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Reduction of CO_2 emissions with automatic mooring systems. The case of the port of Santander

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A B S T R A C T

The revolutions in the maritime industry resulting from the implementation of integrated transport systems (bulk) and containerization (regular lines) at first had little effect on traditional mooring systems for ships in port. However, the research into innovation in automated mooring systems with increasingly advanced technologies carried on regardless.

The so-called "Automatic Mooring Systems" (AMS), automatic systems that allow vessels to be moored without ropes, are being increasingly implemented in numerous ports in many different countries in the world, particularly in those whose traffic volumes have allowed the threshold of profitability of these infrastructures to be reached. But besides the financial benefits, the implantation of the AMS is having positive effects on the environment by reducing CO_2 emissions in many commercial ports.

The present work aims to measure for the first time the reduction in the CO_2 emissions of merchant vessels as a consequence of the substitution of traditional mooring systems with the new automatic systems, continuing along the lines of previous works in the field of the reduction in CO_2 emissions in ports.

The estimation is made by applying the EPA and ENTEC "bottom-up" methodologies to the traffic in the port of Santander (Spain) in the year 2014.

The implementation of the AMS, when compared to the traditional mooring systems, leads to a reduction in CO_2 emissions of 76.78% calculated using the EPA method and 76.63% using the ENTEC method. Hence, the Port Authorities in their long-term planning decisions should promote the introduction of automatic mooring systems wherever the profitability thresholds of traffic allow it, as this will lead to significant environmental benefits by substantially reducing CO_2 emissions during the maneuvers of merchant ships in maritime commercial ports.

1. Introduction

Until the Second World War, the exploitation and organization of sea traffic had not changed very much. The loading and unloading operations followed a slow and laborious process. Therefore, in the post-war era, with the expansion of the market and rapidly rising labor costs, the system was placed under great stress. Congestion in ports increased and new methods had to be found through innovation, both technological and in processes, in response to these problems.

The maritime industry responded to the new challenges with two "revolutions" in the two sub-sectors of maritime transport: in non-regular traffic, through the development of integrated transport systems (bulk) (Vigarié, 1999) and in the regular lines by means of the grouping together of the general cargo (containerization) (Rodrigue and Notteboom, 2009).

These revolutions did not affect the traditional mooring systems of vessels in port. However, the research into innovation on AMS, with increasingly advanced technologies, continued to make

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progress (Cavotec, 2015).

The first results were obtained in 1998 with the first implantation of an AMS in the Port of Picton in New Zealand. Since then, AMS have been implanted in numerous ports in many different countries of the world (USA, Canada, UK, Denmark, Norway, Finland, the Netherlands, Australia, New Zealand, South Africa and The Lebanon), when their volumes of traffic have allowed the threshold of profitability of these infrastructures to be reached (Díaz, 2016).

As well as the financial benefits, the implantation of AMS also leads to important environmental benefits, through the reduction in CO_2 emissions in commercial ports, thanks to the reductions obtained in the operating times of the ship engines (in the main engines in the propulsion of the ship and in the auxiliaries in the generation of electricity). However, these benefits are not generally taken into account when analyzing the impact of these infrastructures.

The aim of this paper is to measure the reduction in CO_2 emissions by merchant ships as a consequence of the substitution of traditional mooring systems with the new automatic systems, by means of a comparative study.

2. Description of the automatic mooring system

This is an automatic system by vacuum cup direct on the hull of the vessels, whose fifth generation of 2013 (Montgomery, 2013) incorporates a remote control system with laser by telemetry that allows simultaneous visualization of the data on board and on land and the transmission of the connection commands from the control station to the AMS. It also includes a program so that the position of the vessel is maintained automatically and each mooring robot can be controlled independently from the rest.

The data received by the processor through some sensors located in the robots are the speed of the ship with respect to the terminal, the acceleration or deceleration of the vessel, the kinetic energy of the vessel and the inertia of the vessel.

It also receives another set of data from the on-board AIS and from the GPS.

This device (see Fig. 1) consists of a certain number of mooring robots, with a coupling mechanism so that the vessel remains perfectly moored in its berth and a system that detects the movements of the vessel.

A processor calculates the movement required by the coupling mechanism of each mooring robot and a controller controls the movement of the mooring robots in response to the information received from the processor.

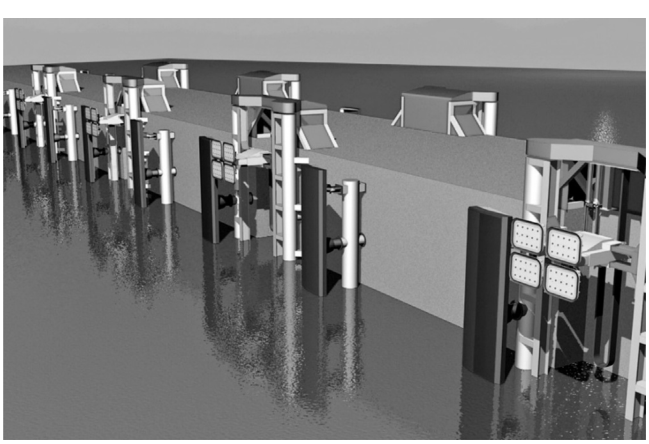

Fig. 1. Automatic Mooring System by vacuum cups.
Source: Cavotec

3. Background: CO_2 emissions in maritime transport

Emissions of gases by vessels in maritime transport are increasingly being subjected to more stringent restrictions at all phases of transport, both at sea and in port, so we will next address the analysis of these emissions.

Maritime transport is a growth sector in the global economy, and although it was expected that contributions to global CO_2 emissions would increase, thanks to the measures taken by the International Maritime Organization (IMO), these have decreased and moreover, this reduction has been achieved at a lower cost than initially expected (Eide et al., 2013).

Some of the fundamental policies of the IMO in recent years have been those aimed at improving the energy efficiency of vessels, the effects of which have led to an immediate reduction in the emissions of greenhouse gases (GHG), most notably those of CO_2.

According to studies by the IMO itself, the world fleet in 2006 generated 3% of the total CO_2 emissions to the atmosphere and 2.2% in 2015 (Oria et al., 2015). Of this amount, breaking it down by vessel type, we found that ships engaged in Ro-Ro transport (vessels designed to carry wheeled cargo), which are the subject of this study, produced by themselves an average of 29.40 Million MT. (Third IMO GHG Study, 2014).

The changes in emissions brought about by the reductions in CO_2 in shipping will obviously be beneficial from the perspective of long-term climate change, and in fact, positive environmental and health effects have already been identified, such as the reduction in concentrations of key short-life pollutants (Eide et al., 2011).

There already exists an extensive literature on the environmental impact of shipping and the direct effects on the contribution of greenhouse gases into the atmosphere from vessels in each of their phases of operation. In this regard, among the most interesting works are those that analyze the environmental impact of shipping in relation to other a priori less efficient means of freight transport (Belmonte and Romero, 2010).

At the same time, shipping companies have been forced to pay increasing attention to improving energy efficiency and reducing CO_2 emissions, which has led to the implementation in big shipping companies of integrated measures of sustainability within the global strategies of corporate social responsibility in order to mitigate the effects of climate change, in keeping with the Ship Energy Efficiency Management Plan (SEEMP): IMO mandatory measures entered into force on 1 January 2013 (Bocchetti et al., 2015).

The objective of the IMO with the inclusion of this plan in the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) is to improve the energy efficiency of vessels through a set of technical operating rules that result in a reduction in the emissions of all substances coming from fuel and its combustion process. To achieve this goal, it encourages the member states to conduct studies on the chemical composition of the exhaust emissions from the engines, both main and auxiliary, of cargo ships and to calculate the Emission Factors (EFS) (Celo et al., 2015). Various methodologies have been used to accomplish this task, some of which, such as the Ship Traffic Emission Assessment Model (STEAM) (Jalkanen et al., 2014) (Johansson et al., 2013), combine information on the characteristics of individual vessels with the Automatic Identification System (AIS), enabling the tracking of vessels with a high spatial resolution.

The measures taken by the shipping industry have taken some time to begin to improve the environmental credentials (Cullinane and Cullinane, 2013), but it is expected to be able to drastically reduce the environmental impact of shipping in the near future through a combination of regulation and technological innovation.

Finally, using an analytical input-output approach (Lun et al., 2015), it is possible to calculate how these ecological or "greening" operations of the shipping companies will affect their own business performance.

Another different approach of the studies related to emissions from ships consists in a comparative analysis of the SEEMP guidelines with the international standard for Energy Management Systems (EMS), ISO 50001, and the International Safety Management Code (ISM), which establishes the requirements for safety management systems in enterprises of maritime transport, claiming that the SEEMP lacks crucial features found in typical standards of management systems (Johnson et al., 2013).

There is also abundant information on the measures proposed, and in some cases already implemented, to reduce these emissions and studies on the costs that the implementation of these measures imply for the operating accounts of the shipping companies. In this sense, some studies have shown that measures such as the reduction in vessel speed leads to lower emissions, with greater reductions the larger the vessels are.

The CATCH model (Cost of Avoiding Tons of CO_2 Heating) is usually applied to evaluate the cost efficiency of speed reduction (Chang and Wang, 2014). In fact, this method has provided results that show that reductions in speed of 10%, 20% and 30% reduce fuel consumption by 27.1%, 48.8% and 60.3% and thus CO_2 emissions by 19%, 36% and 51%, respectively.

In other cases, the effects on greenhouse gas emissions of reduced vessel speed due to bad sea conditions have been studied (Prpic-Orsic and Faltinsen, 2012). Other options considered for reducing emissions are the use of alternative fuels (Hui-Huang, 2015) or changes in the design of shipping routes in certain parts of the world (Song and Xu, 2012) and other authors argue that the reduction in CO_2 emissions depends partly on the Incoterms used in the international fleets (Mckinnon, 2014).

Although CO_2 emissions per ton per mile are very low, shipping activity is so intensive that moving 8000 million MT per year generates as many CO_2 emissions as Japan.

In this regard, the IMO has also adopted mandatory regulations for reducing CO_2 emissions in shipping, which despite being the most efficient form of transport, makes a very high contribution to CO_2 emissions worldwide, due to the great volume of traffic. Hence, since 2013 it has been made mandatory to comply with the required Energy Efficiency Design Index (EEDI) and to adopt an energy efficiency plan. If the vessel does not comply with the required indices, she will have to implement energy improvements which have generally been welcomed by ship-owners, especially in these times of high fuel prices, since they reduce the consumption of their vessels.

At the same time, new European standards (Cullinane and Cullinane, 2013; Johansson et al., 2013) are being devised to limit emissions of greenhouse gases (CO_2). This is the case of the emission of harmful pollutants caused by vessels during operation, both while at sea and in approach and docking and undocking maneuvers. The fluctuations in emissions in these different phases depend on various factors such as the engine regime or the speed control (Chang and Chang, 2013; Eide et al., 2011, 2013), the quality of the fuel used, the condition of the vessel and its hull or the time used to perform the maneuvers of docking and undocking with ropes (Bocchetti et al., 2015; Celo et al., 2015).

Currently there are strict limitations on CO_2 emissions from ships in port, since the main commercial ports are very close to urban centers (Battistelli et al., 2012) and the general tendency is to improve their environmental perception. In this context, we consider it important to verify to what extent the implementation of the AMS are causing a significant reduction in CO_2 emissions from vessels in the phase of maneuvers.

4. Methodology

To calculate the emissions of CO_2, both "top-down" and "bottom-up" methodologies are currently used:

The "top-down" model is used to perform the calculation for total fleets or global fuel consumptions as a function of their annual sales: hence, this one was discarded.

The "bottom-up" model is used for the drawing up of maps of emissions and is used to confirm the location of hot spots inside ports (Tichavska and Tovar, 2015b), or for the use of the air pollutant emission inventory guidebook, EMEP/EEA 1, in which emissions can be estimated at different levels of complexity and separately, depending on the activity of the vessel, whether navigating, maneuvering or at stay (Trozzi, 2010).

What we are looking for in our work are emissions calculated according to the characteristics of the vessel, for a given location (Miola et al., 2010) and a particular activity: therefore, we have used two methods from the so-called "bottom-up" approach: EPA and ENTEC (Oria Chaveli, 2016; Eyring et al., 2010), discarding the following methods:

- The STEM method quantifies and represents geographically traffic between ports (Wang et al., 2007; Jalkanen et al., 2009; Kalli et al., 2013; Tichavska and Tovar, 2015a) while we are interested in emissions during the mooring maneuvers, particularly those with ropes.
- The TNO method is also a methodology for calculating the emissions of vessels at sea in Dutch waters (Denier van der Gon and Hulskotte, 2010)
- The EXTREMIS (Exploring non-road Transport Emission in Europe) method performs its analysis with data on fleet activity (Schrooten et al., 2014).
- The MEET method is a method for estimating emissions which focuses more on land and rail transport (European Commission. Directorate-General Transport, 1999; Hickman et al., 1999). The principle behind this method is the calculation of the energy produced by a specific activity, in order to subsequently estimate the emission of pollutants into the atmosphere.

Thus, we have selected the "bottom-up" EPA (Environmental Protection Agency) and ENTEC (ENTEC UK Limited, environmental and engineering consultancy in the UK) methodologies to analyze the reduction in CO_2 emissions using automatic mooring systems in commercial seaports, as these have been considered to be the most suitable for our study, allowing us to perform the calculations on the emissions of the vessel in port; that is, during mooring and unmooring maneuvers.

In order to apply these methodologies, which are based on activity, it is necessary to:

- Identify the characteristics of the vessels that regularly stop in the selected port
- Quantify the time required to carry out the maneuvers
- Take into account the type of energy installation of the vessel

4.1. EPA methodology

The EPA methodology (EPA United States Environmental Protection Agency. Air and Radiation, 2000) is a mathematical model described in the document "Analysis of Commercial Marine

Vessels Emissions and Fuel Consumption Data", which uses a methodology based on three stages of calculation. The first measures the time the ship takes for the different modes of operation. In the second stage, the fuel consumption is calculated for each operating mode and in the third, the emissions are calculated using the data of the specific emission consumption factor of each fuel. These calculations are made as a function of the type of vessel and the engine power.

In the EPA method, ship emissions *E* are calculated with the following formula:

$$E\,[g] = EF\left[\frac{g}{kWh}\right].\ MCR\,[\%].\ P\,[KW].\ t\,[h] \quad (1)$$

where *EF* is the emission factor of the pollutant, for both the main and the auxiliary engine, and is measured in g/KWh (grams of pollutant emitted per energy unit produced). This factor is obtained by applying the following algorithm:

$$EF = CF\ x\ SFC \quad (2)$$

where *CF* is a dimensionless Conversion Factor which shows the relation between the CO_2 emissions and the weight of the fuel consumed, based on the carbon content, and *SFC* is the certified Specific Fuel Consumption of the engines, measured in g/kWh.

In formula (1), *MCR* is the engine regime used during the undertaking of the maneuvers, expressed as a percentage, and also denominated Load Factor; *P* is the power of the main and auxiliary engines measured in KW and *t* is the time used in the maneuver in hours.

In the EPA methodology, the load percentages (%*MCR*) for each of the operating modes of the main engines for a Ro-Ro vessel are 80% at sea, 30% at low speed and 15% in maneuver. In the case of the auxiliary engines, a percentage of 100% is proposed for the *MCR*.

4.2. ENTEC methodology

The ENTEC method (ENTEC, 2007; Obras Públicas, 2003; Marín, 2005; Obras Públicas, 2003) has been used to develop bottom-up inventories on a European level for several consecutive years (Whall et al., 2010).

In the ENTEC inventories, the emissions are estimated individually for each vessel using weighted emission factors and in order to verify their movements, the Lloyd's Marine Intelligence Unit (LMIU) database is used, this being the only commercial database of all of the movements of vessels in the world, as well as their characteristics, such as type of vessel and speed. The type of vessel data is used mainly to obtain an approximation to general data such as the type of fuel used or the characteristics of the engines.

The formula used to calculate emissions in the ENTEC 2010 report is:

$$E\,(g) = t\,(h)\cdot[ME(kW)\cdot LF_{ME}(\%)\cdot EF(g/kWh) + AE(kW)\cdot LF_{AE}(\%)\cdot EF(g/kWh)] \quad (3)$$

As can be observed, this formula is practically identical to the EPA method, with the only exception that in this one, the emissions of the main and the auxiliary engine are included separately.

The values used by the ENTEC 2002 for the *MCR* or *LF* are 20% for the main engine and 50% for the auxiliary ones.

In the second IMO GHG Studio 2009 (Díaz, 2005) and later in the MEPC 212(63) resolution adopted on 2, March 2012, can be found the guidelines of 2012 on the method of calculating the Energy Efficiency Index (EEDI) for sea vessels. This index calculates the total CO_2 emissions in tons for each vessel as a result of the summing of the emissions produced by the main engines plus those of the auxiliary engines, according to the following equation:

$$EEDIT = \sum_{i=1}^{n} EEDI\ \ ME + \sum_{j=1}^{m} EEDI\ \ AE \quad (4)$$

where, to calculate the value of each of the engines, the following equation is applied:

$$EEDI = C\ x\ C_F \quad (5)$$

C_F according to the MEPC 212/63 on 2 March, for Diesel/Gasoil (with 0.875 carbon content) is 3.206 tons of CO_2 emitted per ton of fuel consumed. It is assumed that the fuel that is normally used throughout the maneuvers in port is Marine Gasoil (MGO).

In [5], *C* is the fuel Consumption in tons which, according to the IMO guidelines, is obtained as follows:

$$C = (SFC\ x\ P\ x\ MCR\ x\ t)/10^6 \quad (6)$$

where the *SFC* values according to ENTEC 2010 are those shown in Tables 1 and 2.

Hence, we get the following expression:

$$EEDI = CF\ x\ SFC\ x\ P\ x\ MCR\ x\ t/10^6 \quad (7)$$

Or, substituting [2], the final equation can be written as follows:

$$EEDI = EF\ x\ P\ x\ MCR\ x\ t/10^6 \quad (8)$$

Thus, since the IMO method is based on the two above methods, we will undertake the comparison of the results obtained in the calculation of the CO_2 emissions in the maneuver phases of mooring and unmooring using the EPA and ENTEC methods, where the only differences are the values of *MCR*.

5. Case study: the port of Santander (Spain)

In 2015, the Port Authority of Santander and the company supplying the AMS analyzed the possibility of implementing the system in Raos Dock 8. The data used in this article is part of the research project developed for this purpose.

In this project, in order to make a comparative study of the time required to carry out maneuvers with the traditional system and with the AMS, a real time maneuver simulator, "Polaris", was used. The Polaris was designed by "Kongsberg Norcontrol Simulations" (Norway) and our model was located in the School of Nautical Studies of the University of Cantabria.

The methodology was applied to the traffic of Ro-Ro vessels in the port of Santander (Spain) (Fig. 2) in the year 2014. Santander is a port that specializes in Ro-Ro freight transport and there are mainly two types of Ro-Ro vessels operating in it: feeder vessels that make regular routes which are under 200 m in length (Matsukura et al., 2010) and larger vessels of over 200 m in length that make transoceanic routes.

Table 1
SFC of main engine.

Age of vessel	SFC Over 5.000 KW
Before 1983	205
1984–2000	185
2001–2007	175

Source: Self-made by authors with data taken from IMO 2009.

Table 2
Calculation of SFC of auxiliary engines.

Age of vessel	Over 800 KW	SFC Under 800 KW
Any	220	230

Source: Self-made by authors with data taken from IMO 2009.

operations increasing the periods to 10 and 5 min respectively, which means that the total time spent to moor and unmoor a vessel is about 15 min, while these operations currently require an average of around 60 min with traditional mooring systems with ropes.

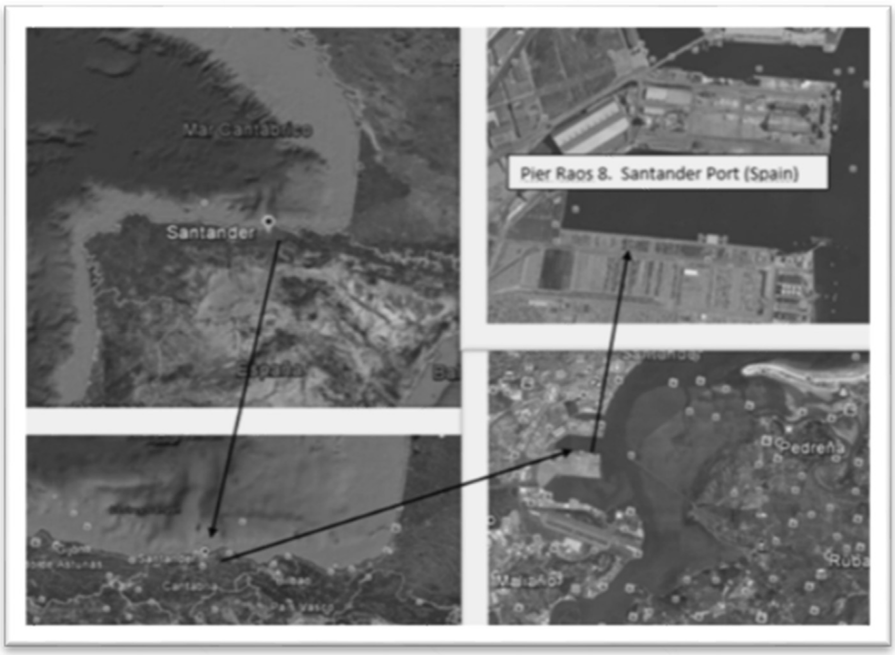

Fig. 2. Location of the Port of Santander. Source: The authors, based on Google earth images.

By applying the data to the methodology, we can calculate fuel consumption and CO_2 emissions into the atmosphere during the mooring maneuvers with both the traditional and the automatic mooring systems for the four Ro-Ro type vessels that moor regularly in Raos Dock 8 and then extend this data to the total Ro-Ro traffic.

Table 3 shows the data of the four vessels selected for the calculations (Parsifal, Tuscany, Autostar and Auto Bay), from the Ro-Ro traffic in this port. In 2014, Autostar and Auto Bay type vessels accounted for 51% of the traffic in Raos 8 with 194 calls and Parsifal and Tuscany type vessels 49% with 187 calls. These vessels represent all the types of Ro-Ro ships that dock at the pier analyzed.

All simulations were carried out in the most favorable weather conditions, that is, with the wind and sea in calm conditions. It should be taken into account that, as the weather worsens, maneuvers can be lengthened with the consequent increase in emissions.

Using the AMS reduces the time required to moor and unmoor a vessel to less than 40 and 20 s respectively, as per the manufacturer's specifications. We have made the calculations for these

Table 4, showing real times of maneuvers, has been obtained from the stops of Ro-Ro vessels entering the Port of Santander between 2011 and 2015.

6. Results

Applying the above-mentioned methodologies (EPA and ENTEC), for the two mooring systems (traditional and automatic), the following results have been obtained and are presented here in two sections. The first outlines the fuel consumptions and CO_2 emissions of the vessels in the maneuver phase in the dock, while the second presents a comparative analysis of the results obtained for the two types of mooring systems.

6.1. Fuel consumptions and CO_2 emissions per vessel

Tables 5 and 6 show the calculations for the two methods of fuel consumption of the main and auxiliary engines for the vessels selected in the maneuvering phase both for the traditional and for the automatic systems.

Table 3
Data on the vessels.

Vessel	Year built	GT	Length (mts)	Power ME (kW)	AE	Power (kW)	SCF ME g/kWh	SCF AE g/kWh
Parsifal	2011	75,251	265	21,770	3	2360	175	220
Toscana	2009	61,328	265	13,240	3	1250	175	220
Auto Bay	1997	19,094	139	14,480	2	600	185	230
Autostar	2000	21,010	140	8400	2	1500	185	220

Source: self-made by authors

Table 4
Times required for performing maneuvers with the traditional and with the automatic systems.

Vessel	All fast ropes (min)	All fast automatic system (min)	Let go Ropes (min)	Let go Automatic system (min)	Saved time (min)
Parsifal	45	10	20	5	50
Toscana	45	10	25	5	55
Auto Bay	40	10	15	5	40
Autostar	40	10	25	5	50
Average value	**42.50**	**10**	**21.25**	**5**	**48.75**

Source: self-made by authors, with data gathered in the Port of Santander.

Table 5
Fuel consumption in the maneuver phase with the traditional system for the EPA and ENTEC methods.

Vessel	EPA Method					ENTEC Method				
	ME MCR	ME C (MT)	AE MCR	AE C (MT)	C ME + AE (MT)	ME MCR	ME C (MT)	AE MCR	AE C (MT)	C ME + AE (MT)
Parsifal	0,15	**0,62**	1	**1,69**	**2,31**	0,2	**0,83**	0,5	**0,84**	**1,67**
Toscana	0,15	**0,41**	1	**0,96**	**1,37**	0,2	**0,54**	0,5	**0,48**	**1,02**
Auto Bay	0,15	**0,37**	1	**0,25**	**0,62**	0,2	**0,49**	0,5	**0,13**	**0,62**
Autostar	0,15	**0,25**	1	**0,72**	**0,97**	0,2	**0,34**	0,5	**0,36**	**0,69**

Table 6
Fuel consumption in the maneuver phase with the AMS for the EPA and ENTEC methods.

Vessel	EPA Method					ENTEC Method				
	ME MCR	ME C (MT)	AE MCR	AE C (MT)	C ME + AE (MT)	ME MCR	ME C (MT)	AE MCR	AE C (MT)	C ME + AE (MT)
Parsifal	0,15	0,14	1	0,39	**0,53**	0,2	0,19	0,5	0,19	**0,39**
Toscana	0,15	0,09	1	0,21	**0,29**	0,2	0,12	0,5	0,10	**0,22**
Auto Bay	0,15	0,10	1	0,07	**0,17**	0,2	0,13	0,5	0,03	**0,17**
Autostar	0,15	0,06	1	0,17	**0,22**	0,2	0,08	0,5	0,08	**0,16**

Tables 7 and 8 show the values of the CO_2 emissions, calculated for the four vessels selected, applying the EPA and ENTEC methodologies and for the maneuver phases with both the traditional and the automatic systems. In both cases, $C_F = 3206$.

6.2. *Annual results of the traditional mooring system versus the automatic system*

The results of the annual quantification of the saving in CO_2 emissions and MGO consumption in Raos Dock 8 of the Port of Santander are shown in Table 9. To obtain these results, the average values of the four representative vessels used throughout this study have been taken.

Table 9 also shows the total quantities of MGO consumed by the ship engines during the time that the mooring and unmooring maneuvers take, first with ropes and then with the automatic system. It can be observed that there is a significant saving in fuel, as this reaches an average of 77% of the consumption (77.27% EPA, 77.00% ENTEC), which means that for each maneuver with the automatic system, there is a saving of approximately one ton of MGO.

If we calculate the relation between the weight of the CO_2 emissions and the weight of the fuel consumed, the result is close to 3.20 which corroborates the calculations since, as we said in the methodology section, the starting point was a value of this relation, or of the conversion factor C_F of 3206.

With respect to CO_2 emissions into the atmosphere, using the automatic mooring system proposed, saves, according to the EPA method, 3.24 tons per maneuver, while 2.46 tons per maneuver would be saved according to the ENTEC methodology. These amounts expressed in annual terms would add up to a total that ranges from 1234–937 MT per year. From this data it follows that, with the installation of the new system, in Raos Dock 8 alone a reduction in emissions of almost 77% (76.78% EPA, 76.63% ENTEC) would be achieved. If we consider that during the year 2014, CO_2 emissions in all of the port of Santander reached 24,199 MT. according to the EPA method and 22,928 MT. according to the ENTEC method (Oria Chaveli, 2016), the implementation of the automatic

Table 7
CO_2 emissions in maneuver phase with the traditional system for the EPA and ENTEC methods.

(Measures in MT) Vessel	C_F CO_2/Comb	EPA Method			ENTEC Method		
		ME CO_2	AE CO_2	ME + AE CO_2	ME CO_2	AE CO_2	ME + AE CO_2
Parsifal	3206	1,98	5,41	**7,39**	2,65	2,70	**5,35**
Toscana	3206	1,30	3,09	**4,39**	1,73	1,54	**3,28**
Auto Bay	3206	1,18	0,81	**1,99**	1,57	0,41	**1,98**
Autostar	3206	0,81	2,29	**3,10**	1,08	1,15	**2,23**

Table 8
CO_2 emissions in maneuver phase with the AMS for the EPA and ENTEC methods.

(Measures in MT) Vessel	C_F CO_2/Comb	EPA Method			ENTEC Method		
		ME CO_2	AE CO_2	ME + AE CO_2	ME CO_2	AE CO_2	CO_2 ME + AE
Parsifal	3206	0,46	1,25	**1,71**	0,61	0,62	**1,23**
Toscana	3206	0,28	0,66	**0,94**	0,37	0,33	**0,70**
Auto Bay	3206	0,32	0,22	**0,54**	0,43	0,11	**0,54**
Autostar	3206	0,19	0,53	**0,72**	0,25	0,26	**0,51**

Table 9
Results obtained for the EPA and ENTEC methods.

(Measures in MT) Maneuver	EPA method (Averages Values)		ENTEC method (Averages Values)	
	CO_2 emissions	MGO consumption	CO_2 emissions	MGO consumption
With traditional system	4.22	1.32	3.21	1.0
With automatic system	0.98	0.30	0.75	0.23
Saving	**3.24**	**1.02**	**2.46**	**0.77**
Annual value (381 maneuvers per year)	**1234.44**	**388.62**	**937.26**	**293.37**

mooring system in a single berth will lead to a reduction of between 5% and 4% of total greenhouse gas emissions at port level, which, from our point of view, represents a significant amount.

7. Discussion

The international community is increasingly sensitized to environmental problems and others related to the preservation of the marine environment, but in the last decade particular attention has been paid to air pollution caused by shipping. Recent studies show that this type of transport is the fifth largest contributor to pollutant emissions on our planet and that emissions of greenhouse gases (CO_2) from vessels account for between 3% and 5% of the total, this amount increasing as international seaborne trade increases. In 1973, The International Maritime Organization, as a specialist agency of the United Nations, adopted an international agreement to prevent marine pollution from vessels (MARPOL). Based on Annex VI of that agreement, which specifies the requirements for the control of emissions from vessels, the member states have drawn up a wide-reaching legislation aimed at limiting the emissions of greenhouse gases.

Within these policies, and considering that there are no easy answers to the problems of air pollution and climate change, numerous measures have been proposed to the legislators and indeed some are already in force, such as limiting emissions, controlling fuel quality, determining specially protected areas or simply modifying ship engines so that they can use clean fuels. In this sense, studies need to be undertaken to estimate the costs of these measures, both political and technical, in order to justify their viability.

Another key issue is to reach an agreement on which of the existing methodologies is the most suitable for calculating the CO_2 emissions from vessels and the reliability of the data sources, as currently there are several methodologies that are being applied depending on the study area and there are also multiple data sources that are even being used in combination to reduce uncertainties.

Being aware that improving air quality is the result of the sum of a great number of actions, this paper aims to contribute to the reduction of CO_2 emissions in the field of port operations by means of the study and technical description of a proposal of the installation of modern restraint systems of ships in port terminals, significantly reducing the maneuvering times and therefore the operating times, of ship engines, which leads to a substantial reduction in emissions.

8. Conclusions

1. The use of the new automatic mooring system considerably reduces the emissions of CO_2 into the atmosphere, since the main and auxiliary engines only consume a quarter of the fuel.
2. The lowering of the CO_2 emissions through the use of AMS leads to a saving with respect to traditional mooring systems of 76.78% using the EPA method and 76.63% with the ENTEC method.
3. The application of these mooring systems does not imply any reduction in safety, in relation to the traditional system, since the movement of the ship is automatically minimized during its stay at berth.

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