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Implementation Multi-criteria Decision Making Technique in Overhaul Power Plants Projects

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ABSTRACT

The aim of this study is to propose a multi-criteria decision making approach (MCDM) in order to evaluate qualitative factors in overhaul power plants projects, with due attention to the rating of qualitative criteria are considered as linguistic variables. Overhaul of the power generation plants affects the performance process. Some qualitative factors are of great importance in improving the quality of the process and avoiding wasting resources. The combined method of analytic network process and DEMATEL technique were used in this study. Four main and 16 secondary factors were identified in the final classification. Empirical results show that the proposed method is viable approaches in solving problem. When the performance ratings are vague and imprecise, this MCDM is a preferred solution method. The results show 8 highest Factors effects on the overhaul of the power plants respectively.

Keywords: Multi-criteria Decision Making, Analytic Network Process, DEMATEL, Overhaul
JEL Classification: O22

1. INTRODUCTION

Manufacturing firms and power plants have found that proper maintenance of equipment and production systems is a critical need (Alsyouf, 2009(. Repair and maintenance are activities that support the main processes in organization (Carlucci and Schiuma, 2008(. Corrective maintenance is operations, which are performed after the defective state, and its goal is to restore the instrument to operating conditions. The internal relations are evaluated by DEMATEL technique. The benefit of this method to network analytic technique is its transparency in reflecting the mutual relations between a wide set of elements as the experts can give their comments in relation to the effects (direction and severity of the effects) between the factors. It can be said that final matrix of DEMATEL technique.

Internal relations matrix formed a part of super matrix DEMATEL technique doesn't act separately and it acts as a sub-system of a great system as analytic network process (ANP). In order to identify the quality factors of the overhaul project, the literature discussed the quality management of projects and maintenance projects. The literature on project management, identified target three criteria for assessment known as the triangle of time, cost and quality (Azar et al., 2008(. The first two measures are relatively simple to define and measure, but defining and measuring the quality of the project as the third dimension of this triangle is much more difficult. Turner is of researchers who tried to define the quality of the project more clearly and put it in two dimensions of product quality and process quality (Turner, 2002). PMBOK guidelines of quality of the project also reflect the design process and the requirements of the process. ISO 10006-quality management standard, guidelines for quality management in projects proposed two aspects of project management processes and processes related to project product for the quality of projects. For clarity in the definition of quality dimensions, Basu has proposed a three-dimensional model for the quality of the project including design quality, process quality and quality of organization (Basu, 2014(. In periodic maintenance projects, quality is considered as adherence to standard operating procedures standards and technical specifications. These procedures will ensure compliance with engineering standards in all activities. Launch events are as a benchmark in quality projects of periodic maintenance (Levitt, 2004).

In another study, he examined the important skills for periodic maintenance project management and their different nature. The findings showed in general, management should expertise in maintenance management, repair and maintenance service, project management techniques, maintenance planning, and logistics. In addition, a good knowledge of health, safety and environmental management is needed (Obiajunwa, 2012). Concerning the application of multi-criteria decision techniques in the field of maintenance, studies done with these techniques mainly include performance appraisal of maintenance system, right choice of methods and policies. Some of them are mentioned as follows. Wang et al. chose the most optimal maintenance strategy using fuzzy process (Wang et al., 2007). Parida and Chattopadhyay (2006) developed a performance evaluation model for maintenance systems using analytical hierarchy process (AHP). The aim of this study is to propose a multi-criteria decision making approach (MCDM) in order to evaluate qualitative factors in overhaul power plants projects, with due attention to the rating of qualitative criteria are considered as linguistic variables.

2. MATERIALS AND METHODS

This section established a structure for identifying the evaluation perspective and criteria as well as their relationships of factors. Identification of factors affecting the quality of overhaul projects was conducted for the development of a prototype, using literature review, interviews with experts of this field and reviews of documents related to the overhaul of plants. After identifying the factors for verification, classification and identification of the model, the consultation meeting held with the participation of experts in the power industry to approve model by experts and factors that do not fit model were corrected or deleted for validation. After identification and categorization, internal relationships between agents due to the impact of factors on each other, weighting of each of them with respect to the target and the weighting of the sub-factors are done through questionnaires. Power industry experts have been selected to respond to the questionnaire. To confirm the validity, the content validity was used in this study.

This validity is achieved by a surveying experts and professionals. Reliability that terms like credibility and stability for which are used, shows logical consistency of response of measurement tool (Azar et al., 2008). Given that in the study, multi-criteria decision technique was used to evaluate the reliability, the inconsistency ratio calculations were used. It should ensure that there is a logical consistency between paired comparisons because the output quality is strictly linked to the compatibility of paired comparisons. Therefore, at this stage ratio of the inconsistency must be calculated. Also calculates an inconsistency index (or consistency ratio) to reflect the consistency of the decision maker's judgments during the evaluation phase. The inconsistency index in both the decision matrix and in pairwise comparison matrices could be calculated with the Equation (1) (Asgharpour, 2013):

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

$$CR = \frac{CI}{IR} \quad (2)$$

Where, λ_{max} the principal eigenvalue of the judgement matrix and n is the order of the judgement matrix. The closer the inconsistency index to zero, the greater the consistency. The consistency of the assessments is ensured if the equality $\left(a_{ij}a_{jk} = a_{ik}, \forall i, j, k\right)$ holds for all criteria. In the above equation, *n* represents the number of rows or columns of matrix (number of criteria). In the next step, the inconsistency ratio (CR) is calculated via equation (2). It should be noted that IR (random inconsistency index) is extracted from the table and if the inconsistency ratio is less than or equal to 0.1 (CR ≤0.1). Then we could conclude there is consistency in pair wise comparisons and otherwise, it is necessary to reconsider the decision in the paired comparisons (Asgharpour, 2013). The relevant index should be lower than 0.10 to accept the MCDM results as consistent. If this is not the case, the decision-maker should go back and redo the assessments and comparisons.

2.1. DEMATEL Approach

The DEMATEL method was developed by the Battelle Geneva Institute (1) to analyze complex "world problems" dealing mainly with interactive man-model techniques; and (2) to evaluate qualitative and factor-linked aspects of societal problems (Meredith and Mantel, 2003(. The applicability of the method is widespread, ranging from industrial planning and decision-making to urban planning and design, regional environmental assessment, analysis of world problems, and so forth. Furthermore, a hybrid model combining the two methods has been widely used in various fields, for example, e-learning evaluation (Saaty, 1996), airline safety measurement (Tabucanon and Dahanayaka, 1989), and innovation policy portfolios for Taiwan's SIP Mall (Stephen, 2000). Therefore, in this paper we use DEMATEL not only to detect complex relationships and build a NRM of the criteria, but also to obtain the influence levels of each element over others; we then adopt these influence level values as the basis of the normalization super matrix for determining ANP weights to obtain the relative importance. To apply the DEMATEL method smoothly, the authors refined the definitions based on above authors, and produced the essential definitions indicated below. The DEMATEL method is based upon graph theory, enabling us to plan and solve problems visually, so that we may divide multiple criteria into a relation-ship of cause and effect group, in order to better understand causal relationships. Directed graphs are more useful than directionless graphs, because digraphs will demonstrate the directed relationships of sub-systems. A digraph typically represents a communication network, or a domination relationship between individuals, etc.

DEMATEL five-degree includes zero to four or a number system of one, three, five, seven, nine (Habibi et al., 2014) of which were used in this study. Respectively, they indicate no impact, low impact, moderate impact, high impact and very high impact (Nikamal et al., 2010 (in this step, direct relationship matrix (A) is obtained based on the relevance and impact of each criterion on each other through paired comparisons.To integrate the expert opinion in this technique, simple arithmetic average is used. The second step is normalization direct matrix: Based direct relation matrix (A), normalized direct relation matrix (X) is obtained by (3) and (4) equations. n represents the number of criteria.

$$X = K.A \tag{3}$$

$$k = \frac{1}{\max \sum_{j=1}^{n} a_{ij}} \tag{4}$$

$1 \leq i \leq n$

The third step – Calculation of the total relationship matrix: Using the matrix X obtained in the previous stage, total relationship matrix (T) is achieved according to equation (5) where I is an identity matrix.

$$T = X(I-X)^{-1} \tag{5}$$

Step four, casual diagram: The total rows and columns of the matrix (T), respectively, are named D and R vectors (6 and 7). $D + R$ and $D - R$ values are calculated by these equations. $D + R$ is the horizontal axis represents and that represents the importance value of criteria and vertical axis ($D - R$) criteria divided criteria into two groups of cause and effect (Wang et al., 2007).

$$D = \left[\sum_{j=1}^{n} t_{ij}\right]_{n*1} = [t_{i,}]_{n*1} \tag{6}$$

$$R = \left[\sum_{i=1}^{n} t_{ij}\right]_{n*1} = [t_{,j}]_{n*1} \tag{7}$$

2.2. ANP Approach

One of the most outstanding MCDM approaches is the AHP, which has its roots on obtaining the relative weights among the factors and the total values of each alternative based on these weights. The AHP method in comparison with other MCDM methods has widely been used in multi-criteria decision-making and successfully has been applied in many practical decision-making problems (Saaty, 1999). In spite of AHP method popularity, this method is often criticized because of its inability in handling the uncertain and imprecise decision-making problems. ANP is general mood of AHP and its extended mode. One serious limitation of AHP is that the interdependencies between the elements of the decision-the criteria, sub-criteria and options-are not considered and it assumes the relationship of them as hierarchical and unilateral. ANP, while having all the capabilities of AHP, including simplicity, flexibility, using quantitative and qualitative criteria simultaneously, the ability to assess the compatibility in judgments, and the possibility of ranking the final options, can overcome its serious limitations, including not taking into account the interdependencies between decision elements and the assumption that the relationship between the elements of decision are hierarchical and unilateral. ANP is acronym of analytical network process. ANP is the evolved form of AHP. In AHP, the dependencies should be linear and top to bottom or vice versa. But if the dependencies are two directional, the weight of criteria is related to the weight of choices and weight of the choices to the weight of criteria. Then, this is not hierarchy and we cannot use hierarchy analytic formula. Saaty presented the developed method of ANP.

Therefore, ANP consists of two parts: Control hierarchy and network relationship. Control hierarchy includes relationship between objective, criteria and sub criteria and is effective internal communication of the system and network relationship includes dependency between the elements and clusters (Saaty, 1999). ANP can be summarized in four stages (Wu, 2008).

- Step 1: Issue/problem should be converted to a clear to a reasonable system, such as a network. At this point, the issue/problem turns to a network structure in which the nodes are considered as clusters. Elements within a cluster may be associated with one or the other cluster elements (affected by them or affect them).
- Step 2: Binary comparison matrix and determining the priority vectors: Similar to binary comparisons in AHP, elements of each of the clusters, based on their importance in relation to the control criteria are mutually compared. Clusters based on their role and their impact on achieving the goal, are mutually compared as well. Decision makers need to decide in pairs about binary comparison of elements or clusters. The effect of each element on other elements can be provided through a special vector. The relative importance is measured by Saaty nine-point scale (similar to AHP). In this section, local priority vector is calculated. It can be obtained through equation 8. Where A is binary comparison matrix, W is eigenvector (coefficient of importance) and λ_{max} is the largest Eigen value number.

$$Aw = \lambda_{max} W \tag{8}$$

- Step 3: To achieve the overall priorities in a system of interactions, local priorities vectors (i.e., calculated W) are entered in the appropriate column a matrix. As a result, a super matrix (in fact, a partitioned matrix) is obtained that each part of the matrix shows the relation between the two clusters. This type of matrix is called super matrix. By placing local priority vectors of (importance coefficients) elements and clusters in initial matrix super, unweighted super matrix is obtained.In the next stage, weighted Super matrix is calculated by multiplying the unweighted matrix values in cluster matrix. Then by normalizing weighted super matrix, the super matrix turns into random mode in term of column (Saaty, 1999). In the second stage, limit super matrix is calculated by exponentiation of all elements of weighted super matrix until the divergence is achieved (through repetition). In other words, until all the elements of super matrix get identical (equation 9)

$$\lim W^{k} k \rightarrow \infty \tag{9}$$

- Step 4: If the former super matrix in the third stage, covers the entire network-options are also included in the super matrix-the overall priority can be achieved from the column of options in the normalized super matrix. If super matrix, only included part of the network that are mutually dependent and options are not considered at Super matrix, further calculations are need to achieve the priorities of options.

3. DATA ANALYSIS

3.1. DEMATEL Calculations

- Step 1: The direct relation matrix, to assess the internal relationship between the factors, some experts will be asked to do pair wise comparisons among the main factors. With these comparisons, initial data of direct relation matrix (A) is obtained in accordance with Table 1. It is calculated using the arithmetic mean of 10 experts
- Step 2: Normalizing direct relation matrix: Based on the direct relation matrix (A) normalized direct relations matrix (X) is obtained through the equations 3 and 4 according to Table 2
- Step 3: Calculating total relation matrix: Using the matrix obtained in the previous stage, total relation matrix (T) is obtained in accordance with the equation 5 and Table 3. To obtain total relation matrix for sub factors we do the same stages listed for the main factors
- Step 4: The causal diagram: Factors with positive $D-R$ are causal and those with negative $D–R$ are effect factors. C1 (the quality of the project team) and C3 (quality of parts and machinery) have more total row than other factors that is indicative of their great influence on other elements of the system. C4 (output quality) and C2 (the quality of the project process) have more total column than main other factors that is indicative of extent of influence on them than others. Factors that have greater interaction with the system (larger $D + R$) (or have significant impact on other factors (bigger D), or are influenced more than other factor (bigger R or both) and $D-R$ is positive are more important for us. About impacted factors, those that have higher interaction with system (larger $D + R$) (more influenced means to have smaller $D-R$), are more important. Here C2 (has high impact and is more affected) and C4 (more affected), respectively, have the greatest values.

Table 1: Direct relation matrix

Criteria	C1	C2	C3	C4
C1	1.000	7.800	1.000	1.800
C2	5.400	1.000	1.000	1.000
C3	6.800	6.900	1.000	1.200
C4	1.900	1.000	2.000	1.000

Table 2: Normalized direct relation matrix

Criteria	C1	C2	C3	C4
C1	0.068	0.418	0.068	0.137
C2	0.139	0.068	0.068	0.068
C3	0.071	0.456	0.068	0.379
C4	0.071	0.068	0.149	0.068

3.2. Ranking Criteria

A dozen of experts were asked to do pair wise comparisons between the main factors. One represents the same significance of both factors with regard to the objective and nine represents the importance of one to others. When there are more than one decision maker rather matrix elements geometric mean can be used. It is calculated through equation 10, where a_{ijl} is element of i^{th} row and j^{th} column of the matrix of l^{th} decision-maker and k number of on decision-makers. Views should be taken into account when compliance rate (CR) of decisions of each decision maker is less than 0.1 (Asgharpour, 2013). Table 4, shows the results of binary comparisons of the main factors and its weighted vector (W21) as well as the CR that was performed using Super decision software.

$$a'ij = \left(\prod_{i=1}^{k} a_{ijl}\right)^{1/k} ;\ l = 1,2,\ldots k \quad (10)$$

$i, j = 1,2,\ldots, n;\ i \neq j$

After the classification, elements were ranked using a combination of ANP and DEMATEL. Table 5 shows the final weight of factors.

4. CONCLUSION

The aim of this study was to investigate, identify and rank the factors affecting the quality of the overhaul of power plants. Overhaul of good quality can have a significant impact on the level of readiness, efficiency and the availability of power plants when required. In addition it reduces emergency shuts down. Qualitative factors identification is done by reviewing the background, interviews with experts in the power industry. After identifying the factors, for verification, classification and determining the model, the consultation meetings were hold attended by professionals and experts in the power industry. Considering that, the results showed the high influence of sub factors of quality of the project team, to enhance the expertise and knowledge of contractors and observers of overhaul it is recommended hold to systematic professional training courses at various levels by relevant organizations.

Table 3: Total relation matrix for main factors

Criteria	C1	C2	C3	C4
C1	0.319	0.763	0.204	0.685
C2	0.229	0.355	0.258	0.654
C3	0.324	0.767	0.319	0.749
C4	0.164	0.238	0.136	0.342

Table 4: Pair wise comparison of main factors

Criteria	C1	C2	C3	C4	W
C1 - Process quality	1.000	0.845	0.845	2.098	0.362
C2 - Quality of machinery	1.143	1.000	0.197	1.892	0.059
C3 - Quality of the project team	0.187	0.197	1.000	0.201	0.361
C4 – Output quality	0.456	0.497	0.497	1.000	0.199

CR=0.028. CR: Compliance rate

Table 5: Weights of ANP research method

Criteria/sub criteria	Weights		Criteria ranking
	Local	Global	
C1 - Process quality	0.362		
SC11: Respect for and compliance with the standard intervals according to manufacturer's instruction	0.419	0.058	8
SC12: Use of materials and equipment in accordance with standard in tests	0.161	0.052	12
SC13: Upgrading and overhaul	0.139	0.050	13
SC14: Safety and environmental considerations	0.072	0.043	16
SC15: Appropriate documentation (reports and test forms)	0.144	0.070	4
SC16: Use of appropriate equipment and systems for recording and analyzing data	0.066	0.053	9
C2 - Quality of machinery	0.059		
SC21: Valid license of parts	0.279	0.068	5
SC22: Use of tools especially designed for the project and which have a valid calibration certificate	0.475	0.059	7
SC23: Renovated components valid license and comply with standards	0.246	0.064	6
C3 - Quality of the project team	0.361		
SC31: Planning in activities	0.095	0.052	10
SC32: The ability to apply the tools and techniques of teamwork, communication and teamwork culture	0.443	0.095	3
SC33: Performance management and self-assessment	0.116	0.099	2
SC34: Contractor, supervisor and project management experience and expertise	0.346	0.117	1
C4. Output quality	0.199		
SC41: The main output: Efficiency	0.516	0.052	11
SC42: Sub output 1: Vibration	0.386	0.048	14
SC43: Sub output 2: Amount of pollutants	0.098	0.045	15

ANP: Analytic network process

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