Immediate Response Against Any Possible Fault Detection for Marine Diesel Engines Auxiliary Systems Using Fuzzy AHP

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Outline

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1. Abstract

- Error Detection problem is a very complex issue and has a lot of criteria that must be taken into account to solve this problem.

- When the structure of the engine room is taken into consideration, taking precaution does not bring 100% solution to a problem that occurs suddenly. *Even a simple mechanical failure can cause irreparable loss.*

- Because of this reason, together with an effective fault management system, take immediate action against any possible fault detection and motor disorders are needed.

- In this study, to make a decision about Any Possible Fault Detection we use Fuzzy AHP to determine fundamental faults affecting marine diesel engines have been prioritized by the Fuzzy AHP method which identified by the **decision-making groups** and to *determine the the most affected alternative by faults.*

2. Introduction

- There have been several techniques discussed in the literature about failure analysis.

–Sharma et al. introduced a multi-factor decision-making approach for prioritizing Failure Mode Analysis using Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [2005].

–Çebi et al. developed an expert failure detection system to anticipate and overcome failures which take place in ship cooling system by the use of PROLOG programming language [2009]. *Taking into consideration the failure types that are already encountered; they created action tables to demonstrate what to do in the event of an emergency.*

–Gonca et al. examined effects of engine design parameters on steam injected diesel engine with exhaust gas recirculation (egr) performance and no emissions using different technics with experimental data [2009].

–Unlugencoglu [2012] 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 [2010] 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 [2010] 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

4. Multi criteria decision making model

AHP (Analitical Hierarchy Process): AHP is a method for ranking decision alternatives and selecting the best one when the decision maker has multible criteria.

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] :

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

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

$$\tilde{r}_i = (\tilde{a}_{i1}^1 \otimes \tilde{a}_{i2}^2 \otimes \ldots \otimes \tilde{a}_{im}^3)^{\frac{1}{n}} \quad (7)$$

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

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

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,

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

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

$$\tilde{R} = \tilde{E}o\tilde{w} \quad (11)$$

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

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

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

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

Step 10: Evaluation is done according to the results.

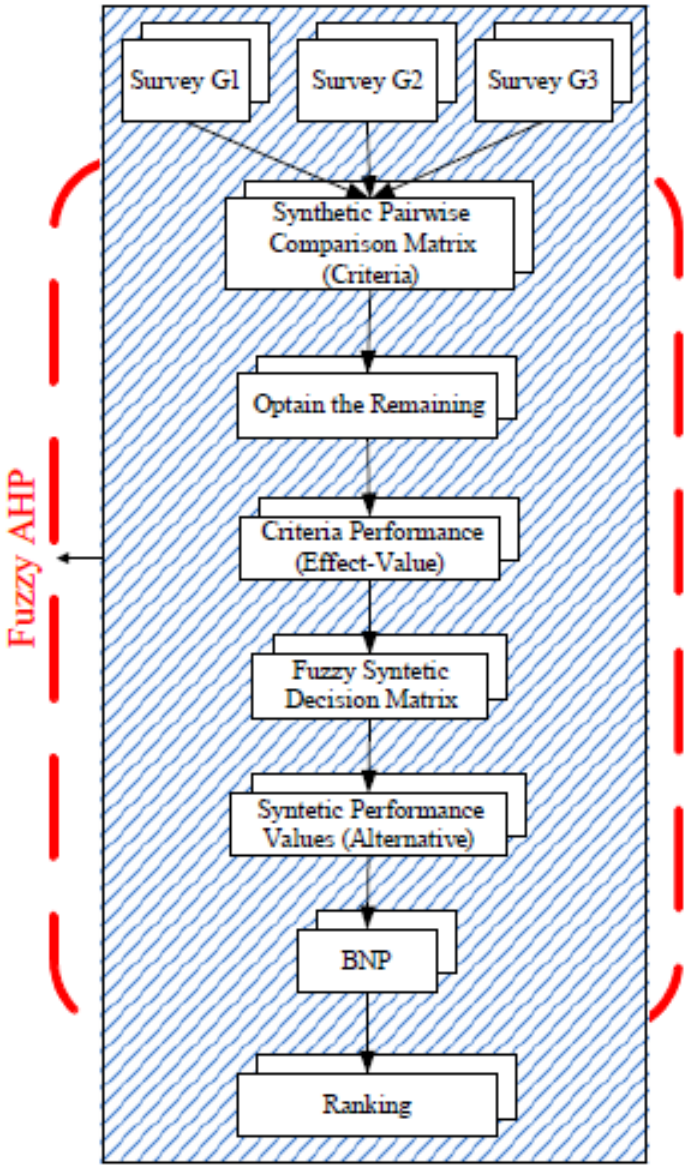
Linguistic Variable: Here, we use this kind of expression to compare energy technology selection criteria performance in table 1,

Linguistic terms	SCALE OF FUZZY NUMBER	SCALE OF RECIPROCAL FUZZY NUMBER
Very poor (VP)	*(0, 0, 1)*	*(1, 0, 0)*
Poor (P)	*(0, 1, 3)*	*(1/3, 1, 0)*
Medium poor (MP)	*(1, 3, 5)*	*(1/5, 1/3, 1)*
Fair (F)	*(3, 5, 7)*	*(1/7, 1/5, 1/3)*
Medium good(MG)	*(5, 7, 9)*	*(1/9, 1/7, 1/5)*
Good (G)	*(7, 9, 10)*	*(1/10, 1/9, 1/7)*
Very good (VG)	*(9,10,10)*	*(1/10,1/10,1/9)*

Using the measurement of linguistic variables to demonstrate the evaluation alternatives in table 2

LINGUISTIC SCALES	FUZZY SCORE
Low (L)	(1,1,3)
Very Low (VL)	(1,3,5)
Medium (M)	(3,5,7)
High (H)	(5,7,9)
Very High (VH)	(7,9,9)

The Fuzzy Multi Criteria Decision Making Process.



5. Application

- In this study, it is aimed to present Fuzzy Analytic Hierarchy Process (AHP) method applied for the expert failure detection of marine diesel engine and auxiliary systems.

–In this respect, the failures of marine diesel engine have been revealed and prioritized.

–Accordingly, the section of the machine from which the failures primarily arise has been determined.

–At the same time, the importance of the effective use of time in determining and responding to the failures has been indicated.

–By means of the evaluation of decision-making groups, the system most severely affected by failures has been decided.

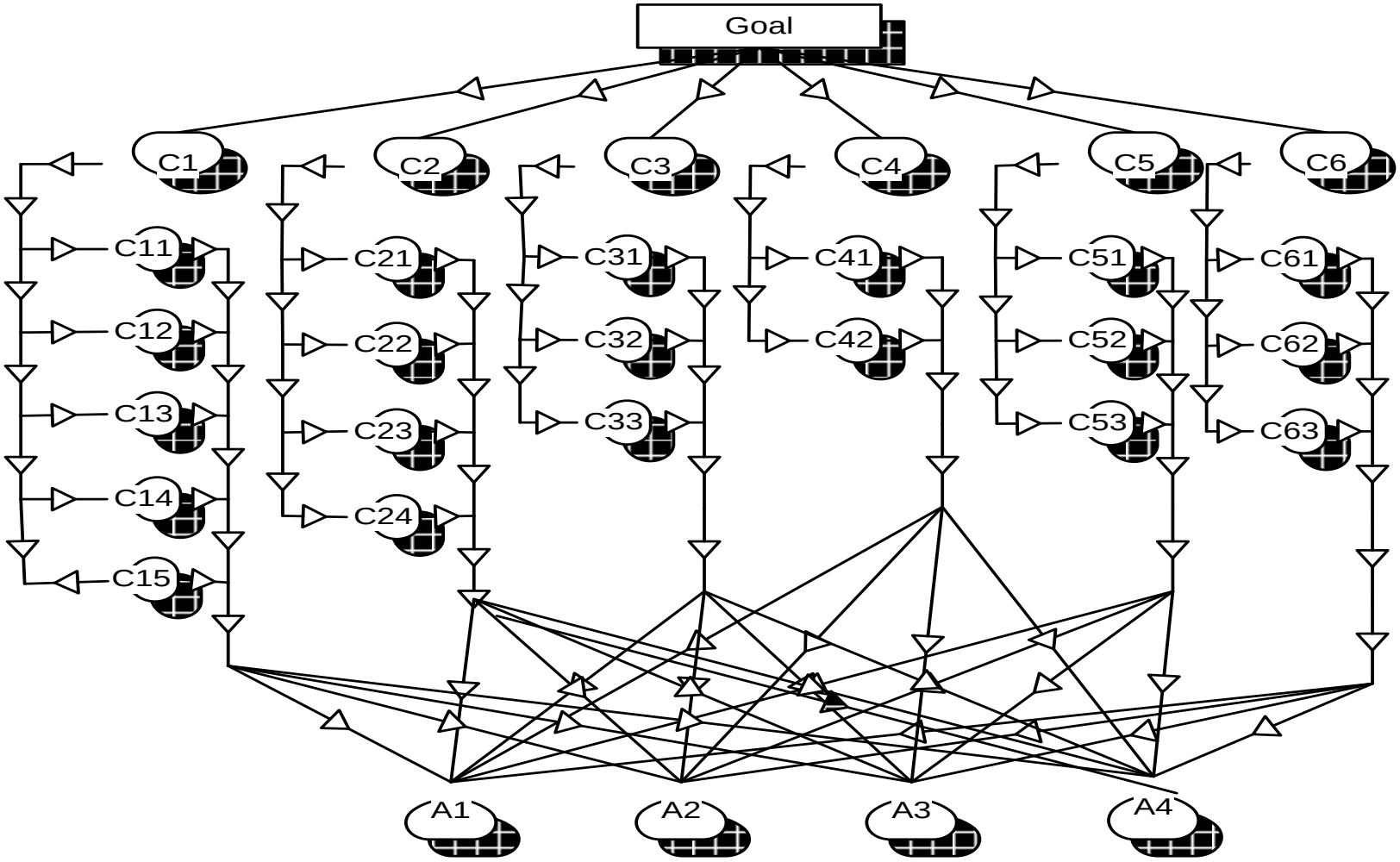


Figure.1

The hierarchical structure for ship engine operation system alternatives assessment.

Auxiliary Systems For Main Engine Failures Criteria

C1. High heat level in all exhaust cylinders of the engine

C11. Fuel injector problems

C12. Exhaust valve failure

C13. Blower not working fully

C14. Wrong adjustment of governor

C15. Insufficient intake air

C2. Unstable engine speed

C21. Dirty fuel oil filter

C22. Booster pump pressure

C23. Fouling in the turbocharger

C24. Wrong adjustment of governor

C3. Shut down of the engine during normal operation

C31. Low-level day tank

C32. Low- low Oil pressure

C33. High Pressure Fuel pump failures

C4. Increase of the oil level during engine operation

C41. Cooling water leakage

C42. Fuel oil leakage

C5. Fire in the Scavenging area

C51. Dirty scavenging manifold inlet

C52. Scuffing of the piston oil ring and piston

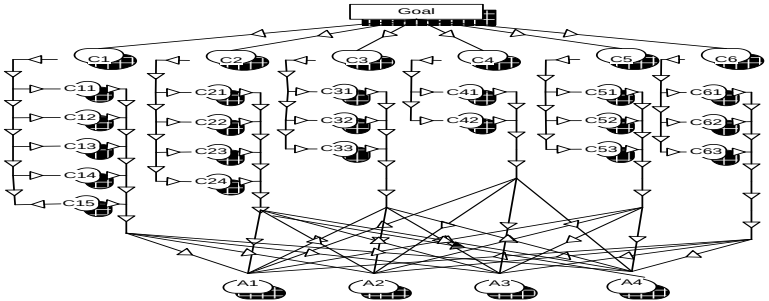
C53. Air cooler problem

C6. Surge in the turbocharger

C61. Exhaust valve burns

C62. Mechanical failure in the turbocharger

C63. Scavenging pressure high



Auxiliary Systems Alternatives

When above-mentioned engine faults, which vary from one another in terms of basic characteristics are technically analyzed with the aim of classifying, ***it is recognized that each has a relationship with a different system.***

Considering the causes for failures, auxiliary systems in connection with the failures can be categorized as follows:

A1. Fuel System

A2. Cooling System

A3. Governor System

A4. Air supply System

Linguistic Variables to Demonstrate the Evaluation «Criteria-Critera» «Alternatives-Criteria»

		C11	C12	C13	C14	C15
C11	G1	1				
	G2	1				
	G3	1				
C12	G1		1			
	G2		1			
	G3		1			
C13	G1	.	.	1	.	.
	G2	.	.	1	.	.
	G3	.	.	1	.	.

Linguistic terms	Scale of Fuzzy Number	Scale of Reciprocal Fuzzy Number
Very poor (VP)	*(0, 0, 1)*	*(1, 0, 0)*
Poor (P)	*(0, 1, 3)*	*(1/3, 1, 0)*
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Very good (VG)	*(9,10,10)*	*(1/10,1/10,1/9)*

Linguistic scales	Fuzzy score
Low (L)	(1,1,3)
Very Low (VL)	(1,3,5)
Medium (M)	(3,5,7)
High (H)	(5,7,9)
Very High (VH)	(7,9,9)

		C11	C12	C13	C14	C15	C21	C22	C23	C24	C31	C32	C33	C41	C42						
A1	G1	H	H	ML	H	ML	H	H	MH	H	MH	ML	H	L	H						
	G2	H	H	M	H	ML	H	H	M	MH	MH	M	H	ML	H						
	G3	H	H	ML	H	ML	H	H	MH	H	MH	M	H	L	H						
A2	G1	L	M	MH	L	MH	L	L	ML	L	ML	L	L	H	L						
	G2	ML	ML	MH	ML	M	L	ML	L	L	M	ML	L	H	L						
	G3	ML	ML	MH	L	M	ML	L	ML	L	ML	L	L	H	L	M	ML	H	MH	ML	M
A3	G1	MH	MH	L	H	L	MH	MH	MH	MH	M	M	MH	L	MH	M	MH	L	MH	MH	MH
	G2	MH	M	ML	H	L	M	MH	M	M	ML	MH	M	L	M	M	M	L	M	M	MH
	G3	M	MH	ML	H	L	MH	M	M	M	ML	MH	MH	ML	MH	ML	M	ML	M	MH	M
A4	G1	L	M	H	L	H	L	L	ML	L	L	L	L	L	L	M	ML	M	M	ML	H
	G2	L	ML	H	ML	MH	L	L	L	L	L	ML	ML	L	ML	M	L	MH	ML	L	H
	G3	L	M	H	ML	H	L	L	ML	L	L	M	ML	ML	ML	M	L	M	ML	L	H

Criteria	Weights			BNP
C1. High heat level in all exhaust cylinders of the engine	(0.076	0.166	0.436)	0.226
C11. Fuel injector problems	(0.186	0.407	0.962)	0.518
C12. Exhaust valve failure	(0.116	0.292	0.667)	0.358
C13. Blower not working fully	(0.038	0.070	0.203)	0.104
C14. Wrong adjustment of governor	(0.058	0.153	0.343)	0.185
C15. Insufficient intake air	(0.030	0.078	0.163)	0.09
C2. Unstable engine speed	(0.021	0.037	0.101)	0.053
C21. Dirty fuel oil filter	(0.091	0.257	0.671)	0.34
C22. Booster pump pressure	(0.064	0.145	0.492)	0.234
C23. Fouling in the turbocharger	(0.112	0.268	0.762)	0.381
C24. Wrong adjustment of governor	(0.107	0.329	0.757)	0.397
C3. Shut down of the engine during normal operation	(0.143	0.318	0.724)	0.395
C31. Low-level day tank	(0.059	0.110	0.317)	0.162
C32. Low- low Oil pressure	(0.128	0.285	0.733)	0.382
C33. High Pressure Fuel pump failures	(0.257	0.605	1.206)	0.689
C4. İncrease of the oil level during engine operation	(0.040	0.095	0.255)	0.13
C41. Cooling water leakage	(0.376	0.781	1.457)	0.871
C42. Fuel oil leakage	(0.132	0.219	0.513)	0.288
C5. Fire in the Scavenging area	(0.132	0.328	0.650)	0.37
C51. Dirty scavenging manifold inlet	(0.128	0.285	0.733)	0.382
C52. Scuffing of the piston oil ring and piston	(0.257	0.605	1.206)	0.689
C53. Air cooler problem	(0.059	0.110	0.317)	0.162
C6. Surge in the turbocharger	(0.024	0.056	0.130)	0.07
C61. Exhaust valve burns	(0.128	0.285	0.733)	0.382
C62. Mechanical failure in the turbocharger	(0.257	0.605	1.206)	0.689
C63. Scavenging pressure high	(0.059	0.110	0.317)	0.162

Weights of dimensions and criteria for decision-making groups

The evaluation criteria

High heat level in all exhaust cylinders of the engine: Wrong adjustment of governor determine the amount of fuel supplied to the combustion chamber. The lack of an optimal mixture ratio in the combustion chamber reduces the combustion quality and this situation causes an increase of the exhaust temperature.

Unstable engine speed: Dirty fuel oil filter and low booster pump pressure reduce the inlet pressure of the fuel supplied to the engine and this situation makes it difficult to provide sufficient fuel and unstable engine speed occur.

Shut down of the engine during normal operation: Low-level day tank give rise discontinuation of fuel supplied to the engine and engine stops. In any pump failure, oil pressure decreases and if oil pressure is not enough, engine will not work so switch gives the instruction and engine is stopped.

Increase of the oil level during engine operation: Cooling water leakage cause water leakage into the crankcase and this situation increases oil level in crankcase. Fuel oil leakage cause spread of fuel into the crankcase.

Fire in the Scavenging area: Dirty inlet manifold means that the presence of combustible materials at the location and combustion takes place here in the formation of the necessary conditions for combustion.

Surge in the turbocharger: Burns that occur in the exhaust valve cause gas leakage into the exhaust manifold except egzost time. This situation cause temperature fluctuations in the turbine inlet and occur the turbine speed fluctuations.

6. Conclusion

Alternatives	Fuzzy Evaluation			BNP	Ranking
A1: Fuel System	0.821	6.009	38.265	15.032	1
A2: Cooling System	0.350	2.999	23.331	8.893	3
A3: Governor System	0.517	4.269	31.553	12.113	2
A4: Air supply System	0.174	2.138	20.294	7.535	4

As can be seen from the results of alternative evaluation in Table, the *Fuel System* is considered as the most affected alternative by errors regarding the weights of all decision-making groups.

Moreover, it can obviously be seen that the air supply system is the least affected alternative by errors in comparison to the other alternatives, which is the most common consensus among the groups.

The results shown in Table demonstrate the common perception that the changes in criteria weights may have an impact on the evaluation outcome to a certain extent.

- The engine can quickly be affected by a failure that occurs in any system and this failure can cause a breakdown or a malfunction in the engine.
- The reason of the failure should be immediately found out and repaired by expert applications.
- To help the chief engineers, the conditions in which those failures occurred in marine engine system should be figured out.

In this paper, the hierarchical structure is adapted to the troubleshooting of main engine auxiliary systems, including cooling, governor, air supply and fuel systems.

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Thank you for your attention.