Journal of Project Management 2 (2017) 1–10

Contents lists available at GrowingScience

Journal of Project Management

homepage: www.GrowingScience.com

A state-of-art survey on project selection using MCDM techniques

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C H R O N I C L E

Article history:
Received: March 5, 2017
Received in revised format: May 16, 2017
Accepted: June 11, 2017
Available online:
June 11, 2017

Keywords:
Project selection
TOPSIS
AHP
ANP
VIKOR

A B S T R A C T

Project selection is considered as the first essential part of project portfolio management. Project selection is also considered as a process to evaluate each project idea and chooses the one with the biggest priority. Project selection plays an essential role in the entire life cycle of different projects. This paper presents a survey for project selection using multiple criteria decision making techniques. The study considers 60 papers from over the period 1980-2017. The results of the survey have indicated that integration of Order of Preference by Similarity to Ideal Solution (TOPSIS) and analytical hierarchy process/analytical network process was the most popular techniques for project selection followed by VIKOR method.

1. Introduction

Project selection is considered as the first essential part of project portfolio management. Project selection is also considered as a process to evaluate each project idea and chooses the one with the biggest priority. Project selection plays an essential role in the entire life cycle of different projects (Wu et al. 2014). The scoring technique is a method where the members of a project selection lists relevant criteria, weighs them based on their relative importance and their priorities and then sums the weighted values (Huang et al., 2008; Ramani et al., 2009; Pirdashti et al., 2009; Bakshi et al., 2012; Adhikary et al., 2015). Project selection often is involved with multiple criteria and it is important to use multiple criteria decision making (MCDM) to find an appropriate assessment. During the past few years, there have been tremendous attempts on using MCDM techniques for project selection. In this paper, we review recent advances on the implementation of MCDM techniques for project selection.

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doi: 10.5267/j.jpm.2017.6.001

2. Multi attributes decision making

The purpose of multi attribute decision making (MADM) is involved with ranking different alternatives subject to some qualitative criteria such as cost, quality, one time delivery, etc.

2.1. Analytical hierarchy process

Analytical hierarchy process (AHP) (Saaty, 1986) is a structured method for analyzing complex decisions, according to mathematics and psychology. Fig. 1 shows a simple AHP implementation for project selection where there are two hierarchy in the process.

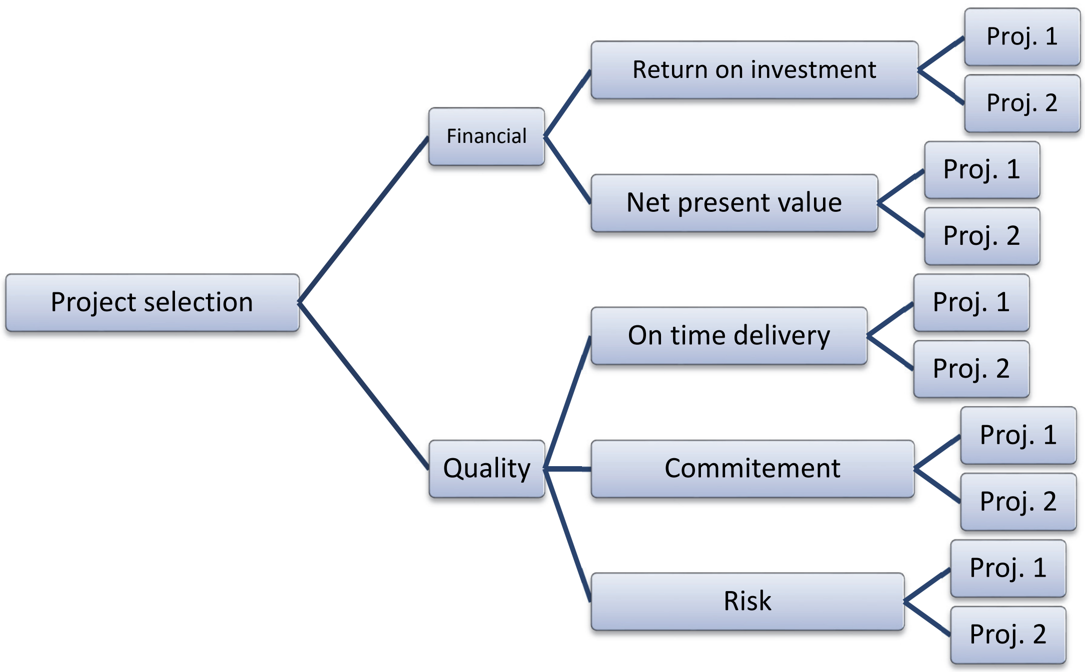

Fig. 1. Analytical hierarchy process

In practice, there are uncertainty (Chen, 2002; Chen & Cheng, 2009) associated with qualitative pairwise comparisons and data are given in an uncertain form. Öztaysi (2015) used a group decision making approach using interval type-2 fuzzy (Zadeh 1965, 1978, 1996) AHP for project selection. Thipparat and Thaseepetch (2013) presented an integrated VIKOR (Opricovic & Tzeng, 2004; Bakshi et al., 2011) and fuzzy AHP technique for evaluating a sustainable research project. Alzober and Yaakub (2014) proposed an integrated model for project selection, which consists of two stages. First, it integrates two MCDM methods of AHP and analytical neural network (ANN) to prepare a shortlist of the best alternatives. Next, they applied statistical model COP to select the optimum alternative from the best alternatives in a shortlist. Li et al. (2008) used AHP method with an integration with other MCDM techniques for ranking different alternatives. Yazdani-Chamzini et al. (2013) used AHP method along with other MCDM techniques for selecting the optimal renewable energy.

2.2 Analytical network process

The analytic network process (ANP) (Saaty, 1996) is a more general form of the analytic hierarchy process (AHP) where interrelationships among different criteria are also considered. There are literally several applications of ANP for project selection (Chen & Tzeng, 2010; Liang et al., 2013; Vinodh & Swarnakar, 2015). Ravi et al. (2008) proposed a hybrid method using ANP and goal programming method for selection of a reverse logistics project for end-of-life computers. Wey and Wu (2007) applied ANP priorities with goal programming in resource allocation in transportation. Bai and Zhan (2011) presented a method for an IT Project selection method based on fuzzy ANP. Lee and Kim (2000, 2001) proposed an improved information system project selection methodology which reflect interdependencies among evaluation criteria and candidate projects using ANP within a zero–one goal programming model. Wang et al. (2012, 2013) used ANP method for project selection in the presence of other MCDM techniques.

2.3. The Technique for Order of Preference by Similarity to Ideal Solution

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is another MCDM method, which was originally developed by Hwang and Yoon in 1981. The following steps demonstrate the implementation of the TOPSIS method.

Step 1*: The quantification and normalization of decision matrix (N):*

To normalize the decision matrix for each element, the following operation is implemented:

$$n_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}} \tag{1}$$

Step 2*: Obtain the weighted normalized matrix (V):*

To obtain the weighted normalized matrix, the normalized matrix (N) is multiplied by $W_{n\times n}$, which is a square matrix, the diagonal elements are the weights of the indicators and the other elements are 0.

$$V = N \times W_{n\times n} \tag{2}$$

Step 3*: Obtain a positive ideal V_j^+ and a negative ideal V_j^- for each indicator.*

Step 4*: Determin the distance between each alternative and its positive and negative ideals.*

$$d_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^+\right)^2} \tag{3}$$

$$d_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2} \tag{4}$$

Step 5*: Determin the relative proximity of each alternative to the ideal solution.*

$$CL_i^* = \frac{d_i^-}{d_i^- + d_i^+} \qquad CL_i^* = \frac{d_i^-}{d_i^- + d_i^+} \tag{5}$$

Step 6*: Rank the alternatives:*

The alternative with the greater CL is the best alternative to choose.

TOPSIS has been used in various forms for project selection (Dodangeh & Mojahed, 2009; Opricovic & Tzeng, 2004). Gao et al. (2008) used Fuzzy TOPSIS algorithm as an MCDM technique with an application in information systems project selection. The work developed a fuzzy technique based on TOPSIS to choose optimal information system in a fuzzy environment where the data are often incomplete. The importance weight of each criterion and the rating of each alternative were explained in linguistic terms and stated in triangular fuzzy numbers. Jafarian et al. (2014) proposed a framework for prioritizing and allocating six sigma projects by using fuzzy TOPSIS and fuzzy expert system. Karaveg et al. (2015) proposed an integrate technique using SEM and TOPSIS for the commercialization capability of R & D project evaluation. Mojahed and Dodangeh (2009) applied engineering economy techniques with group TOPSIS method for project selection management. Baysal et al. (2015) proposed a two phased fuzzy MCDM methodology for project selection in municipality. During the first phase, fuzzy TOPSIS method was implemented to choose the main project group and then fuzzy AHP was applied to choose the best sub-municipal project.

Chang (2013) integrated the ANP and (TOPSIS) to assist Taiwanese managers in century-old food industry firms to make better decisions for new product development (NPD) project selection. Teng et al. (2010) also proposed a systematic budget allocation for transportation construction projects for a case study in Taiwan using MCDM techniques.

Chang (2015) developed a hybrid MCDM model to choose program projects for nonprofit TV stations on the basis of managers' insights. By the concept of balanced scorecard (BSC) (Kaplan & Norton, 1996) and corporate social responsibility (CSR), they gather essential criteria for choosing the best program project. Fuzzy Delphi method was also implemented to modify criteria. Next, by considering the interdependence among the selection criteria, ANP was also implemented to find the weights of them. To prevent calculation and additional pairwise comparisons of ANP, TOPSIS was finally implemented to rank the alternatives. Dodangeh and Mojahed (2009) considered a real application of project selection for Telecommunication projects by gathering the opinions of experts using TOPSIS method. In their method, they used four types of criteria including qualitative, quantitative, negative and positive criteria for choosing the best one amongst five projects. Perçin and Kahraman (2010) applied a modified Delphi method, AHP and fuzzy TOPSIS (FTOPSIS) methodologies for Six Sigma project selection. In their survey, after the evaluation criteria of Six Sigma projects were completed by Delphi method, the weights of criteria were measured by using the AHP method. The FTOPSIS method was then implemented to reach the final ranking results.

2.4. VIKOR

VIKOR, standing for *Vlsekriterijumska Optimizacija I Kompromisno Resenje*, (Bakshi et al., 2011; Ahmad et al., 2015) method is an MCDM method, which was originally developed by Serafim Opricovic to solve decision problems with conflicting and non-commensurable criteria, assuming that compromise is acceptable for conflict resolution. VIKOR ranks alternatives and detects the solution named compromise which is the closest to the ideal.

VIKOR is used to optimize multi-criteria complex systems by focusing on ranking and choosing set alternatives for a problem with conflicting criteria. The compromise solution is a feasible solution closest to the ideal solution. *Compromise*, more specifically, is an agreement built by mutual consensus created between different alternatives. Assuming that each alternative is assessed by a criterion function the compromise ranking could be performed by comparing the measure of closeness to the ideal alternative. The value of *Lp, j* states the distance of each alternative from the best ideal solution. The extended VIKOR method applies the following form of L_P metric:

$$L_{p,j} = \left\{ \sum_{i=1}^{n} \left[W_i (f_i^* - f_{ij}) / (f_i^* - f_i^-) \right]^p \right\}^{1/p} \qquad 1 \leq p \leq \infty \;\; \text{j=1, 2, 3… J}$$

The compromise ranking algorithm of VIKOR involves the following steps:

a) Determine the best f_j^* and the worst f_j^- values of all criteria functions j=1, 2, 3… n

$f_j^* = \max_i f_{ij} \qquad f_j^- = \min_i f_{ij}$

b) Compute the values of S_i and R_i as follows,

$$S_i = \sum_{i=1}^{n} \frac{w(f_i^* - f_{ij})}{(f_i^- - f_{ij})}$$

$$R_i = \max_i \frac{w(f_i^* - f_{ij})}{(f_i^- - f_{ij})}$$

where Wi is the weight of criteria, expressing their relative importance.

c) Compute the values ofQ_i:

$$Q_i = \frac{v(S_i - S^*)}{S^- - S^*} + \frac{(1-v)(R_i - R^*)}{R^- - R^*} \quad (6)$$

where

$$S^* = \min_j S_j \quad , \quad S^- = \max_j S_j$$

$$R^* = \min_j R_j \quad , \quad R^- = \max_j R_j$$

Here *v* is introduced as the weight of the strategy of ‘‘the majority of criteria’’.

d) Rank different alternatives sorting by values of *S*, *R* and *Q* in non-increasing order, Propose as a compromise solution the alternative A(1), which is the best ranked by the measure Q(minimum), if the following two conditions hold:

a. Acceptable advantage. Q $((A^2))$ _ Q $((A^1))$ ≥DQ, where DQ =1.j-1 and A (2) is the alternative with second position in the ranking list by Q

b. Acceptable stability in decision-making. The alternative A (1) has to also be the best ranked by S or and R This compromise solution is stable within a decision-making process, which could be the strategy of maximum group utility (when v >0.5 is needed), or "by consensus" (v>0.5), or with veto (v <0.5). If one of the conditions is not satisfied, a set of compromise solutions has to be proposed as follows,

a. Alternative A(1) and A(2) if only condition b is not met, or
b. Alternatives A (1), A (2)... A (M) if the condition is not met. A (M) is determined by the relation Q $(A^M\text{-}A^1)$ < DQ for maximum M (the positions of these alternatives are "in closeness").

VIKOR method has been extensively used in different classifications of decision making problems (e.g. Mohanty, 1992). Thipparat and Thaseepetch (2013) presented an integrated VIKOR and fuzzy AHP method for assessing a sustainable research project. Ebrahimnejad et al. (2012) proposed a two-phase group decision making approach for construction project selection under a fuzzy environment. In their method, they integrated a modified ANP and an improved VIKOR. In addition, to consider uncertainty and risk, a decision making method was also considered with multiple fuzzy information by a group of experts, and a risk attitude for each expert is taken into consideration linguistically. Salehi (2015) used a hybrid of AHP and VIKOR method for project selection.

2.5. MOORA

The multi objective optimization on the basis of ratio analysis (MOORA) method considers both beneficial and non-beneficial criteria for ranking the alternatives from a set of existing options. The procedure of the MOORA method is described by Patel and Maniya (2015) as follows,

Step 1: Create the dimensionless decision matrix. The normalization of the decision matrix is performed by using Eq. 7:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \qquad i=1, 2, \ldots, m; \quad j=1, 2, \ldots, n \qquad (7)$$

where, r_{ij} is a dimensionless number in the [0, 1] interval representing the normalized performance of i^{th} alternative on j^{th} criteria.

Step 2: Determine the evaluation value of i^{th} alternative with in terms of all the criteria using Eq. (8) in which g is the number of criteria to be maximized, (n-g) is the number of criteria to be minimized, w_j is the compromised weight and y_i is the assessment value (Patel & Maniya, 2015).

$$y_i = \sum_{j=1}^{g} w_j r_{ij} - \sum_{j=g+1}^{n} w_j r_{ij} \qquad j=1, 2, \ldots, n \qquad (8)$$

The higher values of y_i mean that the rank is better.

MOORA has been used for project selection in different applications. Yazdani (2015) proposed intuitionistic fuzzy MOORA technique with triangular fuzzy numbers in a group decision making situation. He also used a case of project selection problem to validate the applicability of the method. Mohamed and Ahmed (2012) analyzed project selection by using SDV-MOORA approach.

2.6. Data envelopment analysis

Data envelopment analysis (DEA) is a method for measuring the relative efficiency of different units where there are more than one input/output. The method was originally developed by Charnes et al. (1978, 1994). There are some applications of DEA method for project selection (Yousefi & Hadi-Vencheh, 2016).

2.7. Gray Relational Analysis (GRA)

The Gray system theory was propsoed by Ju-long Deng (1982). A white system is described when the internal message, such as architecture, operation mechanism, system characteristics and parameters, are known, precisely. On the contrary, if one may not achieve any information and characteristics about the system, then it is considered as a black system. Gray space is thus a system described between the white and black systems (Lu et al., 2008). The gray system theory is used to handle obscure problems discrete data and incomplete data. This theory requires relatively less information with variability in the criteria and generates different and satisfactory output. Just like fuzzy theory, the gray theory is an effective mathematical model for handling uncertain problems (Deng, 1982).

There are literally several applications of GRA for project selection (Morán et al., 2006). Hou (2011) used GRA and TOPSIS method for information technology/information system selection. Zavadskas et al. (2010) considered the application of gray relations methodology for defining the utility of alternatives, and offered a multiple criteria method of Complex Proportional Assessment of alternatives with grey relations for analysis. In this model, the parameters of the alternatives were detected by the grey relational grade and stated in terms of intervals. They also presented a case study for the selection of construction project manager. Their results indicated that the method could be implemented as an effective decision aid in multi-criteria selection.

3. Conclusion

Project selection is considered as the first essential part of project portfolio management. Project selection is also considered as a process to evaluate each project idea and choose the one with the biggest priority. This paper has presented a brief survey on the applications of MCDM techniques for project selection. The survey has indicated that among many existing MCDM techniques, AHP, ANP and TOPSIS has been the most popular methods (See Fig. 2). In many cases, researchers have considered uncertainty in the form of fuzzy or interval data and proposed more sophisticated method for ranking projects (Abbasianjahromi & Rajaie, 2012; Daneshvar Rouyendegh & Erol, 2012; Hashemkhani Zolfani et al., 2015). We hope this survey could shed light into the applications of MCDM techniques for project selections.

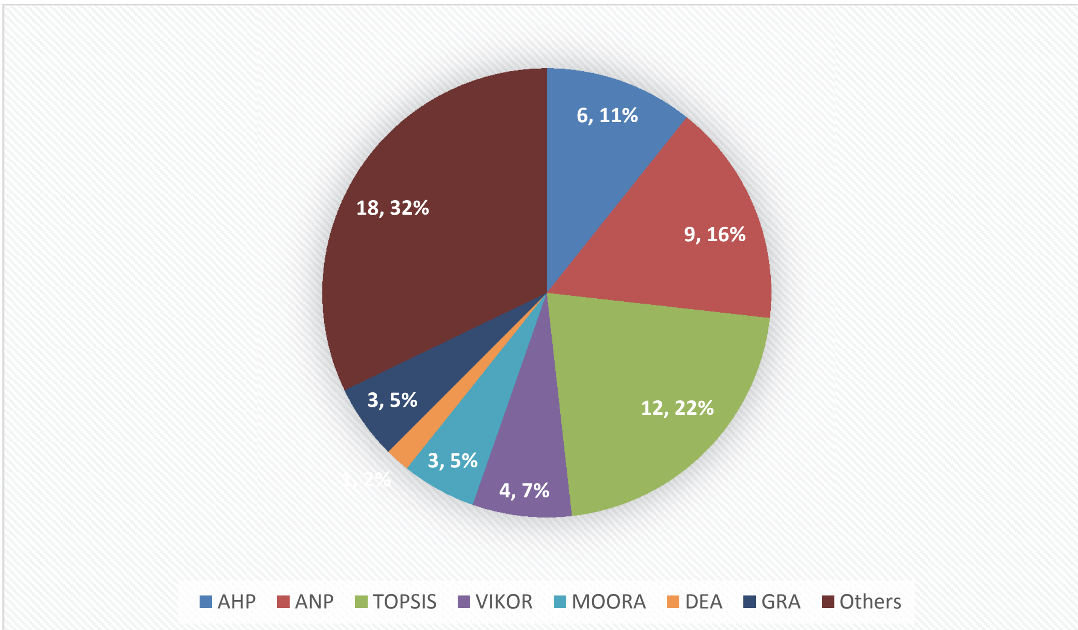

Fig. 2. Distribution of the MCMD applications for project selection

Acknowledgement

The authors would like to thank the anonymous referees for constructive comments on earlier version of this paper.

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