Assignment 3

(OENG 1117)

(Risk & Project Management)

"Low Sulphur Diesel – Spirit of Tasmania"

RMIT UNIVERSITY

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1. Problem diagnosis & Project Proposal

The impacts of greenhouse gases on the environment is a growing concern and has been a popular topic of today's world. Whereas scientists and researchers are working in clean energy for decades, the governing bodies have been stringent with limiting such activities that impacts the environment and burning of heavy fossil fuels is unfortunately one of them. Marine environment is also effected by such emissions and that is why there must be certain restrictions with the burning of these fossil fuels by all ships. With keeping in mind, International Maritime Organization (IMO) proposed a new regulation to reduce the sulphur emissions from 3.5% to 0.5% by ships by which will be fully enforced by the Port State Control in January 2020.

Based on the regulation, currently there are three options that can be considered to effectively minimize the harmful emissions. The use of fuels with low sulphur content, the use of Marine Gas Oil (MGO) or the installation of scrubber technologies in the engine exhaust section to purify the emissions with SO_x emissions before expelling it into the environment. The first two options are indeed permanent solutions to this regulation however with the current technology and research, it is economically not feasible and will undoubtedly topple the whole trade world with the sudden demand of these fuels by the end of this year. However, scrubber technologies are getting popular among the shippers and is an efficient way to save time and money while adhering to these regulations. The report will delineate on the specifics of managing a scrubber installation project starting from the risk analysis project requirements, then the selection of the proposed technology based on feasibility studies and comparison based on economic and non-economic evaluation.

1.1. Project requirements

In order to implement a scrubber system, a ship should take the following parameters into consideration.

a) The life of the ship:

This is one of the most concerned parameters that should be considered before implementing the scrubber technology. According to an investigation conducted by Liping jiang, the installation of the scrubber system is only crucial for ships that are having a life expectancy of 4.5 years. Otherwise, the installation is a total loss. Therefore 4.5 years is considered as the break-even point.

b) Trained personnel:

Without having properly trained personals, it would be risky enough to pursue an innovative technology such as the scrubber system. Well-structured and periodic training should be provided for the trainees.

c) Investors:

Corporates and investors willing to spend approximately $5 million dollar for each ship should take the initiate. It is after proper validation using certain techniques that the investors make sure that they implement this method. The techniques involve Real option analysis, Delphi-technique etc.

d) Operational Cost:

In order to run ships on scrubber system, a consistent running cost is vital.

e) Time frame:

It is of very limited time frame that this technique should be implemented. Therefore, enough time should be set aside to run these techniques properly.

f) Novel Technology: Since very few shipping companies have incorporated this technology, it is not well evident to us that, to what extend this project would be successful.

1.2. Risk Analysis

Analyzing the risk involved in any project is very crucial for its assessment and implementation. There are several subsections that we need to consider in order to validate this. We must have a detailed and precise idea about the project requirements, we should recognize the problems that this project will face on the long run, the possible constraints and much more.

The most prominent risks evaluated for this project are described below

Risks	Likelihood	Consequence	Final Analysis
Cost of implementing the new technology	4	5	20
Maintenance costs	5	4	20
The limited time frame to implement new technologies	5	4	20
Recruitment and Training costs	4	4	16
Disposal of sulphur deposits	5	3	15
Operational costs	4	3	12
Risk involving different grades of fuels	3	4	12

Table 1: Risk Analysis Matrix

1.3. Stake Holders

The potential stakeholders for this project are given below

- Shippers and Charterers.
- Bunker Traders
- Investors
- Customers

2. Project Technical description

A Scrubber is a mechanical device designed to remove SO_x gases from the emissions by ships which in turn enables the ships to use rich Sulphur crude fuels rich while complying with IMO2020 regulations. Dry scrubbing and wet scrubbing are the two most prevalent types of scrubbing in which dry scrubbing operates employing pellets of hydrate lime to remove the Sulphur content. The byproduct formed is gypsum which is discharged at ports and is used in manufacturing of fertilizers and plaster boards. Wet type Industrial effluent gas scrubber systems are a diverse group of air pollution control devices that can be used to remove some particulates and/or gases from industrial exhaust streams utilizing a scrubbing solution (Egan, 1972).

2.1. Types of Scrubber systems

These systems come in further three different types as Open loop scrubbing system, closed loop scrubbing system and Hybrid scrubbing system. All the three types are of our interest for this project and are discussed as below:

1. Open loop Scrubbers
   In this system sea water is used for scrubbing to remove the Sulphur content using the neutral alkali content in water. The relevant sludge is held back and disposed at shore facility. The quantity of water required depends on the engine capacity.
2. Closed loop Scrubbers
   Caustic soda is added to absorb the Sulphur gases with water and sludge is processed as in case of open loop suitable in high seas where neutral alkalinity is less. Fresh water is carried on board or generated onboard. The volume of water is half to that required in open loop.
3. Hybrid loop Scrubbers
   Another subcategory of wet scrubbing is hybrid scrubbing which operates on both open and closed loop. It can be more popular as it can operate in both areas. An innovative technology in wet scrubbing is the use of a membrane which is non-porous through which the exhaust gas is passed. Benefits of this system include smaller volume of water discharge; reduced exhaust contaminates and simplification of water cleaning process.

2.2. Open loop Scrubber Systems

While either one of the three types of wet type Industrial effluent gas scrubber system could accomplish the required task of reducing the Sulphur content in the exhaust from 3.5% m/m to less than 0.5% m/m, it can be observed that installing an Open loop scrubbing system will be a better choice compared to the other systems. The structure and working of an open loop system are illustrated below:

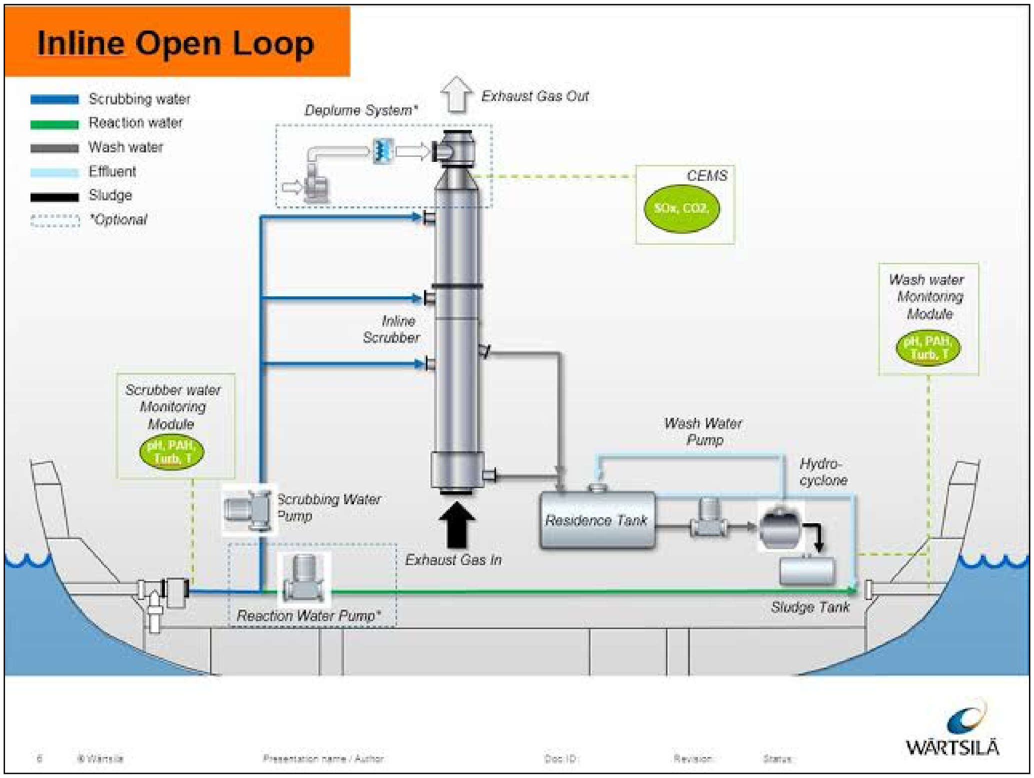

Figure 1: An open loop scrubber (scrubber, 2011)

In an Open loop scrubbing system, the alkaline sea water is utilized as a scrubbing solution. Sea water is pumped inside the system using a water pump which is ultimately fed into the scrubber at three different inlets as shown in the above figure. The exhaust gas from the diesel combustion enters the scrubber and gets sprayed with the pumped sea water, during which the Sulphur oxides (SO_x) in the exhaust react with the sea water and form sulphuric acid, thus reducing the overall Sulphur emission of the gas. The wash water gets collected in the residue tank. This wash water is pumped through a Hydro cyclone using a pump, separating the sludge from it. After removal of the sludge, this water is released back into the sea. Both during entry and exit, the Open loop scrubbing system employs Monitoring module, which measure the pH and other necessary parameters.

3. Economics Based Assessment

Economic based assessment involves the feasibility of whether the project is worth investing or not. These types of assessment helps us to estimate the benefits, the expenditures, the rewards and the risks of starting a new project. There are some of the techniques which help us to quantify economic based assessment for all the three technologies and are discussed as follows.

1.1. Investment Based Appraisal

Investment based appraisal set its eyes on studying the capital costs and operating costs of implementing the project and evaluate it in terms of whether benefits are greater than costs (Benefit cost ratio) or whether the rate at which all of the investment are covered by benefits (internal rate of return) or whether the number of periods required to accomplish that (payback period).

For our case, the capital expenditures are those expenditures that are considered while buying or installing a product. For a typical 36MW cargo ship, the estimated capital costs for each of the technologies (Open cycle scrubbers, closed cycle scrubbers and hybrid scrubbers) are stated below (Shu 2013).

Capital Costs (million US$)	**OCS**	**CCS**	**HCS**
Equipment Cost	3.100	3.850	3.600
Engineering Design (9% of Equipment cost)	0.279	0.347	0.324
Documentation (2% of Equipment cost)	0.062	0.077	0.072
Installation Off-hire loss (1% of Equipment cost)	0.031	0.039	0.036
Installation/ commissioning (80% of Equipment cost)	2.480	3.080	2.880
TOTAL Capital Costs:	**5.952**	**7.392**	**6.912**
Resale Value (10% of capital costs)	0.595	0.739	0.691

Table 2: Capital Cost comparison of three technologies

In order to consider operating costs, Average Engine load is 80% of MCR (36MW) with annual consumption of 8786 metric tons and the rate proposed is 591 US dollars per metric ton (Shu 2013). Based on these calculations, the operating costs of all the three technologies are given below

Operating Costs (million US$/year)	**OCS**	**CCS**	**HCS**
Fuel Costs (annual consumption in metric tons x cost per metric ton)	5.193	5.193	5.193
Maintenance Costs (40% of total capital costs)	0.238	0.296	0.276

Sludge Operation Costs (annual consumption in metric tons x cost per metric ton)	1.933	1.933	1.933
Labour Costs (40% of no. of staff x annual salary)	0.033	0.033	0.033
NaOH Cost (annual consumption in metric tons x cost per metric ton)	0	3.383	3.383
Freshwater Cost (annual consumption in metric tons x cost per metric ton)	0	0.019	0.019
TOTAL Operating Costs:	**7.397**	**10.856**	**10.837**

Table 3: Operating Cost Comparison of three technologies

While the annual benefits that one can expect from the project are stated below

Benefits (million US$/year)	**OSS**	**CSS**	**HSS**
Annual Profits	5.750	5.750	5.750
Fuel surcharge	3.000	3.000	3.000
TOTAL Benefits:	**8.750**	**8.750**	**8.750**

Table 4: Benefits associated with implementing the technology

The economic analysis comparison of the three technologies keeping in mind the scrubber lifetime of 12.5 years (Entec 2005,b) are done as follows

	OSS	**CSS**	**HSS**
PVF (4%)	9.688	9.688	9.688
PVF (7%)	8.154	8.154	8.154
PVF (12%)	6.312	6.312	6.312
NPV (4%)	7.525	27.343	26.707
NPV (7%)	5.339	24.247	23.631
NPV (12%)	2.736	20.507	19.917
BCR	1.077	0.744	0.749
IRR	17.254	39.414	38.815
PB	4.398	6.510	5.312

Table 5: Appraisal comparison of technologies

Based on the results, we can conclude that

- For lifetime of 12.5 which is same for every technology, the highest NPV is considered best and Open loop Scrubber System in this case is the most suited technology.
- For BCR>1, only Open loop Scrubbers meets the requirements of this feasibility criteria.

1.2. Sensitivity Analysis using @Risk7

The sensitivity analysis was simulated based on the same designated capital costs and the results were generated which are as follows

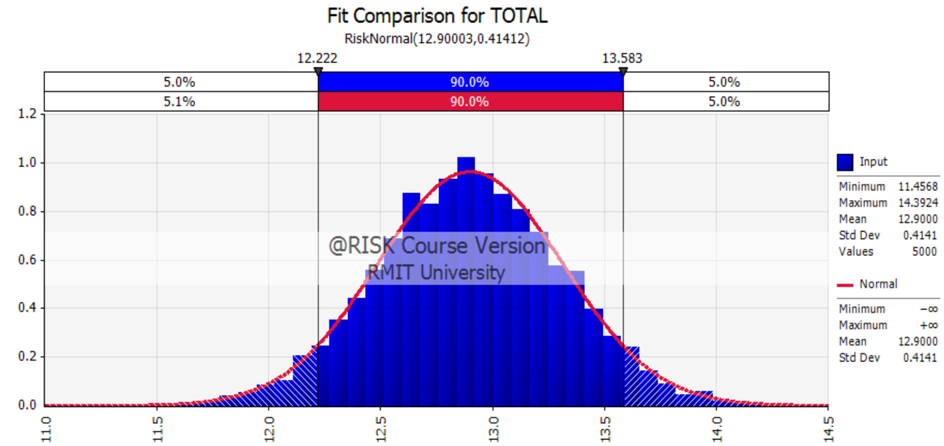

Figure 2 OPEN LOOP FIT DISTRIBUTION

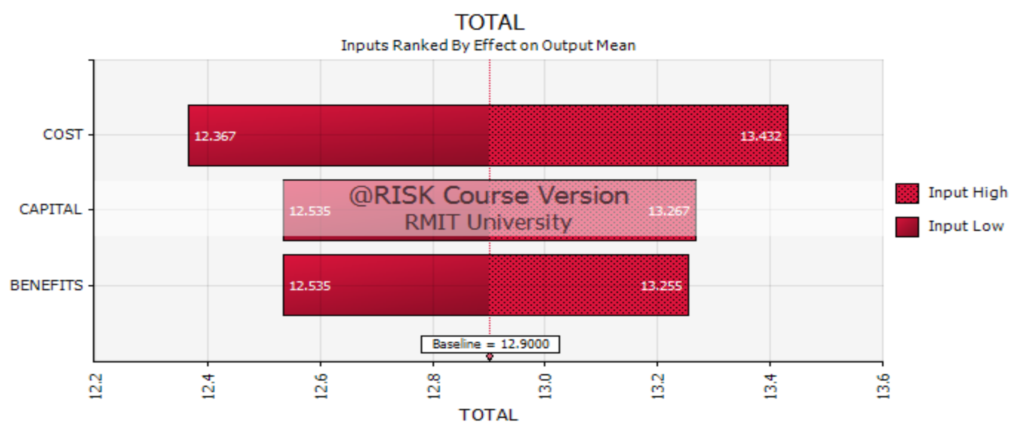

Figure 3 OPRN LOOP TORNADO OUTPUT MEAN

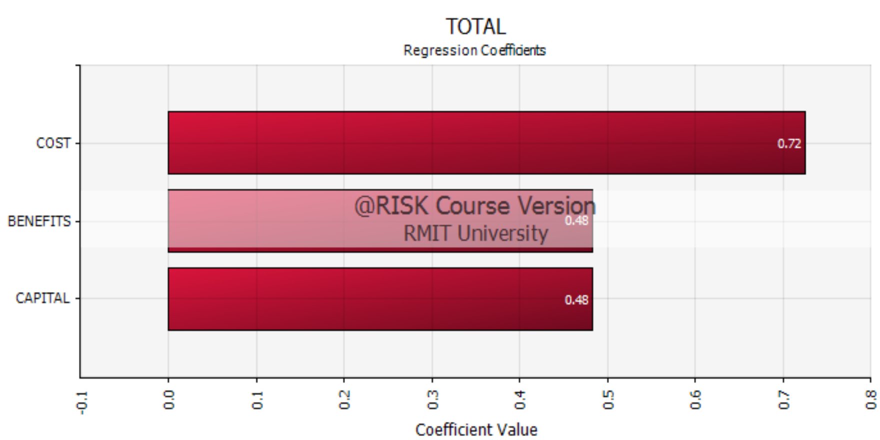

Figure 4 OPEN LOOP TORNADO REGRESSION

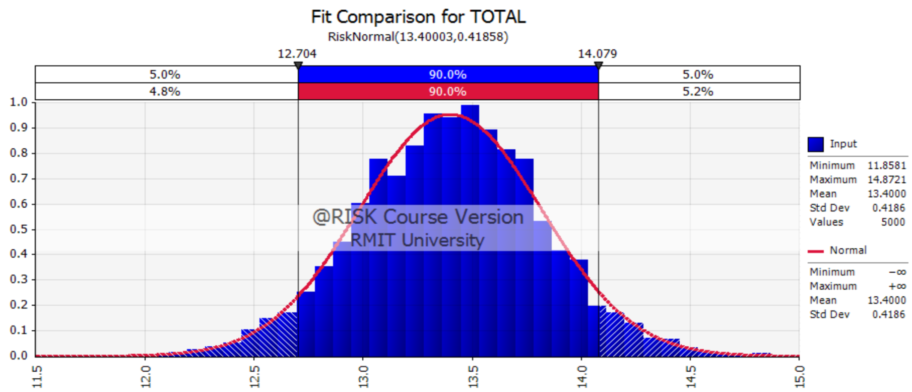

Figure 5 CLOSED LOOP FIT DISTRIBUTION

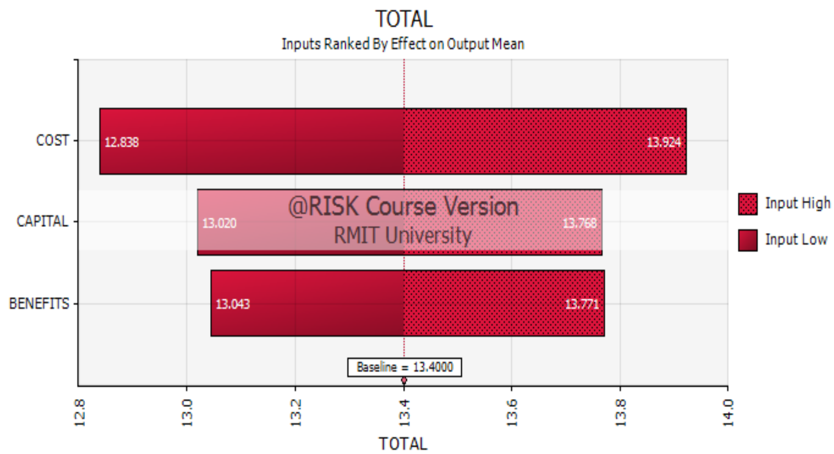

Figure 6 CLOSED LOOP TORNADO OUTPUT

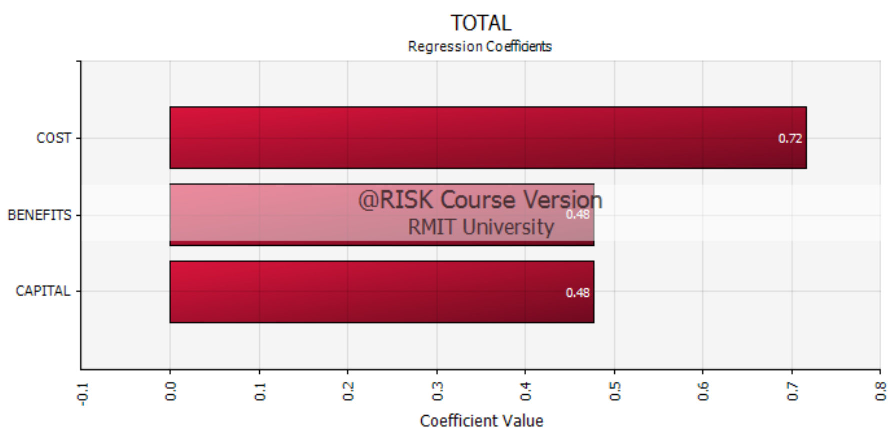

Figure 7 CLOSED LOOP TORNADO REGRESSION

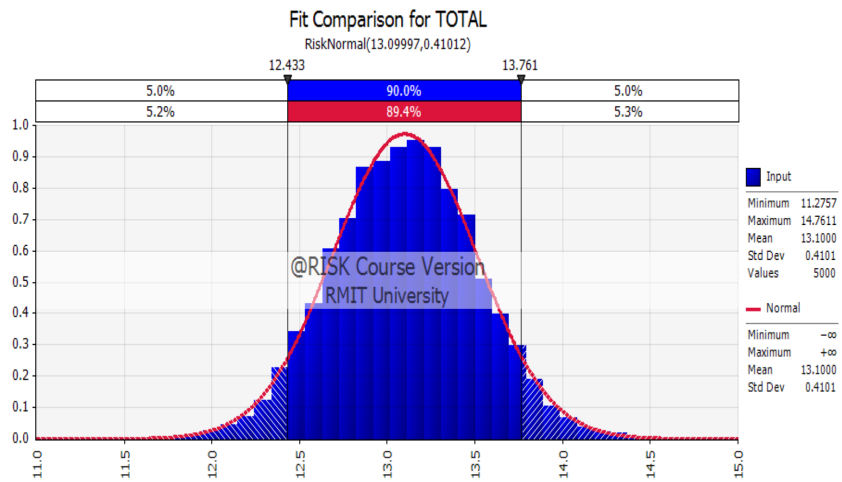

Figure 8 HYBRID FIT DISTRIBUTION

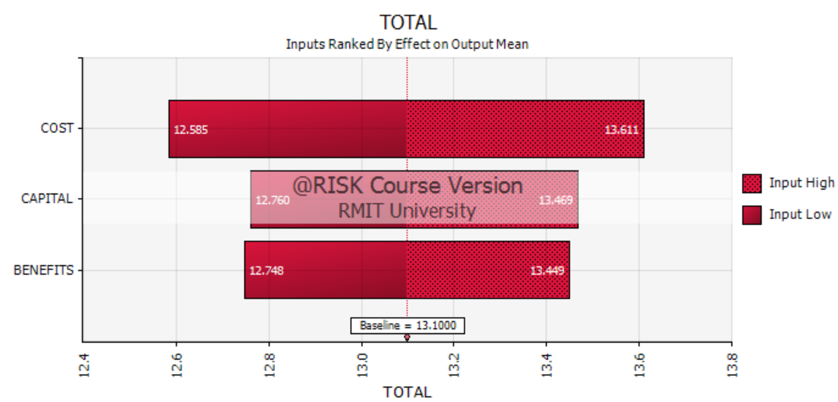

Figure 9 HYBRID TORNADO MEAN OUTPUT

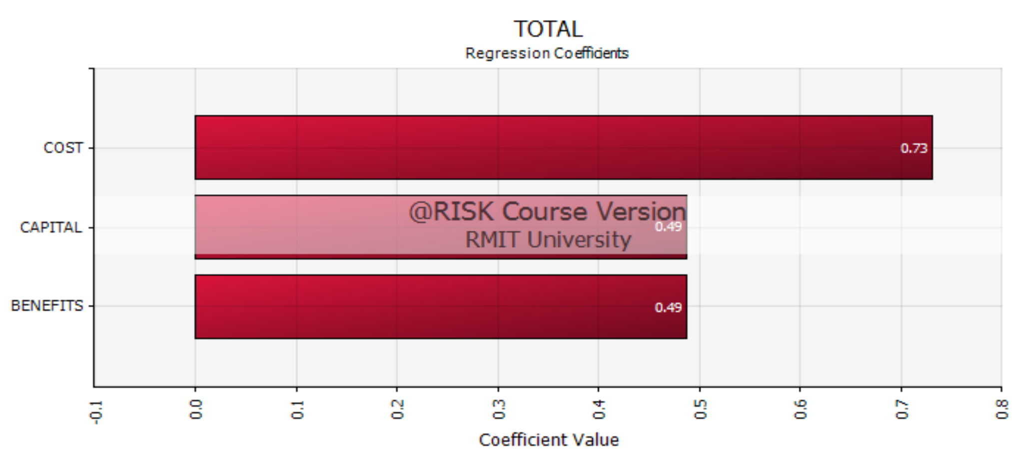

Figure 10 HYBRID TORNADO REGRESSION

4. Non-Economics Based Assessment

The objective of the assessment aims at analyzing the environmental aspects and impact of exhaust gas scrubbers. The scrubbers which are analyzed in the assessment are seawater scrubber (Open-loop scrubbers), freshwater scrubbers (closed-loop scrubbers) and hybrid scrubbers. The Environment Impact Assessment (EIS) would identify the regulations and impacts on the environment in non-economic terms and focus on the operations and efficiency of the scrubbers. The environmental impact assessment is practiced to help and assess the planning, designing and decision-making phase of projects to reduce/mitigate the impacts on the environment. The processes help in understanding the implementation of the plan and adverse effects on the environment considering the laws and regulations of the state, EU and IMO. The environmental impact assessment involves assessing factors based on the scientific change would be implemented in the process along with the design and engineering changes to the project (Prinĉaud, Cornier & Froélich, 2010).

4.1. Choosing assessment methodology

The scrubbers types are machines used to reduce toxic emission gases in exhaust. So, the method of evaluation must be able to consider all criteria on an equal basis and suggest best machine out of the scrubbers available. Hence, evaluation techniques of Rank-sum method to find criterion with most important in increasing effectiveness in reducing emissions and scaled checklist method for overall performance evaluation is chosen.

4.2. Rank-Sum Assessment

The rank sum method assesses the qualitative and quantitative criteria of the scrubbers in every case and helps determining a viable solution comparing the input and output factors of the scrubbers. The individual scores can be marked from -5 to +5 based on impact and is multiplied with weightings to become overall scores. Addition of all factors leads to the conclusion of based on Plan 1, Plan2 and Plan 3.

Criteria	**Scrubber (n=7)**	**Rank (r)**	**Rating (n-r+1)**	**Weighting**	**Individual Score**			**Overall Score**		
					OSS	**CSS**	**HSS**	**OSS**	**CSS**	**HSS**
C1	SOx Reduction	1st	7	0.250	4	4	4	1.000	1.000	1.000
C2	PM Removal	2nd	6	0.214	4	4	4	0.856	0.856	0.856
C3	NOx Reduction	6th	2	0.072	2	2	2	0.144	0.144	0.144
C4	Acidity Change due to discharge water	3rd	5	0.178	-1	0	-1	-0.178	0	-0.178
C5	Concentration of Nitrates	7th	1	0.036	1	1	1	0.036	0.036	0.036
C6	Specific Energy consumption	4th	4	0.143	5	2	3	0.715	0.286	0.429

C7	GHG emissions	5th	3	0.107	1	3	3	0.107	0.321	0.321
		Total Weighting		1.000	**Total Overall Score**			2.680	2.643	2.608

Table 6: Rank- Sum assessment of the project options

4.3. Max-Min Assessment

The Max Min method could be applied to evaluate and help the decision making of the stakeholders. Evaluating all the sectors we could identify the maximum and minimum factors affecting the project positively and negatively and in turn will enable us to find the best option from the worst of the options. The ratings were marked on the overall score of 10 and are depicted in the following table.

	C1	C2	C3	C4	C5	C6	C7	Min
OSS	9	8	7	4	6	9	6	4
CSS	9	8	7	5	6	7	8	5
HSS	9	8	7	4	6	8	8	4

Table 7: Max Min Assessment of the project Options

4.4. Justification of Scores

Most of the SOX and PM pollutants from exhaust gasses were removed from the scrubbers. The relative influence on the number of particles is less than for the weight of particles. A scrubber gathers relatively large-sized particles ((Køcks et al., 2012). Nitrogen oxides only to a very small degree and CO2 is not extracted by scrubber.

Scrubber type	SOx	NOx	PM
Open-loop	90%	Less than 10	60-90 %
Closed-loop	93%	Less than 10	60-90%
Hybrid	95%	Less than 10	60-90%

Table 8: Emission reduction of scrubbers (Eelco et al, 2015)

The Total hydrocarbon levels in discharge waters were below detection in the scrubber trials, even when the soot deposits in the scrubbers had a sheen of hydrocarbon on them. (EPA, 2011). Therefore the PHA is not a big problem in case of any scrubber used. In this case, Open loop, closed loop or Hybrid.

The heavy metals were observed in traces but were justified as wear particles from operation of engine itself. (Eelco et al, 2015). As the below table shows, the closed loop (FW scrubbing) uses 2% more fuel than Open loop(SW scrubbing) therefore is more energy intensive.(EPA, 2011)

	SW scrubbing	FW scrubbing
Pumps	1.0 %	1.0 %
Engine back pressure	0.4 %	0.4 %
Energy at land	0.0 %	2.0 %
Total	**1.4 %**	**3.4 %**

Table 9: Shows Fuel consumption of open loop and closed loop scrubbers (EPA, 2011)

The Hybrid and closed loop systems use NaOH as Neutralizer for SOx but Open Loop Doesn't use any such chemical. The production of NaOH (Sodium Hydroxide) produces Greenhouse gases, 9.8 kg CO_2e/kg NaOH (Dong et al, 2018). The open loop scrubber has a drawback of letting water discharge into immediate surrounding water, so there may be a chance of sea water contamination as reported in (EPA, 2011) but also suggested that seawater has a good dilution effect in deep water, coastal and port water have a higher rate of contamination. By these data collected, the scoring has been done to reflect the importance and effect on the overall performance of Scrubbers.

5. Conclusion

The economic and non-economic analysis summarizes that the Open loop scrubber systems has been found to be marginally better in performance than other two scrubber systems. In addition to the economic and non-economic advantages, Open loop scrubbers are advantageous in many more ways. The installation time for an Open loop scrubbing system is just 3-4 weeks (IMO, 2019). Furthermore, Open loop Scrubbers enjoy a long lifespan of around 12.5 years (Entec, 2005b). These scrubbers have non tangible benefits too. The effect of an open loop scrubber on marine environment is very less. Evaluating on a basin scale, the effect is found out to be after 15-20 years (Turner, Hassellöv, Ytreberg, & Rutgersson, 2017). It is feasible to implement open loop scrubber technology based on the evaluated results.

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