Using Sensitivity Analysis for Selecting of Ship Maintenance Variables for Improving Reliability of Military Ship

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ABSTRACT

This paper describes the original Analytic Hierarchy Process (AHP) as it is implemented in the software package Expert Choice to select multiple variables that affect the military ship's maintenance. In the ships maintenance management system consists of eight variables: Cost, Availability, Reliability, Safety, Human Resources, Operations, Types of Ships and Ship's Characteristics. The eighth selection of the variables was carried out with a questionnaire spread. A questionnaire distributed to 30 crew for selected variables that can be used in a military ship maintenance management. From the results of a questionnaire is produced 7 variables. The next step is using the Expert Choice that produces the influential variables i.e. HR = 0.246, Cost = 0.222 and Availability = 0.197. The judgments were found to be consistent, precise and justifiable with narrow marginal inconsistency values. This paper also presents a thorough sensitivity analysis to demonstrate the confidence in the drawn conclusions.

Keywords: Military ships maintenance, AHP, expert choice, sensitivy analysis

INTRODUCTION

The basic philosophy of a maintenance concept is how to conduct activities to ensure a physical asset can work continuously according to the desired function. In other words, what must be done to maintain the functionality of a system or component in a specific period of time and in certain operating conditions.The ability of an item to work properly according to the desired functionality that should be guaranteed by the concept of maintenance to be chosen later. The level of this ability is usually represented by a probability value is called the Index of Reliability (IR).

In theory, the concept of proper maintenance is maintenance that can produce high reliability indexes on the system, so that the system can operate optimally according to their functions.The development of the concept of the maintenance of the current fourth generation on this still required the development of a concept in the field of maintenance as there are obstacles faced, such as system control a complex impact on the environment, impact on safety, high cost of maintenance or other problems On the fourth generation is characterized by eco-friendly from a system reliability or operational improvement system being treated there from the maintenance activities. In general the function of the maintenance is to restore or maintain conditions of objects preserved in such a way so as to approach the initial conditions of the object when operated (Billinton, 1992).

Based on Figure 1 under when system components are increasingly being performed maintenances so that the system or component reliability conditions are stable as more and more components were treated, the less productive hours so the cost goes up, but on the contrary the less time the care hours productive growing so little cost, maintenance time very influential at the time productive.In this case the need to do a research on machining systems maintenance management in an appropriate vessel so as not to interfere with productive hours

ISSN: 2223-9944, eISSN: 2223-9553

or operations and costs, the primary purpose of the maintenance is to maintain and improve the reliability of the system and the smooth running of production or operation so as to prevent system failure, as well as to restore system function (Ketut Buda A,2003)Relialibity

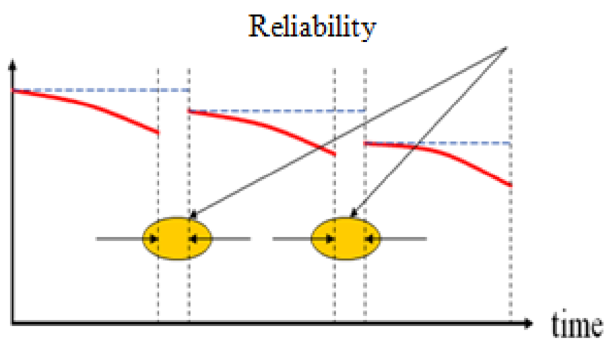

Figure 1. Reliability Function

The recommendations of the management as decision-makers in the discretion of the maintenance is very influential on the wisdom of experience in maintenance, safety and operating conditions, the availability of funds and Manpower, schedule vessel operating, Reliability, Availability, and management and quality assurance, since corresponds to international standard application of encouragement and ISO 9000 so that attention is better than previous years, ultimately focused emphasis on maintenance of critical components, which can affect the reliability of the system (Lava Baliwangi 2006)

Machining maintenance is divided into two: Preventive and Corrective Maintenance. The method of maintenance is done by keeping the equipment in order to work properly (Prevent from Failure) is called Preventive Maintenance. Corrective Maintenance method is a method of maintenance by doing a repair to a piece of equipment can function again, after the crash, this is how similar their observance on military ships given the not exactly maintenance time and budget constraints of maintenance.

Types of care and maintenance according to Gopalakrishnan and Benerjee which are:

Routine Maintenance

Inspection of equipment Activity on a regular basis and held that replacement parts are always prepared when damage ter so with cirri characteristics as follows:

a. Relative cheap cost of damages) if there is damage.
b. HR Power too long idle, because difficulties are insurmountable.
c. Age of equipment/component
d. Relative fast time to repair

Planed Maintenance

Maintenance activities planned with a schedule that is determined by the component maker producen, where each component has different karakteritik, as for the attribute are:

a. Component in accordance with the Age of the plant, the use of relatively long.
b. Cost maintenance is relatively inexpensive.
c. Time maintenance quickly, because the previous spare parts available

Preventive Maintenance

Maintenance activities to minimize kerusakan, by conducting inspections on a regular basis so that the damage can be known early, because if left may result in others with are:

a. Small relative cost of care because the machine is like new condition
b. Replacement parts are always available.
c. Relative maintenance time fast.
d. Damage occurring is not fatal.
e. Activities are drab (routines).
f. Replacement parts are prepared before the damage occurred.
g. Requires experts (hr) experienced

Exposure above can be inferred that there were 8 variables, namely: Cost, Availability, Reliability, Safety, Human Resources, Operations, The number and type of Ship, as well as the Characteristics of the ship. Selection of 3 variables that influence of the variables implemented eighth questionnaire that can be used in the management of the maintenance of military ships.

MATERIALS AND METHODS

Determination of variables begins by determining the 8 variables are generally recognized in theory ship maintenance management. Then given a questionnaire to the 30 crew to select influential determinant variables directly in the field. Further processing of data from 7 variable will use the AHP. Software Expert Choice used to define 3 types of variables that influence in the maintenance of military ships and sensitivity analysis.

HOW TO RESEARCH

Ahp Process Based Variables of Ship Maintenance Model

Method of AHP is one form of a comprehensive decision-making method, and takes into account things that are both quantitative and qualitative. Model AHP wearing human perception are considered expert as its input. AHP is simple, flexible and accommodating of creativity in the design to solve a complex problem (Saaty, 1986).

Developed by the Saaty AHP and used to solve problems that are complex or not dish structured where data and statistical information from the problems encountered very little. In General, a hierarchy can be distinguished into three types, namely:

Structural Hierarchy

Structural Hierarchy i.e a complex problem into its parts or elements is described according to specific characteristics or quantities. This hierarchy is closely related to analyze complex problems by dividing the observed objects into groups.

Functional Hierarchy

It outlines a complex problem into its parts according to its essential relationship. This hierarchy to help resolve problems or affect the complex system it wants to achieve a goal, such as the determination of priority actions, the allocation of resources. The consistency of the matrix that is inkonsitensi of 10% down is the level ofinconsistencies that could still be accepted.

Decision Hierarchy

A typical simple decision hierarchy involves a goal, criteria or objectives and alternatives of choice, see Figure 2. We make judgements on the elements of the hierarchy in pairs with respect to their parent element to derive priorities then synthesise the priorities into an overall result. The Expert Choice software is based on the AHP and offers a systematic framework where you can lay out the elements of the problem in a hierarchy, enter judgements, and derive priorities for action. It engages decision makers in breaking down a decision into smaller parts, proceeding from the goal to criteria to subcriteria and so on down to the altenatives of action. In making the judgements the elements of the problem are looked at in isolation: one element compared against another with respect to a parent element. The decision maker then makes only simple pairwise comparison judgements throughout the hierarchy to derive the priorities of the elements. Expert Choice then synthesises all the judgements into a unified whole in which your alternatives are clearly prioritised from best to worst. To capture the complexity of the decision problem, it is best to have wide participation in constructing the hierarchy. The decision problem may involve social, political, technical, and economic factors. By using a well structured hierarchic framework you will be able to cope with the intuitive, the rational and the irrational, and with risk and uncertainty.

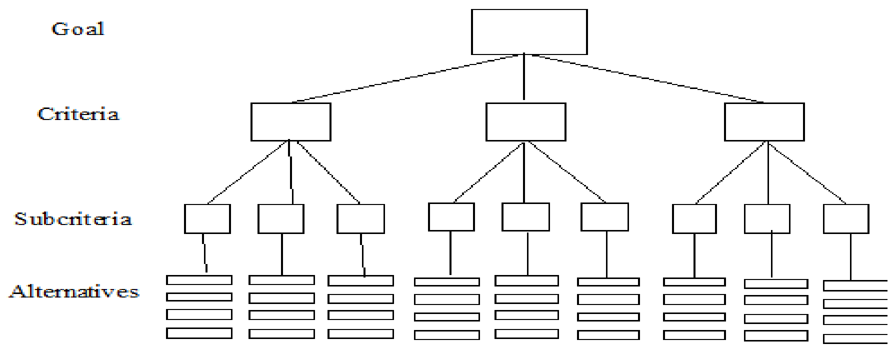

Figure 2. Descision Hierarchy

According to Turban (2005), the Analytical Hierarchy Process (AHP) is a method of analysis and synthesis that can help the decision making process. AHP is a powerful decision-making tool and flexible, which can be assisting in setting priorities and making decisions on which aspects of qualitative and quantitative involved and both must be considered. With the reduction of complex factors into a series of "one on one comparisons" and then synthesizes its results, the AHP will not only help people in choosing the right decision, but it can also give a thought/clear and precise reasons.

Table 1. The Fundamental Scale for Making Judgments

1	Equal
2	Between Equal and Moderate
3	Moderate
4	Between Moderate and Strong
5	Strong
6	Between Strong and Very Strong
7	Very Strong
8	Between Very Strong and Extreme
9	Extreme

Decimal judgments, such as 3.5, are allowed for fine tuning, and judgments greater than 9 may be entered, though it is suggested that they be avoided.

Source: Saaty, 1993

Among the activities with one another on a process of hierarchical analysis of hierarchy models consisting of one purpose, criteria or multiple sub criteria and alternatives for each issue. In determining the assessment among alternatives under certain criteria, then used the paired comparison (table 1) with the use of a certain scale in order to generate the weighting of each alternative decisions. On mathematical formulas on the model of AHP is performed using a matrix. For example subsystems are operating elements n A_1, A_2, ..., A_n, then the result of comparison of the operating elements in pairs will form a comparison matrix where values W_i/W_j with i. j = 1, 2, ..., n is obtained from the participant, i.e. people who are competent in the issues analysed (I GdeAstawa Diputra,2009)

The AHP converts these evaluations to numerical values that can be processed and compared over the entire range of the problem. A numerical weight or priority is derived for each element of the hierarchy, allowing diverse and often incommensurable elements to be compared to one another in a rational and consistent way. This capability distinguishes the AHP from other decision making techniques. In the final step of the process, numerical priorities are calculated for each of the decision alternatives. These numbers represent the alternatives' relative ability to achieve the decision goal, so they allow a straightforward consideration of the various courses of action.

Determination of Goals, Criteria and Alternatives

The main goal of the presented hierarchical model is to select the best maintenance variables that will serve the ship maintenance process in a fairly optimized manner. This is performed through matching the effect of the tree of sub-goals according to their weights of importance. The following criteria items are to be considered:

a. Routine Maintenance

b. Planned Maintenance

c. Preventive Maintenance

Eight alternative variables are selected for this study, namely: Cost, Avialability, HR, Reliability, Safety, Operational, Ship Type and Ship Characteristic. Figure 3 shows the developed hierarchical structure of the problem in which the first level has the goal of selecting the optimal maintenance type. The last level of the hierarchy comprises of the eight alternatives of the available variables of ship maintenance types.

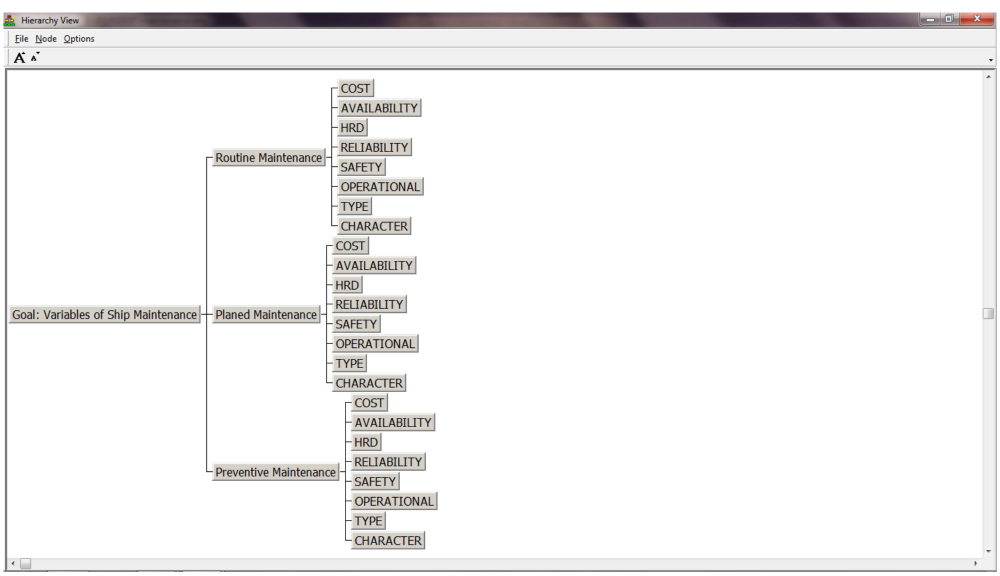

Figure 3. AHP Variable Of Ship Maintenance Selection

Some of the measures used in the study as will be described below:

I. Determines the kinds of criteria that will be used for determining the variable boat care.

II. Devise such criteria in the form of a matrix in pairs as shown in the table below.Make a matrix column.

$$a_{i,j} = a_{i,k} \cdot a_{k,j} \quad (1)$$

$$a_{i,j} = \frac{1}{a_{j,i}} \quad (2)$$

III. Calculate the value of the element with the formula criteria columns each column element is divided by the number of columns of the matrix.

IV. Calculating priority value with the formula make a criteria matrix row results step 4 and the result is divided by the number of criteria 5.

V. Specify the alternatives that would be an option.

VI. Devise alternatives that have been specified in the form of matrix pairs for each of the criteria. So there will be as many as n fruit pairing between alternative matrices.

VII. Each pairing between alternative matrices as much fruit n matrix, respectively in total per matrix columns.

The pair-wise comparison matrices can also be represented as:

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \vdots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} = \begin{bmatrix} w_1/w_1 & \cdots & w_1/w_n \\ \vdots & \vdots & \vdots \\ w_n/w_1 & \cdots & w_n/w_n \end{bmatrix} \quad (3)$$

For a consistent matrix, we can demonstrate that:

$$A = \begin{bmatrix} w_1/w_1 & \cdots & w_1/w_n \\ \vdots & \vdots & \vdots \\ w_n/w_1 & \cdots & w_n/w_n \end{bmatrix} \times \begin{bmatrix} w_1 \\ \vdots \\ w_n \end{bmatrix} = n \begin{bmatrix} w_1 \\ \vdots \\ w_n \end{bmatrix} \quad (4)$$

Or in a matrix form:

$$A \cdot w = nw \quad (5)$$

VIII. Calculate the priority value of each alternative pairing between alternative matrices with the formula as step 4 and step 5.

IX. Test the consistency of each pairing between alternative matrices with the formula of each element of the matrix pair in step 2 multiplied by the value of the priority criteria.

X. The result of each line in total, then the result is divided by the respective values of the priority criteria

XI. Calculate Lamda$_{max}$= n

XII. Calculate Consistency Index (CI)

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (6)$$

XIII. Calculating the Consistency Ratio (CR) with the formula :

$$CR = \frac{CI}{RI} \quad (7)$$

a. Where CR is the value table Saaty If CR = 0.1 then the value comparison < paired on the matrix a given criteria consistently.

b. If CR > 0.1, then the paired comparison value in the matrix of the criteria given are not consistent.

c. So if inconsistent, then charging the values in the matrix are paired on the criteria and alternatives should be repeated.

Table 2. Index Ratio (IR)

n	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

XIV. Compiled a matrix of lines between alternative versus the criteria which result calculation process step 7, step 8 and step 9

XV. The end result is a global priority as values that are used by decision makers based on the highest score.

RESULT AND DISCUSSION

Variables of Maintenance Ship Model

Ishizaka (2009), like several other MCDM methods such as ELECTRE, MacBeth, SMART, PROMETHEE, UTA, etc (Belton and Stewart 2002; Figueira, Greco et al. 2005)), AHP is based on four steps: problem modelling, weights valuation, weights aggregation and sensitivity analysis. In the next sections we will review these four steps used by AHP and its evolutions based on a simple problem: the variable of to ship management.

The data processing is done using Expert Choice according to the kusioner released in 30 crew aboard yielded engine maintenance variable priority ship. The result can be seen in Figure 4. As with all decision-making processes, the facilitator will sit a long time with the decision-maker(s) to structure the problem, which can be divided into three parts: goal (decisive variable for ship maintenance), criteria (routine maintenance, planed maintenance, preventive maintenance and its not sub-criteria) and alternative (Cost, Availability, Reliability, HR, Safety, Operation, Type and Character (Figure 4). AHP has the advantage of permitting a hierarchical structure of the criteria, which provides users with a better focus on specific criteria and sub-criteria when allocating the weights.

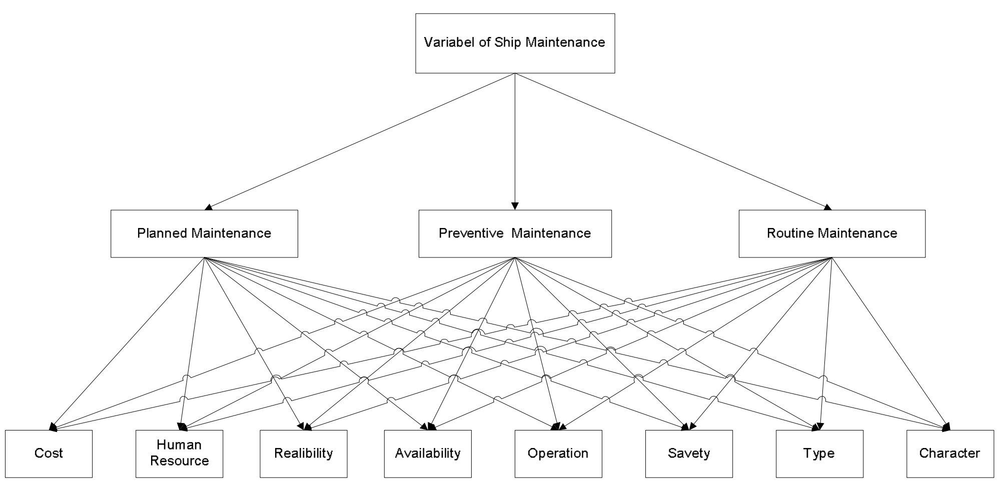

Figure 4. Variables of Ship Maintenance Hierarchy

At each node of the hierarchy, a matrix will collect the pairwise comparisons of the decision-maker (e.g. Figure 5 and 5a). One of AHP's strengths is the possibility to evaluate quantitative as well as qualitative criteria and alternatives on the same preference scale of nine levels. These can be numerical, verbal or graphical scale.

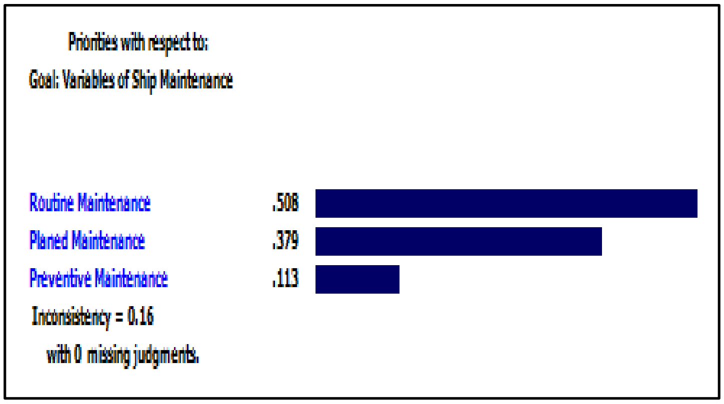

Figure 5. Comparison matrix of the first node

	Routine	Planed	Preventive			
					λ_{max}	3.202104377
Routine Maintenance	1.000	2.000	3.000		CI	0.101052189
Planed Maintenance	0.500	1.000	5.000		CR	0.11228021
Preventive Maintenance	0.333	0.200	1.000			
	1.833	3.200	9.000		Status	**Concistency**
				AVERAGE		
Matrix Normalization	0.5455	0.6250	0.3333	0.5013	Global Weight	
	0.2727	0.3125	0.5556	0.3803		
	0.1818	0.0625	0.1111	0.1185		
Normalize	1.00	1.00	1.00	1.00		

Figure 5a. Example of AHP Matrix Calculation

Once the comparisons matrices are filled, priorities can be calculated. The traditional AHP uses the eigenvalue method. For some users this method seems quite obscure. In order to explain it, we start from the case of a consistent matrix with known priorities *pi*. See in step by step of AHP calculation in page 6.

The data processing is done using Expert Choice according to the questionnaire that was circulated on 30 crew aboard yielded engine maintenance variable priority ship. The result can be seen in Figure 5, the Routine Saturday Maintenance = 0.508. With HR = 0.246, Cost = 0.222 and Availability = 0.197. Details of the value of all alternative results can be seen in Figure 5 and 5a.

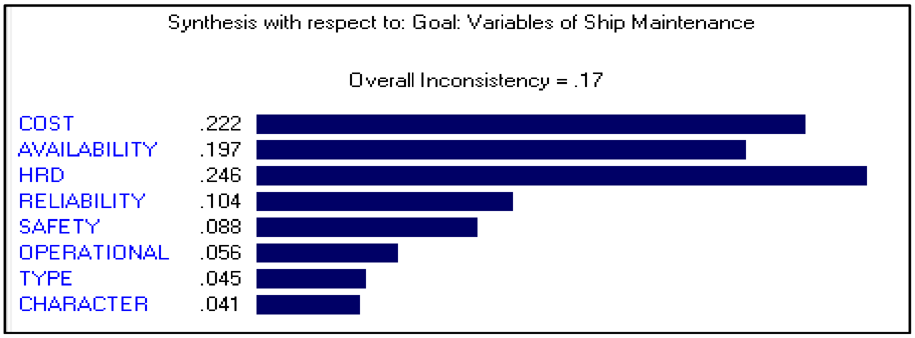

Figure 6. Synthesis with Respect to Goal of Ship Maintenance

On the criteria of Routine Saturday Maintenance resulting in HR = 0.244, Cost = 0.223 and Availability = 0.205. Details of the value of all alternative results can be seen in Figure 6.

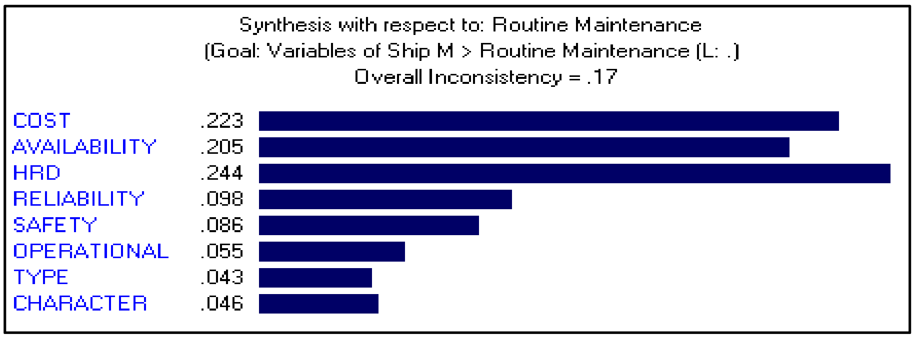

Figure 6. Synthesis With Respect to Routine Maintenance Hierarchy

On the criteria of Planed Maintenance resulting in HR = 0.242, Cost = 0.220 and Availability = 0.181. Details of the value of all alternative results can be seen in Figure 7.

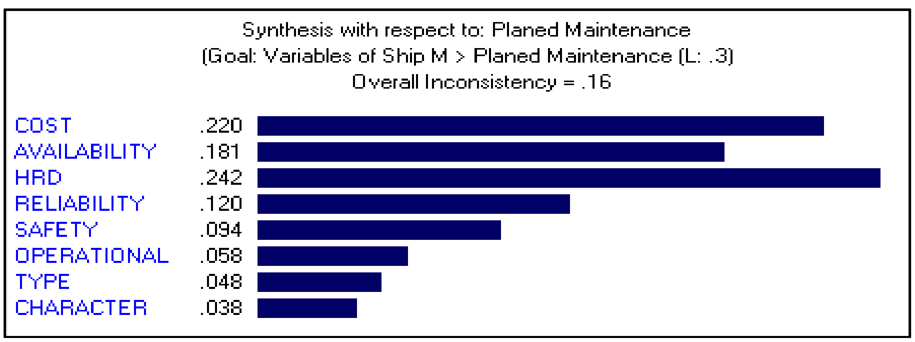

Figure 7. Synthesis With Respect to Planed Maintenance Hierarchy

On the criteria of Preventive Maintenance resulting in HR = 0.277, Cost = 0.224 and Availability = 0.215. Details of the value of all alternative results can be seen in Figure 8.

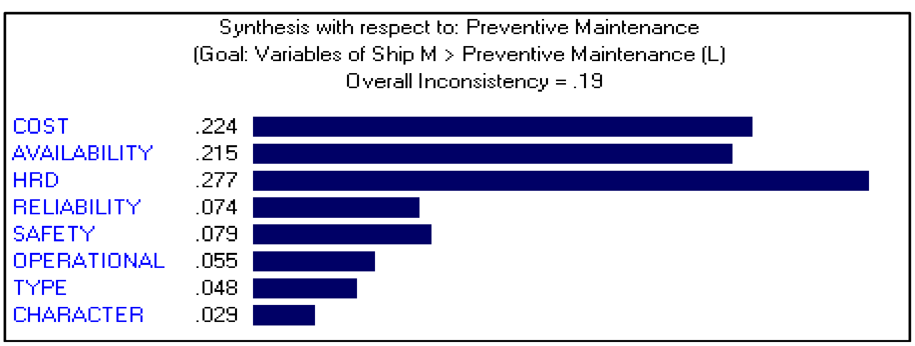

Figure 8. Synthesis With Respect to Preventive Maintenance

ISSN: 2223-9944, eISSN: 2223-9553
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Sensitivity Analysis

The last step of the decision process is the sensitivity analysis, where the input data are slightly modified in order to observe the impact on the results. If the ranking does not change, the results are said to be robust. The sensitivity analysis is best performed with an interactive graphical interface. Expert Choice allows different sensitivity analyses, where the main difference is the various graphical representations in Figure 13. Analysis of the Performance graph Sensitifity in Figure 13 is that the trend of Cost has not changed much in all conditions of maintenance. The lowest Availability variable is Planed Maintenance. For HR the highest value on Preventive Maintenance.

The sensitivity analysis in Expert Choice varies the weights of the criteria as input data. It is also imaginable to have in future a sensitivity analysis by varying interactively the local priorities of the alternatives (there is no mathematical challenge in it). However, sensitivity analysis is a fundamental process in the decision with AHP; it has received little attention from the academic literature (Ishizaka, 2009).

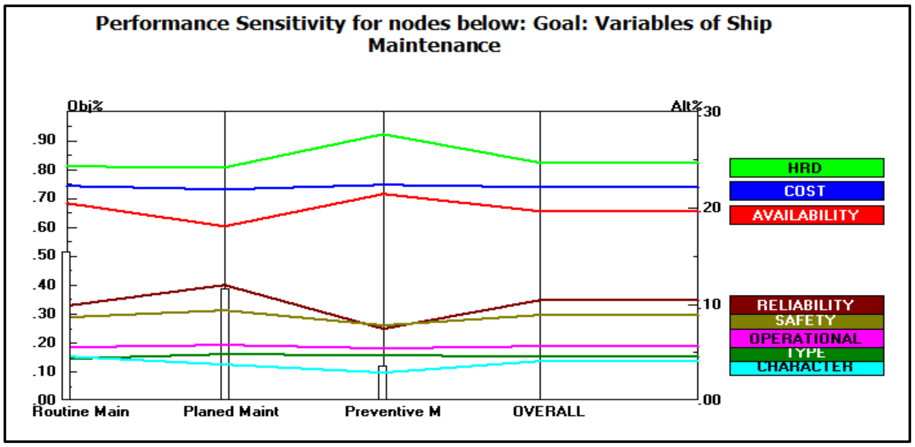

Figure 9. Graphic of Performance Sensitivity

First, consider the Routine Maintenance. By increasing the share of this factor to an extreme of 90% of the main goal, leaving 10% for the others while keeping the proportionality between each, it has been noticed that the model is still in favor of HR with a score of 24.3 %, followed by the Cost and lastly the Availability. The same conclusion can be drawn for the capability factor, where the HR stays as the best choice with a score of 24.6%, Fig. 10.

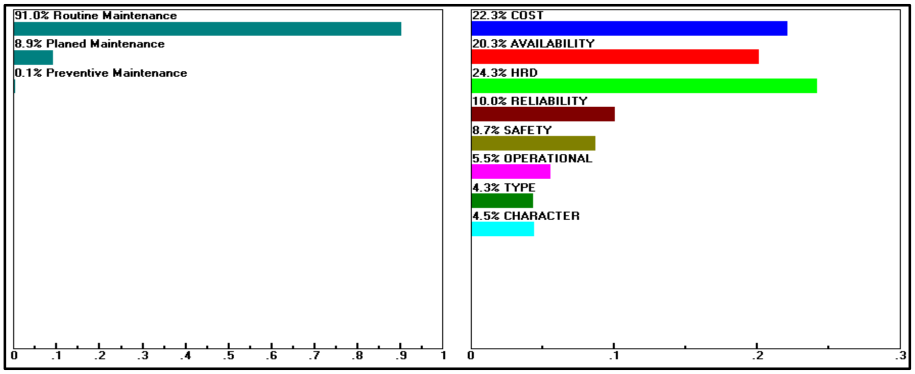

Figure 10. Sensitivity analysis: Routine Maintenance

Second, consider the Planed Maintenance. By increasing the share of this factor to an extreme of 90% of the main goal, leaving 10% for the others while keeping the proportionality between each, it has been noticed that the model is still in favor of HR with a score of 24.2

ISSN: 2223-9944, eISSN: 2223-9553
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%, followed by the Cost and lastly the Availability. The same conclusion can be drawn for the capability factor, where the HR stays as the best choice with a score of 24.6%, Fig. 11.

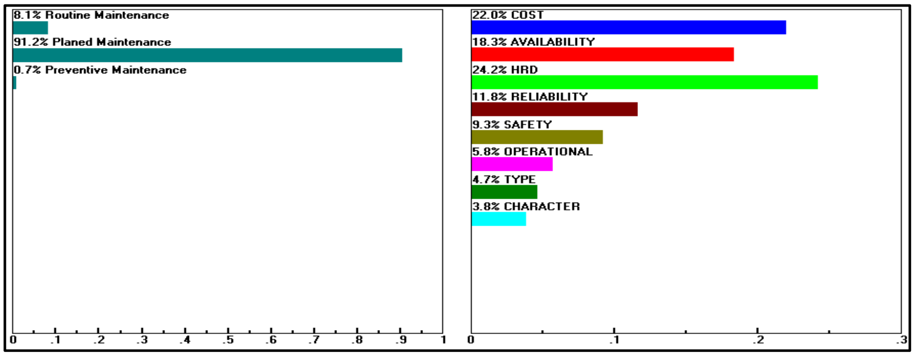

Figure 11. Sensitivity analysis: Planed Maintenance

Third, consider the Preventive Maintenance. By increasing the share of this factor to an extreme of 90% of the main goal, leaving 10% for the others while keeping the proportionality between each, it has been noticed that the model is still in favor of HR with a score of 27.7 %, followed by the Cost and lastly the Availability. The same conclusion can be drawn for the capability factor, where the HR stays as the best choice with a score of 24.6%, Figure 12.

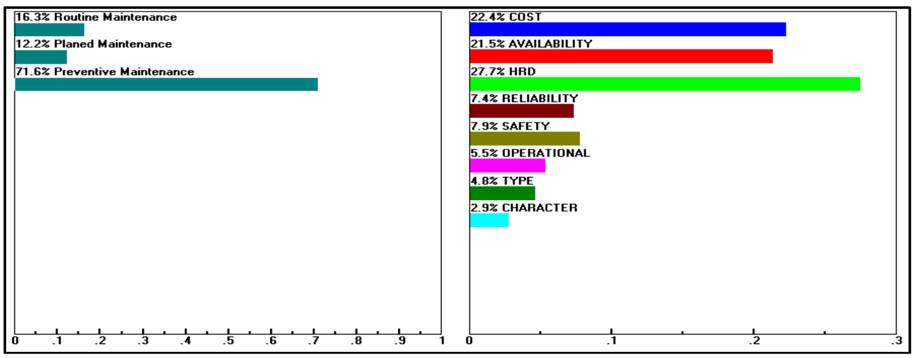

Figure 12. Sensitivity analysis: Preventive Maintenance

Fourth, consider the All Maintenance with Average Score. By increasing the share of this factor to an extreme of 33.3% of the main goal, leaving 10% for the others while keeping the proportionality between each, it has been noticed that the model is still in favor of HR with a score of 25.3%, followed by the Cost and lastly the Availability. The same conclusion can be drawn for the capability factor, where the HR stays as the best choice with a score of 24.6%, Figure 13.

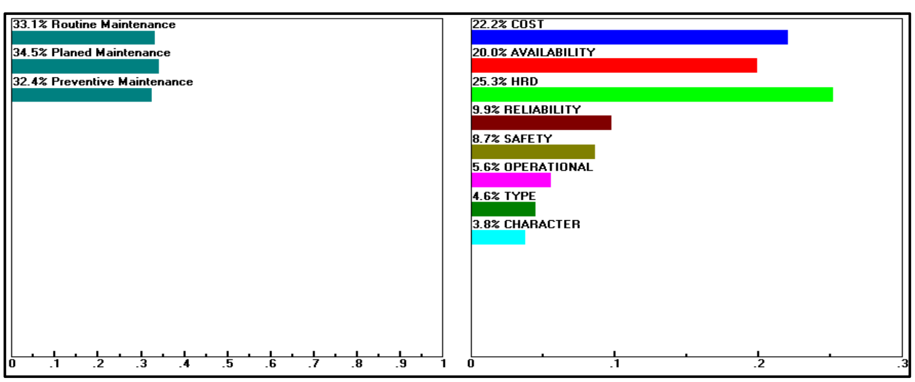

Figure 13. Sensitivity analysis: All Maintenance (Average)

In any definition of sensitivity analysis, the core theme is to investigate the effect of input variables on the output variables. Sensitivity analysis can be used to see if the small variations in the weights would change the decision. If not, we would be reassured that our choice was reasonable. After making judgments about the relative importance of objectives, sub-objectives and alternatives, Expert Choice's sensitivity graphs were used to test the possible changes in the decision. There are four different graphical modes of Expert Choice and each of them provides a different viewpoint to sensitivity analysis. Under any of these four modes, the user can easily manipulate criterion priorities and immediately see the impact of the change over the result.

CONCLUSION

The sensitivity analysis presented here demonstrates how consistent the decision is. The choice of the maintenance variables remain the same even with significant changes on the criteria weights, which can be justified by the consistent judgments made between the siblings of the parent goal and the pair-wise comparisons. AHP analysis demonstrates an efficient knowledge based approach to help quantify expertsknowledge to qualitative analysis that help in multi-criteria decision making.

Finally, the aim of this paper was to show that the systematic approach of AHP is applicable to any kind of decision making problem. It is practical and easy-to-learn and the methodology can reassure users about reasonable results. From this election study found that Routine Maintenance be the best choice in order to maintain the reliability of military ships with decisive variables for ship maintenance are Human Resources, Cost and Availability

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