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Investigation of Marine Pollution Caused by Ship Operations with DEMATEL Method

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ABSTRACT: Ships have an important role in among the factors causing marine pollution. Marine pollution by ships damages sea life, which effects human health indirectly, in addition it restricts usage of sea for different purposes. Increasing comprehensive and compelling liabilities related with environmental components and subjects day by day are expected results for environmental science and engineering applications according to 60% of our responsibilities of European Union Integration development. In today's' world, where global warming is an issue of high priority and makes us feel its impacts in our lives, leaving a livable world to the next generations is now a primary goal for all. Determination of marine pollution caused by ship operations issue is a mu1tiple criteria decision-making (MCDM) problem, and requires MCDM methods to solve it. Therefore, the role of ship factor in maritime pollution and the possible reasons of this argument can be quantitatively evaluated based on expert knowledge and MCDM methodology. To investigate what makes to reduce the first "caused by ship operations " in marine pollution, the decision-making trial and evaluation laboratory (DEMATEL) method approach was applied in this study.

1 INTRODUCTION

Marine pollutions have been always attractive for the mankind since ancient times. Being ecologically very important focal centers, coastal zones have been also experienced human induced negative environmental problems, such as, coastal erosion, urban sprawl and pollution. In the global world of today, the importance of connection between countries and continents is increasing and transportation by sea is preferred due to economical reasons, because it is very cheap with respect to other transportations systems. However, sea transportation causes some problems also. Sea pollution caused by the sea transportation is about 20% of the total sea pollution.

Sea pollution are caused by ships daily activities and accidents. In daily operations, ships are unloading their churns without convenient international rudiments. Sea pollution by accidents of tankers and ships with dangerous loads causes important problems. Sea pollution by ships damages sea habitat, which effects human health obliquely, beside it restricts utilization of sea for different purposes (Yiğit, 2006).

Shipping is principal to our well-being, with around 90% of European Union international trade going by sea and more than 3.7 billion tonnes of freight a year being loaded and unloaded in EU ports. If not correctly controlled, the effect on the environment could be destructive, as ships often carry large volumes of hazardous cargo and generate a significant amount of pollutants throughout their life cycles (EMSA, 2008).

Many of pollutants are released by vessels either operationally or accidentally. The most important environmental damages caused by discharging household wastes and bilge water, dumping ballast water and wash water from tankers, emission of exhaust fumes, leaching of anti-foul paints, pollution with toxic materials, removal, introduction of organisms and acoustic and visual disturbances (Robert, 2001).

Shipping cause problem troubles to the environment both on inland waterways and on the ocean. These problems come from six major origins; routine discharges of oily bilge and ballast water from marine shipping; dumping of non-biodegradable solid waste into the ocean; accidental spills of oil, toxics or other cargo or fuel at ports and while underway; air emissions from the vessels' power supplies; port and inland channel construction and management; and ecological damage in consequence of the introduction of outlandish species transported on vessels (OECD, 1997).

The release of oil and other harmful substances (including noxious liquid substances,sewage,garbage and air pollution) into the marine environment is regulated in great detail in the International Convention for the Prevention of Pollution from Ships (MARPOL). This convention was adopted by the International Maritime Organization (IMO) in 1973. It has been amended a number of times and is being continuously complemented and strengthened to meet the ever-increasing demands of the world community (EMSA, 2008). In the past few decades, international, regional and national regulation over shipping matters such as navigational safety, ship-source pollution and maritime security have grown to such a scope that the global shipping industry today faces a litany of costly regulatory rules. Accordingly, the ship owner's conventional right of free navigation is presently qualified by considerable requisites such as the protection of the marine environment and the promotion of maritime safety. In particular, the emphasis on marine pollution control by relevant coastal and port states has come to fundamentally erode the traditional right of free navigation accruing to maritime states and their shipping interests (Tan, 2006).

Shipping also causes more invisible types of pollution. Recent concerns include the harmful environmental effects of substances in anti-fouling paint used on ships' hulls, and of species which are transported from one sea area to another in ballast water tanks. Also, the bilge water includes a high amount of dirtiness as well as its toxic, corrosive, inflammable / explosive characteristics. Discharging of the bilge water out of the vessel through the pumps and without waiting for a long time is required, but it is pumped directly into the marine environment. Directly discharge process of bilge water is very harmful for marine environment. Both concerns have led the IMO to adopt specific conventions on the topics in 2001 and 2004 respectively. In addition, pollution is caused when ships are constructed and maintained, and when they are dismantled at the end of their life cycles. The latter is of particular concern at the present time, given that much of the world's ship breaking is done in countries where neither workers nor the environment have adequate protection against harmful practices and substances involved in ship recycling. A convention on the safe and environmentally sound recycling of ships is currently being drafted by the IMO and it is set for adoption in May 2009 (Emsa, 2008; Anderson, 2009).

According to the IMO (International Maritime Organization) MARPOL Code, marine pollution caused by ships are affected by factors such as operational pollution and accidental pollution. Operational pollution means the phenomenon that ship-cause marine pollution is not confined to accidents. In fact, the majority of pollutants are released while the ship is on voyage rather than accidentally. In this respect, activities include the chronic discharge of sewage, tank residues, bunker oils and garbage, as well as the exchange of ballast water, emissions from vessels' engines and pollution due to anti-fouling paints on ships' hulls, dumping of garbage and solid waste, resulting of oil and waste water after deck washing operations, pouring of cargo into the sea, giving directly to the sea of raw sewages. In this sense, determination of marine pollution caused by ships operations are a kind of mu1tiple criteria decision-making (MCDM) problem. So, proposed method is developed for selection with decision-making trial and evaluation laboratory (DEMATEL) as a ship routine operations process on marine pollution.

This research utilizes DEMATEL technique to explain the relationships between the various criteria. DEMATEL is a comprehensive method for building and analyzing a structural model involving causal relationships between complex perspectives. This study aims to utilize the a kind of mu1tiple criteria decision-making (MCDM) method, named decision-making trial and evaluation laboratory (DEMATEL) technique approach to recognize the influential criteria of marine pollution caused by ships routine operations.

2 METHODOLOGY

Marine pollution caused by ships usually occur due to combination of coincidental incidents or processes, as a general rule by negligence of one or more independent components that are required to action accurately for the successful finalizations of the system requirements. The process of determination marine pollution caused by ships is required to handle several complicated factors in a better conceivable and logical manner. So, determination of marine pollution caused by ships issue is a kind of mu1tiple criteria decision-making (MCDM) problem. To solve this problem, we used a MCDM method, called DEMATEL. DEMATEL developed by the Science and Human Affairs Program of the Battelle Memorial Institute of Geneva between 1972 and 1976 was utilized to study and resolve the complex and intertwined problem group (Tzeng and Chiang, 2007). In this study, decision-making trial and evaluation laboratory (DEMATEL) method is applied because this method generates causal diagrams to describe the basic concept of contextual relationships and the strengths of influence among the criteria (Wu and Lee, 2011).

In this study firstly, marine pollution caused by routine ship operations criteria was determined. The criteria involved in the marine pollution selection have been chosen according to the IMO (International Maritime Organization) MARPOL Convention. In next step, the DEMATEL analysis was applied in order to determine the criteria as follow section 2.1. To establish the network relationships among criteria in influence each other for the marine pollution selection involves a decision making team which includes 2 academics personal, 4 experienced captains. Then, decision making team E1, E2, . . . E6 is constituted to determine the network relationships. And give the performance scores for each expert in terms of all criteria in the evaluation hierarchical structure respectively. A questionnaire was used to find out influential relations from each expert for ranking each criterion on the appropriate marine pollution caused by ships routine operations with a four-point scale ranging from 0 to 4, representing from 'No influence (0),' to 'Very high influence (4),' respectively. For each pairwise comparison, the decision making team have to determine the intensity of the relative importance between two criteria. The computation of using DEMATEL technique is based upon these six experts' opinions. So there are 6 dimensions, the six 6 X 6 matrices. We utilized the DEMATEL to construct the influence map in accordance with the real situation in which criteria should be interdependent and determine the importance of criteria.

2.1 *DEMATEL Method*

In generally, the DEMATEL method is used to illustrate the relations between criteria and to reach the main factor/criteria to symbolize the impact of factor (Tzeng et. al, 2007; Wu and Lee, 2011). The DEMATEL method is established on digraphs which can discrete involved factors into cause and effect groups (Yang et. al, 2008). This method has also been individually used in many activities such as safety problems (Liou et. al, 2007) , transportation (Chen and Yu, 2008), supply chain management (Chiu et. al, 2007) and automotive industry (Wu and Lee, 2011) .

The DEMATEL method is briefly described as follow (Wu and Lee, 2011; Liou et. al, 2007; Chen and Yu, 2008).

Step 1: Calculating the direct-relation matrix. Suppose we have L experts in this study and n criteria to consider. Firstly, the relationship between criteria requires that the comparison scale be designed as with five levels, where scores ranging from 0 to 4 represent ''no influence'' to ''very high influence'', respectively. Experts are answered the direct influence degree between criterion ''u'' and criterion ''v'', as indicated by Zuv. The initial direct-relation matrix $Z=[Z_{uv}]|Y|$ is determined owing to pairwise comparisons in terms of influences and directions between criteria. Then, as the result of these evaluations, the initial data can be obtained as the direct-relation matrix that is a matrix Z, in which a Z_{uv} is denoted as the degree to which the criterion u affects the criterion v. The scores by each expert will give us a ''n x n'' non-negative answer matrix $X^k=[X^k_{uv}]_{nxn}$, with $1 \le k \le L$. Thus, X^1, X^2, . . . , X^L are the answer matrices for each of the L experts, and each element of is an integer denoted by X^k_{uv}. The diagonal elements of each answer matrix X^k are all set to zero. We can then compute the ''nxn'' average matrix Z for all expert opinions by averaging the L experts' scores as follows:

$$\left[Zuv\right]_{n\times n} = x = \frac{1}{L}\sum_{k=1}^{k}\left[X_{uv}^{k}\right]_{n\times n} \tag{1}$$

Step 2: Normalizing the direct-relation matrix. The normalized direct-relation matrix M can be obtained by formulas:

$$M = Z \times L \tag{2}$$

$$L = \frac{1}{\max 1 \le u \le n \sum_{v=1}^{n} Zuv}, u, \mathrm{v} = 1, 2, ..., \mathrm{n} \tag{3}$$

Step 3: Calculating the total-relation matrix. After the normalized direct-relation matrix M is obtained, the total relation matrix K can be acquired by formula (4), in which the H is represented as the identity matrix.

$$K = M \times \left(H - M\right)^{-1} \tag{4}$$

Step 4: The sum of rows and columns are separately denoted as D and R within the total-relation matrix K through equations (5) to (7).

$$K = \left[k_{uv}\right] u, v = 1, 2, 3, ..., n \tag{5}$$

$$D = \left(D_u\right) = \left(\sum_{v=1}^{n} k_{uv}\right) \tag{6}$$

$$R = \left(R_v\right) = \left(\sum_{u=1}^{n} k_{uv}\right) \tag{7}$$

The DEMATEL method analysis was used to obtain the initial direct-relation matrix with using pairwise comparison with the total relation matrix with D+R, D-R values and build a critical relative graph of criteria in the cluster effect. ''Du'' denotes the row sum of ith row of matrix K. Then, Du denotes the sum of influence dispatching from factor v to the other factors both directly and indirectly. Rv shows the column sum of vth column of matrix K. Rv shows the sum of influence that factor u is receiving from the other factors. The sum of row sum and column sum (D + R) shows the index of representing the strength of influence both dispatching and receiving. Furthermore, if (D- R) is positive, then the factor ''u'' is rather dispatching the influence to the other factors, and if (D - R) is negative, then the factor ''u'' is rather receiving the influence from the other factors.

Step 5: Determining a threshold value to obtain the digraph. Since matrix K provides information on how one factor affects another, it is necessary for a decision maker to set up a threshold value to reduce some negligible effects. For these reason, only the effects greater than the threshold value is chosen and shown in digraph. In this study, the threshold value is set up by computing the average of the elements in Matrix K. The digraph can be acquired by mapping the dataset of (D+ R, D-R).

3 EMPIRICAL STUDY

An empirical example for the most important criteria selection for the marine pollution caused by ship routine operations is illustrated to demonstrate the proposed method to be more rational and suitable in this section.

Six criteria involved in the marine pollution caused by ship operations selection are used in this empirical study. The criteria have been chosen according to the IMO (International Maritime Organization) MARPOL Convention. A decision making team were invited to answer the questionnaire. The computation of using DEMATEL method is based six decision making team's opinions. Using the 6X6 pairwise comparisons, the averages of their opinions were calculated . DEMATEL method was used to evaluate the criteria which potentially effective in determining marine pollution. The critical impact of each node on the marine pollution selection and the network effect were determined. Initial direct relation matrix was created based on pair-wise comparison of total relation matrix values (D+R and D-R) and the criteria were clustered in the form of critical relative graph by applying DEMATEL technique. The relative graph is necessary for explaining the network structure of the clusters in determining the most influential criteria on recreational beach decision. In order to generate the objective super-matrix of ANP, the network effect should be first built using DEMATEL. Then, the average initial direct matrix Z is obtained based on formula (1) as Table 1.

Normalized initial direct-relation matrix M is calculated through formulas (2) and (3). Sequentially, the total relation matrix K is also derived utilizing refer to (4) shown in Table 2.

Total sum of effects given and received by each criterion is seen in Table 3 using formulas (6) and (7).Table 3 provides the direct and indirect effects of six dimensions. Finally, the threshold value (0.7218) used in Step 5 is to compute the average of the elements in Matrix T. The digraph of these six dimensions is demonstrated and the network relationship map of DEMATEL method was obtained and shown in Fig. 1.

Table 1. Initial direct matrix Z.

Criteria	Bunker oils and bilge waters	Ballast waters	Garbage and Solid Wastes	Sewages waters	Anti-fouling paints	Deck, hold, vs washing operations (Daily opr.)
Bunker oils and bilge waters	0,04	0,321	0,302	0.412	0,201	0,329
Ballast waters	0,298	0	0,174	0,185	0,294	0,173
Garbage and Solid Wastes	0,185	0,271	0	0,256	0.112	0,304
Sewages waters	0,271	0,184	0,316	0,02	0,307	0,272
Anti-fouling paints	0,148	0,204	0,194	0,301	0	0,207
Deck, hold, vs. washing operations (Daily opr.)	0,174	0,160	0,217	0,122	0,318	0

Table 2. Total influential relation matrix K.

Criteria	Bunker oils and bilge waters	Ballast waters	Garbage and Solid Wastes	Sewages waters	Anti-fouling paints	Deck, hold, vs washing operations (Daily opr.)	R
Bunker oils and bilge waters	0,612	1,028	0,942	1.109	0,611	1,009	5,311
Ballast waters	0,793	0,687	0,374	0,527	0,594	0,673	2,971
Garbage and Solid Wastes	0,682	0,641	0,527	0,752	0.298	0,904	3,804
Sewages waters	0,385	0,607	1,116	0,497	0,617	0,598	3,816
Anti-fouling paints	0,424	0,404	0,574	0,321	0,745	0,633	3,101
Deck, hold, vs. washing operations (Daily opr.)	0,418	0,468	0,546	0,303	0,731	0,587	3,053
D	3,313	3,835	4,079	3,509	3,596	4,404	

Table 3 shows that a "bunker oils and bilge waters" criterion is the most important dimension with the largest (D + R) value of 8,624 whereas "Anti-fouling paints" criterion is the least important dimension with the smallest value of 6,697. The importance of dimensions can be determined by the (D + R) values. To further investigate the cause-effect relationship of dimensions, ballast waters, garbage and solid wastes and deck, hold, vs. washing operations are net causes based on positive (D - R) values.

Table 3. Sum of influences given and received on each criterion

Criteria	D + R	D - R
Bunker oils and bilge waters	8,624	-1,998
Ballast waters	6,806	0,864
Garbage and Solid Wastes	7,883	0,275
Sewages waters	7,325	-0,307
Anti-fouling paints	6,697	0,496
Deck, hold, vs. washing operations (Daily opr.)	7,457	1,351

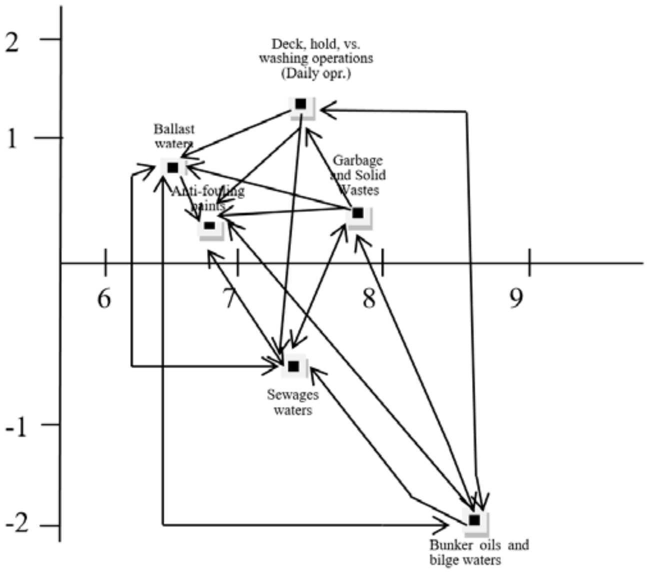

Figure 1. Network relationship map of impacts for the marine pollution caused by ship operations criteria

Bunker oils and bilge waters, and sewages waters are net receivers due to negative (D - R) values. Furthermore, deck, hold, vs. washing operations (Daily opr.), ballast waters and anti-fouling paints are the three most essential dimensions to improve the marine pollution caused ships by further considering the causal relationships. To further investigate the cause-effect relationship of dimensions, “deck, hold, vs. washing operations, (Daily opr.)”, ballast waters, anti-fouling paints and garbage and solid wastes are net causes based on positive (D- R) values. Bunker oils and bilge waters, and sewages waters are net receivers due to negative (D-R) values. From Fig. 1, bunker oils and bilge waters, garbage and solid wastes, and “deck, hold, vs. washing operations (Daily opr.)” are the three most critical dimensions. Specifically, “deck, hold, vs. washing operations (Daily opr.)” directly affects bunker oils and bilge waters and sewages waters. Six dimensions are influenced or mutually influenced by any pair of dimensions except “deck, hold, vs. washing operations (Daily opr.)”. In summary, “deck, hold, vs. washing operations (Daily opr.)” is the most important dimension followed by ballast waters anti-fouling paints then garbage and solid wastes criterion. Therefore, “deck, hold, vs. washing operations (Daily opr.)”, ballast waters and anti-fouling paints are the three most essential dimensions to improve the minimizing marine pollution caused by ship operations by further considering the causal relationships.

4 CONCLUSION

In this paper, we would like to new framework for determine and evaluated the marine pollution related to ship operations with above mentioned these six criteria. This study presents DEMATEL method for analyzing the importance of criteria correlations and also to describe the contextual relationships among these criteria. Based to the results, six criteria have some interrelations with each other. According to the impact-direction map, we can make accurate decisions. Also, the results showed that bunker oils and bilge waters is a key value factor and powerful influential criteria. However, by further considering causal relationships, improving both bunker oils and sewages waters factor dimensions cannot be effectively strengthen minimizing marine pollution caused by ship operations because these two dimensions are influenced by the other dimensions. In contrast, “deck, hold, vs. washing operations (Daily opr.)”, ballast waters, anti-fouling paints and garbage and solid wastes factor are all causal dimensions and have positive impacts on bunker oils and bilge waters, and sewages waters factor such that any improvement on these dimensions would also improve bunker oils and bilge waters, and sewages waters. The proposed framework brings several contributions to marine pollution evaluation and selection. At first, a new model for selecting marine pollution with emphasis on ship operations issues has been developed. At second, the DEMATEL method was applied in selecting marine pollution cause with respect to ship routine operations. This feature is also unique with regard to previous studies. In addition, results of these modeling can be used with other decision making method. Application of other decision support approaches would help to extend the analysis such as analytical network process (ANP).

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