

Selection of a Plant Site: A Multi Criteria Decision Making Using AHP and GRA

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ABSTRACT

Selection of a plant site for setting of production unit is a major concern for entrepreneurs across the world, as these production units requires various inputs to convert in to tangible outputs. So this site selection depends upon various factors listed in literature or otherwise. But the weight-age of these factors varies and solely depend upon the decision makers with respect to choices. So site selection is an multi-criteria decision making process. In this paper an attempt has been made using AHP and Grey relational analysis (GRA) to solve an case of Steel plant site selection problem in India.

Keywords: Site Selection, MCDM, AHP, GRA

1. INTRODUCTION

In establishing a new plant, the first question that needs to be solved is where to locate the plant. Entrepreneur generally tries to minimize the various inputs i.e. 5M, men, machine, material, method, money and maximize the output. Economists generally consider selection of suitable sites as an important criterion for reducing the input resources such as cost of production and time to market, resulted in maximizing profits. These resources are of various type like costs (transportation cost, labor cost, raw material cost, land cost, and utility cost, etc.), labour, time, materials and methods. Decision makers consider these resources in terms of costs, and try to minimize them all, but the nature of the decision often requires that trade-offs between various conflicting choices for selection of a particular site. These types of problem are better known as Multi Criteria Decision Making (MCDM) problem, where the decision maker puts different weight age to different factors with respect to different choices. In our case discussion, we are trying to solve plant site selection in conflicting situation using MCDM models.

2. CASE INTRODUCTION

The site selection process begins with obtaining information and necessary clearance from the government agency. The plant location check list (Apple 1977, Moore 1962), are generally used to remove the unacceptable sites. In this case analysis an entrepreneur has established an XYZ ltd and was interested in setting up an integrated steel

plant in Orissa a state of India. After necessary clearance from the state and central government, XYZ ltd. was having four option i.e S1, S2, S3, S4 (instead of real name), for setting of their plant. Out of these four options, one site needs to be selected, and these selection were based on four criteria as given in the literature i.e. Economic Impacts i.e. less cost, functional impacts ,i.e higher productivity, public acceptance i.e. better community relations, and quality of life i.e. better living conditions. This decision is a MCDM.

3. LITERATURE SURVEY

Multi Criteria Decision Making (MCDM) problem is a discipline aimed at supporting decision makers who are faced with numerous and sometimes conflicting evaluations. The aim of MCDM is to highlight these conflicts and to derive a means of arriving at a compromise and by using a transparent process. Preferences differ so the outcome depends on the decision maker and their particular goals and preferences (Satty, 2005). Many MCDM methods exist today and these include: Aggregated Indices Randomization Method (AIRM), Analytic hierarchy process (AHP), Analytic network process (ANP), Data envelopment analysis (DEA), Dominance-based rough set approach (DRSA), ELECTRE (Outranking), The evidential reasoning approach, Goal programming, Grey relational analysis (GRA), Inner product of vectors (IPV), Multi-Attribute Global Inference of Quality (MAGIQ), Multi-attribute utility theory (MAUT), Multi-attribute value theory (MAVT), New Approach to Appraisal

(NATA), Nonstructural Fuzzy Decision Support System (NSFDSS), Potentially All Pair wise Rankings of all possible Alternatives (PAPRIKA), PROMETHEE (Outranking), Superiority and inferiority ranking method (SIR method), Value analysis (VA), Value engineering (VE), Weighted product model (WPM), Weighted sum model (WSM) All claim to be able to accurately solve this type of problem. However, it is often the case that different methods yield different results for exactly the same problem and thus different solutions for simple problems may be suggested from the same data (i.e., those with very few alternatives and criteria (www.wikipedia). Different authors are also adopting various combinations of these method such as Fuzzy AHP, Fuzzy ANP, Fuzzy DEA etc.

The purpose of location theory is to determine the reasons for and explain why a particular factor is important to one industry and not to another (Greenhut, 1982). It also involves the principle of substitution, where an industry selects a site from alternative locations, which in terms of the economic theory, is similar to the problem of substituting labor for capital or land and vice versa (Greenhut, 1982). To better understand location theory, this study presents the location theories of leading writers as explained by Greenhut (1982). All these theories generally relate the importance of cost advantage to the selection of a site. Some of them also emphasize demand forces influencing the plant location decision. Examination of these writings will build a framework to better understand the rationale behind broiler industry location decisions. The leading theories of plant location begins with Von Thünen's Theory of Location (Greenhut, 1982).

The plant location problem has long been recognized as one which entails multiple factors (attributes). Numerical texts (Apple 1977, Moore 1962, Muther 1973) list the plant location factors which decision makers (DM) should consider in their location/relocation decisions. Practitioners (Levine 1981, Student 1977) specially say that such human consideration as: attractive places for engineers and managers to live in; favorable labour-climates, favorable attitudes of local citizens, etc. should not be overlooked. We generate a general frame of location (Keeney and Raiffa 1976). Four goals are identified in order to result in a good site: less cost, high productivity, better community relation and better living condition. These goals are often in conflict with each other. Multi Criteria Decision Making (MCDM) designated all methodology explicitly dealing with multiple factors/goals/objective/

attributes.

In the past, researchers have already developed many theory and applied different techniques to solve the facility location problems (Fransis and Goldstein, 1973). Randhawa and West, 1995 proposed a solution approach to facility location selection problems while integrating analytical and multi-criteria decision-making models. Houshyar and White, 1997 developed a mathematical model and heuristics approach that assigns N machines to N equal-sized locations on a given site such that the total adjacency flow between the machines is maximized. The proposed model is based on a 0-1 integer programming formulation which may produce an optimal, but infeasible solution, followed by the heuristic which begins with the 0-1 integer solution and generates a feasible solution. Owen and Daskin, 1998 provided an overview of the methodologies that have been developed for solving facility location selection problems. Chu, 2002 presented a fuzzy TOPSIS (technique for order preference by similarity to ideal solution) method-based approach for the plant location selection problems. The ratings and weights assigned by the decision makers are first normalized into a comparable scale. The membership function of each normalized rating of each alternative location for each criterion is then developed. A closeness coefficient is proposed to determine the ranking order of the alternatives. Klose and Drexl, 2005 reviewed in details the contributions to the current state-of-the-art related to continuous location models, network location models, mixed-integer programming models and their applications to location selection decision. Yong, 2006 proposed a new fuzzy TOPSIS method which deals with the selection of plant location decision-making problems in linguistic environment, where the ratings of various alternative locations under different criteria and their relative weights are assessed in linguistic terms represented by fuzzy numbers. Farahani and Asgari, 2007 presented a TOPSIS methodology to find the supportive centers with the minimum number and maximum quality of locations in military logistic systems. Önüt and Soner, 2008 employed a fuzzy TOPSIS based methodology to solve the solid waste transshipment site selection problem, where the criteria weights are estimated using analytic hierarchy process (AHP). Amiri et al., 2009 applied TOPSIS method along with heuristics based on fuzzy goal programming to select the best location. The facility location selection problem is solved in three stages, i.e. (a) finding the least number of distribution centers, (b) locating them in the best possible location, and (c) finding the minimum cost of locating the facilities. Athawale and Chakraborty 2010 applied PROMETHEE II method to tackle this complex

location selection decision-making problem. The Analytic Hierarchy Process (AHP), as applied to the plant location problem, involves the structuring of this decision-making process into different levels. (Andin Wu, Nesa L'abbe Wu, 1984)

4. METHODOLOGY

The MCDM Unlike other methods that assume the availability of measurements, measurements in MCDM are derived or interpreted subjectively as indicators of the strength of various preferences. Preferences differ from decision maker to decision maker, so the outcome depends on who is making the decision and what their goals and preferences are (Satty, 2005). In our case analysis, we will be using AHP (Satty, 1980) to give weightage to various factors, as these data are more qualitative and GRA (Grey Relational Analysis theory) (Deng, 1989) for MCDM. Grey relational analysis in the Grey theory that was already proved to be a simple and accurate method for multiple attributes decision problems (Hsu, 1997, Chang, 1996, Wen, 1994, Luo, 1993), very unique characteristic (Chiang, K.S, 1997, Wu, H.H, 1998)

4.1 Analytic Hierarchy Process (AHP)

AHP, decision elements at each component are compared pair-wise with respect to their importance towards their control criterion, and the components themselves are also compared pair-wise with respect to their contribution to the goal. Decision makers are asked to respond to a series of pair-wise comparisons where two elements or two components at a time will be compared in terms of how they contribute to their particular upper level criterion (Meade, 1999, Saaty, 2006). In addition, if there are interdependencies among elements of a component, pair-wise comparisons also need to be created, and an eigenvector can be obtained for each element to show the influence of other elements on it. The relative importance values are determined with a scale of 1 to 9, where a score of 1 represents equal importance between the two elements and a score of 9 indicates the extreme importance of one element (row component in the matrix) compared to the other one (column component in the matrix) (Meade, 1999, Saaty, 2006). A reciprocal value is assigned to the inverse comparison; that is, $a_{ij} = 1/a_{ji}$; where a_{ij} (a_{ij}) denotes the importance of the i th (j th) element compared to the j th (i th) element. In AHP, pair-wise comparison is made in the framework of a matrix, and a local priority vector can be derived as an estimate of relative importance associated with the elements (or components) being compared by

solving the following formulae:

$$A w = \lambda_{max} w \quad (1)$$

where A is the matrix of pair-wise comparison, w is the eigenvector, and λ_{max} is the largest Eigenvalue of A . If A is a consistency matrix, eigenvector X can be calculated by

$$(A - \lambda_{max} I) X = 0. \quad (2)$$

Consistency index ($C.I.$) and consistency ratio ($C.R.$) to verify the consistency of the comparison matrix. $C.I.$ and $R.I.$ are defined as follows:

$$C.I. = \frac{\lambda_{max} - n}{n - 1}, \quad (3)$$

$$C.R. = \frac{C.I.}{R.I.}, \quad (4)$$

where $R.I.$ represents the average consistency index over numerous random entries of same order reciprocal matrices. If $C.R. \leq 0.1$, the estimate is accepted; otherwise, a new comparison matrix is solicited until $C.R. \leq 0.1$ (Saaty, 2005).

4.2 Grey Theory

The black box is used to indicate a system lacking interior information (Ashby, 1945). Now-a-days, the black is represented, as lack of information, and the white is full of information. Thus, the information that is either incomplete or undetermined is called Grey. A system having incomplete information is called Grey system. The Grey number in Grey system represents a number with less complete information. The Grey element represents an element with incomplete information. The Grey relation is the relation with incomplete information. Those three terms are the typical symbols and features for Grey system and Grey phenomenon (Wu, 1996). There are several aspects for the theory of Grey system (Wu, 1996) :

1. Grey generation: This is data processing to supplement information. It is aimed to process those complicate and tedious data to gain a clear rule, which is the whitening of a sequence of numbers.
2. Grey modeling: This is done by step 1 to establish a set of Grey variation equations and Grey differential equations, which is the whitening of the model.
3. Grey prediction: By using the Grey model to conduct a qualitative prediction, this is called the whit-

ening of development.

4. Grey decision: A decision is made under imperfect countermeasure and unclear situation, which is called the whitening of status.
5. Grey relational analysis: Quantify all influences of various factors and their relation, which is called the whitening of factor relation.
6. Grey control: Work on the data of system behavior and look for any rules of behavior development predict future's behavior, the prediction value can be fed back into the system in order to control the system.

The concept of grey relational space was proposed by Deng based on the combined concepts of system theory, space theory and control theory (Deng, 1982). It can be used to capture the correlations between the references factor and other compared factors of a system (Deng, 1998). One of the features of GRA is that both qualitative and quantitative relationships can be identified among complex factors with insufficient information (relative to conventional statistical methods). Under such a condition, the results generated by conventional statistical techniques may not be acceptable without sufficient data to achieve desired confidence levels. In contrast, grey system theory can be used to identify major correlations among factors of a system with a relatively small amount of data. The procedure for calculating the GRA as followed.

1. Calculate the Grey Relation Grade

Let X_0 be the referential series with k entities (or criteria) of $X_1, X_2, \dots, X_i, \dots, X_N$ (or N measurement criteria). Then

$$X_0 = \{x_0(1), x_0(2), \dots, x_0(j), \dots, x_0(k)\},$$

$$X_1 = \{x_1(1), x_1(2), \dots, x_1(j), \dots, x_1(k)\},$$

$$X_i = \{x_i(1), x_i(2), \dots, x_i(j), \dots, x_i(k)\},$$

$$X_N = \{x_N(1), x_N(2), \dots, x_N(j), \dots, x_N(k)\}.$$

The grey relational coefficient between the compared series X_i and the referential series of X_0 at the j -th entity is defined as:

$$\tilde{a}_{0i}(j) = \frac{\Delta \min + \Delta \max}{\Delta_{0j}(j) + \Delta \max} \quad (5)$$

where $\Delta_{0j}(j)$ is the absolute value of difference between X_0 and X_i at the j -th entity, that is $\Delta_{0j}(j) = |x_0(j) - x_i(j)|$, and $\Delta \max = \max_i \max_j \Delta_{0j}(j)$, $\Delta \min = \min_i \min_j \Delta_{0j}(j)$.

The grey relational grade (GRG) for series of X_i is given as:

$$\tilde{A}_{0i} = \frac{1}{K} \sum_{j=1}^K w_j \tilde{a}_{0i}(j) \quad (6)$$

where w_j is the weight of j -th entity. If it is not necessary to apply the weight, take $w_j = \frac{1}{K}$ for averaging.

2. Data Normalization (or Data Dimensionless)

Before calculating the grey relation coefficients, the data series can be treated based on the following three kinds of situation and the linearity of data normalization to avoid distorting the normalized data (Hsia and Wu, 1998). They are:

- (a). (a). Upper-bound effectiveness measuring (i.e., larger-the-better)

$$x_i^*(j) = \frac{x_i(j) - \min_j x_i(j)}{\max_j x_i(j) - \min_j x_i(j)} \quad (7)$$

- (b). Lower-bound effectiveness measuring (i.e., smaller-the-better)

$$x_i^*(j) = \frac{\max_j x_i(j) - x_i(j)}{\max_j x_i(j) - \min_j x_i(j)} \quad (8)$$

- (c). Moderate effectiveness measuring (i.e., nominal-the-best)

If $\min_j x_i(j) \leq x_{ob}(j) \leq \max_j x_i(j)$, then

$$x_i^*(j) = \frac{|x_i(j) - x_{ob}(j)|}{\max_j x_i(j) - \min_j x_i(j)} \quad (9)$$

If $\max_j x_i(j) \leq x_{ob}(j)$, then

$$x_i^*(j) = \frac{x_i(j) - \min_j x_i(j)}{x_{ob}(j) - \min_j x_i(j)} \quad (10)$$

If $x_{ob}(j) \leq \min_j x_i(j)$, then

$$x_i^*(j) = \frac{\max_j x_i(j) - x_i(j)}{\max_j x_i(j) - x_{ob}(j)} \quad (11)$$

where $x_{ob}(j)$ is the objective value of entity j .

4.3 Case Analysis

The model for site Selection for XYZ Ltd, has been done through AHP and GRA. To start with, we have to Identify the criteria/parameters for site selection. After careful investigation, in order to find best site for plant, four parameters are decided (Yoon and Hwang, 1985) mainly Economic Impact i.e Less cost (C1), Functional Impact i.e High Productivity (C2), Public Acceptance i.e. better community relation (C3), Quality of life i.e Better living condition (C4). The experts are asked to rate the above parameters with respect to each other and mutually agreed weight are represented in Table 1. Initially in order find the priority weight AHP is used with Expert choice 4.0 as software and result is represented in result column in Table 1.

Table 1: Relative Weights of Different Parameters

| Parameters | C1 | C2 | C3 | C4 | Results |
|------------|-----|-----|-----|----|---------|
| C1 | 1 | 5 | 6 | 7 | .636 |
| C2 | 1/5 | 1 | 4 | 3 | .211 |
| C3 | 1/6 | 1/4 | 1 | 2 | .089 |
| C4 | 1/7 | 1/3 | 1/2 | 1 | .064 |

After getting the relative weights of different criteria, each of the four site S1-S4 are rated against the different four criteria's mention above by the same expert group are depicted in the Table 2. In this case the CR is .005, which is less than .1 and resulted in acceptance of the data. A group of assumptions are made for the following: (1) cost: the quantifying value for unit price (smaller-the-better) is 0; (2) High Productivity (larger-the-better) is 5; (3) Public Acceptance: (larger-the-better) is 5; (4) Quality of life (larger-the-better) is 5.

Table 2: Measurement Values for Each Evaluation Attribute

| Site/Criteria | C1 | C2 | C3 | C4 |
|---------------|----|----|----|----|
| S1 | 2 | 2 | 4 | 4 |
| S2 | 4 | 3 | 5 | 3 |
| S3 | 5 | 5 | 3 | 5 |
| S4 | 3 | 4 | 2 | 2 |

Table 2 was rationalized using equations mention (b) above and resulted Table 3. According to our expected

goal for each evaluation factor, an ideal standard series (X0 = 1) is established in the last line in Table 4.

Table 3: Data Rationalizing

| Item Comparative series | C1 | C2 | C3 | C4 |
|-------------------------|------|------|------|------|
| X1 | 1 | 0.00 | .667 | .667 |
| X2 | .333 | .333 | 1 | .333 |
| X3 | 0.00 | 1 | .333 | 1 |
| X4 | .667 | .667 | 0.00 | 0.00 |
| Standard series (X0) | 1 | 1 | 1 | 1 |

Determination of Grey relational coefficient for each evaluation factor by using the Equation (1).

Table 4: The Grey Relational Coefficient

| Item Comparative series | C1 | C2 | C3 | C4 |
|-------------------------|------|------|------|------|
| X1 | 1 | 0.00 | .667 | .667 |
| X2 | .333 | .333 | 1 | .333 |
| X3 | 0.00 | 1 | .333 | 1 |
| X4 | .667 | .667 | 0.00 | 0.00 |

Determination of the relational grade for each agency using the equation-2, weight are taken from the Table1.

$$\Gamma_{01} = 0.62; \Gamma_{02} = 0.97; \Gamma_{03} = 0.84; \Gamma_{04} = 0.576$$

This value of Grey relation is the overall performance that the enterprise requires.

Because of $\Gamma_{02} > \Gamma_{03} > \Gamma_{01} > \Gamma_{04}$, the ranking order for the sites are (1) S2; (2) S3; (3) S1 (4) S4.

5. CONCLUSION

In manufacturing, site selection for plant is a vital problem under Multi Criteria Decision Making environment. It depends upon several parameters and decision maker and their priority. It is important to develop an accurate evaluation method. This selection process generally contains both qualitative and quantitative data. Proposed methodology i.e. combine both AHP and GRA cater to both qualitative and quantitative nature of data in an integrated manner resulted in solving site selection problem.

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2. Manufacturing Plant location analysis by multiple attribute decision making: part-I- Single plant strategy, Kwangsun Yoon and Ching-Lai Hwang, International Journal of Production Research., 1985, Vol 23, No.2, 345-359

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