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Analyzing external environmental costs of cruise traffic in the port of Split

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Abstract

This paper analyzes the external environmental costs and revenues of cruise traffic in the port of Split in 2015. In order to explore the perspectives of increasing the current mode of cruise traffic in the future, results were compared with those previously known for the port of Venice. The use of the same research methodology was an important condition for this comparison. The cruise tourism business has a negative balance sheet when comparing the costs and revenues in both cities: the external costs are higher than the revenues. Growing cruise traffic leads to further growth of the external costs, deepening the negative cost-benefit ratio. Valorization of damage is a sensitive topic which conflicts with the interests of various parties but is also an important factor in the apparent unsustainability of the current mode of cruise tourism. The authors want to highlight the similar problems of the two cities and encourage the authorities to implement the necessary controls to limit such damage.

Introduction

External costs in the transport sector are the costs of damages produced by the transport business which are not covered by stakeholders but which burden the whole society. They are generally divided into environmental costs and the costs of traffic accidents and congestion. Internalization of external costs presents the set of state policy measures by which they are valued and charged. According to transport policy in the European Union, every member country has a duty to control emissions and limit transport damage within well-defined deadlines (White Paper, 2011). There is, accordingly, a need to mark and avoid the modes of transport with the greatest external costs, replacing them with ecologically more acceptable ones.

The external costs in maritime transport are well known and are regularly monitored (Sieber & Kummer, 2008). The study of external costs in cruise traffic is particularly interesting and important today. In the last ten years, cruising was booming with an annual increase of 10–15 % (Rodrigue & Notteboom, 2013). Benefits of cruising in top cruise destinations (Barcelona, Venice, Dubrovnik) are often suspect if the external costs are calculated or estimated and not internalized. This paper will show the external costs of cruise traffic in the port of Split, which is the third top cruise destination at the Adriatic Sea and has become an important cruise destination in the Mediterranean (Horak, 2007).

As usual in maritime transport, the external costs of cruise ships can be regarded as air pollution, sea pollution and the impact on the climate as well as noise, dredging, and accidents. All but accidents belong to the category of environmental damage. Air pollution occurs through emissions that cause an increased concentration of SOx (sulfur oxides),

NO_x (nitrogen oxides), $PM_{2.5}$ (particulate matter), PM_{10}, NM/VOC (non-methane volatile organic compound), CO (carbon monoxide), and CO_2 (carbon dioxide) emissions, damaging human health and contributing to the greenhouse effect and climate change. Sea pollution occurs through the spillage of solid and liquid waste. Liquid waste includes bilge, gray water and black water, which are especially pronounced in cruise ship traffic (Molocchi, 2006). Due to the rarity of accidents in maritime traffic, their external costs may be neglected, but congestion costs of cruise tourism must be added.

Objectives

The methodology of calculating external costs is often the subject of dispute and the most common reason why the results of studies cannot be compared. This paper will put special emphasis on the methodology, the calculation will be made according to the model of calculating external costs of the cruise traffic in Venice (Tattara, 2014), and any deviation from the methodology will be explained in detail. The results will be compared with those made for the port of Venice. The revenue of the cruise traffic in the city of Split will also be estimated. It will be compared with the external costs and the results will be discussed. There is an intention to consider if it is really worthwhile to increase the cruise traffic or if it should be developed under special conditions.

The data on cruise traffic in the port of Split for 2015 are taken from Split Port Authority as well as the price list of the port charge (Split Port Authority, 2016). They were processed using standard, accepted values from the current literature in order to perform a cost-benefit analysis. Considering the relation to external costs, the benefits have been understood only as the revenue, neglecting other indirect indicators in the observed period.

Research methods

The calculation of air pollution was made after an estimation of fuel consumption. All kinds and quantities of air pollutants are produced during fuel combustion depending on the kind of fuel and characteristics of the engine (Miola et al., 2009). The fuel oil consumption is divided into three periods. The cruise period is the period from when the cruise ship enters the coastal seas until it slows down in front of the port. The cruise ships mostly approach the port of Split from W/SW passing 18 NM of coastal seas from Cape of Ploca to Cape of Ciovo. The transit period reflects the period when the ship enters the port, slows down and changes the kind of fuel it uses. This occurs at a distance of 2 NM, from Cape of Ciovo to the port of Split. The approach from S includes navigation through the coastal seas of the islands Vis, Hvar, and Brac, but the distance from Canal of Vis and the west axis of Cape of Ciovo is the same for the cruise period (18 NM) while the transit period is shorter (1 NM). This slight difference in the transit period was neglected. The hoteling period is the period at berth. The calculation is made for a cruise ship of 69 000 GRT (gross register tonnage), capacity of 1500–2000 passengers and 700 crew, with main engine power of 36.01 MW, auxiliary engine power of 9.70 MW, and speed of 21 knots. The model of investigation is the same as in Tattara (2014) for the port of Venice representing a typical cruise ship that visits both ports on the same route; therefore, the results of the two studies are comparable. The modes of the engines and the kind of fuel used (with different sulfur content) in the three periods are shown in Table 1.

Table 1. Modes of used engines and kind of fuel in each period (Tattara, 2014)

Mode	Main engine (%)	Auxiliary engine (%)	Kind of fuel oil (%S)
Cruise	80	30	BFO** (3.5)
Transit	40	50	MDO*** (0.1)
Hoteling	20 (max. 2.5 h)*	60	MDO (0.1)

* A quarter of total time at berth;
** bunker fuel oil (HFO equivalent);
*** marine diesel oil (distillate).

The specific emissions rate according to MARPOL Annex VI Tier 2 standards valuable until 2016 (IMO, 2008) for fuel optimized engines prepared to reduce emissions are shown in Table 2.

Table 2. Specific emissions rates for main (ME) and auxiliary (AE) engines, g/kg of fuel oil, 1% S (Kristensen, 2012)

Emission	ME	AE
CO_2	3206.00	3206.00
NOx	50.30	50.30
CO	2.62	2.62
HC*	2.62	2.62
Particulates	2.30	2.30
SO_2	21.00	21.00

* hydrocarbons

The emissions depend on many factors such as the fuel oil sulfur content, type of engine, the speed of engine or RPM, and systems used to reduce them (e.g. fuel optimized engine) (Merk, 2014). According to Lloyds Register (1995), the SO_2 emissions are modelled according to the formula:

$$21 \cdot S\,(\%) = SO_2\ (\text{g/kg or kg/t}) \quad (1)$$

for the actual sulfur content in the fuel oil (S in percentage). Particulates (PM) are modelled according to the formula:

$$\text{Particulate emission factor in g/kWh} = 0.26 + 0.081 \cdot S\,(\%) + 0.103 \cdot S^2\,(\%) \quad (2)$$

Sometimes, it is better to calculate the emissions per unit of engine power (e.g. PM emission). For marine diesel engines, the variation in steady-state mode is as shown in Table. 3.

Table 3. Emission factors from the combustion of residual oil and marine distillates, sea mode, in g/kWh (Winnes & Fridell, 2009)

Fuel	PM	NOx	HC	CO_2	SO_2
HFO (No. 6)	0.42–1.25	14.00	0.50	677.00	11.50
MDO	0.33*	13.20	0.50	645.00	1.00–4.10

* Factor for distillate oils at sea mode is one-third of emissions during maneuvering

An average value of specific emissions of PM for marine distillates, that disregards any dependence on engine load, results in an emission factor of 0.33 g/kWh with a standard deviation of 0.15. A corresponding emission factor for HFO (heavy fuel oil) is 1.34 g/kWh with a standard deviation of 0.78 (Winnes & Fridell, 2009).

These values are a useful check to confirm that the results are inside the normal distribution. The calculation for every pollutant is checked in this way. The differences in emission rates as a function of engine load are neglected (lower RPM, higher emissions) as well as the differences in fuel consumption between main and auxiliary engines because they are minimal: the value of main engine consumption of 223 g/kWh (Tattara, 2013) was considered in the calculation and is slightly higher than the auxiliary engine consumption (217 g/kWh). The different values for the two types of fuel oil were used in calculations for SOx and PM emissions only.

Table 4. Review of environmental indicators, daily pollution quantities for a cruise ship of 3,000 guest capacity (Carić, 2010)

Environmental indicator	Daily pollution quantity per cruise ship	Daily pollution quantity per cruise guest
Solid waste (kg)	10,500–12,000	5
Air pollution CO_2 (kg/km)	1,203	0.40
Black water (l)	60,000–120,000	40
Gray water (l)	1,020,000	340
Bilge water (l)	30,000	10
Hazardous waste (kg)	390–480	0.16

The calculations of solid and liquid waste quantities were performed using already known data for the cruise ships and cruise guests (TRT, 2007). The quantity of different types of waste produced on a cruise ship is shown in Table 4.

The column showing daily pollution quantity per cruise guest has particular importance because it is an average for the guests on any type of cruise ship. According to Tattara (2013), the value of daily pollution per cruise guest of solid waste is higher by one kilogram.

Results

In 2015, cruise traffic in the port of Split comprised 262 calls with 269,671 passengers in transit. The average period of stay in port was 10.2 hours (Split Port Authority, 2015). The cruise period was estimated at 1 h and the transit period at 0.5 h. The ships Artemis and Athena, with 37 calls and a total of 1611 passengers are excluded from the investigation because they worked in 'home port' mode which was atypical for the port and would have substantially affected the results. The consumption was estimated at €71 per passenger (Horak, 2007), and €25 per crew member (Tattara, 2014). The calculation of fuel oil consumption is shown in Table 5.

The BFO (3.5% S) consumption for 225 calls was 3,181.50 t.

The MDO (0.1% S) consumption for 225 calls was 4,846.50 t.

The total fuel oil consumption was 8,028 t.

Table 5. Calculation of fuel oil consumption per a cruise ship in each mode of engine operation

Mode	Duration (h)	Power calculation (MW)	Total (MWh)	Fuel oil consumption per call (t)
Cruise	1*	$80/100 \cdot 36.01 + 30/100 \cdot 9.70 = 31.71$	63.42	14.14
Transit	0.50*	$40/100 \cdot 36.01 + 50/100 \cdot 9.70 = 19.25$	19.25	4.29
Hoteling	10.20	$60/100 \cdot 9.70 = 5.82$	59.36	17.25
	2.50	$20/100 \cdot 36.01 = 7.20$	18.00	
			160.03	35.68

* Duration of the cruise and transit periods are doubled for arriving and departure

The quantities of pollutants and the external costs of damage produced by cruise ships in the region and port of Split in 2015 are shown in Table 6. The costs per unit (€/t) are taken from TRT (TRT, 2007).

Table 6. Quantities of pollutants (kg, t), current costs (€/t) and external costs of pollutants of cruise traffic in the port of Split and surrounding area in 2015 (€/call)

Pollutant	Cost (€/t)	Ship emissions (kg)			Total (t)	Overall cost (€)
		Hoteling	Cruise	Transit		
NOx	9,500	867.68	711.24	215.79	1.79	17,005
SOx	8,700	36.23	1,039.29	9.00	1.08	9,396
PM	278,200*	62.66		5.20	0.067	18,639
	14,000**		114.16		0.114	1,596
						46,636

* Cost in urban area (PM2.5+PM10)/2; ** Cost in rural area

The calculation of NOx emissions is the most difficult because it depends on more factors than the other emissions. The engine systems applied to reduce these emissions can significantly decrease this value. The control calculation using g/kWh values (Table 3) resulted in a total of 2.24 t of NOx showing a deviation of 20 % or more.

The values of SOx show significant differences in emissions dependent on the type of fuel oil used. The control calculation (Table 3) shows a total of 1.02 t of SOx and with deviation of 5.5 % or less (MDO emission factor 1.0 g/kWh for transit and 3.0 g/kWh for hoteling mode).

The SOx and PM emissions are calculated according to formulae 1 and 2. The control calculation (Table 3) shows a total PM emission of 167.91 kg presenting a deviation of 7 % or less. The PM emission factor for hoteling mode is multiplied by 3 in accordance with the recommendation of Winnes and Fridell (2009). The presented *costs per pollutants* are taken from the program CAFÉ (TRT, 2007) and Tattara (2014) for the port of Venice. There was no need for tugs in the port of Split. The emissions of other pollutants are important but negligible in the light of external costs and the method of their calculation was unclear.

The emission of CO_2 does not depend on the sulfur content of the fuel oil and its specific emission factor for BFO and MDO is the same. In 2015, due to cruise traffic, 114.18 t of CO_2 was released per call in the port of Split and the surrounding area. The size of the damage is very difficult to assess because the cost of CO_2 varies in the range of a couple of dollars up to 220 dollars per ton (Than, 2015). The eco-costs of 1000 kg CO_2 of €135 seems to be correct today (TU Delft, 2012), meaning that in 2015, the total external cost of CO_2 damage due to cruise traffic per call in the port of Split was €15,414.30 or a total of €3,468,217.50 per 225 calls. According to TRT (TRT, 2007), greenhouses gasses make up 1/3 of the overall pollution and this will be taken into consideration in the calculation of total external costs.

The external costs of waste are calculated in accordance with the values of produced waste per cruise guest (Table 4) accepted in current articles (TRT, 2007; Carić, 2010; Tattara, 2014). The input value of time was the sum of the time at berth and twice the time of the transit and cruise periods, giving a total of 13.2 h or 0.55 day. The total number of cruise guests is calculated as 268,060. A value of 147,433 units (guest days) is therefore included in the calculation. The results are shown in Table 7.

Table 7. External cost of all types of waste produced by cruise traffic in the port of Split in 2015 (€)

Indicators	Quantity	Cost per unit	Total (€)
Solid waste (kg)	737,165	0.15 €/kg	110,574.75
Black waters and gray waste waters (l)	56,024,540	0.0089 €/l	498,618.40
Bilge water (l)	1,474,330	0.22 €/l	324,352.60
Hazardous waste (kg)	23,589	1.53 €/kg	36,091.17

Total external costs of different types of waste from cruise traffic in the port of Split were €969,636.92 in 2015. If the same calculation were made with the values presented per cruise ship (Table 4) then the results would have been more than twice those presented in Table 7.

The total of external costs are shown in Table 8. They include the cost of air pollutants, greenhouse gasses (CO_2) and waste. If air pollution and waste together represent 2/3 of the total damage, then 1/3 is attributable to greenhouse gasses, with a cost of €5,731,368.

Table 8. Total external costs from cruise traffic in the port of Split in 2015

Indicators	Per a call* (€)	Total (€)
Air pollutant damage	46,636	10,493,100
Wastes		969,636
Greenhouse gasses		5,731,368
		17,194,104

* 225 calls

Pollutants such as CO, NM/VOC, HC, heavy metals and so on were not taken into account because their roles, due to quantities and prices, are not so important for the calculation of external costs. The same applies to damage from onboard incineration, damage to monuments and damage from dredging. At the cruise ship terminal in Split, the sea depth is 8.2 m, similar to the draft of the largest cruise ship visiting the port. There is no doubt as to whether dredging damage is present or not in the port of Split. Ordinarily, there is no need for tugboats.

The total sum of costs was €17,194,104. Two important notes should be added. Firstly, it is difficult to assess the cost of congestion. In Venice, it was estimated at 50% of cruise tourism revenue (Tattara, 2013). If the same value is used for the port of Split, the total external costs will increase by €9,516,130 to a total calculated external cost of €26,710,234.

The estimation of revenue generated by cruise traffic for the city of Split in 2015 is shown in Table 9.

Table 9. Revenue from cruise traffic in the port of Split in 2015

Revenue of consumption	Consumption (€/guest)	€/ship	€/transit guest	Total
Cruise guests	71			19,032,260
Crew*	25			1,968,750
Revenue of ship**		4899	0.95	1,356,932
				22,357,942

* Half of a crew stays on board
** Tariffs of port dues, Split Port Authority, 2016

The calculation was made for 225 calls, 700 members of crew per a call and a total of 268,060 passengers.

Secondly, some other port authority services and taxes, as well as discounts and price increases, are not taken into account because they do not substantially affect the total sum. Consumption in the form of urban transport and excursions made by some tourists are also not included, neither are their associated external costs.

Discussion

The cruise tourism business in both cities, Venice and Split, has a negative balance sheet comparing their costs and revenues: the external costs are higher than the revenues. The results are better for the city of Split: each euro of revenue produces €1.2 of the external costs. In Venice, the ratio is 1:1.5 (Tattara, 2014).

There are several possible reasons for this: longer duration approaches to port, the need for a tugboat and longer stay time in the port of Venice (10.2 versus 19.5 h in average). The estimation of the consumption per guest in Split could also affect the final results if it is assumed to be too high (71 €/per a guest); however, another argument is that maybe this figure is too low in Venice (79 €/per a guest).

There is no doubt that cruise ships produce some environmental damage, but the dispute is over the amount of damage. The valorization of damage is a sensitive topic presenting conflicts of various interests. The cost attributed to pollutants is one of the key points.

The measurement of CO_2 pollution in kg/km, €/km or kg/km per cruise guest is not suitable at all. This emission is a product of fuel combustion no matter whether moving the ship or the guests on it. Including these kinds of values enables exaggeration or underestimation of the scale of air pollution and its importance. It is also related to the damage assessment where it enables significant misinterpretation of the results.

Controversies regarding the costs of CO_2 make the air pollution problem more confused (Vogtlander et al., 2009). When such calculation is connected to climate changes, which has been already burdened with the uncertainty, then the doubts grow even more. Not only for CO_2 emissions, but for every pollutant or waste, the costs cannot be the same in the urban, rural or uninhabited areas (e.g. open sea). We have seen already the enormous differences in the costs of PM emissions between different areas (from 5300 €/t at sea, to over 14 000 €/t in rural areas and several hundred thousand Euros per ton in the urban environment) (TRT, 2007). Although pollutants cause environmental damage globally, a distinction should be made between their importance when they directly threaten human life and when they affect nature or the climate over time. In these different marginal costs, one can see the argument to move ports outside of urban centers; however, a visit to the historical and cultural attractions, such as urban centers and old ports, reflects the essence of cruise tourism. Standardization of the costs of pollutants is very important for their internalization as well as for comparing the results of investigations.

The benefits of cruise tourism do not lie only in pure revenue; however, when external costs are significantly higher than the revenue of a certain business, the price of such capital is very high (20–50% higher than pure revenue in these cases). The total benefits should be discussed in a future investigation.

The methodology of investigation is probably the most important factor for the credibility of results. In this study, the control results showed a variation of 20% although the values of fuel consumption and pollutant emissions were previously validated. If the calculations had been made in terms of €/km or quantity of waste per cruise ship then the sum of the external costs in this study would have been higher by half. Discussing the quality of units used to express the results of the investigation the authors can highlight a level of credibility in the results. Standardization of the methodology is also a task for future research.

The ship at berth produced 93.52% of the total PM, 48.60% of the total NOx and 48.35% of the total CO_2 in the port of Split and surrounding area. By using, exclusively, electrical energy in the port it would not contribute to air pollution during the hoteling period. The port authority has the possibility of selling electricity and saving the ships' fuel at the same time. There is also a possibility that ships could use MDO during the cruise period. In this period the cruise ship produced 96.23% of the total SOx. By using 0.1% MDO, the SOx emissions calculated in this research would decrease from 1.04 t to 29.70 kg. Sulfur content in the fuel oil directly influences the level of PM emissions and indirectly influences the level of NOx emissions. The possible financial savings are significant only in regards to decreasing CO_2 emissions which prevail in the costs but do not depend on the sulfur content of the fuel oil. However, the impacts of air pollutants on health are well known and their removal from the urban center is a more important task.

Increasing cruise traffic will produce further growth of the external costs, deepening the negative cost-benefit ratio. The results of investigations should be considered in the planning of future developments, accepting the ideas and recommendations for current cruise tourism to become sustainable. Scientists will have to make the effort to accept a common method of calculating external costs in order to generate unique and credible results.

Conclusions

The external costs were 20% higher than the revenue generated by cruise tourism in the city of Split in 2015. Considering the methodology, the quality of input data and the estimates made, the real external costs are probably even slightly higher. The same cannot be said for the income that was objectively assessed in the maximum amount. Referring to the recent literature, the results are evaluated as expected. This study was performed by the same method and is therefore comparable with the results of the study in Venice which shows similar problems and consequences of the increasing cruise traffic. The experiences from both cities should encourage the authorities to implement the necessary strategies to limit damage.

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