APPLICATION OF FUZZY ANALYTIC HIERARCHY PROSES FOR ERROR DETECTION OF AUXILARY SYSTEMS OF SHIP MAIN DIESEL ENGINES

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SUMMARY

Ship engine room has a structure which has to meet a number of needs with regard to administrative conditions. Therefore, when the complicated structure of engine room are considered, even a simple mechanical failure, if no measures taken abruptly, grows into irreversible condition, causing losses that cannot be compensated. A well-qualified ship engine conductor along with an effective error detection system is needed to detect failure and act immediately against any engine impairments possible. This study aims to manage troubleshooting in main engine auxiliary systems which cover cooling, lubricating and cooling oil and fuel systems. The study is also thought to be a good reference for maintenance processes for marine engineering operators. Breakdown of main engine equipment are examined and troubles hooting program is developed for using Fuzzy Analytic Hierarchy Process (F-AHP) determine solution methods and causes of such breakdowns. In this paper, a fuzzy Multi Criteria Decision Making (MCDM) methodology was proposed to determine the most effected system of the ship main diesel engine. The results showed that fuel system was the most effected alternative, as being followed subsequently by cooling system, governor system, air supply system and oiling system. The results were based upon the opinions of three experts groups who ranked the ship main diesel engine systems alternatives according to twenty-nine criteria expert selected.

1. INTRODUCTION

Engine room is composed of main engine auxiliaries designed to supply the power necessary for operating the ship and fuel, oil, exhaust, cooling, air supply, and control systems that meet all the operational needs. Engine room is under the category of systems with high complexity; also it is made up of sub-systems that meet a number of needs. Diesel engines account for 98% of the resources producing power to operate ships. Marine diesel engines are more likely to encounter sudden and unexpected breakdowns than those stemming from long term use and wear in time. Overlooking, ignoring, or being unable to notice small impairments are among the reasons for large scale breakdowns [1].

Any simple engine failure may lead to another one unless it is noticed at a short time and measures are taken. These failures, occurring subsequently, grow into such an extent that they can lead to losses which cannot be reversed along with causalities. The important thing is to curb and take action against those failures before they become impossible to overcome. Any possible main engine failure can easily be detected by means of effective main engine failure detection. In addition to observed symptoms and detected failures, Frequency of the failures and their relations with auxiliary systems must also be taken into consideration to take the account of the possible causes of failures, which lengthens its productivity.

In addition, checking the pressure and heat of exhaust, combustion air, oil, and cooling water, as well as checking the turbocharger along with marine diesel engine would be instrumental in detecting failures [2].

Sharma *et al.* [3] in their work presented Failure Mode and Effect Analysis (FMEA) listing all possible failure modes and their causes of industrial system. So as to avoid failures in ship engine auxiliaries enjoying PROLOG programming language, Cebi *et al.* [4] set up an expert failure detection system. Through an application which they had developed for ship cooling system, they formed action tables displaying what to do in case of emergency taking the types of failures encountered before and changes in indicative value limits. As a result of their study, it is emphasized that detecting failures in time and shortening the intervening time in the trade ships in the critical seas while maneuvering will raise the operational efficiency. Unlugencoglu [5] developed a troubleshooting programme by using C# programming language to determine solution methods and causes of such breakdowns in main engine auxiliary systems which cover cooling, lubricating and cooling oil and fuel systems. Ozsoysal [6] studied the possible reason or reasons of failure exhaust and its effects on the damage size at high speed marine diesels in Turkish ambulance boats. Gourgoulis [7] studied turbo engine driven electro generators used in maritime engineering for the auxiliary electrical power supply system of the ship. He made failure analysis and besides to provide solutions for real operating problems.

In this study, six failure types of high importance, first seen in marine diesel engine, have been determined. Possible causes for these failures were categorized into subtitles. Based on expert group decision, the article has been demonstrate which type of the failure was the most critical and which system was the most influenced by the failure.

2. FUZZY AHP METHODOLOGY

A set of methods resting on fuzzy sets theory have been set forth to acquire the final assessment thanks to expert's remarks. Cholewa [8] suggested various axioms for fuzzy weighted opinions. Analysis by Dubois and Koning [9] resulted in various fuzzy set aggregation connectives to evaluate the suitability as for social choice functions. Kacprzyk *et al.* [10] focused on fuzzy preference relation. Authors concluded vitality of fuzzy relations by all experts, by means of which authors attained a resulting preference relation from the point of view of individual fuzzy preference relations with the aim of choosing the best option. Mohammad *et al.* [11] put a new approach to handle problem of parametric form of fuzzy numbers and applied it to a case study of diversion of water. Lee [12] established an iterative approximation procedure to collect individual opinions into an optimal consensus. Jiang and Fan [13] worked on the possibility degree for triangular fuzzy number and introduced a new method based on judgment matrix. Xu and Da [14] stressed the possibility degree of interval number and several properties proved to be true. Yeh and Chang [15] offered a hierarchical weighting method to analyze weights, and additionally submitted an algorithm for grouping MDCM to involve criteria weights out of decision makers' subjective judgments. Ma et al. [16] formulated a decision support system relevant with a model to promote the satisfaction throughout the whole process in the multi-criteria group decision making. Fan and Liu [17] gave rise to a method for group decision-making dependent on the multi-granularity uncertain linguistic information.

Linguistic variable: A Linguistic variable refers to a variable whose values are not numbers but words or sentences in a natural or artificial language. In this paper, such statements are used for making comparison of auxiliary system selection evaluation criteria through five basic linguistic terms which are ''absolutely important'', ''very strongly important'', ''essentially important'' ''weakly important'' and ''equally important'' with regard to a fuzzy five level scale [18]. In this present study, the computational technique based on the fuzzy numbers is explained below in Table 1.

Table 1. Membership function of linguistic scale, [19]

Fuzzy number	Linguistic scales	Scale of fuzzy number	Scale of Reciprocal Fuzzy Number
$\tilde{1}$	Equally important (EQ)	(1,1,3)	1/3,1,1
$\tilde{3}$	Weakly important (WK)	(1,3,5)	1/5,1/3,1
$\tilde{5}$	Essentially important (ES)	(3,5,7)	1/7,1/5,1/3
$\tilde{7}$	Very strongly important (VS)	(5,7,9)	1/9,1/7,1/5
$\tilde{9}$	Absolutely important (AB)	(7,9,9)	1/9,1/9,1/7

The linguistic variables presented in Table 1 are used to demonstrate the superiority or weakness status of AHP method by the five designated groups in the criteria-criteria comparison.

Alternatives measurement: It is referred to the use of the measurement of linguistic variables to indicate the criteria performance (effect-values) by means of statements such as ''very good'', ''good'', ''medium good'', ''fair'', ''medium poor'', ''poor'', ''very poor''. The evaluators are requested to conduct their subjective judgments and each linguistic variable can be demonstrated by a Triangular Fuzzy Number (TFN) within the scale range of 0–10, as presented in Table 2.

Table2. Fuzzy evaluation scores for the alternatives [20]

Linguistic terms	Fuzzy score
Very poor (VP)	(0, 0, 1)
Poor (P)	(0, 1, 3)
Medium poor (MP)	(1, 3, 5)
Fair (F)	(3, 5, 7)
Medium good (MG)	(5, 7, 9)
Good (G)	(7, 9, 10)
Very good (VG)	(9, 10, 10)

The linguistic variables presented are used to demonstrate the superiority or weakness status of F-AHP method by the five designated groups in the alternative-criteria comparison in Table 2.

Moreover, the evaluators can subjectively give their personal range of linguistic variable that can display the membership functions of each evaluator's expression values. Take E_{ij}^{k} to denote the fuzzy performance value of evaluator k towards alternative i under criterion j, and all of the evaluation criteria will be displayed by $E_{ij}^{k} = (LE_{ij}^{k}, ME_{ij}^{k}, UE_{ij}^{k})$. Since each evaluator's perception differs from one another in their experience and knowledge, and the descriptions of the linguistic variables show an alteration as well, this study uses the idea of average value to integrate the judgment values of m evaluators in fuzzy type, that is,

$$\hat{E}_{ij}^{k} = 1/m(LE_{ij}^{k}, ME_{ij}^{k}, UE_{ij}^{k}) \tag{1}$$

demonstrates the average fuzzy number of the decision-makers' judgment which can be represented by a triangular fuzzy number as $LE_{ij}^{k}, ME_{ij}^{k}\, and\, UE_{ij}^{k}$. The end-point values LE_{ij}, ME_{ij} *and* UE_{ij} can be figured out by the method proposed by Buckley [26], that is,

$$LE_{ij}^{k} = \frac{\sum_{k=1}^{m} LE_{ij}^{k}}{m}; ME_{ij}^{k} = \frac{\sum_{k=1}^{m} ME_{ij}^{k}}{m}; UE_{ij}^{k} = \frac{\sum_{k=1}^{m} UE_{ij}^{k}}{m} \tag{2}$$

Fuzzy synthetic decision: Besides the fuzzy performance values, the evaluation of the weights of each criterion of auxiliary systems selection must be incorporated by the computation of fuzzy numbers located at the fuzzy performance value (effect-value) of the integral assessment. According to the each criterion weight obtained by FUZZY-AHP, the criteria weight vector $\widehat{W} = (\widehat{W}_1 ......\widehat{W}_j ......\widehat{W}_n)^t$ j can be acquired, while the fuzzy performance matrix $\widehat{E}$ of each of the alternatives can also be derived from the fuzzy performance value of each alternative under n criteria, that is, $\widehat{E} = \widehat{E}_{ij}$ From the criteria weight vector $\widehat{W}$ and fuzzy performance matrix $\widehat{E}$, the ultimate fuzzy synthetic decision can be carried out, and the obtained result will be the fuzzy synthetic decision matrix $\widehat{E}$, that is,

$$\widehat{R} = \widehat{E} o \widehat{w} \quad (1)$$

The symbol "o" denotes the computation of the fuzzy numbers including fuzzy addition and fuzzy multiplication. Due to the complexity of the calculation of fuzzy multiplication, it is usually indicated by the approximate multiplied outcome of the fuzzy multiplication, and the approximate fuzzy number $\widehat{R}$ i, of the fuzzy synthetic decision of each alternative can be represented as $\widehat{R} = (L\widehat{R}_i, M\widehat{R}_i, U\widehat{R}_i)$, where, $L\widehat{R}_i, M\widehat{R}_i \; and \; U\widehat{R}_i$ are the lower, middle and upper synthetic performance values of the alternative i, that is:

$$LR_i = \sum_{j=1}^{n} LE_{ij} x Lw_j ; MR_i = \sum_{j=1}^{n} ME_{ij} x Mw_j ; UR_i = \sum_{j=1}^{n} UE_{ij} x Uw_j ; \quad (4)$$

Ranking the fuzzy number: The outcome of the fuzzy synthetic decision obtained by each alternative is a fuzzy number. Consequently, it is necessary to employ a non-fuzzy ranking method for fuzzy numbers in order to make comparisons of each alternative. That is to say, the defuzzification procedure is needed to locate the Best Nonfuzzy Performance value (BNP). Methods of defuzzified fuzzy ranking such as Mean of Maximal (MOM), Center of Area (COA), and a-cut are generally included. It is an easy and applicable method for utilizing the COA method to find out the BNP, and it is not necessary to appeal to the preferences of any evaluators. Therefore, the COA method is used in this study. The BNP value of the fuzzy number $\widehat{R}_i$ can be reached by the equation below:

$$BNP_i = [(UR_i - LR_i) + (MR_i - MR_i)]/3 + LR_i \qquad \forall i \quad (2)$$

According to the value of the acquired BNP for each of the alternatives, the ranking of the auxiliary systems can be proceeded.

F-AHP Methodology steps of application is summarized as follows in Figure 1.

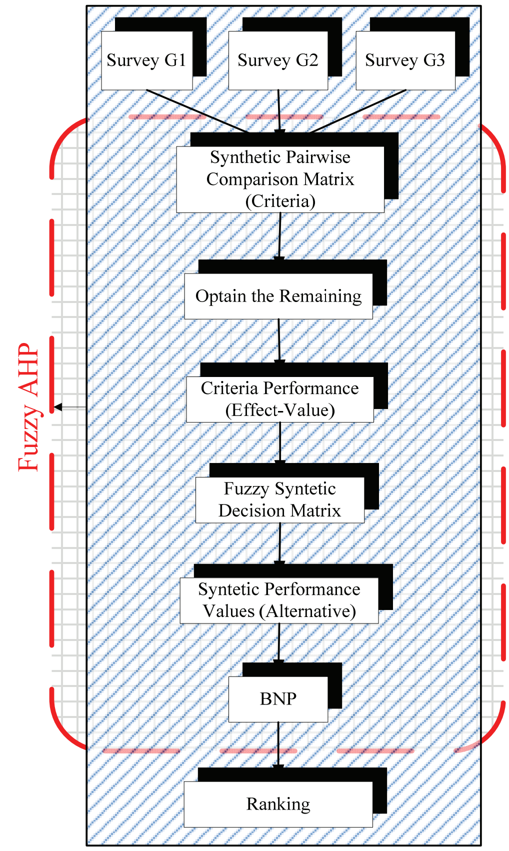

Figure 1. F-AHP method

Step 1: Construct pairwise comparison matrices among all the criteria in the dimensions of the hierarchy system.

Step 2: Calculation the elements of synthetic pairwise comparison matrix by using the geometric mean method suggested by Buckley [21] :

$$\widehat{a}_{ij} = (\widehat{a}_{ij}^1 \otimes \widehat{a}_{ij}^2 \otimes ... \otimes \widehat{a}_{ij}^n)^{\frac{1}{n}} \quad (6)$$

Step 3: In the same way, we can obtain the remaining $\widehat{r}_i$:

$$\widehat{r}_i = (\widehat{a}_{i1}^1 \otimes \widehat{a}_{i2}^2 \otimes ... \otimes \widehat{a}_{in}^3)^{\frac{1}{n}} \quad (7)$$

Step 4: For the weight of each dimension, it can be performed as follows:

$$\widehat{w}_i = \widehat{r}_i \otimes (\widehat{r}_1 \oplus \widehat{r}_2 \oplus ... \oplus \widehat{r}_n)^{-1} \quad (8)$$

Step 5: Alternatives measurement: Using the measurement of linguistic variables to demonstrate the criteria performance (effect-values) by expressions.

$$\hat{E}_{ij}^k = 1/m(LE_{ij}^k, ME_{ij}^k, UE_{ij}^k) \quad (9)$$

Step 6: The end-point values LE_{ij}, ME_{ij} and UE_{ij} can be solved by the method put forward by Buckley, (1985), that is,

$$LE_{ij}^{k} = \frac{\sum_{k=1}^{m} LE_{ij}^{k}}{m}; ME_{ij}^{k} = \frac{\sum_{k=1}^{m} ME_{ij}^{k}}{m}; UE_{ij}^{k} = \frac{\sum_{k=1}^{m} UE_{ij}^{k}}{m} \qquad (10)$$

Step 7: Fuzzy synthetic decision matrix $\widehat{R}$, that is,

$$\widehat{R} = \widehat{E} o \widehat{w} \qquad (11)$$

Step 8: Synthetic performance values of the alternative i, that is:

$$LR_i = \sum_{j=1}^{n} LE_{ij} x Lw_j; MR_i = \sum_{j=1}^{n} ME_{ij} x Mw_j; UR_i = \sum_{j=1}^{n} UE_{ij} x Uw_j; \qquad (12)$$

Step 9: Ranking the fuzzy number: The BNP value of the fuzzy number $\widehat{R}_i$ can be found by the following equation:

$$BNP_i = [(UR_i - LR_i) + (MR_i - MR_i)]/3 + LR_i \quad \forall i \qquad (13)$$

Step 10: Evaluation is done according to the results.

3. A REAL CASE APPLICATION FOR SHIP DIESEL ENGINE TROUBLE SHOOTING

When the causes and signs of faults encountered in marine diesel engines are investigated, it is seen that they are mostly the indicators of another malfunction. There is a reason in each case of failure and that reason may occur in the course of operation. The hierarchical structure applied in this study to overcome the operational problems of the machine assessment for ships is demonstrated in Figure. 2.

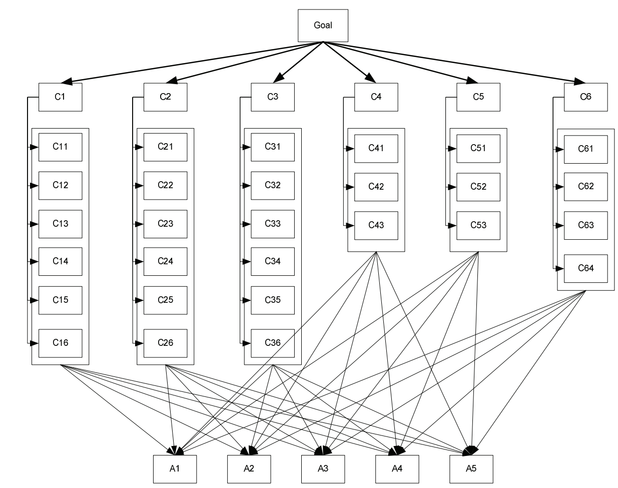

Figure 2. The hierarchical structure for ship engine operation system alternatives assessment.

The main dimensions of the criteria for evaluating and selecting the systems of engine operation for the alternative ship were obtained with an extensive research and consultation with three groups in which one professor from the department of Naval Architecture and Marine Engineering was involved. The groups were requested to grade the criteria dimensions in terms of their accuracy, sufficiency and significance in order to validate the content of these criteria for engine failure evaluation. Reasons of failures in the main engine systems were derived from former reports, maintenance logbooks, and the acquired data were combined with the personnel's experiences. When the examination of these failures are taken into account, it appears that there are six types of failures of high priority that come forth as shown in Table 3. Failures are coded as where i is the number of related failure.

C1. High heat level in all exhaust cylinders of the engine
- C11. Fuel oil quality
- C12. Fuel injector problems
- C13. Fuel oil pump failures
- C14. Fuel oil leakage in cylinders
- C15. Air fun not working fully
- C16. Wrong adjustment of governor

C2. Fluctuation in engine rotations
- C21. Dirty fuel oil filter
- C22. Fuel oil pump pressure
- C23. Fuel oil temperature
- C24. Insufficient intake air
- C25. Mechanical failure in the turbocharger
- C26. Wrong adjustment of governor

C3. Sudden shut down of the engine while it is working usual
- C31. Low level fuel oil tank
- C32. Insufficient intake air
- C33. Oil pressure
- C34. Oil leakage,
- C35. Insufficient cooling water
- C36. Fuel oil pump failures

C4. Rise in the oil level in crankcase while the engine is working
- C41. Cooling water leakage
- C42. Shut off valve on oil tank open
- C43. Fuel oil leakage

C5. Fire in the Scavenging area
- C51. Dirty scavenging manifold inlet
- C52. Abrasive oil ring and piston
- C53. Air cooler problem

C6. Surge in the turbocharger
- C61. Exhaust valve burns
- C62. Insufficient turbocharger oil
- C63. Low level oil in the governor
- C64. Insufficient intake air
- C65. Scavenging pressure high

Table 3: Weights of dimensions and criteria for decision-maker groups

Dimension and Criteria	Local weights	Overall Weights	BNP
C1	(0,048 0,102 0,263)		0,138
C1.1	(0,167 0,327 0,647)	(0,012 0,047 0,182)	0,380
C1.2	(0,102 0,213 0,470)	(0,007 0,030 0,132)	0,262
C1.3	(0,054 0,113 0,259)	(0,004 0,016 0,073)	0,142
C1.4	(0,033 0,072 0,137)	(0,002 0,010 0,038)	0,081
C1.5	(0,122 0,230 0,391)	(0,009 0,033 0,110)	0,247
C1.6	(0,022 0,045 0,101)	(0,002 0,006 0,028)	0,056
C2	(0,025 0,050 0,172)		0,083
C2.1	(0,100 0,244 0,619)	(0,007 0,035 0,174)	0,321
C2.2	(0,064 0,167 0,476)	(0,005 0,024 0,134)	0,236
C2.3	(0,051 0,125 0,315)	(0,004 0,018 0,088)	0,163
C2.4	(0,068 0,178 0,454)	(0,005 0,025 0,128)	0,234
C2.5	(0,035 0,095 0,239)	(0,002 0,014 0,067)	0,123
C2.6	(0,075 0,191 0,444)	(0,005 0,027 0,125)	0,236
C3	(0,131 0,323 0,848)		0,434
C3.1	(0,066 0,129 0,256)	(0,005 0,018 0,072)	0,150
C3.2	(0,156 0,286 0,496)	(0,011 0,041 0,140)	0,313
C3.3	(0,224 0,364 0,555)	(0,016 0,052 0,156)	0,381
C3.4	(0,037 0,069 0,156)	(0,003 0,010 0,044)	0,087
C3.5	(0,032 0,061 0,132)	(0,002 0,009 0,037)	0,075
C3.6	(0,046 0,090 0,187)	(0,003 0,013 0,053)	0,108
C4	(0,131 0,351 0,747)		0,410
C4.1	(0,201 0,319 0,473)	(0,014 0,046 0,133)	0,331
C4.2	(0,183 0,270 0,407)	(0,013 0,039 0,115)	0,287
C4.3	(0,264 0,411 0,664)	(0,019 0,059 0,187)	0,446
C5	(0,046 0,124 0,312)		0,161
C5.1	(0,280 0,441 0,818)	(0,020 0,063 0,230)	0,513
C5.2	(0,232 0,417 0,659)	(0,016 0,060 0,185)	0,436
C5.3	(0,072 0,143 0,235)	(0,005 0,020 0,066)	0,150
C6	(0,021 0,050 0,144)		0,072
C6.1	(0,152 0,339 0,711)	(0,011 0,048 0,200)	0,401
C6.2	(0,068 0,114 0,286)	(0,005 0,016 0,080)	0,156
C6.3	(0,185 0,396 0,790)	(0,013 0,057 0,222)	0,457
C6.4	(0,066 0,151 0,339)	(0,005 0,022 0,095)	0,185

When engine failures separated from each other based on basic characteristics above with the intention of categorizing are technically examined, it appears that each has a relationship with a different system. Failures have been established in accordance with the opinion of specified groups. Factors for failures are concerned, auxiliary systems connected with the failures can be categorized as follows;

A1. Fuel System
A2. Cooling System
A3. Oiling System
A4. Governor System
A5. Air supply System

Heat operating value, critical for operating marine diesel engines, are the values of cooling water and oil which act as the main factor that cools the engine and keeps the heat stemming from fuel out of running engine away. In addition to these values, heat value of exhaust gases is the factor that gives important information about combustion process, combustion productivity, and power obtained from the engine.

At ship operations, an extensive intervention is required to control heat of oil and cooling water, depending on irregular alterations in marine diesel engine load. More effective energy gain and safer marine diesel engine operation are ensured keeping values of cooling water and oil heat at an optimum level. The heat of the cylinder wall cooling water can affect the formation of oil film at the cylinder wall. Operation algorithm of central cooling system which is frequently encountered marine diesel engines is shown in the Figure 3.

In diesel engines, fuel and governor systems are required to work perfectly to gain desired power and rotation.

Rotation intervals for the engines to work safely are determined by the engine manufacturers. Operating the engine out of this range and for a longer period causes the exhaust heat to increase. As the engine rotation increases, emission of the exhaust gases flow rises, and this end up in increase in turbine rotation. The control of the amount of fuel sent to the injector from fuel pump is ensured by the governor to operate at a stable speed.

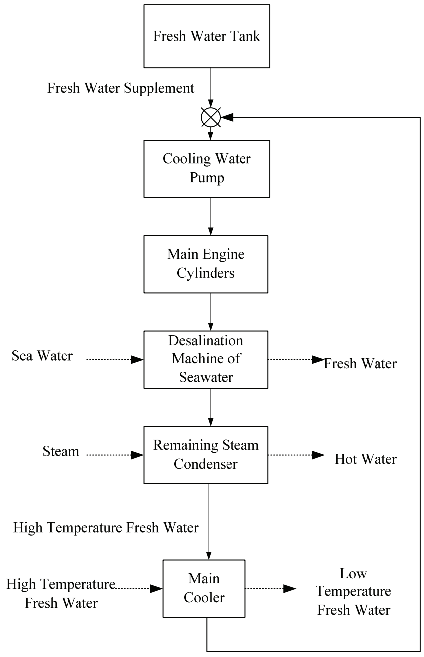

Figure 3. Structure of Main Engine HTFW System, [22]

Proper functioning of diesel engine and turbo charger is prevented by high level exhaust gases heat, blocked filters, unwanted substances stuck in the compressor or the turbine. Excessive dirt and blockage in air supply filters cause fire in suction manifold. Difficulty in pushing the gases in the area exhaust thorough the chimney with the force of counter pressure and decrease in the inlet pressure cause the engine to fail to bear the load.

The weights for the criteria for decision making groups can be found as shown in Table 3. And we listed the final BNP value of groups in Table 4. From the FAHP results, for the decision maker groups, we find the first two most important aspects are Sudden shut down of the engine while it is working (**C3:0,434**) and Rise in the oil level in crankcase while the engine is working (**C4: 0,410**); whereas the least important is Surge in the turbocharger **(C6: 0.07).** The important first two sub-criterias in Sudden shut down of the engine while it is working are Oil pressure **(C33:0.381)** and Insufficient intake air **(C32: 0.313)** according to the decision maker groups, the least is Insufficient cooling water **(C35: 0.075).** In addition, the important sub-criteria's in Rise in the oil level in crankcase while the engine is working are displayed in order of arrival Fuel oil leakage **(C43: 0.446)**, Cooling water leakage **(C41: 0.331)** and Shut off valve on oil tank open **(C42: 0.287)** for the experts groups. However, the first two important dimensions in least important criteria are Low level oil in the governor **(C63: 0.457)** and Exhaust valve burns **(C61: 0.401)**, and Insufficient turbocharger oil is the least **(0.156)**.

These results indicate that the decision making groups are worried about the safety of managing Sudden shut down of the engine while it is working, in addition, the decision making groups also cares about the Rise in the oil level in crankcase while the engine is working which will be considering the convenience of freighter operating. The decision making groups focus on the related professional issues for Sudden shut down of the engine while it is working, but they deem that the Oil pressure and insufficient intake are certain to be safe under calculations, so they ranked it with the most importance.

As for the criteria hierarchy, all decision maker groups deem dirty scavenging manifold inlet (C51) to be the most important (0,513). This may reflect the operating performance and combustion process efficiency of engine. Dirty scavenging manifold inlet was followed in importance by Low level oil in the governor (C63:0.457), Fuel oil leakage (C43: 0.446), and Abrasive oil ring and piston (C52: 0.436) for decision maker groups. On the other hand, all decision maker groups rely Wrong adjustment of governor (C16) to be the least important by (0.056). This may not lead to a serious fault but it can cause more fuel consumption. Wrong adjustment of governor was follow up Insufficient cooling water (C35: 0.075), Fuel oil leakage in cylinders (C14: 0.081), Oil leakage (C34: 0.087) and Fuel oil pump failures (C36: 0,108).

We can obtain the BNP values of other alternatives for comparison purposes; finally, details of the results are presented in Table 4.

Table 4: Ranking by criteria weightings

ALTERNATIVES	BNP	RANKING
A1: Fuel System	8,773	1
A2: Cooling System	5,894	2
A3: Oiling System	4,811	5
A4: Governor System	5,795	3
A5: Air Supply System	5,196	4

As can be seen from the alternative evaluation results in Table 4, the Fuel System is the most affected alternative (BNP value: 8,773) by errors considering the weights of all decision maker groups. The results in Table 3 reflect the common consensus that changes in criteria weights may affect the evaluation outcome to a certain degree. Besides, the Oiling System has the least affected alternative (BNP value: 4,811) by errors relative to other alternatives, which is the most common perception among the groups.

4. CONCLUSION

In the engine room, all engines work in an integrated manner and due to this reason, any fault happening in any

system can quickly affect the whole system. A small failure may grow to a failure of the whole system to turn the situation into a life-threating danger. This shows that in any case of engine breakdown or failure, the engine operators need to address cause as quick as possible. That cause must be easily found and corrected by expert applications.
In this study, the hierarchical structure adapted to the troubleshooting of main diesel engine auxiliary systems which cover cooling, lubricating oil, governor, air supply and fuel systems.

The major causes of system errors have been determined by evaluation of experts using F-AHP method. The way in which systems are affected from possible defects revealed. Besides this, operator indicated any fault which will primarily intervene. Summing all together the alternative Fuel System is the most affected system when failures of this kind occurred.

The study is also thought to be a good reference for maintenance processes for ship engine officers. Future research in this direction is really needed, in order to provide policy-makers a wider perspective on the ship diesel engine troubleshooting systems control.

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