. Assume that fuel usage is proportional to total power installed to assign statistical fuel consumption to different ES/FC

6. Estimate national emissions with Tier 2 EFs
Tier 2 – Elaboration of data from Lloyd’s DB for 1997 (Meet project) and 2010 world fleet

- Average main engine power (total power of all engines) by ship category for 1997 and 2010 fleets (Table 3-6)
- Percentage of installed Main Engine power by engine type/fuel class for 2010 fleet (Table 3-7)

Tier 2 – Emission factors

- Tier 2 EFs are assumed equal to Cruise Tier 3 EFs for main engines, updated as described below
In recent years emissions estimate methods have always been oriented towards the use of the installed capacity for estimating emissions of pollutants while EMEP/CORINAIR used also fuel consumption methodology as an alternative.

The last version of Guidebook use only fuel consumption methodology; the choice was due to the fact that it was available, even if not updated, the correlation functions of fuel consumption with gross tonnage, which is the statistical information available from the ports.

This update use again both approach as alternative for emission estimates.
Tier 3

◆ The old chapter don’t introduce subdivision between Main and Auxiliary Engines

◆ In the review of the chapter the methodology is updated to take into account both the main and auxiliary engines; auxiliary engines are operated as in cruise and manoeuvring as in hotelling, with main contribution in hotelling if and when main engine is shut down; the update of methodology includes separate calculation of emissions from main engines and from auxiliary engines assuming different % of load of the two engine classes in the different navigation phases
Tier 3 – Emission estimate methodologies

- Where fuel consumptions are known:
  \[ E_i = \sum_e (FC_{ie} * EFC_e) \]

- Where fuel consumptions are not known:
  \[ E_i = T_i \times \sum_e (P_e \times L_e \times EFP_{ie}) \]

  * $i$, phase (cruise, hotelling, manoeuvring)
  * $e$, engine (main, auxiliary)
  * $LF$, load factor
  * $EFC$, Fuel consumption based Emission factors
  * $P$, engine power
  * $L$, load factor
  * $EFP$, power based Emission factors
Tier 3 - Revision of the emission factors

- Tier 3 EFs (Entec, 2002) have been reviewed and updated (using a more recent study for Concawe by Entec, 2007)

- The main changes include:
  - the introduction of fuel base (g/tonn) and power based (g/kWh) EFs
  - the introduction of EFs for auxiliary engines and the unification of main engines emissions factors for hotelling and manoeuvring.
  - the differentiation of NO\textsubscript{x} EFs between “valid up to 2000” (indicated as 2000) and 2005
Tier 3 – NOx Tier 3 emission factors

◆ NOₓ 2000 EFs are representative of the fleet before application of IMO NOₓ Technical Code while 2005 EFs are reduced of 3.4% to account for the new engines introduced by 2005

◆ the reduction is calculated on assumption that a new engine has 17% lower NOₓ than a pre-2000 engine, using an average 4% annual rate of replacement for vessels from 2000 and 2005, based on the following assumptions:
  ◆ new low NOₓ engines coincide with new vessels, as is not possible to establish the number of annual engine replacements within the fleet
  ◆ the overall fleet size remains constant
  ◆ 25 years life cycle for a marine engine
Tier 3 – Other minor revision on emission factors

- Some small difference was detected and corrected even on previously published data
- PM emission factors were included from ENTEC, 2007
- A note about NMVOC factors is introduced: the values have been derived as 98 % of the original HC value (based on reported CH4 factors from IPCC, 1997)
Tier 3 – methodology “fuel based”

This procedure is applicable only where detailed FCs for each ship/engine type combination in the different navigation phases are available.

1. Obtain fuel consumption for each individual ship, engine type/fuel class and ship activity (for the whole year or a representative sample of the year, for all ships or for a representative sample of the ships for each ship category and engine type/fuel class).

2. Calculate emissions for each ship category and engine type/fuel class multiplying by the emission factors.
Tier 3 – methodology “power based”

1. Obtain ship movement data: place of departure, place of arrival, time of departure and time of arrival for each individual ship.

2. Determine sailing routes and distances between ports.

3. Characterize each ship by ship category (as in Table 3 6) and engine type/fuel class (if unknown use Table 3 7) and record the installed main or auxiliary engine power; if engine power is unknown, and only gross tonnage (GT) is available, installed main engine power can be obtained from Table 3 12 (with reference to 1997 world fleet, 2010 world fleet and 2006 Mediterranean Sea fleet) and then installed auxiliary engine power from Table 3 13 (with reference to 2010 world fleet and 2006 Mediterranean Sea fleet; 1997 auxiliary engine data are not available).
Tier 3 – methodology “power based”

4. Determine the total sailing time for each ship category and engine type/fuel class, either based on the distance and average cruise speed (Table 3.14) or time of departure and arrival.

5. Determine total hotelling and manoeuvring time for each ship category and engine type/fuel class by port survey or on the basis of average time spent values reported in Table 3.14.

6. Calculate emissions for each ship category and engine type/fuel class multiplying total time spent in each phases as determined in previous steps 4 and 5 by the installed main and auxiliary engine power, for each ship category, calculated as determined in step 3, load factors (and for main engine % time of operation) from Table 3.15 and emission factors from Table 3.10.
Tier 3 – Elaboration of data from Lloyd’s DB for 1997 (Meet project) and 2010 world fleet

- Average main engine power (total power of all engines) by ship category for 1997 and 2010 fleets (Table 3-6)
- Percentage of installed Main Engine power by engine type/fuel class for 2010 fleet (Table 3-7)
- Installed main engine power as a function of gross tonnage (GT) by Ship (Table 3-12)
- Estimated average vessel ratio of Auxiliary Engines / Main Engines by ship type (Table 3-13)
- Estimated average cruise speed and average duration of import activities (Table 3-14)
- Estimated % load of MCR (Maximum Continuous Rating) of Main and Auxiliary Engine for different ship activity (Table 3-15)
Tier 3 – Main Power vs GT for 1997 world, 2010 world, and 2007 Mediterranean sea fleets