SCENARIO-BASED DYNAMIC SHIP EMISSION STUDIES

Yuwei Yin, Maritime Institute, Nanyang Technological University, Phone: +65 90843626, Email: yinyw@ntu.edu.sg

Prof. Dr. Jasmine Siu Lee Lam, School of Civil and Environmental Engineering, Nanyang Technological University, Phone: +65 67905276, Email: SLLam@ntu.edu.sg

Overview

This study aims at investigating various methods for ship emission mitigation, quantifying the level of improvements, and visualizing the corresponding emission density under each scenario. In the past decade, great attentions have been paid on maritime emissions. Academic researchers have also devoted significant efforts constructing Emission Accounting models, for different geographical areas and for various ship types. However, Emission Accounting is just the first step of effective emission management. According to the base year emission conditions, certain countermeasures, such as speed control and berth time reduction, could be implemented for pollution mitigation. For each measure, a comprehensive emission study should help to justify its effectiveness, and to reflect the resulting level of emission decrements. Given the preliminary Emission Accounting model, scenario-based analysis should be applied as a follow-up elaboration. Scenarios are constructed based on candidate emission management strategies, as well as probable changes in shipping patterns in the foreseeable future. If there is any ongoing port expansion project or any probable change in the future transportation pattern, a robust emission model should be able to demonstrate the respective changes in the emission volume, the emission density and the spatial distribution. In this study, based on a well-developed Emission Accounting model, such follow-up analysis will be applied using the *System Dynamic* approach. The model coefficients and simulation settings are based on rigorous statistical analysis using ship movement data, extracted from the Automatic Identification System(AIS) installed onboard the ocean-going vessels. In this way, this emission model can aid the decision-making process for the port management authorities, and can be widely applied to other geographical regions with adjustments in local emission parameters.

Methods

The System Dynamic model is constructed using the VENSIM simulation software.

In the beginning, an Emission Accounting model has been established based on massive AIS data for ship activities within the Singapore territory in the year of 2016. Referring to this model, the primary equations and data are integrated in the VENSIM model to construct the base year scenario.

After that, several runs of simulations should be applied to test different scenarios. Firstly, this paper depicts the effects of speed reduction on port emission mitigation. Secondly, this study examines to which degree berth time reduction policies can be translated into emission reduction. Thirdly, for future port expansion and changes in transportation density, this model illustrates how the emission density and the spatial distribution will change accordingly. By adjusting the settings and parameters of the VENSIM model, the forecast results can be obtained and visualized.

ArcGIS is used to visualize ship movements and the specific emission density under each scenario.

Results

Firstly, we identify the trade-off of speed reduction within the port area. On one hand, it helps to reduce ship emission generated in the maneuvering mode and the cruising mode. On the other hand, it extends the hoteling time within port area, which may further increase the pollutants generated from auxiliary engines and boilers. In total, the pollution increments in the hoteling mode could be even higher compared with the decrements in the other two dynamic modes.

Secondly, various strategies for berth time reduction may have diverse effects on emission mitigation. Generally speaking, decreasing the hoteling time will lead to a significant emission reduction.

Thirdly, we visualize the future changes in the emission spatial distribution diagram. In particular, as more ship operations are consolidated to Tuas (in the west of Singapore), the emission density will also change accordingly.

Conclusions

On a global scale, more emission studies have been focused on Europe, United States, Australia and China. Limited attempts were found for the rest of the world, especially the ASEAN countries. Hence, this study can narrow such a literature gap by presenting a comprehensive model for Emission Accounting and emission management.

For ship segment, compared with the dry bulk ships and tankers, the emission analysis on container vessels are of higher accuracy given the higher quality and better availability of ship movement data.

For pollutant type, CO_2 occupied a very large proportion in the total emissions. However, mitigation measures tend to have more significant effects on reducing SO_x, NO_x and Particular Matters (PM).

In the future, the effects of weather, sea conditions and vessel trims should also be considered so as to further improve the accuracy of emission analysis.

This paper can contribute as a pioneer emission study on Port of Singapore, starting from Emission Accounting, followed by emission management strategies, and finally concluded with evaluations of different strategies and forecasts of future emissions. Furthermore, this model has great potential to be generalized and applied in other Emission Management projects around the world.

References

Ascui, F., Lovell, H. (2011): "As Frames Collide: Making Sense of Carbon Accounting". 24 (8), 978-999.

Goldsworthy, L., & Goldsworthy, B. (2015): "Modelling of ship engine exhaust emissions in ports and extensive coastal waters based on terrestrial AIS data–An Australian case study". Environmental Modelling & Software, 63, 45-60.

IMO (2015): "Third IMO Greenhouse Gas Studies 2014". International Maritime Organization, London
Imoorg. (2016). AIS transponders. Retrieved from: http://www.imo.org/en/OurWork/safety/navigation/ais.aspx

IPCC (2007): "Climate Change 2007: Synthesis Report". Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

Koto, J., & Rashidia, M. (2014): "Prediction of CO_2 Emitted by Marine Transport in Batam-Singapore Channel using AIS". Jurnal Teknology, 69(7), 121–126.

Leong, S. C., Hargreaves, C., Singhal, P., & Yuan, J. (2014): "Estimation of CO_2 Emission from Marine Traffic in Singapore Straits Using Automatic Identification Systems Data". In Environmental Science and Information Application Technology: Proceedings of the 2014 5th International Conference on Environmental Science and Information Application Technology (ESIAT 2014), Hong Kong, November 7-8, 2014 (p. 177). CRC Press.

Mjelde, A., Martinsen, K., Eide, M., & Endresen, Ø. (2014): "Environmental Accounting for Arctic Shipping–A Framework Building on Ship Tracking Data from Satellites". Marine Pollution Bulletin, 87(1), 22-28.

Saputra, H., Muvariz, M. F., Koto, J., & Satoto, S. W. (2015): "Estimation of Exhaust Ship Emission from Marine Traffic in The Straits of Singapore and Batam Waterways Using Automatic Identification System (AIS) Data". Jurnal Teknologi, 77(23), 47–53.

Spiro, P.A., Jacob, D.J., Logan, J.A. (1992): "Global Inventory of Sulfur Emissions with 1° × 1° Resolution". Journal of Geophysical Research. 97(5), 6023-6036

Wang, H., Liu, D., & Dai, G. (2009): "Review of maritime transportation air emission pollution and policy analysis". Journal of Ocean University of China,8(3), 283-290.

Winther, M., Christensen, J. H., Plejdrup, M. S., Ravn, E. S., Eriksson, Ó. F., & Kristensen, H. O. (2014): "Emission Inventories for Ships in the Arctic Based on Satellite Sampled AIS Data". Atmospheric Environment, 91, 1-14.