EVALUATION OF ENVIRONMENTAL PERFORMANCE INDICES FOR SHIPS

Mr Martin Gibson (corresponding author)

(m.t.gibson@newcastle.ac.uk)

Dr Alan J Murphy

(a.j.murphy@newcastle.ac.uk)

Dr Kayvan Pazouki

(kayvan.pazouki@newcastle.ac.uk)

Marine, Offshore & Subsea Technology, School of Engineering, Newcastle University, Newcastle upon Tyne, NE1 7RU

This research has been funded by the EPSRC through PhD sponsorship.

ABSTRACT

Pollution from ships is a significant environmental concern. Maritime environmental legislation has tightened in recent years since the introduction of the MARPOL 73/78 regulations, however there is often a significant time gap between when the regulations are adopted and when they legally enter force. The emergence of private voluntary environmental initiatives has occurred in an attempt to bridge this gap, reduce environmental impacts, and raise the environmental profile of ships. However, there are inconsistencies in the methodologies used to define ship performance, and the number and diversity of initiatives available for use can cause confusion, hindering progress towards greater sustainability. A critical analysis of existing environmental initiatives in the shipping industry has been conducted, challenging the applicability, scope, and environmental ambition of the methodologies adopted. The analysis highlights significant limitations of initiatives with regards to transparency, assessment rationale and environmental scope, and flexibility to be ship specific. Many show bias towards certain environmental indicators, while others have limited ambition. This paper challenges the effectiveness of existing environmental initiatives used in the shipping sector to promote environmental improvements beyond current regulatory requirements, and proposes an objective, quantifiable approach to assessing vessel environmental performance.

Key words

Environmental assessment; environmental performance indices; policy; shipping index; environmental initiative.

1. Introduction

Shipping has a considerable impact on the environment due to the release of pollutants as a by-product of ship operation. According to the Third IMO Study on Greenhouse Gas emissions (Smith *et al.,* 2014), shipping accounts for approximately 3% of global anthropogenic CO_2 emissions. Ships also emit significant volumes of air pollutants such as Nitrogen and Sulphur Oxides (NO_X & SO_X), Volatile Organic Compounds (VOCs), Carbon Monoxide (CO), and Particulate Matter (PM) due to the use of heavy fuel oil (Corbett *et al.,* 2007; Smith *et al.,* 2014). Ships release toxic chemicals into the marine environment through use of antifouling coatings (Hallers-Tjabbes *et al.,* 2003), oil spills, and oil and chemical leakages during routine operation (Talley, 2003). Shipping can also affect local marine ecosystems due to transport of alien species attached to the hull and in ballast water discharge (Andersson *et al.,* 2016).

Regulations exist to limit the impacts of ships on the environment. The IMO introduced environmental regulations in shipping as early as the 1950's with the adoption of the OILPOL Convention in 1954, and since then regulations targeting pollution have been developed. Once new laws are adopted they must be ratified by a specific number of member countries representing a proportion of the world's gross tonnage in order to become legally binding, hence it can take many years before they come into force. The MARPOL Convention for the prevention of pollution from ships was originally adopted in 1973, however it did not fully enter force until 1983. Similarly, and more recently, the Ballast Water Management convention was adopted in 2004 and did not enter force until 8th September 2017, some 13 years later.

The protracted process for which regulations become legally binding has resulted in the proliferation of *'independent voluntary initiatives'* to improve environmental credentials and meet the demands of customers and other stakeholders (Lister, 2015).

However it has been suggested (Lister *et al.,* 2015) that the number and diversity of initiatives available for use in the shipping sector can cause confusion, add a significant administrative burden and even hinder progress towards greater sustainability due to the widely different audiences they are designed to target.

Some of the existing initiatives provide an indication of a ship's performance based on a selection of environmental factors and may be considered as *'performance indicators'*, and others are designed as incentive schemes where environmental improvements to ships or shipping practices are rewarded, often with certification or class notation, or economic gains to provide market advantage.

Many initiatives focus on a single environmental issue while others are designed to assess a broad range of environmental concerns, and may use several indicators to provide an overview of a ship's environmental performance. Many initiatives have been designed for a particular use in a specific location or for a certain vessel type, and are limited in their environmental scope.

A number of studies have identified the existence of environmental initiatives in the shipping sector, however the effectiveness of such schemes in delivering improved environmental performance has been questioned. Murphy *et al.,* (2013) conducted a comparative analysis of the Clean Shipping Index (CSI) and Environmental Ship Index (ESI), suggesting there are weaknesses in the methods used to assess environmental performance. Scott *et al*. (2017) examine the use of *'private standards'* and their role in assisting the mitigation of greenhouse gas emissions from shipping, and note concern over a lack of transparency and ambition of some of the schemes analysed. A study by Centobelli *et al.* (2017) provides a taxonomy of green initiatives adopted by logistics service providers which includes but is not exclusive to the shipping sector, while Hossain *et al.* (2019) reviews the use of sustainability initiatives in Canadian ports, and is not specifically focused on ships.

This paper highlights the limitations with independent voluntary initiatives used in the shipping sector and challenges the applicability, scope, and environmental ambition of the methodologies adopted. An alternative method for assessing ship environmental performance is proposed which uses an objective, quantified approach to determine pollutant weighting factors, and recommends an assessment framework based on vessel operational data rather than design characteristics.

2. Identification and categorisation of initiatives

A number of studies have attempted to identify and catalogue the various environmental initiatives available for use in the shipping sector (Fridell *et al.,* 2013; Svensson and Andersson, 2011; EMSA, 2007; Pike *et al.,* 2001; SSI, 2013; Stuer-Laridsen *et al.,* 2014). Approximately 50 initiatives are identified in the Clean Baltic Sea Shipping (CBSS) CLEANSHIP project (Fridell *et al.,* 2013), and other reports by Svensson & Andersson (2011) and EMSA (2007) have compiled inventories of 38 and 47 respectively. Pike *et al.*, (2011) review 29 different schemes, while the Sustainable Shipping Initiative (SSI, 2013) have created a search and compare tool containing 11 schemes, and a report by the Danish environmental protection agency (Stuer-Laridsen *et al.*, 2014) discusses 10 different schemes in some detail. The existing research into such schemes tends to be in the form of review, and stops short of analysing the effectiveness of the methodologies adopted to assess ship environmental performance.

Based on the inventories compiled in the literature, at least 85 different environmental initiatives in the shipping sector have been identified. Some of these are no longer active due to a variety of reasons including changes in regulations (e.g. OVG Hong Kong), and project closures. A large number of initiatives are in use, and it is clear that the origin, design, intended purpose, and uptake of the schemes differs considerably. Previous studies in this field have used different criteria to categorise ship environmental initiatives in to groups (EMSA, 2007; Pike *et al.*, 2011; Svensson and Andersson, 2011; Fridell *et al.*, 2013; SSI, 2013; Stuer-Laridsen *et al.* 2014), and it is evident that no single, unanimously accepted system of classification exists. This study compiles the inventories developed in previous research and classifies the initiatives according to Figure 1.

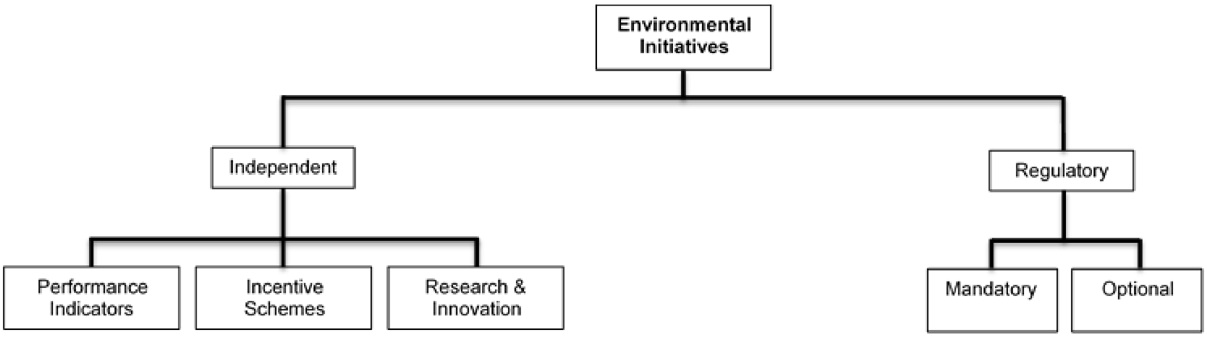

Figure 1 Categorisation of environmental initiatives in shipping

The initiatives are classified initially as either '*Regulatory*' or '*Independent*' schemes. Regulatory schemes are those developed by the regulator (IMO), and independent schemes are those which are not developed by the IMO. The regulatory initiatives can be further classified as '*Mandatory*' or '*Optional*'. The independent initiatives are classified into 3 groups based on intended purpose, as:

- *'Performance Indicators'* - to provide an indication of environmental performance;

- *‘Incentive Schemes’* - to provide an incentive to improve environmental performance; and

- *‘Research & Innovation’* - innovative research activities, strategies or actions designed to improve the environmental landscape in shipping, and /or raise awareness and promote sustainability in the shipping sector.

The 85 initiatives identified in the literature have been systematically categorised according to Figure 1, summarised in Table 1.

Table 1 Summary of initiative categorisation

Classification	No. of initiatives
Independent Initiatives	**80**
Performance Indicators	28
Incentive Schemes	30
Research & Innovation	22
Regulatory Initiatives	**5**
Mandatory	3
Optional	2
Total	***85***

Several of the initiatives identified are mandatory and optional instruments developed by the IMO such as the EEDI, EEOI and SEEMP and are categorised as ‘*regulatory’* in Table 1, however the vast majority can be considered to be *‘independent initiatives’* developed by or for other actors in the shipping industry such as classification societies, national maritime bodies, port authorities and research groups. A large proportion of the initiatives identified can be described as *‘incentive schemes’*, developed by the port authorities or by other independent bodies with the intention of using the schemes to reward ship owners for achieving certain environmental targets in ports, typically through financial compensation.

Around a third of the initiatives identified can be described as *‘performance indicators’*, developed to provide an indication of a vessels environmental performance based on pre-defined thresholds and targets. Many performance indicators, such as the CSI and

ESI involve complex calculations of scores using multiple indicators and parameters to provide a detailed assessment of environmental performance, while others such as RightShip's Existing Vessel Design Index (EVDI) - a tool used to compare ship energy efficiency - are focussed on individual environmental issues.

Some of the initiatives identified in the literature – such as the DK Group Air Cavity System (Pike *et al.,* 2011) – are research projects categorised as *'research & innovation'* these initiatives are designed to improve sustainability in the shipping sector and in many cases focus on the development of new technologies and/or strategies for environmental improvements.

While many of the existing initiatives are well marketed and can be found in the public domain via web searches, a significant proportion of those mentioned in the literature are less transparent. The next section investigates the motive and scope of the initiatives identified and, where possible, compares the methodologies implemented to assess vessel performance.

3. Analysis of existing environmental initiatives

A large number of environmental schemes have been identified in the literature, however the scope and purpose of such schemes is not evident. This section provides an explanation of the transparency, scope, and ambition of existing environmental initiatives used in the shipping industry.

3.1 Transparency of assessment methods and results

Each of the initiatives identified in the existing literature were searched for by name using google. It was found that many of them do not have their own website, or any other reference to published documentation outlining the requirements of the scheme or methods for carrying out performance assessments. There are 47 initiatives referenced in the literature where information was found to be publically transparent, i.e. have their own website, or there is published documentation made available on a company website which directly refers to the scheme in question. However, information regarding the scope and implementation of the initiatives is in many cases not forthcoming. Of the initiatives identified, 16 were found to have published detailed methodologies, enabling further analysis to be carried out, a list of which is provided in Table 2. In accordance with the initiative categorisation in Figure 1, 12 of the schemes have been classified as performance indicators, two as incentives, and two as regulations, and therefore the sample of initiatives analysed broadly covers the categories in Figure 1, with the exception of research & innovation.

It was found that despite the availability of information regarding each scheme in the public domain, detail of assessment outcomes was less transparent. The Clean Cargo Working Group (CCWG) for example publishes a list of participants to its '*environmental performance scorecard*' but does not provide detail of the assessment outcomes, such information is only available to members who are participants of the scheme, and access is conditional upon signing a non-disclosure agreement (Scott *et al*., 2017). The Green Award lists the holders of the Green Award certificate by company name and by individual vessel including the date of certification, however there is no detail of the environmental assessments that have been carried out (Green Award, 2018). From the information available it is not possible to ascertain vessel environmental performance.

Table 2 List of initiatives with public level of transparency

Initiative	Category
Green Ship Incentive Programme	Incentive Schemes

Norwegian NO_X fund	
ABS Enviro	Performance Indicators
ABS Enviro+	
CCWG (Environmental performance scorecard)	
CSI	
DNV Clean	
DNV Clean Design	
ESI	
EVDI	
Green Award (oil tankers; bulk carriers; LNG carriers; chemical tankers; container ships; LPG carriers; inland vessels)	
RINA Green Plus	
RINA Green Star	
The Blue Angel (ship operation)	
EEDI	Regulation
EEOI	

By contrast, the ESI lists the top 50 vessels participating in the scheme in order of decreasing score, the dates in which the assessment is valid (2 years from when the assessment takes place), and a breakdown of performance in each of the assessment categories, so it is possible to determine how well a vessel has performed in each category based on publically available information. Only 50 ships are listed, however there are over 8000 vessels with a recorded ESI score which can be found using the search function on the ESI website. While ESI scores are visible, there is no breakdown of actual emissions or detail of how vessel scores are awarded (ESI, 2018). RightShip's EVDI (in conjunction with the Carbon War Room) have taken steps to improve transparency by making performance assessment outcomes available for participating vessels, however access requires registration via the website (Scott *et al.,* 2017).

This lack of transparency means it is not possible determine how well vessels which use the schemes are performing, and to what extent they are impacting on the environment. It is also not possible to compare schemes like for like where information outlining the performance assessment methodologies is limited.

3.2 Environmental scope

Some of the initiatives have a wide environmental scope and are made up of several indicators with different weightings, while others use single indicators to assess specific pollutants. Five of the schemes analysed in this research are single pollutant indicators: the Norwegian NO_X fund, which is a tax incentive scheme set up to reduce NO_X emissions from ships in Norway; Green Ship, which is a financial incentive programme implemented at the Port of Long Beach in the United States which also targets NO_X reductions; the EEDI and EEOI, which are indicators of a vessels CO_2 emissions designed by the IMO; and the EVDI, which is a CO_2 indicator developed by RightShip to calculate EEDI scores for existing vessels.

Many of the schemes that assess multiple pollutants do not assign specific weighting factors to pollutant indicators, and use audit style checklists to assess vessel performance, requiring ships to meet a list of mandatory criteria in order to qualify for certification. In such cases, all criteria must be met in order to achieve accreditation and therefore the schemes are not suitable for comparing vessels' environmental performance. The only distinction that can be made is between vessels with or without certification. From the list in Table 2, the Clean and Clean Design eco-labels developed by DNV, the Enviro and Enviro+ eco-notations developed by ABS, and the RINA Green Star notation do not use weighting factors and are therefore not included in further analysis.

Many initiatives are designed for performance benchmarking, allowing ships to be distinguished from others by a system of ranking. Such schemes use thresholds and scales to assess and grade environmental criteria, and allocate points for each criteria which can be totalled to give an overall score. Total scores can then be used to compare against other vessels, or benchmarked against threshold values for which different ratings or levels of certification can be achieved. Figure 2 provides a breakdown of the scope of each initiative and the weighting assigned to each pollutant category.

3.3 Pollutant weighting factors

The weighting factors assigned to each pollutant vary significantly between initiatives. Many of the initiatives allocate a different number of points for each individual criteria, as shown in Figure 2. Some initiatives group pollutants into sub categories in an effort to simplify the scoring system. In the CSI, environmental pollutants are split into 5 equally weighted groups – CO_2, NO_X, SO_X, Chemicals, Water & Waste Control - with 30 points available for each group, adding up to a total of 150 points. However if the groups are broken down into individual pollutants, the number of points available for each criterion varies considerably. For example, within the water and waste control category, grey water accounts for 2.6% of the total index score, and bilge water treatment accounts for 5.3%. The difference in criteria weighting suggests that in some initiatives, certain environmental pollutants are prioritised over others.

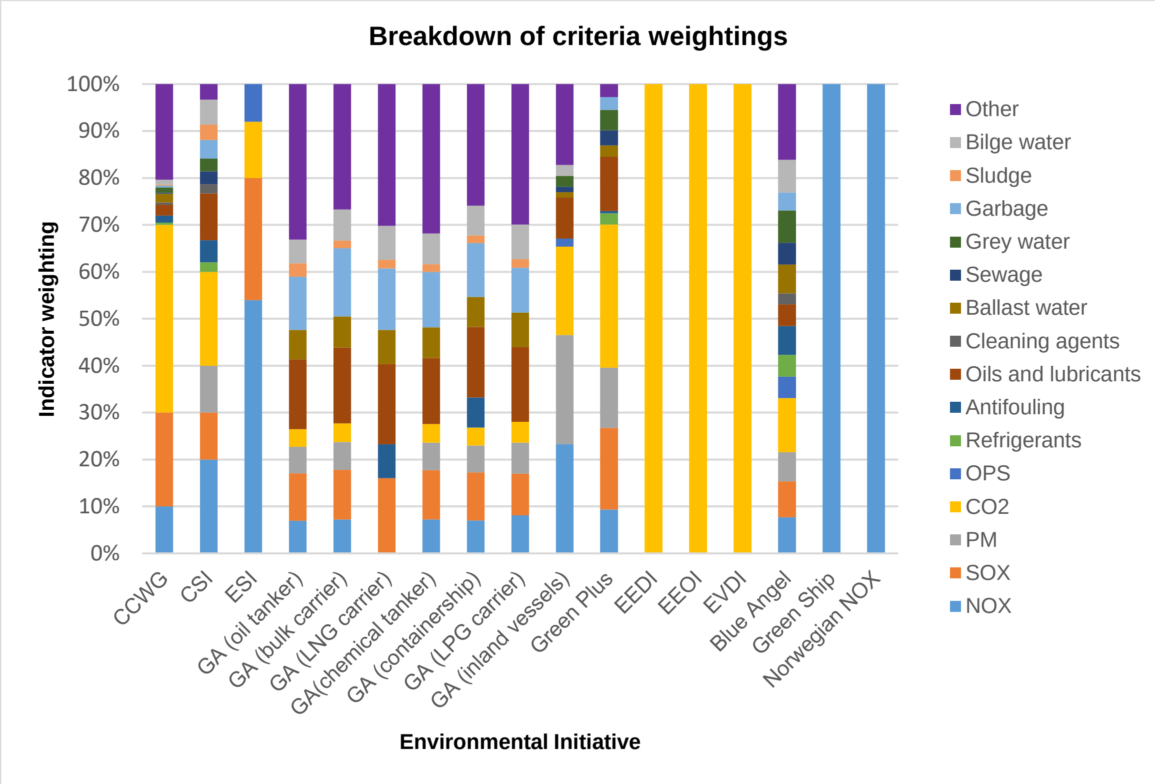

Figure 2 Breakdown of criteria weightings

Comparisons between the weighting factors of each pollutant for each initiative can be made by categorising the criteria into groups (Table 3). Pollutant criteria are categorised based on interaction type with the environment. The pollutant criteria listed in Figure 2 can be categorised as '*emissions to air*', '*discharges to sea'*, or '*other*'. Using this method of categorisation, NO_X, SO_X, PM CO_2, OPS and Refrigerants are classed as emissions to air, and Antifouling, Oils and lubricants, Cleaning agents, Ballast water, Sewage, Grey water, Garbage, Sludge, and Bilge water are classed as discharges to sea. All other criteria are categorised as other.

The method of categorisation in Table 3 shows a clear difference between initiatives in the weighting factors used for each type of environmental interaction. Each of the single criteria initiatives are designed to assess air emissions only, while the weighting factors used in the multi criteria initiatives vary greatly. CCWG, CSI, ESI and the RINA Green Plus eco label clearly prioritise pollutant emissions to air over discharges to sea and other criteria. The weighting factors for emissions to air and discharges to sea in The Blue Angel are equally split (42% each), while the Green Award initiatives are weighted more heavily in favour of discharges to sea.

Table 3 Criteria weightings per interaction type with the environment

	Environmental initiative	Weighting factor		
		Emissions to air	Discharges to sea	Other
Multi-criteria	CCWG	*71%*	*9%*	*20%*
	CSI	*62%*	*35%*	*3%*
	ESI	*100%*	*0%*	*0%*
	GA (oil tanker)	*27%*	*40%*	*33%*
	GA (bulk carrier)	*28%*	*46%*	*27%*
	GA (LNG carrier)	*16%*	*54%*	*30%*
	GA (chemical tanker)	*28%*	*41%*	*32%*
	GA (containership)	*27%*	*47%*	*26%*
	GA (LPG carrier)	*28%*	*42%*	*30%*
	RINA Green Plus	*72%*	*25%*	*3%*
	The Blue Angel	*42%*	*42%*	*16%*
Single criteria	EEOI	*100%*	*0%*	*0%*
	RightShip EVDI	*100%*	*0%*	*0%*
	Green Ship Incentive Program	*100%*	*0%*	*0%*
	Norwegian NO_X Fund	*100%*	*0%*	*0%*

Many of the initiatives have a broad environmental scope but the weightings of the criteria vary significantly. For example, 54% of the points available in ESI are allocated to NO_X, significantly more than in any of the other multi criteria initiatives (ESI, 2017). NO_X is allocated 20% in CSI, 10% in CCWG and less than 10% in each of the other schemes with the exception of the Green Ship incentive programme and the Norwegian NO_X fund, which are specifically designed to promote NO_X reductions from shipping.

Vessels with low NO_X emissions are likely to receive a high overall score in ESI even if they score low in the other categories. A ship with zero NO_X – assuming it does not score points in any of the other categories - would gain a score of 67 points in ESI (54% of the total).

Many ports around Europe use the ESI as a benchmarking tool, and offer financial incentives if vessels meet a minimum point's threshold (Table 4). The number of points required to receive discounts varies from 20 to more than 50, depending on the policy of the port. A score of 67 points for achieving zero NO_X is enough to comfortably receive maximum financial benefit from each of the example incentive schemes shown in Table 4. A vessel with zero NO_X clearly has some significant environmental benefits, however it may not necessarily be considered ‘eco-friendly’ in other pollutant categories.

Table 4 ESI points requirement for reduced duty fees at selected ports (adapted from CNSS, 2014)

Port	Minimum ESI points requirement	Discount
Rotterdam	*≥ 31*	*10%*
	*≥ 31 total and ≥ 31 NO_X**	*20%*
Oslo	*25-49*	*20%*
	≥ 50	*40%*
Bremen & Bremerhaven	*≥ 20*	*5%*
Kiel	*≥ 31*	*10%*
Setubal	*≥ 31*	*3%*
Hamburg	*> 50*	*10% (capped at €2,000)*
Antwerp	*≥ 31*	*10%*
Wilhelmshaven	*≥ 31*	*5%*
Zeebrugge	*≥ 20*	*10%*
Groningen sea ports	*≥ 20*	*5%*

* The discount is doubled if the ship also has an individual ESI-NOx score of 31.0 or more

3.4 Environmental ambition

The purpose of the initiatives analysed in this study is to provide an indication of the environmental performance of vessels, often by benchmarking against the performance of other vessels. The ESI is a tool for calculating environmental performance scores for individual ships, scores can then be compared against each other to rank their environmental performance. Additionally, vessel scores can be benchmarked against a threshold value as shown in Table 4, and used to determine eligibility for incentives such as port discounts. Unlike other schemes such as those presented in Table 5, ESI does not use a benchmarking points system, in that vessels must not acquire a minimum number of points overall in order to receive certification, however vessels must meet certain minimum standards for individual pollutants.

CSI uses its own benchmarking scheme to classify ships based on environmental performance. CSI-class 1 is awarded to vessels scoring between 0-37 points using the CSI scoring system, with higher classifications awarded to vessels achieving higher scores. Ships are awarded the highest classification (CSI-class 5) if they receive 125 points or more.

While CSI uses multiple classifications to rank ship environmental performance, other initiatives are less ambitious, with just a single classification. In order to qualify for the RINA Green Plus certification vessels must be awarded 100 points or more out of 621 (16%) while vessels taking part in the Blue Angel scheme must achieve 40 out of 113 points (35%). In the examples in Table 5, the number of points required to achieve accreditation is low. In each case, the minimum point threshold is a requirement to obtain overall certification of the award. There are no minimum thresholds set for individual pollutants. An oil tanker using Green Award (GA – oil tanker) for example is not required to obtain any points for reduction of NO_X, Particulate Matter or CO_2, therefore a vessel can obtain the award by gaining a satisfactory number of points in other criteria.

Incentive based initiatives such as those outlined in Table 4 also set unambitious environmental targets for vessels. The highest achievable score in ESI is 100 points (Murphy *et al.*, 2013), however the maximum threshold for the incentive schemes in Table 4 is capped at 50 points. Scott *et al.* (2017) suggests that one of the reasons for this is to not discourage participation by setting standards that are deemed 'too high' or unrealistic for many vessels. However, a more ambitious system, such as that adopted by Port Metro Vancouver (Port Metro Vancouver, 2019) , using multi-tiered benchmarking offering bigger financial incentives for high scoring vessels and smaller incentives for lower scoring vessels could encourage a wide uptake. It is also noted that the incentives offered are small relative to the total operating costs of a ship, and hence may not be very enticing (Murphy *et al.*, 2013; Scott *et al.,* 2017).

Table 5 Points thresholds for accreditation

Environmental initiative	Point threshold (%)
GA (oil tanker)	*20%*
GA (bulk carrier)	*21%*
GA (LNG carrier)	*40%*
GA (chemical tanker)	*20%*
GA (containership)	*26%*
GA (LPG carrier)	*18%*
RINA Green Plus	*16%*
The Blue Angel	*35%*

Where possible, initiatives were analysed to determine the level of ambition in regards to individual pollutant criteria. Many of the schemes are considered to go '*beyond regulatory requirements'* (Scott *et al*., 2017) however further analyses suggest that most of the schemes are unlikely to encourage pollutant reductions significantly below the levels set out in MARPOL Annex VI. Some of the schemes do not measure pollutants in absolute terms, and performance is assessed relative to emissions from other vessels, or average emissions from similar vessels.

For example, the CCWG assesses vessel CO_2 emissions relative to a calculated trade lane average. Vessel emissions must be below the trade lane average to obtain a minimum score, and 10% below the trade lane average to achieve the maximum score. CCWG also uses relative thresholds rather than absolute thresholds for SO_X emissions. The minimum requirement is an average fuel S content of 15% above the trade lane average, and the maximum score is achieved if it is 15% below the trade lane average. Therefore if the trade lane average S content rises, the S content required to achieve a score will also rise.

The NO_X and SO_X criteria for a selection of initiatives are compared in Figures 3 and 4. Each of the initiatives in Figure 3 and 4 use the requirements set out in MARPOL Annex VI as a scale to assess performance. For all of the initiatives, vessels are required to achieve at least Tier 1 emission levels in order to score points, while some set more stringent minimum requirements. CCWG is one of the more ambitious schemes in this regard, setting the minimum NO_X threshold at 20% below Tier 1 levels, however the maximum score is capped at Tier 3. Each of the Green Award initiatives offer maximum points for vessels achieving better than Tier 3 emissions, while CCWG, CSI, The Blue Angel and Green Ship Incentive Programme (Green Ship) set the maximum threshold at the regulatory limit (i.e. Tier 3).

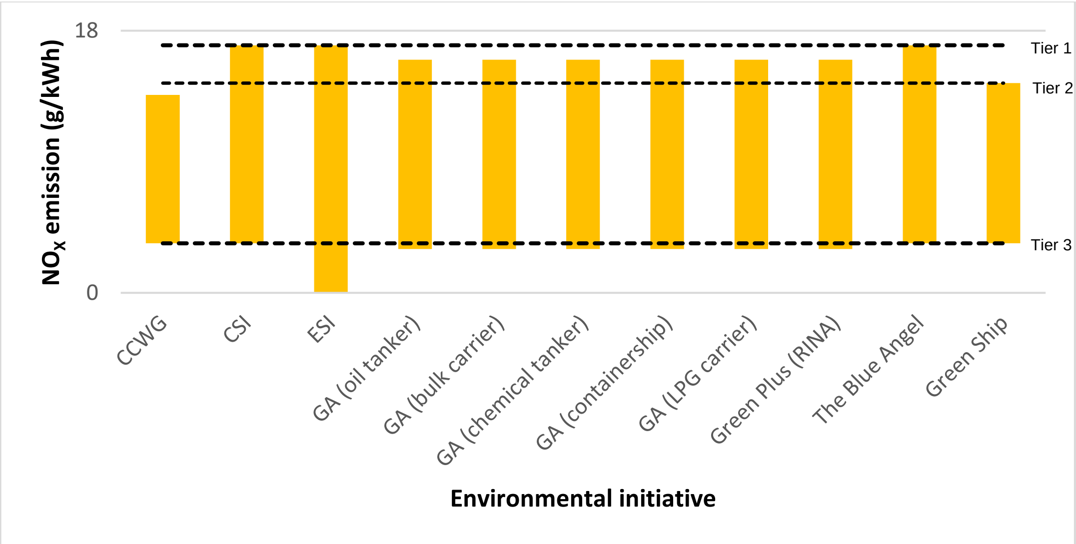

Figure 3 NO_X scoring range

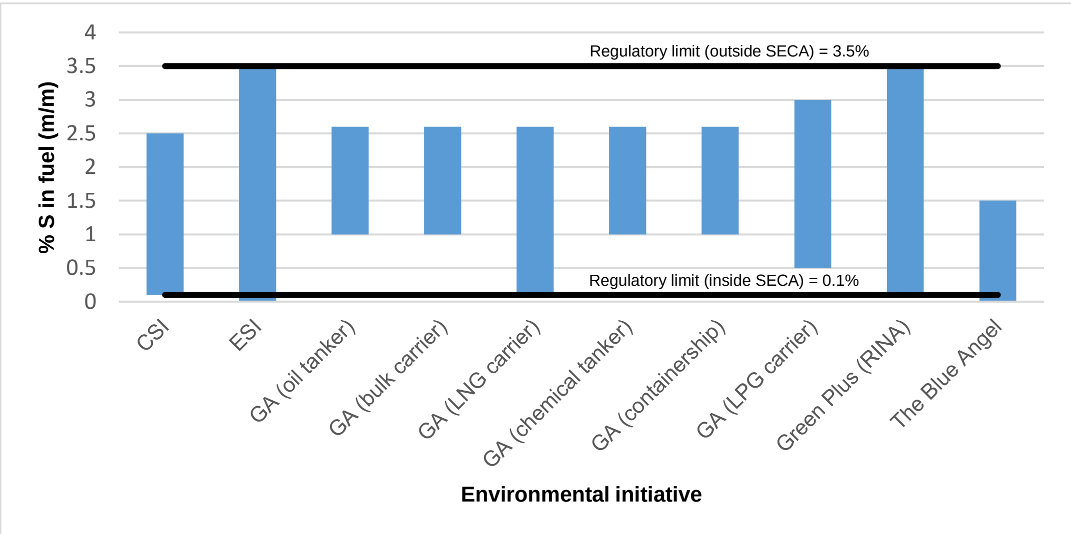

Figure 4 SO_X scoring range

The ESI is by far the most ambitious scheme with regards to assessment of NO_X and SO_X. It is the only scheme that rewards ships for reducing NO_X and SO_X emissions to zero, using a calculation based methodology to determine points based on emission level rather than using threshold values. However it is limited in assessing CO_2, apportioning only 20% of the total available points in the scheme to CO_2 related criteria, 4% for reporting of EEOI on fuel consumption and distance sailed and up to 8% for energy efficiency improvements, and an additional 8% if the vessel has OPS capability on board.

As shown in Figure 4, the initiatives use more ambitious thresholds to assess SO_X emissions with only ESI and RINA Green Plus setting the minimum requirement at the regulatory limit, the other schemes require a fuel S content lower than 3.5% in order to qualify. However only ESI and the Blue Angel use a scoring range which goes beyond the regulatory limit for SECA's of 0.1% S. The low level of ambition shown for parameters such as NO_X, SO_X and CO_2 questions the success of private initiatives in the context of improving sustainability, as in many cases the criteria do no more than reinforce the regulatory standards set out by the IMO.

It is also noted that most of the initiatives analysed use one single, rigid assessment methodology for all ships, and only the Green Award uses different scoring criteria for different vessel types. The other schemes analysed have a standard methodology which is either applied to a range of ship types, or is only suitable for application to one type of ship e.g. the CCWG is for container ships only. In some cases, additional or alternative bonus points are available for different ship types where the criteria is relevant to a specific characteristic of a ship e.g. the Blue Angel offers more points for passenger ships using OPS while in port than other ship types. The extent to which a ship impacts on the environment may vary depending on the characteristics of the vessel, and assuming that different ship types affect the environment in different ways, a '*one size fits all*' performance assessment methodology for all ships is not appropriate.

Investigation into the scoring mechanisms of each initiative shows that most of the schemes assess emissions based on vessel design criteria or fuel specification rather than actual or calculated emission data. The ESI for example requires evidence of a vessels EIAPP certificate for validation of NO_X emission performance, which is the recorded engine NO_X rating under test conditions, and SO_X emissions are assessed based on the fuel S content. Murphy *et al.* (2013) demonstrate how assessing SO_X performance based on fuel specification can be misleading, and may not necessarily represent actual fuel consumption. The CSI and CCWG also use certified NO_X ratings rather than actual emissions, however CO_2 is measured based on calculated EEOI using voyage data rather than design criteria, and compared against reference EEDI values for a given ship type. Environmental assessment based on actual performance data rather than performance under test conditions provides a more accurate understanding of a vessels true environmental impact.

4. Proposed alternative environmental assessment method

There is no evidence provided in the published methodologies to justify the weighting factors for pollutants used in the existing indices, therefore it is assumed that the weightings have been decided subjectively by the initiative developers. A more transparent method would be to use an objective, quantifiable approach to assess pollutants and allocate weighting factors, as outlined in Figure 5. Using such an approach, weighting factors are assigned by following a series of steps. First, the pollutant is identified, then the impact of the pollutant on the environment is established; the impacts are quantified in terms of severity using objective environmental indicators; perhaps based on already established indicators of environmental performance such as Global Warming Potential (GWP) for greenhouse gases. The results of the severity assessment are then used to determine pollutant indicator weightings factors. By doing this, pollutants can be assessed objectively and weightings assigned based on their environmental impacts.

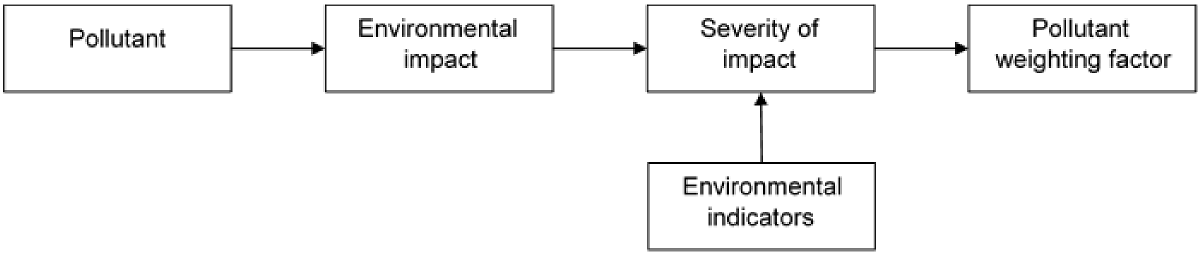

Figure 5 Proposed method for assigning pollutant weighting factors

A method is also proposed to assess vessel performance based on voyage data rather than design criteria (Figure 6). The accuracy of assessment is dependent on the type of operational data available. A vessel with species specific continuous emissions monitoring equipment installed on board provides the most accurate measurement of pollutant emissions. The technology can be expensive, however with the introduction of EU MRV regulations the industry is moving towards highly monitored voyages and hence the method has been developed with this in mind. Where such technology is unsuitable or not available, estimates based on fuel use can be calculated. To compare pollutants on a per voyage basis from different vessels, emissions must be converted into standard units (e.g. grams of pollutant per tonne mile) to give a pollutant score. The pollutant score is multiplied by the pollutant weighting factor to calculate an environmental score per pollutant. Such a method assesses vessel environmental performance based on operational data and provides a way of prioritising pollutants based on objective weighting factors.

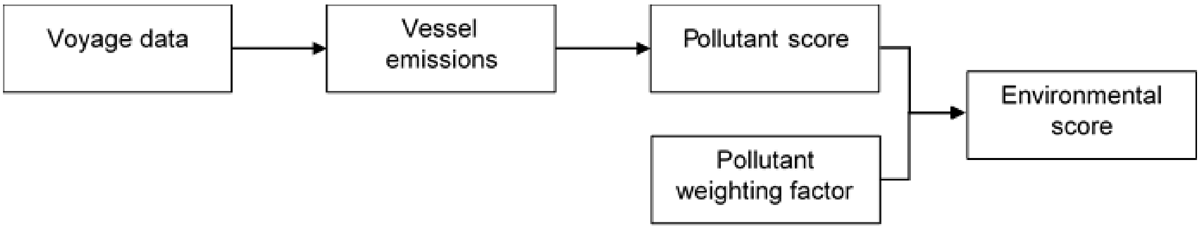

Figure 6 Proposed method for assessment of pollutants based on operational performance

Alongside the development of a universal method for environmental assessment of ships, one must also consider its implementation and enforcement. Previous studies by Lister *et al.* (2015) consider the application of transnational environmental governance in order to regulate and enforce more stringent environmental standards, while Port State Control may also offer a feasible mechanism for widespread implementation of environmental requirements. It is evident from this research that the current methods for environmental assessment of ships are fragmented and a more holistic approach is required, however the use of initiatives to assist regulatory enforcement may prove favourable, demonstrating reciprocal benefits for both implementation of regulations and uptake of voluntary initiatives.

5. Conclusion

The research highlights a large number of environmental initiatives currently available for use in the shipping industry. Some are regulatory instruments developed by the IMO, but the vast majority can be described as independent voluntary schemes. They have been categorised based on intended purpose as incentive schemes, research and innovation activities, and performance indicators.

The number of initiatives mentioned in the literature is significant, however more than 80% of those identified are not accessible in the public domain and could not be investigated in detail. Those which were analysed were found to lack transparency regarding publication of assessment outcomes, and hence it is difficult to ascertain the impact of participating vessels on the environment.

The analyses highlight differences in the environmental scope of the schemes, with some focussing on a single pollutant while others assess multiple emissions and discharges to the environment. The indices with multiple pollutant criteria assign weighting factors to each, which vary considerably between initiatives. In some cases, the indices assign dominant weighting factors to certain pollutants and hence scoring can be biased towards vessels which focus reduction commitments on pollutants with high weighting factors. The rationale behind the allocation of pollutant weighting factors is also unclear, hence the variation in scope between initiatives.

Many of the initiatives are described as going beyond regulatory requirements, however the analysis shows that the thresholds for achieving certification are generally low, and in many cases scoring is capped at the regulatory limit (e.g. Tier III for NO_X). In most cases, pollutants are assessed based on design parameters rather than the operational performance of the vessel, for example SO_X is assessed based on the S content of the fuel, and NO_X assessed based on the NO_X emission rating of the engine under test bed conditions.

This research proposes a framework for an alternative method of environmental assessment that is transparent, uses objective weighting factors based on the environmental impacts of pollutants, and uses operational data rather than design parameters to determine vessel environmental performance.

References

ABS (2009) Guide for the environmental protection notation for vessels. American Bureau of Shipping: Houston, Texas.

Andersson, K. Brynolf, S. Lindgren, J. F. Wilewska-Bien, M. (2016) Shipping and the environment. Improving environmental performance in marine transportation. Springer: Berlin-Heidelberg.

The Blue Angel (2010) Environment-conscious ship operation [online] available from: https://www.blauer-engel.de/en/companies/basic-award-criteria (accessed 07/11/2017).

Blue Circle Award (2015) Eco-action [online] available from: https://www.portvancouver.com/wp-content/uploads/2015/07/2015-06-03-FINAL-EcoAction-Brochure.pdf (accessed 07/11/2018).

Carl Moyer Program [online] available from: https://www.arb.ca.gov/msprog/moyer/moyer.htm (accessed 07/11/2017).

Centobelli, P. Cerchione, R. Esposito, E. (2017). Developing the WH^2 framework for environmental sustainability in logistics service providers: A taxonomy of green initiatives. *Journal of Cleaner Production.* Vol. 165 pp. 1063-1077.

Clean Cargo Working Group (2015) Collaborative Progress. [Online] available from: https://www.bsr.org/reports/BSR_Clean_Cargo_Working_Group_Progress_Report_2015.pdf (accessed 07/11/2018).

CNSS (2014) Clean North Sea Shipping Final Report: Key findings and recommendations [online] available from:

https://www.hzg.de/imperia/md/images/hzg/presse/pressemitteilungen/imperiamdimagesgksspressepressemitteilungen2014/cnss_finalreport.pdf (accessed 07/11/2017)

Clean Shipping Index (2017) Methodology and reporting guidelines 2017. Clean Shipping Index, Gothenburg, Sweden.

Corbett, J. J. Winebrake, J. J. Green, E. H. Kasibhatla, P. Eyring, V. & Lauer, A. (2007) Mortality from ship emissions: A global assessment. Environmental Science and Technology. Vol. 41 (24). Pp. 8512-8518.

DNV (2011) Environmental class. [Online] available from: https://rules.dnvgl.com/docs/pdf/DNV/rulesship/2011-01/ts612.pdf (accessed 07/11/2018).

ESI (2017) ESI fundamentals 2017 [online] available from: http://www.environmentalshipindex.org/Content/Documents/ESI-Fundamentals.pdf (accessed 07/11/2018).

ESI. (2018). List of participating ships. [Online] available from: http://www.environmentalshipindex.org/Public/Ships (accessed 16/10/2018).

European Maritime Safety Agency - EMSA (2007) Study on ships producing reduced quantities of ships generated waste – present situation and future opportunities to encourage the development of cleaner ships. [Online] Available from: http://emsa.europa.eu/implementation-tasks/environment/port-waste-reception-facilities/items/id/714.html?cid=147 (accessed 07/11/2018).

Fridell, E. Winnes, H. & Bergholtz, J. (2013). An analysis of environmentally differentiated port fees. Clean Baltic Sea Shipping [online] Available from: http://www.clean-baltic-sea-shipping.com/uploads/files/An_analysis_of_environmentally_differentiated_port_fees _Task_4.6.pdf (accessed 07/11/2018).

Green Award. (2018). [Online] available from: http://www.greenaward.org/greenaward/ (accessed 07/11/2018).

Green Flag Incentive Program {online] available from: http://www.polb.com/environment/air/greenflag.asp (accessed 07/11/2018).

Green Marine [online] available from: http://www.green-marine.org/program/ (accessed 07/11/2017).

Green Ship Incentive Program [online] available from: http://www.polb.com/environment/greenship.asp (accessed 07/11/2018).

Hallers-Tjabbes, C. C. T. Wegener, J. W. Van Hattum, B. Kempf, J. F. Hallers, E. T. Reitsemae, T. J. Boon, J. P. (2003) Imposex and organotin concentrations in Buccinum undatum and Neptunea antiqua from the North Sea: relationship to shipping density and hydrographical conditions. Marine Environmental Research. Vol. 55 (3) pp. 203-233.

Hossain, T. Adams, M. Walker, T. R. (2019). Sustainability initiatives in Canadian ports. *Marine Policy*. Vol. 106, article 103519.

Lister, J. (2015) Green Shipping: Governing sustainable maritime transport. Global Policy. Vol. 6 (2) pp. 118-128.

Lister, J. Poulsen, R. T. & Ponte, S. (2015) Orchestrating transnational environmental governance in maritime shipping. Global Environmental Change. Vol. 34 pp. 185-195.

LR Eco Notation [online] available from: http://www.lr.org/en/services/environment-and-sustainability/ECOnotation.aspx (accessed 07/11/2018).

Murphy, A. J. Landamore, M. J. Pazouki, K. & Gibson, M. (2013) Modelling ship emission factors and emission indices. Low carbon shipping conference, 2013. [Online] available from: http://www.lowcarbonshipping.co.uk/files/ucl_admin/LCS%202013/Murphy_et_al.pdf (accessed 07/11/2018).

Norwegian NO_X Fund [online] available from: https://ec.europa.eu/transport/sites/transport/files/modes/maritime/events/doc/2011_06_01_stakeholder-event/item14_norway_business_sector_nox_fund.pdf (accessed 07/11/2018).

Pike, K. Butt, N. Johnson, D. & Walmsley, S. (2011) Global Sustainable Shipping Initiatives: Audit and Overview 2011. A Report for the WWF. [Online] Available from: http://awsassets.panda.org/downloads/sustainable_shipping_initiatives_report_1.pdf (accessed 07/11/2018).

Port Metro Vancouver. (2019). Eco Action Program Brochure. [Online]. Available from: https://www.portvancouver.com/wp-content/uploads/2015/05/4747-PMV-Eco-Action-Program-Brochure-Online.pdf (accessed 28/06/2019)

RightShip Existing Vessel Design Index (EVDI™) EVDI and methodology [online] available from: http://shippingefficiency.org/evdi-and-methodology (accessed 07/11/2017).

RINA (2012) RINA Green Plus [online] available from: http://www.rina.org/en/Lists/PageAttachments/brochure_Green_Plus_EN.pdf (accessed 07/11/2018).

Scott, J. Smith, T. Rehmatulla, N. Milligan, B. (2017). The promise and limits of private standards to reduce greenhouse gas emissions from shipping. *Journal of Environmental Law* 29 (2).

Smith, T. W. P. Jalkanen, J. P. Anderson, B. A. Corbett, J. J. Faber, J. Hanayama, S. O'Keeffe, E. Parker, S. Johansson, L. Aldous, L. Raucci, C. Traut, M. Ettinger, S. Nelissen, D. Lee, D. S. Ng, S. Agrawal, A. Winebrake, J. J. Hoen, M. Chesworth, S. Pandey, A. (2014) Third IMO GHG Study 2014. International Maritime Organisation (IMO), London, UK.

Stuer-Lauridsen, F. Bergstrom, M. Overgaard, S. B. Kristensen, D. (2014) Environmental classification of ships. Miljostyrelsen: Kobenhavn. [Online] available from: https://www2.mst.dk/Udgiv/publications/2014/06/978-87-93178-59-5.pdf (accessed 07/11/2018).

Sustainable Shipping Initiative (2013) Sustainability Rating Schemes in Shipping - A resource for logistics managers, charterers and ship owners [online] available from: http://ssi.brenock.com/ (accessed 07/11/2018).

Svensson, E. & Andersson, K. (2011) Inventory and Evaluation of Environmental Performance Indices for Shipping. International Association of Maritime Economics Conference 2012. [Online] Available from: http://publications.lib.chalmers.se/records/fulltext/162305.pdf (accessed 07/11/2018).

Talley, W. K. (2003). Environmental impacts of shipping. In the Handbook of Transport and the Environment by Hensher, D. A. & Button, K. J. 2003. Elsevier: Oxford. Pp 279-290.