A Combined AHP-QFD-TOPSIS Approach for Supplier Selection

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ABSTRACT

The main purpose of the supply chain system is to make profit and meet customers' expectations simultaneously. All members in the supply chain play an active role in achieving this purpose. Supplier is the first and crucial step in the supply chain and so supplier selection is an important strategic decision for reducing costs, improving competitiveness and increasing customer satisfaction. Selected suppliers should take the "voice" of customers into account by providing the company's requests. In this context, Quality-function deployment (QFD) ensures that customer needs influence supplier evaluation index. Therefore, an integrated Analytic hierarchy process (AHP)-QFD-Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methodology is presented for supplier selection problem in this study. First, AHP is used to determine priority ratings of supplier's customer (stakeholder) requirements. Next, QFD is used to establish a relationship matrix in order to identify degree of relationship between customer requirements and supplier selection criteria and calculate the importance weights of evaluating criteria. Finally, TOPSIS is used to rank alternative suppliers for optimal selection.

INTRODUCTION

Recently, the awareness of the vital role played by purchasing has increased in order to ensure that a company to be competitive. The most important task of purchasing is the selection of an innovative supplier with high quality, low cost and deliver on time qualifications [1]. Finding the best supplier is a critical factor for the welfare of every company. This decision significantly affects the overall performance of an organization. In competitive markets, customer satisfaction is a vital corporate goal as well as the selection of appropriate suppliers. Customer satisfaction is highly dependent on the quality of the final products and services. The quality of products is greatly affected by the quality of the raw materials or services supplied [2], [3].

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In today's business world, having a customer-focused perspective instead of a product-focused perspective has become a necessity for companies to compete and even survive. The fact that customer has many alternative choices in the business world with intense competition and the necessity to respond quickly and fully to the changing demands and requirements of the customers directs the companies to develop customer-focused strategies in order to gain new customers and keep their existing customers. In fact, there are two separate customer definitions; internal customer (employees working in the organization and using the output of a previous process in their own process) and external customer (final consumer receiving product or service). Any stable supplier evaluation system should also take into account the environment of the entire supply chain particularly customer needs. In this case, a means to link customer and stakeholder attitudes to relevant supplier criteria is necessary. This means is called QFD and it helps ensure that the customer voice - the specific needs and desires of a particular customer segment - is clearly heard and monitored in the development and distribution of a product [4], [5]. In this study, QFD will be used to define the wishes of firm as an internal customer and to determine how the supplier will meet these requirements.

Changing customer preferences require a wider and faster supplier selection. In such cases decision-making plays an important role. In an optimal supplier selection process, many factors such as price, quality, delivery, production plan, facilities and other specific sub-factors need to be considered, which is similar to multi-criteria decision-making (MCDM) problem. Modern operations research offers a range of methods and techniques that can support the increasing complexity and importance of supplier selection decisions and multi-criteria decision-making approach has proven to be better than considering only a single approach [2], [5], [6].

The rest of the paper is organized as follows: The following section presents the literature review on supplier selection with OFD approach. Section 3 provides the problem definition and the main steps of the solution procedure with results. Finally, conclusions of the study with suggestions for future work are presented in Section 4.

**Supplier Selection Methodologies**

Bevilacqua [7] suggested fuzzy QFD method for supplier selection process of an industry that manufactures complete clutch couplings. Ni et al. [8] develop a supplier selection methodology based on extended QFD and data-mining (DM) techniques and verified the feasibility and efficiency of their method in an automobile manufacturing enterprise. Kumaraswamy et al. [9] proposed a methodology based QFD, AHP and TOPSIS for the purpose of the decision-making for supplier selection in SMEs.

Ho et al. [10], Rajesh and Malliga [2] and Jain and Singh [11] presented a strategic supplier selection based on integrated approach of AHP and QFD. Dursun and Karsak [12] developed a fuzzy multi-criteria group decision making approach that used QFD concept for supplier selection process. They computed bounds of the weights of criteria and ratings of suppliers by using the fuzzy weighted average (FWA) method. Tidwell and Sutterfield [1] presented a structured management approach- QFD methodology- to analyze the common purchasing problem of supplier selection for toothpaste packaging. Alinezad et al. [6] developed an integrated multiple criteria fuzzy decision-making approach (QFD and fuzzy AHP) to measure the performance of alternative supplier for a pharmaceutical company.
Yazdani et al. [5] proposed an integrated model of supplier selection problem considered customer attitudes using Step-Wise Weight Assessment Ratio Analysis (SWARA), QFD and Weighted Aggregated Sum Product Assessment (WASPAS). Asadabadi [3] proposed an innovative customer based approach integrating ANP, QFD, and a Markov chain to discuss the supplier selection problem. Pramanik et al. [13] designed a fuzzy-multi-criterion group decision making approach, AHP-QFD-TOPSIS, to develop a flexible supplier selection process. Yazdani et al. [14] presented an integrated approach, Decision Making Trial and Evaluation Laboratory (DEMATEL)-QFD-Complex Proportional Assessment (COPRAS), for green supplier selection and used proposed methodology in a case study to reveal its applicability. Azadnia et al. [15] presented a model of supplier selection and order allocation based on the sustainability Triple Bottom Line approach based FAHP-QFD. They used a fuzzy multi-objective mix integer non-linear programming model for allocating orders to suppliers in a real-world application of food industry. Babbar and Amin [16] proposed two phases approach namely a two-stage fuzzy QFD and a stochastic multi-objective mathematical model, for supplier selection and order allocation in the beverages industry.

PROBLEM DEFINITION

The supplier selection problem is a difficult decision-making problem that requires a large number of criteria to be taken into consideration. The solution of the problem correctly with this structure is made possible by the use of scientific methods in the decision process. Problem is related to the decision of supplier selection for a company that manufactures a single type of product. This company has 10 potential suppliers to supply the materials required for production. The company is determined to employ a systematic method to find the favorable one-two suppliers based on customer desires. The data used for proposed supplier selection method were collected by the customers, suppliers, stakeholders and management of the company.

The proposed supplier selection procedure is described in the following steps [1], [2], [7], [10], [11], [12]:

**Steps 1:** Identifying the WHATS, customer (stakeholder) requirements; Fair price, serviceability, punctuality, reliability, durability, corporation and flexibility and environment friendly are the characteristics determined by the company for the suppliers.

**Steps 2:** Identifying HOW, the supplier selection criteria relevant to supplier assessment; Unit purchase price, Quality management system certification, Flexibility of response to the customer's requests, Percentage of late delivered products, Percentage of defected products, Green design, green packaging, Reuse and recycle rate.

**Step 3:** Determining weights of WHATs, priority ratings of supplier’s customer (stakeholder) requirements, using AHP; Pair-wise comparison matrix is generated in Table I.
Table 1. The pair wise comparisons among the WHATs.

|          | Fair Price | Serviceability | Punctuality | Reliability | Durability | Corporation and Flexibility | Environment friendly |
|----------|------------|----------------|-------------|-------------|------------|-----------------------------|---------------------|
| Fair Price | 1.00       | 3.00           | 2.00        | 5.00        | 2.00       | 3.00                        | 5.00                |
| Serviceability | 0.33       | 1.00           | 1.00        | 2.00        | 0.50       | 1.00                        | 2.00                |
| Punctuality  | 0.50       | 1.00           | 1.00        | 2.00        | 0.50       | 2.00                        | 3.00                |
| Reliability  | 0.20       | 0.50           | 0.50        | 1.00        | 0.33       | 0.50                        | 1.00                |
| Durability   | 0.50       | 2.00           | 2.00        | 3.00        | 1.00       | 3.00                        | 2.00                |
| Corporation and Flexibility | 0.33       | 1.00           | 0.50        | 2.00        | 0.50       | 1.00                        | 1.00                |
| Environment friendly | 0.20   | 0.50           | 0.33        | 1.00        | 0.50       | 1.00                        | 1.00                |

Table 2. The normalized matrix for the WHATs.

|          | Fair Price | Serviceability | Punctuality | Reliability | Durability | Corporation and Flexibility | Environment friendly |
|----------|------------|----------------|-------------|-------------|------------|-----------------------------|---------------------|
| Fair Price | 0.33       | 0.33           | 0.27        | 0.31        | 0.39       | 0.26                        | 0.33                |
| Serviceability | 0.11       | 0.11           | 0.14        | 0.13        | 0.10       | 0.09                        | 0.13                |
| Punctuality  | 0.16       | 0.16           | 0.14        | 0.13        | 0.10       | 0.17                        | 0.20                |
| Reliability  | 0.07       | 0.07           | 0.07        | 0.06        | 0.06       | 0.04                        | 0.07                |
| Durability   | 0.16       | 0.22           | 0.27        | 0.19        | 0.19       | 0.26                        | 0.13                |
| Corporation and Flexibility | 0.11       | 0.11           | 0.07        | 0.13        | 0.06       | 0.09                        | 0.07                |
| Environment friendly | 0.07   | 0.06           | 0.05        | 0.06        | 0.10       | 0.09                        | 0.07                |

After AHP analysis for determining weights of WHATs, it is observed that the weights of Fair price: 0.32, serviceability: 0.11, punctuality: 0.14, reliability: 0.06, durability: 0.20, corporation and flexibility: 0.09 and environment friendly: 0.07.

\( n_{\text{max}} = 7.15 \), Consistency index (CI) = 2.51\%, Consistency Ratio (CR) = 1.77\%. The consistency ratio is less than 10\% so within limits.

**Step 4:** Determining the WHAT–HOW relationship scores and constructing the House of Quality (HOQ). HOQ is a matrix of QFD providing products to be designed to reflect the customers' wishes [17]. We will consider it House of Supply Chain Management (HSCM) for our study.; A relationship matrix is established using the variable Strong (9), Medium (3) and Weak (1) the impact of each HOW on each WHAT is recorded in order to identify degree of relationship between customer requirements and supplier selection criteria.

Table 3. Relationship matrix.

|          | Weight | Unit | purchase price | Quality management system certification | Flexibility of response to customer's request | Percentage of late delivered products | Percentage of defected products | Green design | Green packaging | Reuse and recycle rate |
|----------|--------|------|----------------|------------------------------------------|-----------------------------------------------|--------------------------------------|-------------------------------|----------------|------------------|----------------------|
| Fair Price | 0.32   | 9    | 3              | 3                                        | 3                                             | 3                                   | 3                             | 1              |                 |                      |
| Serviceability | 0.11   | 1    | 3              | 9                                        | 9                                             | 9                                   | 1                             | 1              |                 |                      |
| Punctuality  | 0.14   | 1    | 3              | 9                                        | 3                                             | 3                                   | 9                             | 1              | 1                | 3                    |
| Reliability  | 0.06   | 1    | 3              | 1                                        | 3                                             | 3                                   | 9                             | 1              | 1                | 3                    |
| Durability   | 0.20   | 1    | 9              | 3                                        | 9                                             | 9                                   | 1                             | 1              | 1                | 3                    |
| Corporation and Flexibility | 0.09   | 1    | 9              | 1                                        | 3                                             | 3                                   | 9                             | 9              | 9                | 9                    |
| Environment friendly | 0.07   | 1    | 1              | 1                                        | 3                                             | 9                                   | 9                             | 9              | 9                | 9                    |
**Step 5**: Determining the weight of the HOWs; The importance weights of the HOWs (evaluating criteria) are calculated from the House of Quality using customer importance ratings and score of relationship matrix.

![Figure 1. The House of Quality (House of Supply Chain Management).](image)

| What                         | Weight | Unit purchase price | Quality management system certification | Flexibility of response to the customer's requests | Percentage of late delivered products | Percentage of defected products | Green design | Green packaging | Reuse and recycle rate |
|------------------------------|--------|---------------------|-----------------------------------------|-----------------------------------------------------|--------------------------------------|---------------------------------|--------------|----------------|------------------------|
| Fair Price                   | 0.32   | 9                   | 3                                       | 1                                                   | 3                                    | 3                               | 1            | 1              | 1                      |
| Serviceability               | 0.11   | 1                   | 3                                       | 9                                                   | 9                                    | 1                               | 1            | 1              | 1                      |
| Punctuality                  | 0.14   | 1                   | 3                                       | 9                                                   | 1                                    | 1                               | 1            | 1              | 1                      |
| Reliability                  | 0.06   | 3                   | 9                                       | 1                                                   | 1                                    | 1                               | 1            | 1              | 1                      |
| Durability                   | 0.20   | 9                   | 1                                       | 3                                                   | 3                                    | 3                               | 3            | 3              | 3                      |
| Corporation and Flexibility  | 0.09   | 1                   | 9                                       | 1                                                   | 1                                    | 1                               | 1            | 1              | 1                      |
| Environment friendly         | 0.07   | 1                   | 1                                       | 9                                                   | 9                                    | 9                               | 9            | 9              | 9                      |
| **Total**                    | 3.07   | 3.39                | 2.65                                    | 3.62                                                | 3.3                                  | 1.00                            | 0.88         | 1.55           |                        |

| Relative Weight of Criteria  | 0.158  | 0.174               | 0.136                                   | 0.186                                               | 0.170                                | 0.052                           | 0.045        | 0.080          |                        |

From the scores it is revealed that Percentage of late delivered products is the major criteria followed by Quality management system certification.
Step 6: Preparing the matrix for correlating the HOWs with alternative suppliers: All suppliers are compared on every criteria.

Table 5. Evaluation of suppliers for each criteria.

| Supplier | Unit purchase price | Quality management system certification | Flexibility to the customer’s requests | Percentage of late delivered products | Percentage of defected products | Green design | Green packaging | Reuse and recycle rate |
|----------|---------------------|-----------------------------------------|----------------------------------------|---------------------------------------|-------------------------------|--------------|-----------------|-----------------------|
| Supplier 1 | 3                   | 5                                       | 7                                      | 7                                     | 6                             | 10           | 8               | 5                     |
| Supplier 2 | 9                   | 6                                       | 4                                      | 5                                     | 4                             | 6            | 3               | 2                     |
| Supplier 3 | 5                   | 7                                       | 8                                      | 7                                     | 7                             | 4            | 5               | 5                     |
| Supplier 4 | 8                   | 4                                       | 7                                      | 6                                     | 5                             | 3            | 5               | 2                     |
| Supplier 5 | 10                  | 5                                       | 1                                      | 3                                     | 4                             | 1            | 2               | 3                     |
| Supplier 6 | 1                   | 10                                      | 10                                     | 8                                     | 7                             | 8            | 1               | 2                     |
| Supplier 7 | 4                   | 9                                       | 8                                      | 6                                     | 7                             | 5            | 7               | 5                     |
| Supplier 8 | 7                   | 6                                       | 8                                      | 4                                     | 5                             | 3            | 1               | 2                     |
| Supplier 9 | 2                   | 8                                       | 6                                      | 7                                     | 6                             | 10           | 9               | 10                    |
| Supplier 10 | 6                   | 6                                       | 8                                      | 5                                     | 5                             | 3            | 5               | 2                     |
| **Weights of Criteria** | |                          |                       |                          |                          |              |         |                |
|           | **0.158**           | **0.174**                           | **0.136**                            | **0.186**                           | **0.170**                        | **0.052**             | **0.045**                   | **0.080**                |

Table 6. Normalized decision matrix.

| Supplier | Unit purchase price | Quality management system certification | Flexibility to the customer’s requests | Percentage of late delivered products | Percentage of defected products | Green design | Green packaging | Reuse and recycle rate |
|----------|---------------------|-----------------------------------------|----------------------------------------|---------------------------------------|-------------------------------|--------------|-----------------|-----------------------|
| Supplier 1 | 0.15                | 0.23                                    | 0.31                                   | 0.37                                  | 0.33                          | 0.53         | 0.43            | 0.27                  |
| Supplier 2 | 0.46                | 0.28                                    | 0.18                                   | 0.26                                  | 0.22                          | 0.32         | 0.16            | 0.11                  |
| Supplier 3 | 0.25                | 0.32                                    | 0.36                                   | 0.37                                  | 0.39                          | 0.21         | 0.27            | 0.27                  |
| Supplier 4 | 0.41                | 0.18                                    | 0.31                                   | 0.32                                  | 0.28                          | 0.16         | 0.27            | 0.11                  |
| Supplier 5 | 0.51                | 0.23                                    | 0.04                                   | 0.16                                  | 0.22                          | 0.05         | 0.11            | 0.16                  |
| Supplier 6 | 0.05                | 0.46                                    | 0.44                                   | 0.42                                  | 0.39                          | 0.37         | 0.43            | 0.32                  |
| Supplier 7 | 0.20                | 0.42                                    | 0.36                                   | 0.32                                  | 0.39                          | 0.27         | 0.38            | 0.27                  |
| Supplier 8 | 0.36                | 0.28                                    | 0.36                                   | 0.21                                  | 0.28                          | 0.16         | 0.05            | 0.11                  |
| Supplier 9 | 0.10                | 0.37                                    | 0.27                                   | 0.37                                  | 0.33                          | 0.53         | 0.48            | 0.54                  |
| Supplier 10 | 0.31                | 0.28                                    | 0.36                                   | 0.26                                  | 0.28                          | 0.16         | 0.27            | 0.11                  |

Table 7. Weighted normalized decision matrix.

| Supplier | Unit purchase price | Quality management system certification | Flexibility to the customer’s requests | Percentage of late delivered products | Percentage of defected products | Green design | Green packaging | Reuse and recycle rate |
|----------|---------------------|-----------------------------------------|----------------------------------------|---------------------------------------|-------------------------------|--------------|-----------------|-----------------------|
| Supplier 1 | 0.02                | 0.04                                    | 0.04                                   | 0.07                                  | 0.06                          | 0.03         | 0.02            | 0.02                  |
| Supplier 2 | 0.07                | 0.05                                    | 0.02                                   | 0.05                                  | 0.04                          | 0.02         | 0.01            | 0.01                  |
| Supplier 3 | 0.04                | 0.06                                    | 0.05                                   | 0.07                                  | 0.07                          | 0.01         | 0.01            | 0.02                  |
| Supplier 4 | 0.06                | 0.03                                    | 0.04                                   | 0.06                                  | 0.05                          | 0.01         | 0.01            | 0.01                  |
| Supplier 5 | 0.08                | 0.04                                    | 0.01                                   | 0.03                                  | 0.04                          | 0.00         | 0.00            | 0.01                  |
| Supplier 6 | 0.01                | 0.08                                    | 0.06                                   | 0.08                                  | 0.07                          | 0.02         | 0.02            | 0.03                  |
| Supplier 7 | 0.03                | 0.07                                    | 0.05                                   | 0.06                                  | 0.07                          | 0.01         | 0.02            | 0.02                  |
| Supplier 8 | 0.06                | 0.05                                    | 0.05                                   | 0.04                                  | 0.05                          | 0.01         | 0.00            | 0.01                  |
| Supplier 9 | 0.02                | 0.06                                    | 0.04                                   | 0.07                                  | 0.06                          | 0.03         | 0.02            | 0.04                  |
| Supplier 10 | 0.05                | 0.05                                    | 0.05                                   | 0.05                                  | 0.05                          | 0.01         | 0.01            | 0.01                  |
Step 7: Determining each potential supplier’s weights; Alternative suppliers are ranked using TOPSIS for optimal selection.

| Supplier   | Si⁺ | Si⁻ | Ci   | Weights | Ranks |
|------------|-----|-----|------|---------|-------|
| Supplier 1 | 0.07| 0.07| 0.478| 0.091   | 9     |
| Supplier 2 | 0.07| 0.07| 0.523| 0.100   | 5     |
| Supplier 3 | 0.05| 0.08| 0.592| 0.113   | 1     |
| Supplier 4 | 0.06| 0.07| 0.537| 0.103   | 4     |
| Supplier 5 | 0.09| 0.07| 0.438| 0.084   | 10    |
| Supplier 6 | 0.07| 0.10| 0.567| 0.108   | 3     |
| Supplier 7 | 0.06| 0.08| 0.580| 0.111   | 2     |
| Supplier 8 | 0.07| 0.07| 0.505| 0.097   | 7     |
| Supplier 9 | 0.07| 0.07| 0.494| 0.094   | 8     |
| Supplier 10| 0.06| 0.07| 0.511| 0.098   | 6     |

The ranking of the suppliers in the order are S₃, S₇, S₆, S₄, S₂, S₁₀, S₈, S₉, S₁ and S₅.

Result

The result of the proposed method, we can say that the company should work with Supplier 3 and/or Supplier 7.

Full compliance with suppliers may not always be achieved when selecting suppliers. In such cases, the nearest suppliers to the ideal supplier can be selected and if possible, the suppliers can be developed later. In other words, if the Supplier 3 and/or Supplier 7 is still not enough for the company, it is possible to develop the Supplier 3 and/or Supplier 7 according to the implications obtained with the QFD methodology for this study.

CONCLUSIONS

This paper presents an integrated hybrid AHP-TOPSIS based QFD methodology to evaluate suppliers. At the first step, AHP is used to determine priority ratings of supplier’s customer (stakeholder) requirements. Next, HOQ that one of the tools of QFD is transformed into HSCM to establish a relationship matrix in order to identify degree of relationship between customer requirements and supplier selection criteria. Then, the importance weights of evaluating criteria are calculated using customer importance ratings and weights of relationship matrix. Finally, based on the weights of criteria, alternative suppliers are ranked by TOPSIS for optimal selection.

For future research the problem could be dealing with multiple products and multiple relationships of the supply chain, such as manufacturer-retailer or manufacturer-third-party logistics provider. Moreover, other ranking methods can also be considered to obtain priority weights of customer requirements and rank of suppliers and compared in terms of suitability. Additionally, In the next stage the obtained weights can be integrated mathematical models for optimizing various purposes.
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