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EVALUATION OF IT PROJECTS FOR INVESTMENT USING TOPSIS

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Abstract: The rapid development of IT and potential growth in digital economy draw considerable attention of investors towards the investment in IT projects. The investment in IT projects normally demands large amounts of investment and has high risk of failure. The process of evaluating and ranking IT projects involves multiple conflicting criteria and possibly more than one decision makers. In this paper, the ranking of IT projects for the purpose of investment decision using TOPSIS is proposed. It is shown through the illustrative example that the complication in the decision making process is resolved using the proposed methodology.

Keywords: IT project investment, multi-criteria decision making, TOPSIS.

1. INTRODUCTION

The rapid development of IT and potential growth in digital economy draw considerable attention of investors towards the investment in IT projects. An example is the so-called angel investors who are willing to invest in the web-based technologies and mobile apps (see e.g. *http://www.venturegiant.com/angel-investor-221-angel-investment-web-technologies-mobile-apps.aspx*) (Venture Giant, n.d.). The investment in IT projects normally demands large amounts of investment. Unfortunately, the failure rate of IT projects is reportedly high. A study by the Standish Group showed that only 28 percent of IT projects were completed on time, on budget and with the promised functionalities (Standish Group, 2001). The process of evaluating and ranking IT projects is complex and challenging. It is naturally an MCDM problem (Harnpornchai and Thananchana, 2017) where there are multiple conflicting criteria and possibly more than one decision makers. Important quantitative and qualitative factors which involve in the evaluation include predicted returns, investment costs, degree of project complexity, capability of development team, and degree of external environmental changes (Guo, 2013).

The decision making with multiple criteria is referred to as the multiple criteria decision making or multi-criteria decision making (MCDM). Among the afore-mentioned methods, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) (Yoon, 1980) is one of the most frequently applied MCDM methods (Mardani *et al.*, 2015). TOPSIS is used for a number of advantageous reasons (Zeleny, 1982):

1. TOPSIS logic is rational and understandable;
2. the computation processes are straightforward;
3. the concept permits the pursuit of the best alternatives for each criterion depicted in a simple mathematical form;
4. the importance weights are incorporated into the comparison procedures.

In this paper, the ranking of IT projects for the purpose of investment decision using TOPSIS is proposed. After this introduction, TOPSIS is described in details. The evaluation criteria for IT project investment are then summarized. The proposed methodology is demonstrated through an example. Conclusion is given at the end.

2. DESCRIPTION OF TOPSIS

The fundamental concept of TOPSIS is that the best solution is the one with the shortest distance to the positive ideal solution and the farthest distance from the negative ideal solution (Hwang and Yoon, 1981; Lai *et al.*, 1994; Yoon 1980). Accordingly, TOPSIS can be considered as a geometry-based method. TOPSIS assumes that each attribute has the utility with a monotonic nature. In other words, each attribute takes either monotonically increasing or monotonically decreasing utility. TOPSIS divides the criteria into two groups, namely benefit/profit/positive and cost/loss/negative criteria. By definition, the positive ideal solution is composed of all best attribute values attainable whereas the negative ideal solution is composed of all worst attribute values attainable.

TOPSIS consists of 6 steps as follows.

1. Construction of normalized decision matrix. Since each criterion evaluation may result in different unit of measurement, the normalization of the evaluated performances is recommended in order to transform them into dimensionless quantities, which allows the comparison across all evaluated performances. An element r_{ij} of the normalized decision matrix $\boldsymbol{R}$ is defined as

$$r_{ij} = \frac{z_{ij}}{\left(\sum_{i=1}^{m} z_{ij}^2\right)^{1/2}} \;;\; i = 1,\ldots,m \text{ and } j = 1,\ldots,n \tag{1}$$

2. Construction of weighted norma1ized decision matrix. The preference in the criteria is taken into account in this step via the weights associated with each criterion. The weighted normalized decision matrix $\boldsymbol{V}$ is obtained as

$$\boldsymbol{V} = \begin{bmatrix} v_{11} & v_{12} & \ldots & v_{1n} \\ v_{21} & v_{22} & \ldots & v_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ v_{m1} & v_{m2} & \ldots & v_{mn} \end{bmatrix} \tag{2}$$

, where $v_{ij} = w_j r_{ij}$; $i = 1,\ldots,m$ and $j = 1,\ldots,n$ (3)

3. Determination of positive ideal solution $\boldsymbol{V}^+$ and negative ideal solution $\boldsymbol{V}^-$. Both solutions are defined as:

$$\boldsymbol{V}^+ = \left\{\left(\max_i v_{ij} \mid j \in C^+\right), \left(\min_i v_{ij} \mid j \in C^-\right) \middle| i = 1,\ldots,m\right\} \equiv \left\{v_1^+, v_2^+, \ldots, v_n^+\right\} \tag{4}$$

$$\boldsymbol{V}^- = \left\{\left(\min_i v_{ij} \mid j \in C^+\right), \left(\max_i v_{ij} \mid j \in C^-\right) \middle| i = 1,\ldots,m\right\} \equiv \left\{v_1^-, v_2^-, \ldots, v_n^-\right\} \tag{5}$$

, where $C^+ = \{j = 1,\ldots,n \mid j$ is associated with benefit/profit/positive criteria$\}$ (6)

$C^- = \{j = 1,\ldots,n \mid j$ is associated with cost/loss/negative criteria$\}$ (7)

4. Calculation of separation measure. Since each alternative is represented by a point in the n-dimensional space, the separation between two alternatives can be measured as the distance between them in the space. The Euclidean distance is used for the purpose. Accordingly, the separation between an alternative and the positive ideal solution $\boldsymbol{V}^+$, s_i^+, is

$$s_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^+\right)^2} \;;\; i = 1,\ldots,m \tag{8}$$

The separation between an alternative and the negative ideal solution $\boldsymbol{V}^-$, s_i^-, is

$$s_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2} \;;\; i = 1,\ldots,m \tag{9}$$

5. Calculation of the relative closeness to the positive ideal solution. The relative closeness of the alternative A_i with respect to V^+, κ_i, is defined as

$$\kappa_i = \frac{s_i^-}{s_i^+ + s_i^-};\ i = 1,...,m \tag{10}$$

6. Ranking of the preference order. The alternatives are preferred in accordance with the descending order of κ_i, i.e. the alternatives with higher κ_i's are preferred to the ones with lower κ_i's.

When the decision making involves the opinion from many decision makers, the decision matrix then contains their alternative ratings and weight ratings. The final decision is the result from the process of preference aggregation. The aggregation methods can be classified into two groups, namely external aggregation and internal aggregation (Shih *et al.*, 2007). The external aggregation utilizes some operations to manipulate the alternative ratings and weight ratings. The internal one aggregates the preference of individuals within TOPSIS as an integrated procedure. It is noted that there is not much difference in the results between both aggregation groups (Shih *et al.*, 2007). The details of both external aggregation and internal aggregation will be explained in the followings.

The external aggregation determines the representative decision matrix and weights for all decision makers. The decision matrices and weights from respective decision makers are transformed into a final decision matrix and final weights before being processed by MCDM methods. Therefore, the final decision matrix and final weights are independent from MCDM methods and can be processed by any MCDM methods like TOPSIS in order to obtain the preference order. The notion of taking the arithmetic mean of the quantities from all decision makers as the final quantities is well accepted and widely used. Accordingly, such a notion is explained here.

Let the decision matrix $\boldsymbol{D}_d$ of the dth decision maker from N_D decision makers be

$$\boldsymbol{D}_d = \begin{bmatrix} z_{11}^d & z_{12}^d & z_{13}^d & \cdots & z_{1n}^d \\ z_{21}^d & z_{22}^d & z_{23}^d & \cdots & z_{2n}^d \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ z_{m1}^d & z_{m2}^d & z_{m3}^d & \cdots & z_{mn}^d \end{bmatrix};\ d = 1,\ldots, N_D \tag{11}$$

Note that $\boldsymbol{D}_d$ is composed of the objective value matrix and the subjective rating matrix. The final decision matrix $\boldsymbol{D}$ is defined as the arithmetic mean of all $\boldsymbol{D}_d$'s, i.e.

$$\boldsymbol{D} = \frac{1}{N_D}\sum_{d=1}^{N_D} \boldsymbol{D}_d \tag{12}$$

Let w_j^d be the weight of the jth criterion corresponding to the dth decision maker. The criterion weights from the dth decision maker can be written in the matrix form as

$$\boldsymbol{w}^d = [w_1^d \ \ \ldots \ \ w_j^d \ \ \ldots \ \ w_n^d] \tag{13}$$

, where $\boldsymbol{w}^d$ is the matrix of the criterion weights from the dth decision maker.

The final weight w_j for all decision makers is taken as the arithmetic mean of all w_j^d's. That is

$$w_j = \frac{1}{N_D}\sum_{d=1}^{N_D} w_j^d \tag{14}$$

The final decision matrix $\boldsymbol{D}$ according to Eq.(12) and the final weight w_j according to Eq.(14) are then further processed according to the steps in TOPSIS (1) - (10) to obtain the preference order for decision making.

3. INVESTMENT CRITERIA FOR IT PROJECTS

There have been studies of what criteria should be considered for IT project investment. A strategic grid model was proposed to explore the critical selection criteria (Jiang and Klein, 1999). Accordingly, six critical criteria were obtained. They include financial, organizational, competing environment, technical, project risk, and managerial aspects. Santhanam and Kyparisis (Santhanam and Kyparisis, 1995; Santhanam and

Kyparisis, 1996) identified corporate priorities, financial benefits and costs, intangible measures such as project risk, availability of IT resources, and interdependencies among projects as selection criteria. Another study (Bradri *et al.*, 2001) considered benefits, hardware, software, related costs, risk factors, cost of additional manpower required, completion time, training time constraints, and contingency requirements in the decision making process. Another proposal of IT project selection include outside environment conditions, expected returns, development costs, project risks, degree of ease to operate, and management ability of the organization (Guo, 2013). The scrutiny of the afore-mentioned criteria informs of their similarity of finance, project complexity, management team credibility, and uncertainty in environment-related factors.

4. ILLUSTRATIVE EXAMPLE

Four candidates IT projects are considered by three decision makers. The criteria considered in this example include C1-Benefit-Cost Ratio (BCR), C2-payback period, C3-project complexity, C4-management team credibility, and C5-uncertainty in environment. It should be noted that the positive criteria consists of C1 and C4 whereas the negative ones are C2, C3, and C5. In addition, the objective criteria are C1 and C2 while the subjective ones are C3, C4, and C5. The performance evaluation for the subjective criteria is based on the score with the scale from 1-10. For positive criterion, the higher the score is, the higher the advantage is. On contrary, for negative criterion, the higher the score is, the higher the disadvantage is. For examples, the IT project with the score of 8 in the criterion of management team credibility has higher credibility than the one with the score of 4. The IT project with the score of 9 in the criterion of project complexity is more complex than the one with the score of 1.

Suppose that each decision maker gives the criterion weights as follows:

$$\boldsymbol{w}^1 = \begin{bmatrix} 0.25 & 0.25 & 0.2 & 0.2 & 0.1 \end{bmatrix} \qquad (15)$$

$$\boldsymbol{w}^2 = \begin{bmatrix} 0.3 & 0.05 & 0.3 & 0.2 & 0.15 \end{bmatrix} \qquad (16)$$

$$\boldsymbol{w}^3 = \begin{bmatrix} 0.2 & 0.1 & 0.3 & 0.2 & 0.2 \end{bmatrix} \qquad (17)$$

The common criterion weights are obtained following Eq. (14).

$$\boldsymbol{w} = \begin{bmatrix} 0.25 & 0.13 & 0.27 & 0.2 & 0.15 \end{bmatrix} \qquad (18)$$

The decision matrix from each decision maker is shown below:

$$\boldsymbol{D}_1 = \begin{bmatrix} 2 & 4 & 4 & 9 & 5 \\ 2.5 & 5 & 6 & 5 & 6 \\ 1.8 & 3 & 3 & 4 & 3 \\ 2.8 & 6 & 8 & 8 & 7 \end{bmatrix} \qquad (19)$$

$$\boldsymbol{D}_2 = \begin{bmatrix} 2 & 4 & 5 & 8 & 5 \\ 2.5 & 5 & 5 & 6 & 5 \\ 1.8 & 3 & 4 & 3 & 4 \\ 2.8 & 6 & 7 & 9 & 8 \end{bmatrix} \qquad (20)$$

$$\boldsymbol{D}_3 = \begin{bmatrix} 2 & 4 & 4 & 6 & 6 \\ 2.5 & 5 & 5 & 5 & 6 \\ 1.8 & 3 & 6 & 4 & 5 \\ 2.8 & 6 & 8 & 8 & 7 \end{bmatrix} \qquad (21)$$

The final decision matrix is taken as the average of the decision matrices from all decision makers, i.e.

$$\boldsymbol{D} = \frac{1}{3}\sum_{d=1}^{3} \boldsymbol{D}_d = \begin{bmatrix} 2 & 4 & 4.33 & 7.67 & 5.33 \\ 2.5 & 5 & 5.33 & 5.33 & 5.67 \\ 1.8 & 3 & 4.33 & 3.67 & 4 \\ 2.8 & 6 & 7.67 & 8.33 & 7.33 \end{bmatrix} \qquad (22)$$

Construct the normalized decision matrix for the decision matrix.

$$\boldsymbol{R} = \begin{bmatrix} 0.3062 & 0.3598 & 0.4096 & 0.4156 & 0.3453 \\ 0.3828 & 0.2878 & 0.3328 & 0.2891 & 0.3250 \\ 0.2756 & 0.4797 & 0.4096 & 0.1988 & 0.4605 \\ 0.4287 & 0.2399 & 0.2315 & 0.4518 & 0.2512 \end{bmatrix} \qquad (23)$$

The weighted norma1ized decision matrices are then:

$$V = \begin{bmatrix} 0.0766 & 0.0480 & 0.1092 & 0.0831 & 0.0518 \\ 0.0957 & 0.0384 & 0.0888 & 0.0578 & 0.0488 \\ 0.0689 & 0.0640 & 0.1092 & 0.0398 & 0.0691 \\ 0.1072 & 0.0320 & 0.0617 & 0.0904 & 0.0377 \end{bmatrix} \quad (24)$$

The positive ideal solution V_{DI}^{+} and negative ideal solution V_{DI}^{-} are:

$$V_{DI}^{+} = \{0.1072, 0.0320, 0.0617, 0.0904, 0.0377\} \quad (25)$$

$$V_{DI}^{-} = \{0.0689, 0.0640, 0.1902, 0.0398, 0.0691\} \quad (26)$$

The separation between each alternative and V_{DI}^{+} is given in the vector $s^{+DI} = [s_i^{+DI}]_{4\times1}$:

$$s^{+DI} = \begin{bmatrix} 0.1155 \\ 0.0885 \\ 0.1997 \\ 0 \end{bmatrix} \quad (27)$$

Similarly, the separation between each alternative and V_{DI}^{-} is given in the vector $s^{-DI} = [s_i^{-DI}]_{4\times1}$:

$$s^{-DI} = \begin{bmatrix} 0.0843 \\ 0.1112 \\ 0 \\ 0.1997 \end{bmatrix} \quad (28)$$

The relative closeness of each alternative with respect to V_{DI}^{+} is computed and collected in the vector $\kappa^{DI} = [\kappa_i^{DI}]_{4\times1}$:

$$\kappa^{DI} = \begin{bmatrix} 0.4220 \\ 0.5569 \\ 0 \\ 1 \end{bmatrix} \quad (29)$$

According to the relative closeness, the preference of IT project investment in the descending order is the fourth, second, first, and third project, respectively. It should be noted that such a preference is based on the consideration that the project complexity and BCR are relatively more important than the others.

Let the final weight matrix be:

$$w = [0.15 \quad 0.05 \quad 0.35 \quad 0.10 \quad 0.35] \quad (30)$$

This is the case of distinct preference in the project complexity and uncertainty in environment over the rest. The corresponding relative closeness κ^{DI} then becomes

$$\kappa^{DI} = \begin{bmatrix} 0.3705 \\ 0.5565 \\ 0 \\ 1 \end{bmatrix} \quad (31)$$

The resulting preference of IT project investment in the descending order is still the same as before.

When the financial criteria are considered more important than the others and the rest are equally important, the following criterion weight matrix reflects such a situation.

$$w = [0.35 \quad 0.35 \quad 0.10 \quad 0.10 \quad 0.10] \quad (32)$$

The resulting relative closeness is

$$\kappa^{DI} = \begin{bmatrix} 0.4261 \\ 0.6694 \\ 0 \\ 1 \end{bmatrix} \quad (33)$$

The preference of IT project investment in the descending order remains unchanged.

The sensitivity analysis with respect to the criteria above informs that the fourth project is superior to the other projects in all criteria and should be considered first for the investment while the third project should be considered as the last alternative.

5. CONCLUSIONS

IT projects generally require substantial financial investment. However, the IT projects have high risk of failure. In addition, the investment decision involves multiple and conflicting criteria. When there are several candidate projects to be selected for investment, it is thus not a trivial task of decision making. In this paper, the ranking of IT projects for the purpose of investment decision using TOPSIS is proposed. The application of TOPSIS includes the case of more than one decision maker. It is shown through the illustrative example that the complication in the decision making process is resolved using the proposed methodology.

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