BARRIERS TO SHIP ENERGY EFFICIENCY: PRIORITIZATION USING THE ANALYTIC HIERARCHY PROCESS

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ABSTRACT

Increased energy efficiency will be paramount in mitigating economic and environmental impacts from shipping. There are a substantial amount of measures that typically increase energy efficiency, such as technical, operational and human factors. However, the presence of a variety of barriers in organizations is often explained in literature. This paper aims to present an overview of the potential barriers. The identification of relevant barriers and their appropriate prioritization is a need to effectively tackle them. This paper identifies relevant barriers to ship energy efficiency and, the barriers are prioritized using the analytic hierarchy process (AHP). In conclusion, this paper recommends the relative importance of each barriers for ship energy efficiency.

Keywords: Ship, Energy Efficiency, Barriers, Analytic Hierarchy Process (AHP)

1. INTRODUCTION

Transportation, and especially maritime industry, plays a significant role in the economic and is one of the main enablers of globalization. Shipping activity will continue to increase by around 200- 300% by 2050 (Buhaug et al., 2009; Smith et al., 2014). This continuing growth rate brings with it serious challenges to the sustainability of the maritime industry; one of them being environmental performance of shipping.

Shipping is a large and growing share of global carbon emissions. According to the International Maritime Organization (IMO), CO_2 emissions from shipping have grown by 86% from 1990 to 2007. These emissions may increase by double or even triple by 2050 in a business-as-usual scenario (Buhaug et al., 2009).

Besides, shipping companies are faced with high risks as a result of rising fuel prices to conserve their competitive power in the market. Presently, fuel cost in shipping generally constitutes between 50% and 70% of the total operating cost of a shipping company.

There are operational or technological measures that can improve energy efficiency. Operational practices, new technologies and improved logistic systems are key strategies to increase energy efficiency. IMO’s Marine Environment Protection Committee (MEPC) added a new chapter (Chapter 4) related energy efficiency of ships to MARPOL (International Convention for the Prevention of Pollution from Ships) Annex VI. Through this, as from 1st of January 2013, an Energy Efficiency Design Index (EEDI) is mandatory for all new ships and all ships have to carry a Ship Energy Efficiency Management Plan (SEEMP) (IMO, 2011).

While EEDI requires technical measures (for technology and design) at a minimum level with a long term impact for new ships, SEEMP establishes a mechanism to increase the energy efficiency through the operational measures using existing technologies in ships.

Operational practices, technological measures and improved logistic systems that can improve energy efficiency are identified as key strategies in terms of both environmental and economic concerns. Although there are many approaches to enhance ship energy efficiency, they are not always implemented properly. The difference between optimal and actual implementation is often explained by the being of some ship energy efficiency barriers (Jaffe and Stavins, 1994).

The focus of this paper is mainly on barriers to ship energy efficiency. The main objective of this paper is to identifying and prioritizing the ship energy efficiency barriers. We use analytic hierarchy process (AHP) to examine these barriers analytically and the ratio of effect of each barrier has been determined. The outcomes of this paper should be of interest to decision makers (ship owners and (energy) managers) that need to reduce the energy consumption of their ships. The results of this study will provide them with the strategic approach needed to plan for overcoming these barriers and reducing energy consumption.

The remainder of this paper is organized as follows. Section 2 examines ship energy efficiency barriers. After explaining the method used in this article in Section 3, results and discussions are presented in Section 4. Finally, conclusions are drawn in Section 5.

SHIP ENERGY EFFICIENCY BARRIERS (B)

To identify barriers in a shipping company and determine the most feasible measures for overcoming these barriers are the most critical approaches. The barriers are categorized into five groups: (i) Technology barriers, (ii) Policy barriers, (iii) Organizational barriers, (iv) Economic barriers, (v) Geographical barriers.

1.1 TECHNOLOGY BARRIERS (B1.1)

There could be incompatibilities between technologies and ship types creating technology barriers. New technologies are not generally preferred by ship owners due to their technical risks and long installation time.

A significant technology barrier is the incompatibility between energy-efficient technologies and their special operational conditions. For example, in some cases, the technologies are not useful anymore with the changing conditions in time.

The complexity of measures which requires the more knowledge and investment is the barrier. Therefore, the measure may be rejected.

1.2 POLICY BARRIERS (B1.2)

There are conflicting international regulations which results in more fuel consumption. For example, it is forbidden to wash ship hulls in ports, and thus fuel consumption may raise as a result of increased roughness of ship hulls (Jafarzadeh and Utne, 2014).

1.3 ORGANIZATIONAL BARRIERS (B1.3)

Organizational behaviours can increase investments in energy-efficient measures. Investors may put more importance on initial cost that have an effect on decision making while preferring a measure to invest in.

The lack of energy management is another barrier. The lack of information about individual's' responsibilities may lead the lack of trust in the organization and the trouble when adopting of energy-efficient measures.

Energy awareness makes individuals and parties to utilize their knowledge and skills for the use of technologies on board ships in an efficient way. It also causes stimulating motivation and focus on daily operational activities.

In addition, the lack of training is also a barrier. Crew should be trained with the update information.

Ship energy efficiency measures will need the cooperation of different stakeholders. If the departments and the individuals in the organization cannot show the required expertise, they may not overcome difficulties in applying of measures.

1.4 ECONOMIC BARRIERS (B1.4)

The high expenses of ship energy efficient technologies and limited access to capital are the causes of economic barriers. Economic barriers include external risk (includes overall economic trends, fuel price, policy and regulation.) and business risk (includes financing risk and sectoral trends) that can impede investments (Sorrel et al., 2000).

The lack of information about all costs related energy efficiency and unrealistic basis for cost-benefit analyses carried out to justify the implementation of ship energy-efficient measures can impede investments.

1.5 GEOGRAPHICAL BARRIERS (B1.5)

Geographical navigational areas and special routes may be another barriers. For instance, while the ship is operating in piracy waters, it should increase the ship speed due to the need for security, which leads increased fuel consumption. In addition, specific ship energy-efficient measures are only operational in specific routes.

2. ANALYTIC HIERARCHY PROCESS (AHP)

Saaty (1980) developed Analytical Hierarchy Process (AHP) as a 'Multi Criteria Decision Making' process that helps the decision-maker to develop a simple way for complex problems.

AHP enables to capture both qualitative and quantitative aspects of a decision. In addition, AHP provides a useful technique for checking the consistency of the evaluations, thus elimination the bias in decision making process.

Unlike the conventional methods, AHP method uses a ratio scale. Pairwise comparisons are carried out typically to derive accurate ratio and scale priorities. In the pairwise comparison, a judgment expresses how much more important criterion 1 alternative is from criterion 2 and the other alternative 3. These judgments are converted into quantitative values using the fundamental scale of the AHP. Table 1 shows a typical nine-point scale for an AHP model. In this way, the relative weights of the decision criteria and the relative rankings (priority) of alternatives are determined. A complex decision problem is the hierarchical structure consisting of three levels: the main objective in the decision making process at the top level, followed by a medium level consisting of the possible solutions for the lowest level decision problems.

Table 1: The fundamental scale of absolute numbers (Saaty, 1994).

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor one
4	Moderate plus	activity over another
5	Strong importance	Experience and judgment strongly favor one
6	Strong plus	activity over another
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	The evidence favoring one activity over another is
9	Extreme importance	of the highest possible order of affirmation
Reciprocals of above	If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	A reasonable assumption
Rationals	Ratios arising from the scale	If consistency were to be forced by obtaining n numerical values to span the matrix

3. RESULTS AND DISCUSSION

In our study, the questionnaire developed by Saaty on the basis of AHP’s basic scale was implemented in order to determine the significance levels of the ship energy efficiency barriers. A 10 person group of experts consisting of ship captains, chief engineers and energy managers of shipping companies who have at least over 10 and 15 year experience on board a ship. In order to analyze the data obtained from the questionnaire with the AHP method, the software ‘Super decisions’ was utilized. Establishment of hierarchy in the Super decisions software for the ship energy efficiency barriers is presented in Fig. 1.

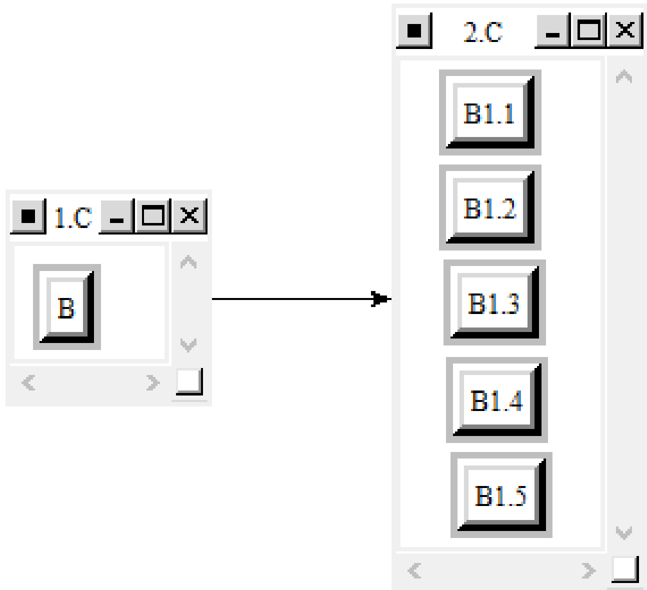

Fig. 1: Hierarchy of the ship energy efficiency barriers

Data from the questionnaires were entered into the software as shown in Fig. 2 after the establishment of hierarchy.

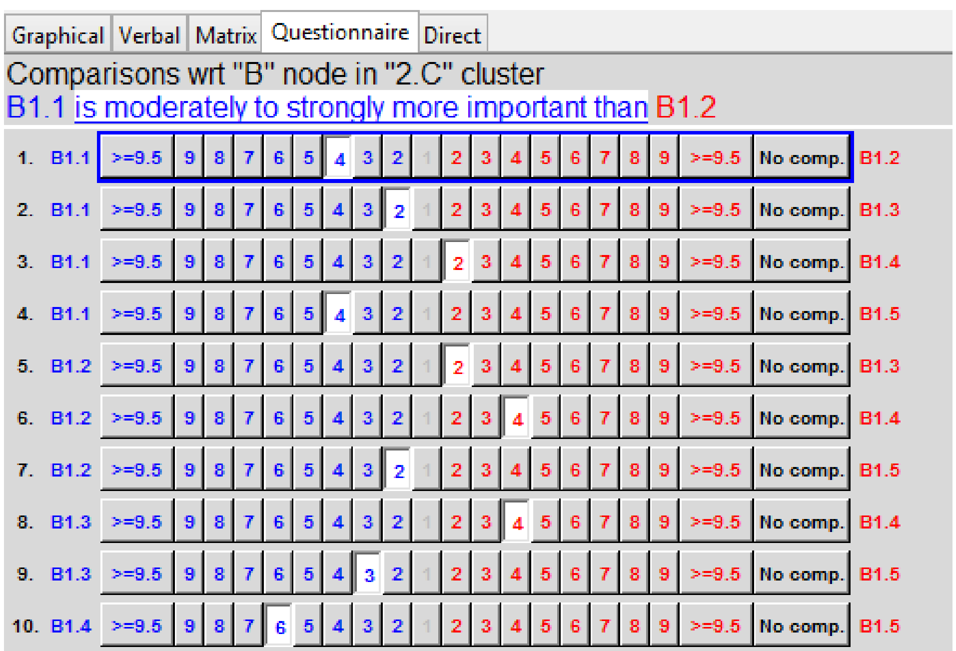

Fig 2: Pair-wise comparisons between barriers.

After the pairwise comparisons of the ship energy efficiency barriers, significance weights were determined as illustrated in Fig. 3. Among the barriers, economic barriers (B1.4) has prominence with a significance degree of 44%. Technology barriers (B1.1) were determined to have a significance degree of 27%. It was determined that ship specific factors (B1.3) and environmental factors (B1.2) have quantitative priority of 14% and 9%, respectively. It was determined that geographical barriers (B1.5) has the lowest quantitative priority of 6%.

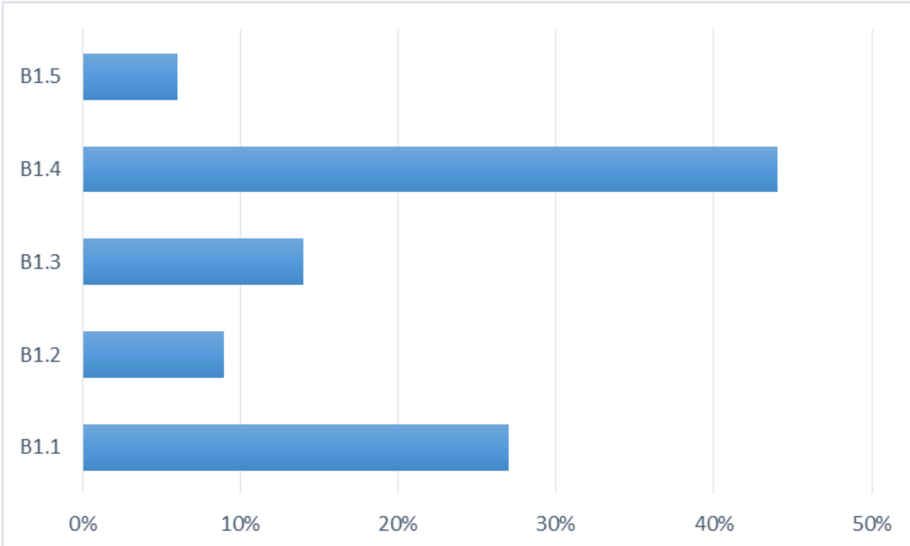

Fig.3: Effectiveness ratios of ship energy efficiency barriers

Within the scope of our study the quantitative priorities of the ship energy efficiency barriers were determined through the use of the AHP method. As it is generally observed, the most effective factors on ship energy efficiency is the economic barriers (B1.4) and technology barriers. Therefore, these criteria are the key barriers that should be considered for overall ship energy efficiency management.

To overcome the ship energy efficiency barriers various solutions can be suggested. Economic barriers can be solved by using precise measurement tools and acquiring proper feedback to have a clear information about the energy consumption. By this way, the investors would continue/stop investing in that ship energy-efficient measures. Technologies which are flexible and compatibility with energy efficiency operations should be offered. Manufacturers should be informed about this requirement. The technologies should be modified in order to fulfil new operations. Energy awareness can be increased in organizations by workshops and trainings. Individual's responsibilities regarding saving energy can be raised (Jafarzadeh and Utne, 2014).

4. CONCLUSION

As mentioned earlier there are several implementations to improve the energy efficiency of new and existing ships through technical and operational measures. Although there are many approaches to enhance ship energy efficiency, limitations of these measures cause some ship energy efficiency barriers.

We focused on the ship energy efficiency barriers and prioritize them using the AHP approach, which is a multiple criteria decision making method.

Various barriers are faced in shipping. The results of this research shows that economic and technology barriers are the most important barriers to deal with. The results of this study can provide decision makers (ships' masters, energy managers and ship owners) with the strategic approach for selecting the most important barriers and producing an energy efficient solution for the shipping industry. With the help of such decision-making tools shipping industry can establish and evaluate the priority energy efficiency barriers against high fuel prices and carbon emissions.

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