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Ship emissions and their externalities in cruise ports

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ABSTRACT

This paper presents an estimation and analysis of ship exhaust emissions and their externalities in the popular cruise destinations of Dubrovnik (Croatia) and Kotor (Montenegro) along the eastern coast of the Adriatic Sea. To this extent, the recent record (2012–2014) of cruise ships calling at these ports is used to model and estimate the ship exhaust emission inventories and externalities within the associated bays and ports.

The results indicate that cruise ship traffic produces continuously increasing air pollution in both ports over recent years. More importantly, however, the analysis of the ship operating characteristics reveals that for any given ship traffic involving specific vessels using marine fuel of a given quality, the presence of other factors (e.g. berth availability, berth accessibility etc) can also influence the ship emission levels. This is particularly evident in the case of the port of Kotor where berth space insufficiency dictates the need for ship anchorage thus leading to increased air pollution and costs of associated damage.

The application and results of the aforementioned ship activity-based methodology to the ports of Dubrovnik and Kotor improves our understanding of ship emissions in cruise bays and ports, and contributes toward the implementation of port policies for the effective control of air quality in such environmentally sensitive locations.

Introduction

Within the general challenge of controlling the exhaust emissions produced by ships, navigation in bays and ports has attracted over the last decade increasing attention due to the significance of air pollution on the natural and built environment of coastal regions. The ability to reliably model, estimate and analyze ship emissions in these regions and particularly in ports is a fundamental prerequisite for exploring the feasibility of adopting supplementary emission control measures beyond those dictated by the regulations for the prevention of air pollution from ships under the international framework of Annex VI MARPOL 73/78 and at European level according to the provisions of Directive 2012/33/EU.

For the navigation in ports, the structure of the emission modeling methodology relies on the distinction of the various activity phases performed by each port-calling ship and the emission estimation utilizes real and empirical data with regard to the operating characteristics of each ship during its approach, stay and departure from the port. Over the last decade, representative research of this approach constitutes the work of Saxe and Larsen (2004) for three Danish ports, Yang et al. (2007)

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for the port of Shanghai and De Meyer et al. (2008) for four Belgian ports. Most recently, Deniz et al. (2010) and Deniz and Kilic (2010) addressed the issue of ship emissions for Candarli Gulf and the port of Ambarli, in Turkey, respectively. Hulskotte and Denier van der Gon (2010) estimated ship emissions at berth in the Port of Rotterdam, Yau et al. (2012) and Ng et al. (2013) for the port of Hong Kong, whilst Chang et al. (2013) and Song and Shon (2014) addressed the Korean ports of Incheon and Busan, respectively.

Furthermore, the in-port ship activity constitutes the basis for modeling the evaluation of the air pollution damage caused by ships in ports, as applied by Tzannatos (2010a) for the passenger and cruise terminal of the port of Piraeus in Greece. Similarly, the work of Chang and Wang (2012) compared the techno-economic effectiveness of ship speed reduction and shore-side electricity in lowering the ship emissions in the port of Kaohsiung in Taiwan, whilst Berechman and Tseng (2012) evaluated the emission damage of ships and trucks for the same port. Most recently, the ship activity-based approach was applied by McArthur and Osland (2013) for the evaluation of the emission damage in the port of Bergen, by Castells Sanabra et al. (2014) for the Spanish port network, by Song (2014) for the Shanghai Yangshan port and finally by Tichavska and Tovar (2015a) for Las Palmas Port.

Taking into account that cruise vessels because of their high propulsion and hoteling energy requirements are the most fuel demanding amongst all ship types (Howitt et al., 2010) and cruise destinations by virtue of their natural and cultural attractiveness are highly sensitive to air pollution, the assessment of ship emissions produced in ports of high cruise activity has attracted particular attention. More specifically, cruise ship emissions in ports has been the focus of the work by Maragkogianni and Papaefthimiou (2015) for five Greek ports evaluating the external costs of air pollution, Tichavska and Tovar (2015b) for ferry and cruise vessel air pollution in Las Palmas Port, Poplawski et al. (2011) for the impact of cruise ships in James Bay at Victoria, Canada, and finally by Tzannatos (2010a,b) for the emission inventories, externalities and control options associated with the cruise and ferry operations within the main port of Piraeus.

The aforementioned research work generally covers the estimation of the ship emission inventories whilst in port, the evaluation of their associated damage costs and the examination of their control through the use of low-sulfur fuel, the installation of scrubbers or the provision of shore-side electricity. However, with regard to ship emission control, it is important to note that the level of engine exhaust emissions is primarily dependent upon the fuel consumption during the various phases of ship activity. This is particularly important for cruise ships because as opposed to cargo vessels they need to constantly produce adequate power to support the high demand for the provision of their onboard hoteling services and whilst in port they opt for self-reliance in covering the power requirements for maneuvering, berthing or anchoring in order to avoid the additional costs which an external assistance for such frequent operations would incur. Ease of maneuvering, berthing or anchoring, as well as berth availability influence the fuel consumption and hence the level of ship emissions whilst in port. Therefore, port traffic vis-a-vis port basin features and facilities is a critical factor of ship exhaust emissions in cruise ports and the need of further investigation on this issue is fully justified.

It is within this background of research interest, regulations and practices for controlling the ship emissions in ports that Dubrovnik and Kotor are considered to be a suitable reference for conducting a ship activity-based research on ship emissions in an effort to enrich the relevant knowledge and experience beyond the issues addressed by the currently available research literature. More specifically, in the current case, the ship activity-based approach is utilized to capture and analyze on a comparative basis the influence of the ship operational factors in the two ports. Although by vitrue of their vicinity the ports are exposed to similar cruise market characteristics within the Adriatic and Eastern Mediterranean region, they have distinct port calling demand and port characteristics which can affect the emission inventories and their externalities, as well as the control of the produced air pollution. In terms of the port importance, the Adriatic hosts currently the second (after the West Med.) cruise market within the Mediterranean, accounting for nearly 22% of all port calls (MedCruise, 2015). Dubrovnik is the third Mediterranean cruise port in terms of calls (following Civitavecchia and Barcelona) and Kotor occupies the 13th place, whereas they are the first and fourth busiest ports of call within the Adriatic–Ionian region, respectively.

The structure of the paper is as follows. The first section presents and compares the port characteristics and practices, as well as the ship traffic data in both ports. The methodology for estimating ship emissions and their externalities is explained in the second section. The following section reports the results of emission inventories, related externalities results and alternative scenarios in the case of the port of Kotor. Concluding remarks are included in the last section.

Cruise shipping in Dubrovnik and Kotor

Adriatic gates and routes contain more than twenty cruise ports with almost five million passenger movements based on the report from ASF (2015), where is Croatia a second ranking country by achieved cruise traffic with 1247 port calls while Montenegro hits the fourth place with 353 calls in 2014. Dubrovnik and Kotor have diverse cultural-historical attractions and are a part of UNESCO World Heritage (Carić, 2015; Carić and Mackelworth, 2014; Carić et al., 2014).

Over recent years, Dubrovnik has become a leading Croatian cruise port with more than 500 port calls involving more than 700,000 visiting passengers per year. As shown in the port layout of Fig. 1, this trend followed the various stages of port development through the recent reconstruction of berth facilities of more than 1 km in length (berths 8–12) and a depth of 11 m capable of accommodating more and larger cruise ships (DPA, 2014), whilst plans for further berth extensions are also

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