

Selection of Plant Location for a Steel Project by TOPSIS

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Abstract: In a complex business environment, the leadership team has to take certain decisions based on several criteria associated with the decision, some of which are quantifiable with real numbers while the remaining may be subjective or qualitative in nature, which may possibly be expressible linguistically or as a subjective comparison, though equally important for the final decision making. Such decision problems are called Multi-Criteria Decision Making (MCDM) problems. There are techniques available to deal with such problems by integrating all the criteria, quantitative or qualitative, in the decision algorithm and arriving at the most suitable alternatives among several choices available, through certain process steps. MCDM problems may be encountered in many areas of business like key project decisions, strategic decisions on inward and outward logistics, marketing decisions, process technology selection, supply chain decisions, marketing strategies, plant layout optimization etc. The major algorithms that can be conveniently applied to crack such decision problems are Analytic Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Weighted Sum Method (WSM). This article will attempt to solve a site selection problem for a Greenfield integrated steel project, considering several key selection criteria and certain alternative locations. For performing this exercise, the article shall use TOPSIS as the algorithm.

Keywords: Project-decisions, Decision Problems, MCDM, TOPSIS

1. Introduction

Projects are manifestation of decision requirement at every step it progresses beginning with investment decisions until project closure. Such decision problems can be of diverse nature and complexities with varying ramification on the project objectives and organisational strategies. It is therefore an imperative for the project and business leadership to make analytic and accurate decisions to minimise the negative impact of an unfounded decision.

As long as the Decision problems has a single criteria and the data participation in the decision making algorithm are quantitative represented in real numbers, there are several mathematical and statistical techniques to reach an optimal solution for decision making. However, in real life situations often there are many criteria that have to be considered and synthesised into the decision making process and decide the correct alternative amongst a set of choices available to the decision maker. Further, some of the criteria could be qualitative or intangible, not representable in real numbers. Such decision

problems are known as Multi-Criteria Decision Making (MCDM) problems, which compares the degree of relevance of each criteria with respect to the each available alternative and aggregates such data to identify the best alternative [4].

One of such technique which is widely used is known as - *Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)*.

TOPSIS is Multi-Criteria Decision Analysis (MCDA) method which identifies the alternative that is at closest geometrical (Euclidean) distance from the positive ideal solution (PIS) and farthest from the negative ideal solution. It was originally developed by Ching-Lai Hwang and Yoon in 1981 with further developments by Yoon in 1987 and Hwang, Lai and Liu in 1993 (*Wikipedia*) [1, 3].

In this article we shall try to solve a MCDM problem for selecting most suitable plant location for a Greenfield project out of many possible locations based on five key criteria using TOPSIS [2].

2. Selection of Plant Location for a Steel Project

Problem statement:

Based on a strategic business decision, Company - X has decided to construct a Greenfield integrated iron and steel project at a suitable location in USA. After a preliminary survey, the company has short listed five states as follows

1. South Carolina
2. North Carolina
3. Kentucky

4. Georgia

5. Texas

Having identified these possible locations, certain key information were gathered by the company that would have substantial impact on the success of the endeavour and its sustainability. These key criteria with their numeric values wherever quantifiable or relative importance in a scoring scale from 1 to 5 (1 – Most preferred, 5 - Least preferred), are indicated below in Table 1.

It must be noted that in some of the parameters lowest value is ideal while others higher value may be the ideal value.

Table 1. Criteria Matrix.

Location	Water cost (\$/m ³)	Power cost (\$/unit)	Natural gas cost (\$/msm ³)	Surface transport facility (1 to 5)	Water Transport Facility (1 to 5)
South Carolina	1178	5.78	5.01	2	4
North Carolina	1610	6.23	7.12	4	4
Kentucky	1075	5.28	5.26	3	2
Georgia	1398	5.54	4.84	5	4
Texas	1567	5.13	3.26	4	5
Rooted summation of the squared values	3090	13	12	8	9

The first step is to normalise the vectors, called vector normalisation. This is done by adding the squares of each cell for a particular column and taking a square root of the sum.

$$\sqrt{\sum_{i=1}^n X_{ij}^2} \quad (i = 1 \dots n, j = \dots m)$$

Accordingly, rooted summation for Water cost shall be = $\sqrt{1178^2 + 1610^2 + 1075^2 + 1398^2 + 1567^2} = 3090$.

Now divide each cell value (x_{ij}) by the rooted sum to compute the normalised matrix. This means – $1178 \div 3090 = 0.38$ is the normalised cell value of $x_{1,1}$. Similarly, $1610 \div 3090 = 0.52$ is the normalised value of $x_{2,1}$... etc. Working out this way, we generate the normalised values for all the cells in the matrix. The resultant normalised matrix is under (Table 2). The values in the cells are known as *Performance values*.

Table 2. Normalised Decision Matrix.

Location	Water cost (\$/m ³)	Power cost (\$/unit)	Natural gas cost (\$/msm ³)	Surface transport facility (1 to 5)	Water Transport Facility (1 to 5)
South Carolina	0.38	0.44	0.42	0.25	0.44
North Carolina	0.52	0.48	0.59	0.33	0.44
Kentucky	0.35	0.41	0.44	0.25	0.22
Georgia	0.45	0.43	0.40	0.42	0.44
Texas	0.51	0.39	0.27	0.33	0.56

We have now found a matrix which looks somewhat ordered. However, depending upon the criterion's impact on the overall decision, we may like to fix some weightages to the parameters and then have a look at the weighted matrix to identify the ideal number for each criterion and the most negative number of the same criterion. In our example, we chose to attach equal weight to each criterion, which is 20%.

Multiplying each normalised value by the corresponding weight, the weighted normalised values are found.

For example, weighted normalised water cost in South Carolina = 20% of 0.38 = 0.0762 while the corresponding value for North Carolina = 20% of 0.52 = 0.1042. Repeating the step for required number of time results in the weighted matrix (Table 3).

Table 3. Weighted Normalised Matrix.

Weights	20%	20%	20%	20%	20%
Location	Water cost (\$/m ³)	Power cost (\$/unit)	Natural gas cost (\$/msm ³)	Surface transport facility (1 to 5)	Water Transport Facility (1 to 5)
South Carolina	0.0762	0.0889	0.0835	0.0500	0.0889
North Carolina	0.1042	0.0958	0.1187	0.0667	0.0889
Kentucky	0.0696	0.0812	0.0877	0.0500	0.0444
Georgia	0.0905	0.0852	0.0807	0.0833	0.0889
Texas	0.1014	0.0789	0.0543	0.0667	0.1111
$V_j +$	0.0696	0.0789	0.0543	0.0500	0.0444
$V_j -$	0.1042	0.0958	0.1187	0.0833	0.1100

Next, we identify the ideal best and the worst of each criteria. For example, lowest water cost is most ideal while highest water cost is the worst value. Hence, for water cost we select 0.0696 as the most ideal value and designate it as V_j^+ . Similarly we select 0.1042 as the worst value and designate it as V_j^- . Working in this manner for all the criteria vectors, we identify the ideal and the worst values for each criterion as shown in the two bottom rows of the table above highlighted with thick borders.

TOPSIS methodology considers that value as most

preferred, which is at the nearest Euclidean distance from the ideal value and farthest from the worst.

A Euclidean distance is the shortest distance in space connecting two points joined by a straight line. Therefore, in a two dimensional space, it is the diagonal calculated as the square root of the perpendicular and base. For a three dimensional space again it will be calculated the same way for all the three dimensions. Following illustrations shall clarify the method of calculating the Euclidean distances between two points in two and three dimensional spaces.

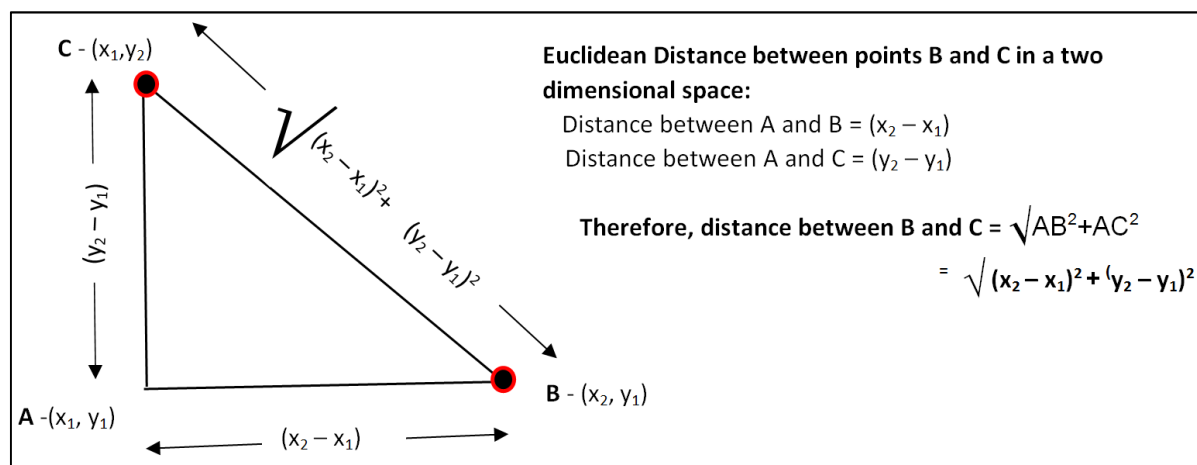


Figure 1. Euclidean Distance – 2D space.

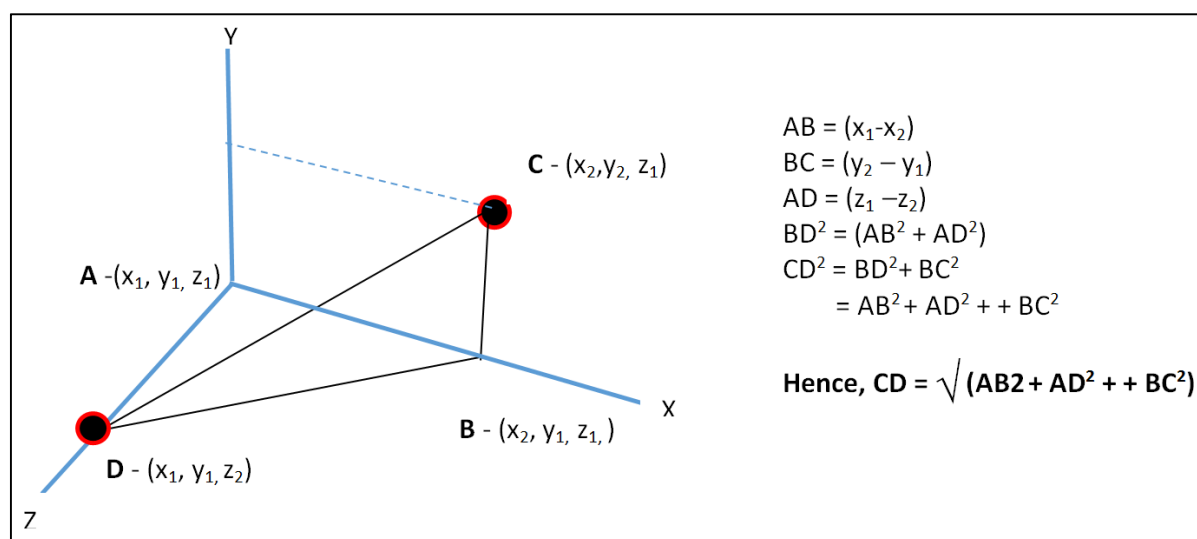


Figure 2. Euclidean Distance – 3D space.

We shall apply the same methodology to calculate the Euclidean distances of each performance value in Table 3. Designating nearest distance from ideal value as S_i^+ and farthest from worst value as S_i^- .

$$S_i^+ = \sqrt{(0.0762 - 0.0696)^2 + (0.0889 - 0.0789)^2 + (0.0835 - 0.0543)^2 + (0.0500 - 0.0500)^2 + (0.0889 - 0.0444)^2} = 0.0546$$

So, this is the synthesised preferred performance value of South Carolina considering all the criteria. In a similar manner we calculate the preferred values for all the other states.

Next, we calculate the distances from the worst values same way but with respect to the least-preferred values,

$$S_i^- = \sqrt{(0.0762 - 0.1042)^2 + (0.0889 - 0.058)^2 + (0.0835 - 0.1187)^2 + (0.0500 - 0.0833)^2 + (0.0889 - 0.1100)^2} = 0.0602$$

In the similar manner the other values of S_i^- are calculated. The result is tabulated in Table 4.

Table 4. Calculation of Euclidean distances from ideal and worst values.

Weights >	20%	20%	20%	20%	20%	Distance from Ideal	Distance from most negative
Location	Water cost (\$/m ³)	Power cost (\$/unit)	Natural gas cost (\$/msm ³)	Surface transport facility (1 to 5)	Water Transport Facility (1 to 5)	S _i ⁺	S _i ⁻
South Carolina	0.0762	0.0889	0.0835	0.0500	0.0889	0.0546	0.0602
North Carolina	0.1042	0.0958	0.1187	0.0667	0.0889	0.0888	0.0269
Kentucky	0.0696	0.0812	0.0877	0.0500	0.0444	0.0334	0.0882
Georgia	0.0905	0.0852	0.0807	0.0833	0.0889	0.0653	0.0468
Texas	0.1014	0.0789	0.0543	0.0667	0.1111	0.0758	0.0687
V _j ⁺	0.0696	0.0789	0.0543	0.0500	0.0444		
V _j ⁻	0.1042	0.0958	0.1187	0.0833	0.1100		

In the last step we have to synthesise the value of S_i⁺ and S_i⁻ to arrive at the final performance ranking vector by using the following formula –

$$P_j = S_i - / (S_i^+ + S_i^-)$$

where P_j is the synthesised performance value of each location (state). This step is shown in Table 5 along with the *Ranking* of the locations (States).

Table 5. Final performance Values and Ranking.

Location	Si+	Si-	Si ⁺ + Si ⁻	Pj (Performance)	Ranking
South Carolina	0.0546	0.0602	0.1148	0.5244	2
North Carolina	0.0888	0.0269	0.1157	0.2325	5
Kentucky	0.0334	0.0882	0.1216	0.7253	1
Georgia	0.0653	0.0468	0.1121	0.4175	4
Texas	0.0758	0.0687	0.1445	0.4754	3

Since the highest P_j score is in favour of Kentucky, Kentucky has been ranked 1, South Carolina ranked 2 and so on. Similarly, the least preferred location in the example is North Carolina for the criteria we have considered to be the decision drivers.

3. Conclusion

Any major project, be it an industrial or an infrastructure project, calls for several strategic decisions with a number of key criteria to optimize to ensure long term fulfillment of the business objectives once the project is delivered. Such strategies include, but not limited to, the businesses' logistic strategy [5, 13], supply chain management [14], marketing strategy [7], process technology selection [10], optimal layout design [6], mining strategy [15] etc., to name a few.

In addition to the aforesaid strategic level decisions, several other key decisions can be conveniently optimized at the functional levels like - optimizing manufacturing process [8], vendor and contractor selection [9, 11, 12].

Most of such decisions involve several quantitative as well as qualitative criteria which need to participate in the decision algorithm to result in near-accurate decision options with preference ranking. AHP (Analytic Hierarchy Process) and TOPSIS and Weighted Sum Method (WSM) are three such popular algorithms of which TOPSIS has been used in this article to illustrate a very common MCDM problem with a case study.

Having gone through this example, the readers might be able to realise the benefits of applying TOPSIS in complex and critical decision making problem. In this example, we have taken a 5x5 matrix for simplicity and used Excel for solving the problem at the background. However, in some integrated large projects the number of locational choices and criteria may be quite large and therefore managing them through Excel may be tedious and time taking. In such situations Software like DECERNS, *TOPSIS*, TOPSIS Solver 2012 etc., may come handy.

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Biography



Partha Sarathi Ghose, PMP, currently a President & Chief of Projects in a reputed speciality steel making and forging company – Kalyani Steels Ltd., India, is a post-graduate engineer with management education from premier institutes of India with more than 43 years of experience in heavy manufacturing industries in core sectors such as ferrous and non-ferrous metallurgy, bulk chemicals, power and infrastructure, in areas of large and mega integrated projects and operations—managing the functions from the field through to leadership positions.