OXFORD ECONOMICS

ENVIRONMENTAL IMPACT OF CRUISE TRAFFIC WITHIN BARCELONA

REPORT PRODUCED FOR: CRUISE LINES INTERNATIONAL ASSOCIATION

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EXECUTIVE SUMMARY

- **University Rovira i Virgili (URV) researchers have developed a predictive machine learning algorithm to accurately and precisely isolate the impact of cruise ship activity on the pollution levels in metropolitan areas.** This innovative methodology has been applied to a study of the impact of cruise ships in Barcelona.
- **66 cruise ships would need to dock in Barcelona simultaneously to lift mean NO_2 concentrations to levels deemed "Poor" by the European Environment Agency (EEA).** Similar results were found for other air pollutants, suggesting that cruise activity alone is not capable of producing unhealthy air quality in these destinations, which is supported by other recent studies that have found residential activity and other local factors to be greater determinants of air quality.
- **Future development of environmentally friendly technologies, such as the transition to cleaner fuels, increased Onshore Power Supply (OPS) availability, and energy efficient ship designs, are expected to further mitigate the impact of cruise ships on the local environment.**

INTRODUCTION

The energy intensive operations of cruise ships, which encompass hoteling and transportation, are often scrutinized as a major contributor to local air pollution, particularly in port cities. Key focus is on the production of nitrogen dioxide (NO_2), sulfur dioxide (SO_2), particulate matter (PM), and carbon monoxide (CO), due to their harmful effects on human health. Recent environmental developments have heightened the recognition of the need to curtail air emissions, and the cruise industry's position in the tourism and maritime shipping sectors afford it a prominent role in the environmental movement.

Cruise ships operate as floating cities, providing passengers with hotel, catering, and entertainment services. These non-transportation activities have substantial energy requirements, which continue while docked. Such energy intensive operations raise the potential for subsequent air emissions to impact local areas. Since cruise ships share space with a variety of ships at port, separating their environmental impact from other marine vessels as well as other emission contributors in the cities, such as flights and automobiles, is vital in order to quantify the realized impact of cruise ships on the local air quality.

Researchers pioneer novel methodology isolating the impact of cruise ships on air quality in Barcelona.

Researchers at the University Rovira i Virgili (URV) in Tarragona, Spain have pioneered a predictive machine learning model to disentangle the air pollution impact of cruise ships from other urban effects, overcoming some of the inherent error in traditional approaches due to difficulties in precisely reconstructing a natural hydrodynamic field and pollutant characterizations. This innovation allows for each pollutant source's direct impact on the local air quality to be isolated, including cruise ships, eliminating extraneous concurrent factors. This report will delve into the results of these recent studies, the environmental impact of cruise ships in Barcelona, and advancements of the cruise industry in furthering its environmental goals.

NEW CRUISE IMPACT STUDIES

3.8%

Increase in NO_2 level above mean concentration per additional cruise ship

As measured at Barcelona's Ciutadella station

The novel machine learning methodology laid out in Fabregat et al. (2021) was utilized in separate studies examining the air quality in Barcelona[1]. This location was selected due to data availability and the level of cruise ship traffic its port receives. While this study incorporated pollution readings from multiple monitoring stations throughout the city, not all stations are designed to track the same pollutants. Thus, the geographic coverage within Barcelona is not uniform for all pollutants. However, the results of the study found that while cruise ships do contribute to the levels of most air pollutants, it is often negligible and not a determining factor in pushing pollution to unhealthy levels.

Each additional cruise ship registered an increase of 3.8% in the mean concentration of NO_2 at the nearest monitoring station to the port in Barcelona (Ciutadella), where the cruise emissions were among the highest.

[1] Fabregat et al., 2021

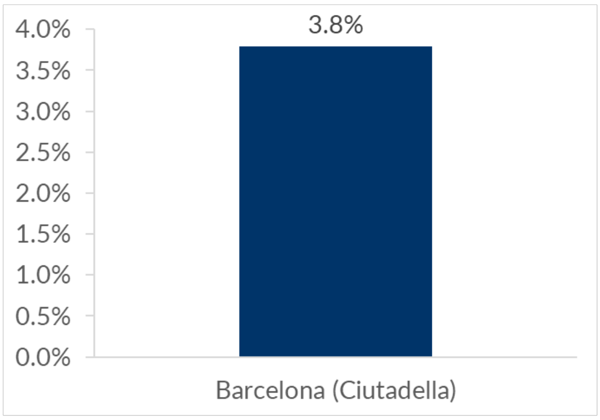
0.15%

Largest expected increase in mean CO levels at a monitoring station per additional cruise ship

Across all monitoring stations in a range of port cities

Marginal impact of cruise ships on NO_2

Average % change in concentration from mean

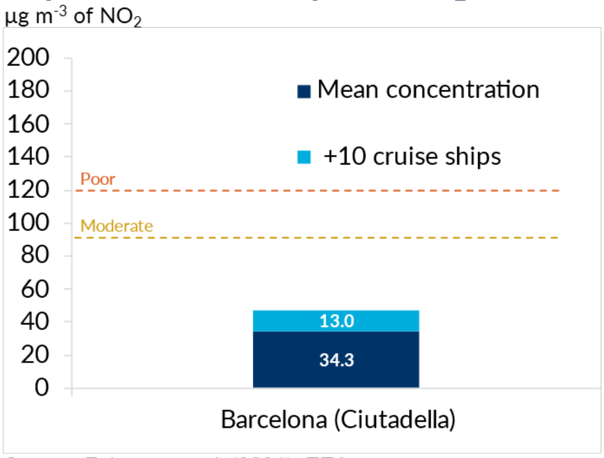


Source: Fabregat et al. (2021)

The mean NO_2 concentration in Barcelona (34.3 µg m3) is well within what the European Environment Agency (EEA) deems as “Good” as per its Air Quality Index (AQI). An additional 10 cruise ships would push it into low “Fair” territory (AQI bands are “Good”, “Fair, “Moderate”, “Poor”, “Very Poor”, “Extremely poor”). At the Ciutadella station – the port station with the greatest percentage increase in NO_2 levels per additional cruise vessel – 66 simultaneously docked ships would be needed to push the mean NO_2 value to an AQI reading of “Poor” (the level at which it is advised for “sensitive populations” to consider limiting outdoor activities). Such a volume of cruise ships is well beyond Barcelona’s current cruise port capacity.

Impact of cruise ships on NO_2

µg m^{-3} of NO_2



Source: Fabregat et al. (2021), EEA

Similarly, the predicted impact of cruise ships in this study on SO_2 and PM_{10} fails to be a significant enough factor on its own to result in unhealthy Air Quality Index readings. In Barcelona, 55 simultaneously docked cruise ships would be needed to reach a mean PM_{10} reading that the EEA classifies as “Poor.” The predicted impact of an additional cruise ship on the SO_2 readings in Barcelona indicates an impossibly large number of simultaneously docked cruise ships (8,000+) would be necessary to lead to the air quality deteriorating to a level deemed “Poor” by EEA’s Air Quality Index.

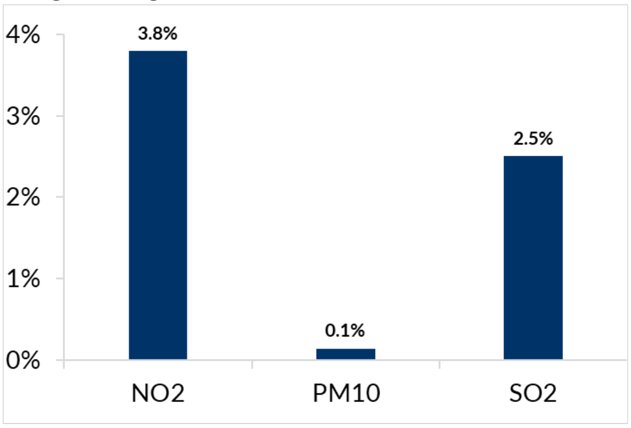
2.6%
Share of NO_x linked to maritime in Bordeaux.

57% comes from road activity.

Overall, cruise ships were not found to have a discernible impact on the mean level of CO, on average. For the other pollutants examined (NO_2, SO_2, and PM_{10}), the average percentage increase at local monitoring stations of an additional cruise ship vessel was 2.5% for SO_2, while increases in NO_2 and PM_{10} on the same basis were 3.8% and 0.1%, respectively.

Marginal impact of cruise ships at local stations

Average % change in mean concentration



* PM_{10} and SO_2 data not collected at Ciutadella monitoring station in Barcelona.
Source: Fabregat et al. (2021), Tourism Economics

Compared to other modes of transportation modeled the average SO_2 contribution of one additional cruise ship was found to be within the margin of error as one additional ferry, flight, other marine vessel, and 100 cars.

Several studies have found that local activity, rather than cruise activity, to be the driving factor in poor air quality. Atmo Nouvelle-Aquitaine – a regional air observatory certified by the Ministère de la Transition Écologique – found the main factors influencing air quality in Bordeaux were nearby road traffic, residential activity, and the rail sector.[2] Congruently, in a 2019 air quality impact assessment in Juneau (Alaska), the Alaska Department of Environmental Conservation (ADEC) found that notable effects on $PM_{2.5}$ levels from cruise ships dissipated within two hours. Instead, wildfires and local activity – such as construction, grilling, and bonfires – had more pronounced impacts on air quality and visibility.[3]

85%
Fewer NO_x emissions from LNG

And virtually zero sulfur emissions

Future implementations of the URV researchers' model are intended to incorporate adequate data on electricity consumption to account for residential emissions, as well as industrial and agricultural sources. The advancements in environmentally friendly technologies for the cruise industry and the pace of implementation is expected to lead to further mitigating the impact of cruise ships on the air quality of the port cities they visit.

TECHNOLOGICAL PROGRESS

The cruise industry continues to demonstrate a commitment to the development and application of environmentally responsible technologies, policies, and practices. Cruise lines remain at the forefront of investing in and adopting responsible environmental practices and innovative technologies, which benefit the entire

[2] Atmo Nouvelle-Aquitaine, 2018
[3] DEC – Alaska, 2021

maritime industry. Key approaches being utilized to improve the environmental performance of cruise ships include implementing more sustainable specifications for new-build ships, retrofitting ships in operation to replace and improve technologies, and investing in a variety of onboard and portside green technologies, as well as cleaner fuel sources.

Presently, Liquified Natural Gas (LNG) is the primary alternative fuel source being utilized due to its strong environmental performance, growing land-based infrastructure, and established technological viability. Burning LNG produces virtually zero sulfur emissions, 85% fewer nitrogen oxide emissions, 95-100% fewer particulate emissions, and the industry estimates up to 20% fewer greenhouse gas (GHG) emissions than heavy fuel oils. Cruise ships on order or under construction that rely on LNG propulsion comprise 52% of new passenger capacity.[4] With the objective of further reducing carbon intensity, current research initiatives are exploring the long-term viability of biofuels, ammonia, hydrogen, other alternative fuels, fuel cells, and battery power on cruise vessels.

Since its inception as a maritime fuel, LNG has provided substantial reductions in air emissions but has also entailed the risk of methane slip – producing an impactful greenhouse gas – occurring from gas leaking or from fuel that fails to burn during the combustion process. Engine manufacturers across the industry are pushing technology developments to upgrade existing engines to increase accessibility and speed up the transition to the latest innovations, including ones that correct for methane slip. For example, Wärtsilä, a Finnish-based leader in innovative marine technology manufacturing, has continuously honed its engines to reduce the risk of methane slip, with the latest engine generations achieving a 20% improvement over its predecessor.[5] In addition to developing new low-carbon fuel options, enhancing existing technologies offers the cruise industry opportunities for rapid gains in eco-friendliness to meet short- and medium-term goals.

Ships will also benefit from advancements and diversification in port energy supply. Onshore Power Supply (OPS) will enable ships to turn off engines while at port and use more efficient local power systems. Corbett and Comer (2013) estimated that the implementation of OPS in the Port of Charleston (USA) would reduce emissions using the same fuel mix for the electrical grid as in 2011, of which coal consisted of 48% of the fuel. Transitioning the electrical grid to less dependency on coal and greater reliance on clean fuels would result in even greater emissions reductions.[6] Expanding the availability of high-wattage power sources at ports globally and utilizing municipal grids run on renewable energy will increase benefits.

CONCLUSION

The necessary tools to accurately measure and analyze cruise-related pollution are a recent technological innovation and further refinements could yield more insights. Due to the challenge of monitoring all direct pollution sources in order to distinguish the impact of cruise ships from alternative sources, proxies for other pollution-causing activities are commonly used. Gaseous diffusion makes measuring direct emissions a complex undertaking, thereby requiring expensive yet limited technology to isolate cruise-specific emissions. Varying equipment standards and geographical coverage

[4] Molon and Sacks, 2021

[5] Wärtsilä, 2023

[6] Corbett and Comer, 2013

of measuring stations used in the collection of data across studies present potential error in the accuracy and precision of readings and inequitable comparisons. Data collection consistency is also susceptible to fluctuations in local weather conditions.

Future research will shed light on the progress made by cruise ships. The ability of advanced machine learning techniques implemented in Fabregat et al. (2021) to extract the effect of cruise ships' emissions from overall port effects presents a valuable template that utilizes big data to accurately measure the environmental impact that can be replicated in additional locations. Their results for Barcelona indicate that pollution concentration levels are not highly influenced by cruise activity, but rather other localized factors, and when isolated from extraneous effects, cruise ship emissions do not significantly alter local air quality. The impact from cruise ships' presence alone does not appear to be significant enough to elevate AQI readings to unhealthy levels. Rather, some evidence suggests that emissions from other nearby activities, such as road traffic or residential activity, are more consequential to the local air quality.

Constructing panel data series through prolonged high-quality air quality monitoring can highlight changes in performance after new regulations and technologies have been introduced. Quantifying reductions brought about by the transition to cleaner fuels, increased OPS availability, and implementation of enhanced, energy efficient ship designs can inform policymakers and the public of the sources of environmental degradation, the expected returns on investment of these enhancements, and the areas of potential improvement in the goal of preserving local environments.

The continued improvement in data collection and analysis technology will allow for a better understanding of the effect of cruises on the air quality of ports. Coupled with increasing global sustainability reforms and more energy efficient technology, cruise ships will be able to lessen their environmental impact on the communities they visit even more so. While the cruise industry continues to strive towards reductions in emissions, the scientific literature indicates that the current impact of cruises on local air quality has been curbed through prior initiatives and is modest in nature.

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The modelling and results presented here are based on information provided by third parties, upon which Oxford Economics has relied in producing its report and forecasts in good faith. Any subsequent revision or update of those data will affect the assessments and projections shown.

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