The reviewer critisizes that we apply a generalized load factor of 0.3 to auxiliary engines of sailing ships. He recommends to introduce a size dependent factor for container vessels and to distinguish between general cargo and container vessels. In order to do this he recommends us to take into account the findings by Starcrest (Air Emissions Inventory 2014 for the Port of Long Beach, see also the Air Emissions Inventory 2013, section 2 for a description of the methods)
Some considerations about this:

1 Power of aux engines

In the emission study for the Port of Long Beach by Starcrest, a table connecting container vessel size classes in TEU with the load applied for auxiliary engines is provided. No auxiliary engine powers are shown but load factors in KW. Thus, we tried to find a relation between the ship size and the total power of auxiliary engines using our data base. Unfortunately, only 2.3% of the container ships have a value in totalpowerofauxiliaryengines field, but the relation seems to be linear (Figure 1).

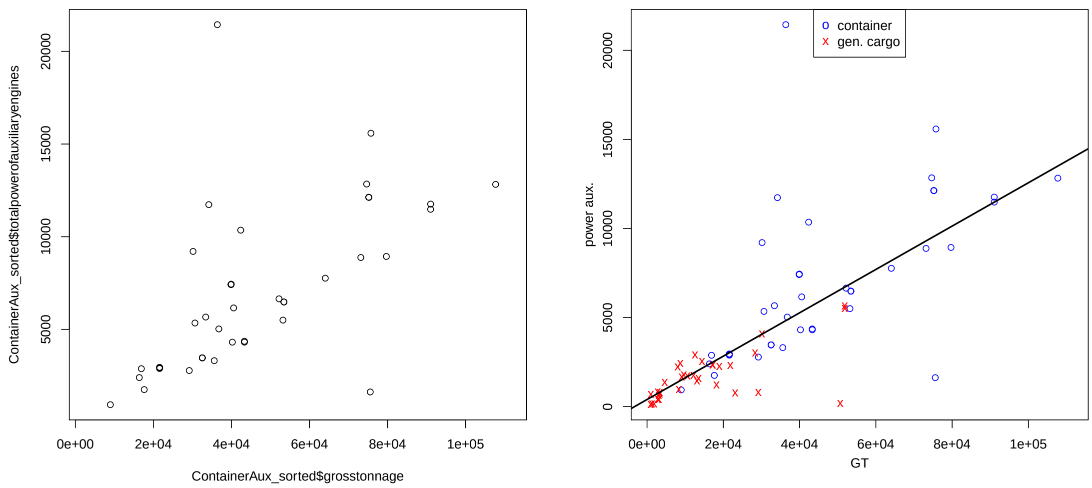

Figure 1: The relation between ship size and auxiliary engine power.

This linear relation seems to be applicable also for non-container cargo vessels.

2 Loads for container and cargo (POLB)

2.1 Container ships

For containers a linear relationship between TEU and GT can be assumed – the factor is 10. Thus, the linear equation found for the relationship between GT and power aux. can be directly applied to show the relation between TEU and the applied load during transit. Certainly, the big container vessels that have up to 6 auxiliary engines would switch off those not needed and run the needed ones at a higher load. However, as for engines with D2 applications Zeretzke did not find a load dependency this does not play a role for our model.

The graphics shows the relation between the TEU of container ships and the load applying during transit (Figure 2). Considering uncertainties and omitting the high load assumed for small container ships, this plot does not contradict the assumption of a constant load factor, even though it is smaller than the one proposed by Whall et al. We agree that this relation cannot be applied to the use of shaft generators. However, for container ships 4-stroke engines are a rare exception. Actually, the most important factor determining the load of auxiliary engines is the amount of containers that have to be cooled, but this is unknown.

Starcrest show average loads and average energy demand, no temporal resolution or frequency distribution is provided. This makes it impossible to estimate the uncertainty of the method. The average loads are derived from on-board surveys. From our own experience with similar surveys at the ports of Hamburg, Bremerhaven, Rotterdam and Antwerp we know that returned survey sheets are often incomplete or contain implausible entries (http://cnss.no/wp-content/uploads/2014/03/CNSS_Final_Report_web.pdf). The validity and representativity of the survey is not discussed, e.g. how many correctly filled in forms per ship size were returned. Power and number of auxiliary engines for the size classes are not provided (Figure 3).

2.2 General cargo

We calculated the same grosstonnage-power-aux curve for cargo vessels with 2-stroke engines (75% of all propulsion types). In the Starcrest study, the load factor in KW

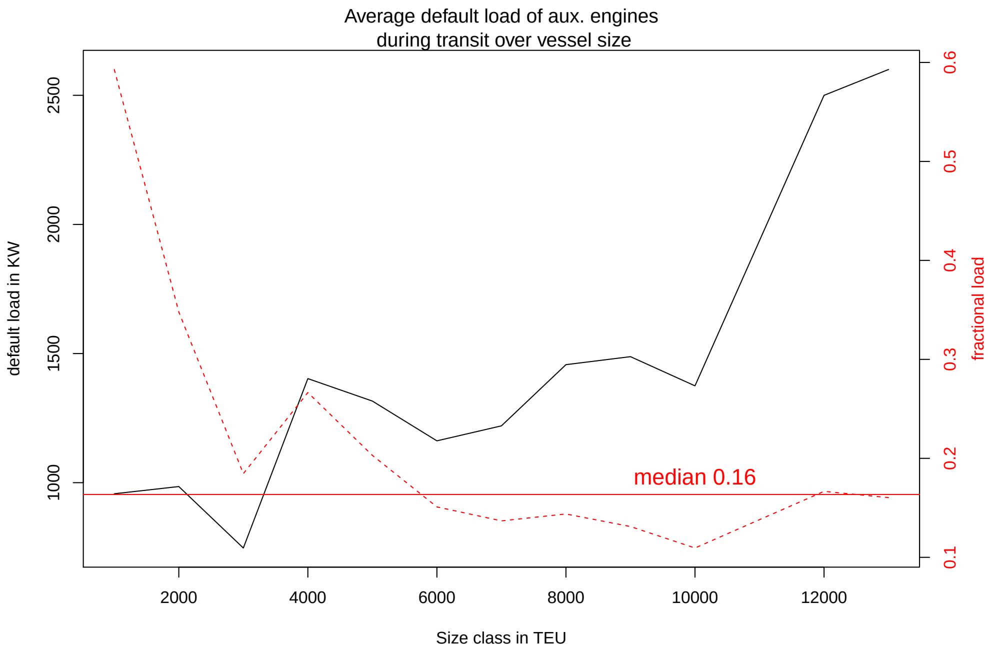

Figure 2: The relation between ship size and auxiliary engine load for container vessels.

is not divided into size classes. However, also cargo vessels have auxiliary engines of different sizes. This graphics suggests a generally lower load for general cargo than for container vessels (Figure 4).

3 Summary

In case the shown relations are realistic we would certainly overestimate the emissions by cargo vessels because we assume for both cargo and container vessels an average load of 30%, whereas for container vessels the average load may be 20% and 10% for general cargo. In addition, one could take into account that 25% of the general cargo vessels have 4-stroke engines (and produce their electricity with the main instead of auxiliary engines). These 25% are, however small vessels having little impact on the overall emissions. At the same time, we already pointed out that a deviation of the load factor by 10% (applied to the whole fleet) would result in a deviation of 4% concerning fuel consumption in our entire inventory.

2.3.5 Vessel Boarding Program Survey Data

The best sources to obtain local activity data and ship parameters are the shipping lines that own and/or operate the vessels. The Port's Vessel Boarding Program (VBP) provides for an in-depth survey of OGVs during which Starcrest consultants board individual ships and interview the ship's executive and engineering staff, which usually includes the captain and chief engineer. Data collected from individual vessels includes:

- Main engine power
- Auxiliary engine power
- Auxiliary engine load
- Boiler fuel consumption
- Vessels that switched fuels
- Emission reduction technologies such as slide valves

For this inventory, information gathered from previous years' vessel boardings, along with new boarding data, has been used.

Figure 3: Clipping from the Air emissions inventory 2013 (prepared by Starcrest)

Starcrest investigates the behavior of port-approaching vessels, that means the speed for fast container vessels is set to 11kn – while the big vessels rather go 20kn and more at open sea. Thus, it is unclear if the behavior of ships while appraoching the port (called transit in the Starcrest study) is directly applicable to sailing the open sea because several devices that require electricity produced by auxiliary engines are more active in the vessels' normal operation mode. This is mostly the case for equipment needed for cooling and lubrifying the engine and ventilating the engine rooms. Hence, we think it is not recomendable to assume the same load for auxiliary engines if a vessel is sailing at slow speed and if it is sailing at normal cruising speed.

On the one hand, we think the work of Starcrest is valuable and should be considered when estimating ship emissions. On the other hand, we cannot see that their findings (applying overall to port areas) make the sugesstions of Whall et al. invalid.

A size dependency of auxiliary engine loads is obvious when comparing small and large vessels because many of the smaller vessels use shaft generators to produce the electricity needed. However, the share of these vesells in the total fuel consumption and emission is relatively small. It is thinkable to consider this size dependency in a future model update, but we do not think that it is justified to reformulate the model and recalculate the emissions and concentration levels including the scenarios for the study presented here.

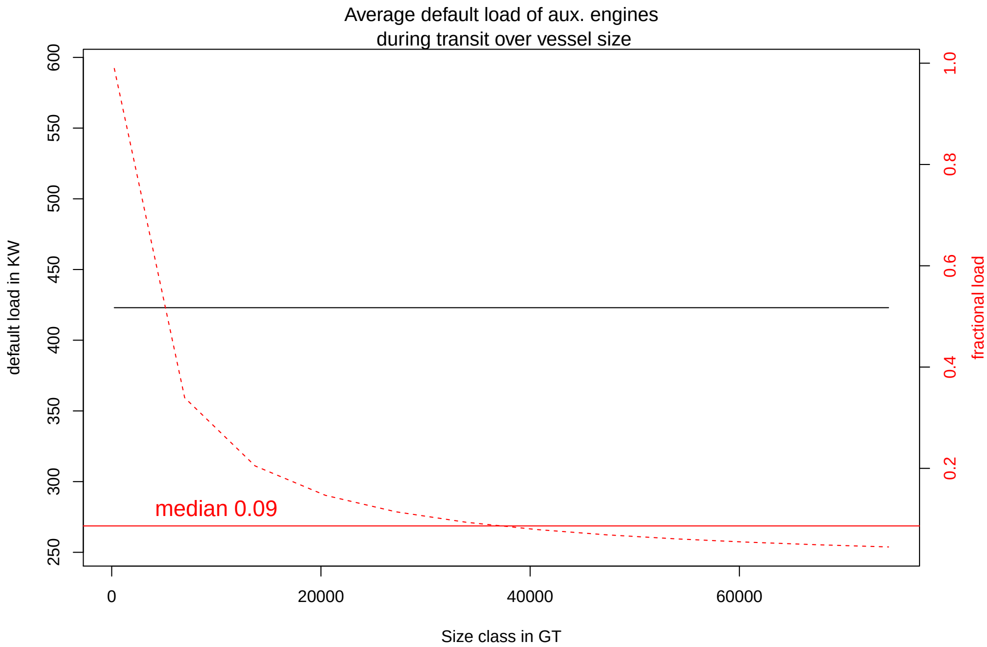

Figure 4: The relation between ship size and auxiliary engine load for general cargo.