# SUPPLIER SELECTION IN REAL ESTATE INDUSTRY USING FUZZY AHP AND FUZZY TOPSIS: A CASE STUDY IN THAILAND

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## Introduction

Supplier selection is the process by which firms identify, evaluate, and contract with suppliers. The supplier selection process deploys a tremendous amount of a firm's financial resources. In return, firms expect significant benefits from contracting with suppliers offering high value. For this reason, the company will purchase the construction materials from the material suppliers they selected in order to ensure the building quality and cost control. The cost of the construction project could be broadly divided into three major groups, namely: materials, labor, and overhead. The materials can typically account for around 40% to 45% of the total cost in the construction industry. In addition, the labor cost in the construction industry is generally governed by the availability of workers within the proximity, only the construction materials can provide the greatest flexibility in seeking the lower cost for the construction companies. Therefore, an effective and efficient material supplier selection model which can help the company to select the "best" suppliers at the right cost, in the right quantity, with the right quality at the right time has a significant effect on the business success of real estate industry. The research on the supplier selection has a historical record. It is basically a multiple criteria decision making (MCDM) problem, which consists of three major stages: evaluation, prioritization, and selection of alternatives. This study aims to provide a user-friendly supplier selection model for real estate industry to select their best material suppliers effectively and efficiently. Supplier selection it is also possible to anticipate evaluation of the potential of suppliers to establish a collaborative relationship. Supplier selection is a decision process with the aim of reducing the initial set of potential supplier to the final choice, decision are based on evaluation of supplier on multiple quantitative as well as qualitative criteria.

## Literature

### Fuzzy set theory

Fuzzy set theory has been used for modelling decision-making processes based on imprecise and vague information such as the judgment of decision makers. Qualitative aspects are represented by means of linguistic variables, which are expressed qualitatively by linguistic terms and quantitatively by a Fuzzy set in the universe of discourse and respective membership function. Fuzzy set theory combined with multi-criteria decision making (MCDM) methods has been extensively used to deal with uncertainty in the supplier selection decision process, since it provides a suitable language to handle imprecise criteria, being able to integrate the analysis of qualitative and quantitative factors. The axiomatic bases of fuzzy set theory are manifold. We shall concentrate on the elements of the theory itself

Definition 1 If X is a collection of objects denoted generically by x, then a fuzzy set A in X is a set of ordered pairs:

$$A = (x, \boldsymbol{\mu_A} (x)|x \in X) \quad (1)$$

Definition 2 A type m fuzzy set is a fuzzy set whose membership values are type m − 1, m > 1, fuzzy sets on [0, 1].

Definition 3 A probabilistic set A to X is defined by defining function $\boldsymbol{\mu_A}$,

$\boldsymbol{\mu_A}$ : X × $\boldsymbol{\Omega}$ ∋(x, ω) →$\boldsymbol{\mu_A}$ (x, ω) ∈ $\boldsymbol{\Omega_C}$ (2)

and ($\boldsymbol{\Omega_C}, \boldsymbol{B_C}$) = [0, 1] are Borel sets.

Definition 4 A linguistic variable 2 is characterized by a quintuple (x,T(x),U,G, ˜M), in which x is the name of the variable, T(x) (or simply T) denotes the term set of x, that is, the set of names of linguistic values of x. Each of these values is a fuzzy variable, denoted generically by X and ranging over a universe of discourse $\boldsymbol{\mu}$, which is associated with the base variable u; G is a syntactic rule (which usually has the form of a grammar) for generating the name, X, of values of x. M is a semantic rule for associating with each X its meaning. M(X) is a fuzzy subset of U. A particular X, that is, a name generated by G, is called a term.

Definition 5 A fuzzy number M is a convex normalized fuzzy set M of the real line R such that

1. It exists exactly one $\mathbf{X_0}$ ∈ R $\boldsymbol{\mu_M}$ ($\mathbf{X_0}$) = 1 (x0 is called the mean value of M).

2. $\boldsymbol{\mu_M}$ (x) is piecewise continuous.

Definition 6 A fuzzy number ˜M is of LR-type if there exist reference functions L (for left) and R (for right), and scalars α > 0, β > 0, with

$\boldsymbol{\mu_M}$ (x) = L $\left(\frac{m-x}{\alpha}\right)$ for x ≤ m (3)

= R $\left(\frac{m-x}{\beta}\right)$ for x ≤ m = R (4)

Definition 7 The support of a fuzzy set A, S(A) is the crisp set of all x ∈ X such that $\boldsymbol{\mu_A}$ (x) > 0

The (crisp) set of elements that belong to the fuzzy set ˜A at least to the degree α is called the α-level set:

$\boldsymbol{A_\alpha}$ = {x ∈ X|$\boldsymbol{\mu_A}$≥ α} (5)

$\boldsymbol{A'_\alpha}$ = {x ∈ X|$\boldsymbol{\mu_A}$≥ α} is called strong α-level set or strong α-cut.

Definition 8 A fuzzy set ˜A is convex if

$\boldsymbol{\mu_A}$ (λ$\boldsymbol{x_1}$+ (1 − λ) $\boldsymbol{x_2}$) ≥ min {$\boldsymbol{\mu_A}$ ($\boldsymbol{x_1}$), $\boldsymbol{\mu_A}$ ($\boldsymbol{x_2}$)}, $\boldsymbol{x_1}$, $\boldsymbol{x_2}$ ∈ X, λ ∈ [0, 1]. (6)

Definition 9 For a finite fuzzy set A, the cardinality |A| is defined as

|A|= $\sum_{x\in X} \boldsymbol{\mu_A}$ (x) (7)

||A|| =$\frac{|A|}{|X|}$ is called the relative cardinality of A

**Triangular Fuzzy Numbers (TFN)**

Practices for the property developers, a supplier selection process involves indistinct needs and vague preferences such as reputation, relationship, etc. Such subjective, imprecise and uncertain information need to be translated into quantitative data for decision making. Fuzzy sets, which were first introduced by Zadeh, are one of the widely used methods to solve this kind of problem. It is specially designed to mathematically represent uncertainty and vagueness and provides formalized tools for dealing with the imprecise and intrinsic factors to many decision problems. In this study, one of the most widely used fuzzy set, i.e. triangular fuzzy set is employed to quantify the qualitative information. As a result, all the fuzzy variables are represented as Triangular Fuzzy Numbers A. The reason of using TFN method is because of its intuitive, easy to use, computational simplicity, useful in promoting representation and information processing in a fuzzy environment. According to Lam et al.

**Fuzzy TOPSIS**

This research is the case of Fuzzy AHP (Fuzzy Analytic Hierarchy Process), Fuzzy TOPSIS (Fuzzy Technique for Order Preference by Similarity to Ideal Solution). The Fuzzy TOPSIS method was proposed by Chen to solve multiple criteria decision-making problems under uncertainty. Linguistic variables are used by the decision makers. Define the ranking of the alternatives according to the closeness coefficient, CCi, in decreasing order. The best alternative is closest to the FPIS and farthest to the FNIS. Evaluations of the weight of the criteria and the ratings of the alternatives were made by the decision makers, according to the linguistic terms. Based on Chen, triangular fuzzy numbers (TFN) were used to specify the linguistic values of these variables.

In this study, all the qualitative information, i.e. the importance weights of decision makers and the ratings assigning to the candidates by of decision makers in accordance with the subjective criteria should be firstly decided. For the weighting, the five-point-scale can be defined as: Of little importance (VL), Moderately important (MI), Important (I), Very important (VI), Absolutely important (AI). For the rating, the five-point-scale can be defined as: Very Low (VL), Low (L), Medium (MI), High (H), and Excellent (EX), as presented in Table 1 and Table 2.

| **Linguistic terms** | **Fuzzy triangular number** |
|---|---|
| Of little importance (VL) | (0.0, 0.0, 0.25) |
| Moderately important (MI) | (0.0, 0.25, 0.50) |
| Important (I) | (0.25, 0.50, 0.75) |
| Very important (VI) | (0.50, 0.75, 1.0) |
| Absolutely important (AI) | (0.75, 1.0, 1.0) |

Table 1: Linguistic scale to evaluate the weight of the criteria.

| **Linguistic terms** | **Fuzzy triangular number** |
|---|---|
| Very low (VL) | (0.0, 0.0, 2.5) |
| Low (L) | (0.0, 2.5, 5.0) |
| Good (G) | (2.5, 5.0, 7.5) |
| High (H) | (5.0, 7.5, 10.0) |
| Excellent (EX) | (7.5, 10.0, 10.0) |

Table 2: Linguistic scale to evaluate the ratings of the alternative suppliers.

Linguistic judgments of the weights of the criteria and the ratings of the alternatives for the three decision makers involved in the selection process. The linguistic variables are converted into TFN. The parameters of the TFN resulting from the aggregation of the judgments, which represents the fuzzy decision matrix. Linguistic ratings of the alternative suppliers by different decision makers.

According to Chen, the Fuzzy Positive Ideal Solution (FPIS, A+) and the Fuzzy Negative Ideal Solution (FNIS, A−) were defined as

$$A+=\{\boldsymbol{v}_1^+ +,\boldsymbol{v}_j^+,\ldots,\boldsymbol{v}_m^+\} \quad (8)$$

$$A-=\{\boldsymbol{v}_1^- +,\boldsymbol{v}_j^-,\ldots,\boldsymbol{v}_m^-\} \quad (9)$$

where $\boldsymbol{v}_j^+=(1,1,1)$ and $\boldsymbol{v}_j^-=(0,0,0)$ .

The distances source of the ratings of each alternative from A+ and A–, calculated according to

$$d_i^+ = \sum_{j=1}^{n} d_v(v_{ij}, v_j^+) \quad (10)$$

$$d_i^- = \sum_{j=1}^{n} d_v(v_{ij}, v_j^-) \quad (11)$$

where d(.,.) represents the distance between two fuzzy numbers according to the vertex method. For triangular fuzzy numbers

Compute the closeness coefficient, $CC_i$, according to Eq. (12).

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-} \quad (12)$$

**Fuzzy AHP**

Chang 1996 proposed a Fuzzy AHP approach based on the extent analysis method, which is widely used in supplier selection problems. This method uses linguistic variables to express the comparative judgments given by decision makers. In the method proposed by Chang, each object, xi, is taken and extensive analysis is performed for each goal. Thus, extent analysis values for each object can be obtained. Compute the value of the fuzzy synthetic extent with respect to the i object according to

$$S_i = \sum_{j=1}^{m} M_{gi}^i \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^i\right]^{-1} \quad (13)$$

Compute the vector W′, which is given by

$$W' = (d'(A_1), d'(A_2), \ldots, d'(A_k))^T \quad (14)$$

assuming that

$$d'(A_I), = \min V(S_i \geq S_j), \quad \text{for } i=1,2,..,k,\ j=1,2,\ldots,k,\ k \neq j \quad (15)$$

The normalized vector is indicated by

$$W = (d'(A_1), d'(A_2), \ldots, d'(A_k))^T \quad (16)$$

where W is a non-fuzzy number calculated for each comparison matrix.

The linguistic terms presented were used by the decision makers to comparatively evaluate the weight of the criteria and the ratings of the alternatives. Following Chang, TFN were used to specify the linguistic values of these variables, as presented in Table 3**.**

| Linguistic terms | Fuzzy triangular number |
|---|---|
| Equally preferable (EQ) | (1.0, 1.0, 3.0) |
| Slightly preferable (SP) | (1.0, 3.0, 5.0) |
| Fairly preferable (FP) | (3.0, 5.0, 7.0) |
| Extremely preferable (XP) | (5.0, 7.0, 9.0) |
| Absolutely preferable (AP) | (7.0, 9.0, 9.0) |

Table 3: Comparative linguistic scale for ratings of alternatives and weights of criteria.

Comparative judgments of the weights of the criteria made by the three decision makers involved already converting into TFN. The results of aggregation of these fuzzy values are presented in and were obtained by the arithmetic mean of the judgments. Likewise, the fuzzy values of the aggregated comparative judgments of the alternative suppliers for each criterion made by the three decision makers.

**Case Study**

This real estate company has 9 important tasks and 41 main materials. We have group materials for 8 groups based on the material type and same supplier include Piling work process, Pile

Steel, Steel Grating, roof structure, roof material, Cement, Tiles, and Sanitary ware. In this research, we are interested in Piling work process material. In (Weber et al. 1991) the authors present a classification of all the critical published since 1996 a cording to the treated criteria, based on 74 papers, they observe that price, delivery, Quality and Production capacity and Location are the criteria most often treated in the literature. The quality of the selection model's final outcome has largely relied on the criteria it used and the weighting it assigned. Such steps are significant to ensure the selected criteria are critical to the real estate industry. Traditional qualitative measures of performance, such as quality, delivery time or cost, another measure of subjective evaluation. There are several criteria that must be considered in the selection process, both quantitative and qualitative lists some important criteria for supplier selection based on 30 papers, as presented in Table 4. And three expert interviews are a compliment prior to a quantity. The aim of these structured interviews is the viewpoint collector of several criteria, as presented in Table 5.

| No. | Criteria | Frequency |
|---|---|---|
| 1 | Price / Material costs | 19 |
| 2 | Delivery / Lead time | 16 |
| 3 | Quality control and standards | 16 |
| 4 | Production Capacity | 9 |
| 5 | IT Software communication sophistication | 9 |
| 6 | Supplier's financial strength | 8 |
| 7 | Performance history | 8 |
| 8 | Communication openness | 6 |
| 9 | Problem solving | 6 |
| 10 | Flexibility | 6 |
| 11 | After Sales Support | 6 |
| 12 | Management and organizational framework | 5 |
| 13 | Reliability | 5 |
| 14 | Price Stability | 5 |
| 15 | Cooperation & Communication | 4 |
| 16 | Technical assistance & Support | 4 |
| 17 | Payment terms | 4 |

Table 4: Importance criteria for supplier selection from literature review.

| No. | Criteria |
|---|---|
| 1 | Price of the material |
| 2 | Quality of the material |
| 3 | Delivery of the material |
| 4 | Performance History |

Table 5: Importance criteria from expert.

The fundamental criteria, which are the basic requirements imposed on the material are defined. In accordance with the literature sources, the price, delivery, quality, and services were the four main categories which were widely and traditionally used as the fundamental criteria in appraising the performance of suppliers. Define the specific selection criteria for the real estate industry. According to the literature sources, some of the specific criteria for the construction industry are summarized, the cost, delivery, and quality which was defined as the fundamental criteria above are also widely used in the construction material supplier selection process According to Ka-Chi Lame et al. Some of the specific criteria for the construction industry were determined as follows: cost; deliver; quality; payment terms; past performance; reliability; flexibility; and technical characteristics.

We used the above criteria as starting point and literature criteria were further decomposed to sub-criteria to formulate a model able to supplier selection, as presented in Figure 1. Based on the determined selection criteria, the candidate suppliers' performance data (both quantitative and qualitative) are collected. For the quantitative data, e.g. unit price, freight terms, scrap rate, and production volume can be collected from the tender documents or suppliers' information directly. On the contrary, the qualitative data, e.g. reputation, flexibility, relationship, etc. is generated by the subjective judgments given by the Decision-maker

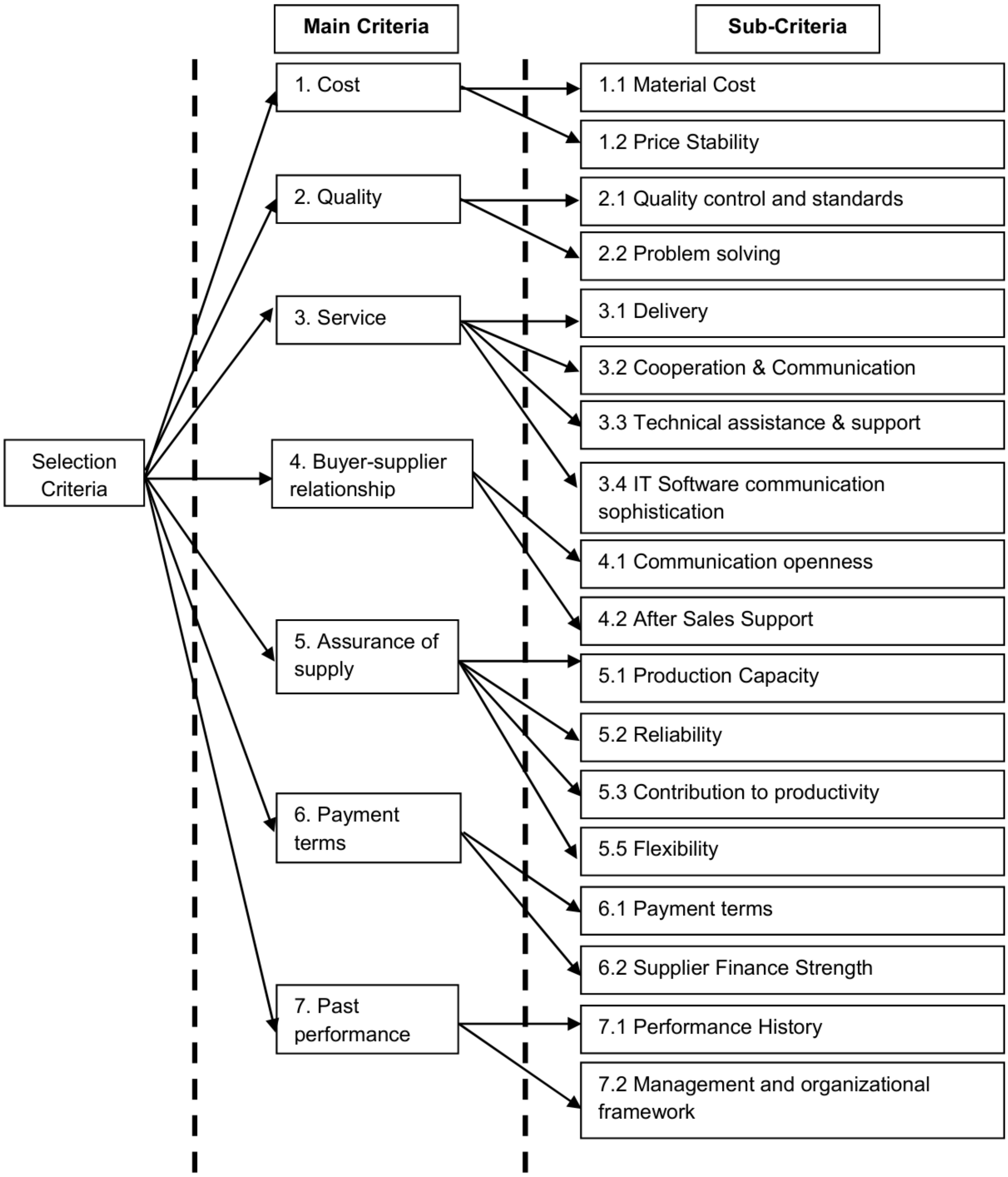


Figure 1: The selection criteria system for the proposed model

## Comparative analysis of Fuzzy TOPSIS and Fuzzy AHP methods

The global performance of each supplier alternative to the Fuzzy TOPSIS method is given by the closeness coefficient, $CC_i$, calculated as in Eq.(12) and presented in Table 6. Finally, this calculation led to the outranking presented in Table 6, meaning that supplier A2 is the best alternative. And the global performance of the other alternative suppliers was computed similarly. Table 6 presents the global performance for all the alternatives and their ranking position in Fuzzy AHP. Therefore, following this procedure, similarly to the application of Fuzzy TOPSIS, supplier A2 is the best evaluated alternative.

| **Fuzzy TOPSIS** | | | **Fuzzy AHP** | | |
|---|---|---|---|---|---|
| Suppliers | CCi | Rank | Suppliers | Global performance | Rank |
| A1 | 0.42 | 3th | A1 | 0.81 | 3th |
| A2 | 0.68 | 1st | A2 | 1.00 | 1st |
| A3 | 0.52 | 2nd | A3 | 0.87 | 2nd |

Table 6: Comparative analysis of Fuzzy TOPSIS and Fuzzy AHP methods

## Conclusion

In the case of Fuzzy AHP method, the use of pairwise comparisons by means of comparative linguistic variables is itself a way to deal with imprecision. This feature makes this method more appropriate than the Fuzzy TOPSIS when the purpose is to replace a supplier. Other advantages of the Fuzzy AHP compared to Fuzzy TOPSIS in this example are fewer judgments and less computational complexity. This paper presented a new study comparing the Fuzzy AHP and the Fuzzy TOPSIS methods in regard to 7 main criteria and 17 sub-criteria that are particularly relevant to the problem of supplier selection. The comparative analysis of Fuzzy AHP and Fuzzy TOPSIS has shown some interesting outcomes that one should take into account so as to better align the technique to the particularities of the problem at hand. The obtained results concerning the analysis of the seven factors are valid for the context of supplier selection.

Concerning the agility in the decision process, Fuzzy TOPSIS performs better than Fuzzy AHP in most cases except when there are very few criteria and suppliers. In addition, the increase in the number of supplier alternatives imposes some limitation to Fuzzy AHP. As for the Fuzzy TOPSIS, this is not a restriction to the use of the method. In the case of the number of criteria, the intrinsic limitation imposed by the Fuzzy AHP method can be overcome by deploying the criteria into the Fuzzy AHP hierarchy structure. At the same time that the Fuzzy TOPSIS does not constrain the number of criteria, it does not allow the deployment of the criteria into sub criteria, which can be understood as a weakness of the method when applied to the problem of supplier selection. A further study could focus on the adaptation of the Fuzzy TOPSIS so as to accommodate the criteria and sub criteria into the decision matrix.

Both methods adequately support group decision making. It is worth to mention that weighted mean could be used to aggregate judgments instead of the arithmetic mean commonly used. By doing that, one could give different importance to different decision makers. Although both methods are equally adequate to deal with the lack of precision of scores of alternatives as well as the relative importance of different criteria, it is worth noting that the Fuzzy AHP is more appropriate than the Fuzzy TOPSIS when the purpose is to replace a supplier.

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