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A novel hybrid approach based on QFD-TOPSIS method for supplier selection in IT Area (Case Study: A Private Bank in Iran)

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Abstract

An accurate selection of suppliers in the information technology supply chains of the service-based companies like banks has significant effects on chain flexibility and business continuity plan. In this paper, in order to contribute to the selection of suppliers in these firms, a novel Multiple Criteria Decision Making method by using a hybrid QFD-TOPSIS solution is suggested. The objectives of the proposed method are both finding the most related criteria and presenting an optimized solution to the supplier selection problem. The greatest contributions of this method are closing the opinions of employers to the technical requirements of information technology supplier qualifications in banks and also finding the best supplier by calculating the nearest distance to the ideal and the farthest one to the negative-ideal solution. Finally, a sensitivity analysis is designed to find the most sensitive sub-criteria. That is the results of ranking alter if sensitive sub-criteria change.

Keywords:

Multiple Criteria Decision Making, Quality Function Deployment, TOPSIS, Banking, Supply Chain and Information Technology

1. **Introduction & Research Literature:**

In the current competitive market, banks as the financial arm of countries need to make a long-time and stable relationship with their suppliers and partners, so they should develop favorable strategies with their partners specially suppliers. Strengthening the supplier networks needs correct verification and selection of the suppliers. Additionally, servicing the customers in the banks is real-time and disconnection of IT services to the customers leads to expose banks to resource decrease that it not only causes massive loss but also it endangers branding facets. Some problems that the service-based agencies especially the banks are facing in case of not having an efficient supplier selection procedure include:

- ✓ Financial loss in the firms by the invalid suppliers
- ✓ Increase in technical risks at on-time repairs
- ✓ Probability of mistakes in supplying goods or services
- ✓ Increase of security risk
- ✓ Applying more pressure on the employees to compensate the loss originated from the invalid suppliers

In addition, servicing all the customers by the internal forces of an organization is often time and cost consuming. Therefore, the service agencies need to outsource a great part of the services to the suppliers. It is obvious that determined criteria and at least a model for ranking suppliers based on the scores are required in order to verify valid suppliers.

Up to now, most of the criteria used in supplier selection problems include cost, quality and time. Although some of the researches used different criteria. Quality Function Deployment[1] as one of total quality management[2] methods is a planning tool for meeting the customers' needs. In fact, it is a systematic

[1] QFD
[2] TQM

approach for product design, engineering and production and it also provide detailed possibility of a product assessment [1]. House of Quality[3], the main body of QFD, shows the relationship between the voice of customers and the engineering characteristics [2]. TOPSIS is one of the Multiple Criteria Decision Making[4] methods that calculate the nearest distance to the ideal and the farthest one to the negative-ideal solution [3]. In the proposed research, in order to optimize the QFD method, TOPSIS is presented in combination at a deterministic area. Among extensive researches conducted in the last issues, the following recent works can be mentioned in chronological order.

Bevilacqua et al. (2006) developed a fuzzy-QFD approach to supplier selection. This research verified the features of the purchased products (Whats) and continued the solution with finding the related criteria (Hows) to assess the suppliers and at last they ranked the suppliers by fuzzy numbers. The formation of HOQ in their paper made the two classes of criteria to be correlated in order to help the researchers understand how each feature of the supplier (Hows) succeed in meeting the requirements established for the product being purchased outside the company [4]. Kwong (2007) proposed a methodology of determining aggregated importance of engineering characteristics in QFD [5]. Ha and Krishnan (2008) presented a hybrid method, which incorporates multiple techniques (Analytic Hierarchy Process [5], Data Envelopment Analysis [6]And Neural Networks [7]) into an evaluation process, in order to select competitive suppliers in a supply chain. In their paper a combined supplier score and a supplier map were devised [6]. Amin and Razmi (2009) used a fuzzy model that was integrated with the QFD for the selection of suppliers who provided internet services in the informatics sector in Iran. At the end of the study, alternative suppliers were arranged and a sensitivity analysis was conducted [7]. Amiri (2010) had used AHP and fuzzy TOPSIS methods in order to do a project selection for oil fields development. After criteria determination and AHP usage for weighing them, he used the fuzzy TOPSIS method to rank the projects finally [8]. Sun (2010) constructed a fuzzy AHP and fuzzy TOPSIS model to evaluate different notebook computer ODM companies [9].

Kumaraswamy et al. (2011) presented an integrated QFD-TOPSIS methodology for supplier selection in small and medium-sized enterprises. First of all, they identified the Customer Requirements[8] and then they used AHP method to obtain preference weights of customer requirements. Afterwards, they found the Technical Requirements[9] and constructed the central relationship matrix of QFD and determined the weights of TRs. then, they ranked the suppliers By TOPSIS method [10]. Liao and Kao (2011) used the fuzzy TOPSIS and GP methods to select material suppliers for the purchase of key components in a firm producing clocks. In their study, a three-member decision-making committee assessed five alternative suppliers who were selected according to the predetermined criteria of supplier selection. At the end of their study, the number of products to be received from suppliers was also determined [11]. In a study performed in an automotive production factory that sought to purchase inside and outside mirrors for three automobile models Zeydan et al. (2011) used three multi-criteria decision making methods to find efficient and inefficient suppliers sensitively. In the first step, fuzzy AHP was used for the determination of criteria weights and fuzzy TOPSIS to transform the qualitative variables into only one quantitative variable. In the second step, DEA was used for the ranking of efficient and inefficient suppliers [12]. Rajesh and Malliga (2013) provided a new hybrid solution using AHP and QFD methods. They started verifying the products characteristics in order to meet the requirements. Then they found the weights and afterwards, by the formation of the HOQ, they created a relationship between the products characteristics and the suppliers' features. After extracting the supplier weights from the relational matrix, the suppliers had been compared with an AHP method [13]. Dursun and Karsak (2013) showed a QFD-based fuzzy MCDM approach for supplier selection. The method started with the building the first HOQ and then continued with calculating the upper and lower bounds of the weight. After Building the HOQ for rating suppliers and calculating Fuzzy weighted average, they ranked the suppliers [14]. Rodrigues Lima Junior et al. (2014) presented a comparative analysis of two methods in the context of supplier selection decision making. The comparison was made based on the factors: adequacy to changes of alternatives or criteria; agility in the decision process; computational complexity; adequacy to support group decision making; the number of alternative sup-pliers and criteria; and modeling of uncertainty. The research showed 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 [15]. Ming Li et al. (2014) proposed a new MCDM method combining QFD with TOPSIS for knowledge management system selection from the user's perspective in intuitionistic fuzzy environment. After determining the two classes of criteria and then gathering the decision makers' [10]opinions and next transforming them into intuitionistic fuzzy numbers, they calculated the overall relationship between

[3] HOQ
[4] MCDM
[5] AHP
[6] DEA
[7] NN
[8] CR
[9] TR
[10] DMs

customer requirements and engineering characteristics. In the next step they extracted the related weights and at the last phase, they determined the priority of alternatives by TOPSIS method [16]. Daneshvar Rouyendegh and Eko Saputro (2014) presented an integrated fuzzy TOPSIS and Multi-choice Goal Programming[11] model to solve the supplier selection problem. The fuzzy TOPSIS was applied to make a judgment about the intangible criteria of suppliers. So, it could be considered as parameters to measure the eligibility of each supplier. In their paper, the supplier selection was dealing with the multiple-sourcing because of the inability of each supplier to satisfy all the needs of the buyer. Hence, The MCGP was intended to perform the integration of intangible and tangible criteria with multi-choice aspiration levels [17].Beikkhakhian et al. (2015) presented a model to evaluate agile suppliers by using fuzzy TOPSIS-AHP methods. It began with identifying the criteria to evaluate agile suppliers. Then these factors were ranked and categorized using the interpretive structural model. The results of this study depicted that the delivery speed variable lays on the bottom level of the model outlet with quite high driving power. The delay reduction variable had the same characteristics. Next, using fuzzy hierarchical analysis method, the weight of the agility evaluation criteria of suppliers were measured and put as TOPSIS model input. Finally, six suppliers were rated using fuzzy TOPSIS method. The results of this study showed that the criteria with higher driving power and lower dependence had higher weight in AHP model [18]. Kumar Kar (2015) proposed a hybrid group decision support system for supplier selection using AHP, fuzzy set theory and neural network. The computational process took place in three phases. In the first phase, the individual priorities of the decision makers were evaluated using the fuzzy AHP. In the next phase, these individual priorities were aggregated and converted into collective priorities under consensus. Subsequently, the fuzzy NN has been used for mapping the suppliers (represented as supplier performance vectors) to two classes, namely the high quality suppliers and the low quality suppliers [19]. Yıldız and Yayla (2015) reviewed 91 studies that were performed between 2001 and 2014 on the multi-criteria supplier selection in order to determine the criteria used for the selection of suppliers and methods. They classified the methods into three main sections: individual, hybrid, and hybrid fuzzy methods [20]. Tavana et al. (2016) provided an integrated ANP[12]-QFD approach to sustainable supplier selection problems. Their study was conducted in five phases. At first phase they identified all relevant sustainable factors, sub-factors and decision criteria. Secondly, they weighted customer factors and decision criteria where they used ANP to weigh customer factors and sub-factors and they also used the weights of the customer factors and sub-factors in QFD to weigh the decision criteria. At the third phase, AHP method was used to rank the suppliers with respect to TRs. At the next step the suppliers were ranked with WASPAS[13]and MOORA[14]. At last the validation of results was done [21]. Yazdani et al. (2016) presented an integrated QFD-MCDM framework for green supplier selection. The DEMATEL-QFD phase of the proposed method provided a simple to implement costumer-dependent weighting method for decision criteria, which played a fundamental role in situations where the satisfaction of external stakeholders and customers entered the decision process. At the first phase, they identified all relevant sustainable factors (customer and technical requirements). Secondly, they weighted the CRs with DEMETAL method. The normalized prominence values of DEMATEL were considered as the weights of the respective CRs which were further used for QFD-based analysis. Those weights were used in QFD to weight the TRs. After formation of HOQ, they ranked the suppliers per each TR according to the DMs' opinions. The questions aimed at establishing how much one of the suppliers was preferred to another one with respect to each specific decision criterion (TR). The pairwise comparisons were carried out. At last, COPRAS[15]and MOORA were applied to rank the candidate suppliers. To implement these methods, both the weights of all the TRs from phase two and the supplier rankings (one per each of the TRs) obtained in phase three were used [22].In the current proposed method, a renewed research on the classification of banking criteria that are related to the supplier selection problem in the area of Information Technology[16] is done by a classic Delphi method that will be explained in the future sections with details. The novelties of the proposed method are first in the related criteria of supplier selection process in IT area of banking industry and then in finding an optimized solution for ranking the suppliers.

The problem along with its state of the art is described in section 2. Problem definition of this model is provided in section 3. Section 4 is mathematical formulation & conceptual method of research. Case study of the research is presented in section 5 to demonstrate the applicability of the proposed method. Model reliability and sensitivity analysis are given in sections 6 and 7, respectively. Finally, the conclusion is given in section 8.

2. State of the Art:

A. Quality Function Deployment

[11] MCGP

[12] Analytic Network Process

[13] Weighted Aggregated Sum Product Assessment

[14] Multi-Objective Optimization on the basis of Ratio Analysis

[15] Complex Proportional Assessment

[16] IT

QFD is a well-structured, cross-functional planning technique that is used to hear the customers' voice throughout the product planning, development, engineering and manufacturing stages of any product [23]. QFD in services-based companies is a bit different. However, the whole supplier selection process procedure based on QFD is characterized by the fallowing steps:
A.1.Identifying the internal variables (Whats)
A.2.Identifying the external variables (HOWs)
A.3.Determining the relative importance of Whats
A.4.Determining the What-How correlation scores and constructing the HOQ
A.5.Determining the weights of Hows
A.6.Preparing the matrix for correlating the Hows
A.7.Determining the potential suppliers impact on Hows
A.8.Drawing up the final ranking on suppliers [4]

B. Technique for Order Preference by Similarity to an Ideal Solution[17]

In the TOPSIS as a technique for order preference by similarity to an ideal solution, two artificial alternatives are defined as positive-ideal and negative-ideal solution. The positive ideal solution is a solution that maximizes the benefit criteria and minimizes the cost criteria, whereas the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria [24]. In short, the positive ideal solution is the one which has the best level for all attributes considered, whereas the negative ideal solution is the one which has the worst attribute values. TOPSIS selects the alternative that is the closest to the positive ideal solution and farthest from negative ideal solution [25].

3. Problem Definition:

In this paper a novel hybrid approach based on QFD-TOPSIS method is proposed. The objective of this model is finding supplier selection criteria in IT department of financial institutions and simultaneously providing a framework for supplier ranking in such service-based organizations. The following assumptions are used for formulating the problem:
1. *s* is the number of suppliers.
2. *m* is the number of decision makers.
3. *sc* is the number of sub-criteria.
4. c is the number of criteria.
5. Each of decision makers expressed his/her opinion independently.
6. The opinions have been expressed verbally in high (H), medium (M) and low (L) levels and the numerical values of 9, 3 and 1 were assigned.
7. The scores calculated in deterministic scale.
8. Criteria selection is based on classic Delphi method in four rounds.

[17] TOPSIS

4. Mathematical Formulation & Conceptual Method:

4.1. Notations of Formulations:

GMC: The Geometric mean of main criteria.
DC: The matrix which has main criteria in columns and DMs in rows.
NGMC: Normalized GMC
DS: The correlation matrix which has sub-criteria in columns and main criteria in rows.
WS: The weights of sub-criteria.
NDS: Normalized DS
SM: The supplier matrix which has sub-criteria in columns and alternatives in rows.
r_{ij}: The array in row *i* and column j
n_{ij}: Euclidean normalized array in row *i* and column j
ND: Euclidean normalized SM matrix.
V: The weighted Euclidean normalized matrix.
A^+: The Ideal solution.
A^-: The negative ideal solution.
cl^+: The alternative final score.
d^+: The distance of the Alternative I from the ideal solution.
d^-: The distance of the Alternative I from the negative ideal solution.

4.2. Design of A novel hybrid approach based on QFD-TOPSIS method for supplier selection:

The stages of the proposed method are configurable with the following steps:
Stage 1. Verification of Whats (Main Criteria)
In this stage, the main criteria (Whats) are selected based on the opinions of the experts.
Stage 2: Determination of Hows (Sub-Criteria)
In this stage, after selecting the panel members, a classic Delphi method in four rounds is used. Then by gathering the opinions in an expert survey procedure, the sub-criteria (Hows) are found.
Stage 3: Determination of weights of Whats
In this stage, according to the number of main criteria and considering all of decision meker's votes, "Group Method" is used. After the main criteria being verified, the panel members' ideas of the organization about the importance of each main criterion by using Semi Metric Scale (between 0 to 100) in a format of a questionnaire were assessed. In fact, every member expressed his or her idea about the significance of each main criterion by a percent scale (Eq.1). In this step, gained percent for each main criterion are turned in to a constant percent for that criterion by using Geometric mean (Eq.2).

$$DC = \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{pmatrix} ;$$

$$a_{ij} = The\ DM\ i\ opinion\ about\ the\ criterion\ j \quad (1)$$

$$\mathrm{GMC} = \sqrt[m]{\prod_{i=1}^{m} a_{ij}} \ ; j=1,2,\ldots,n \quad (2)$$

by applying this method, not only the panel member's different ideas are used in the percent of the importance of each criterion, but also this application can help gain a constant percent W for every criterion. Now, the weight of each main criterion is obtained by using normalization with the Eq.3[26].

$$NGMC = \frac{a_i}{\sum_{i=1}^{n} a_i} \quad (3)$$

Stage 4: Formation of the correlation Matrix

In this stage, Panel members expressed their opinions verbally about the impact of each sub-criterion on every main criterion in high (H), medium (M) and low (L) levels and the numerical values of 9, 3 and 1 were assigned (Eq.4).

$$DS_k = \begin{pmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{pmatrix} ;$$

$$r_{ij} = The\ DM\ k\ opinion\ about\ the\ effect\ of\ sub\ criterion\ i\ on\ the\ criterion\ j$$

$$; k= 1,2,\ldots,m \quad (4)$$

Stage 5: Calculation of weights of Hows

The consequent is calculated by using Geometric mean in a unit form.

Then, the weight of each main criterion is multiplied with the value of each array of the correlation Matrix(Eq.5).

$$\mathrm{WS} = \mathrm{NDS} * \mathrm{NGMC} \quad (5)$$

At last the weight vector of Hows is obtained that is the input of the next stage.

Stage 6: Rating the Suppliers

In this stage, the DM's should rate the suppliers with a scale of 0 to 100. Then by calculating the Geometric mean, the consequent of their opinions is obtained (Eq.6).

$$SM = \begin{pmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{pmatrix} ;$$

$$r_{ij} = The\ DM\ i\ opinion\ about\ the\ criterion\ j \quad (6)$$

Stage 7: Ranking the suppliers using TOPSIS method

The matrix of the previous stage is multiplied with the weight vector of Hows. Afterward, according to the TOPSIS method, the weighted matrix should be normalized with Euclidean Normalization. Then, the ND matrix is multiplied with the weights vector of Hows (Eq.7 & 8).

$$n_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^{y} r_{ij}^2}} \quad (7)$$

$$V = ND * WS \quad (8)$$

After Calculating the ideal solution and the negative ideal solution (Eq.9 &10), the distance of them from the V matrix is measured (Eq.11 &12).

$$A^{+} = \left\{ \left(max_i\, v_{ij} \;\middle|\; j\epsilon J \right), \left(min_i\, v_{ij} \;\middle|\; j\epsilon J' \right) \;\middle|\; i = 1,2, \ldots m \right\}$$

Ideal Solution (9)

$$= \{V_1^{+}, V_2^{+}, \ldots V_j^{+}, \ldots, V_n^{+}\}$$

$$A^{-} = \left\{ \left(min_i\, v_{ij} \;\middle|\; j\epsilon J \right), \left(max_i\, v_{ij} \;\middle|\; j\epsilon J' \right) \;\middle|\; i = 1,2, \ldots m \right\}$$

Negative Ideal Solution (10)

$$= \{V_1^{-}, V_2^{-}, \ldots V_j^{-}, \ldots, V_n^{-}\}$$

$$d_{i^+} = \left\{ \sum_{j=1}^{n} \left(V_{ij} - V_j^{+} \right)^2 \right\}^{0.5} ; i = 1,2, \ldots, m$$

(11)

$$d_{i^-} = \left\{ \sum_{j=1}^{n} \left(V_{ij} - V_j^{-} \right)^2 \right\}^{0.5} ; i = 1,2, \ldots, m$$

(12)

At last, the cl_{i^+} is obtained by the Eq.13. This parameter is between 0 and 1 and the closer score to 1 is the winner.

$$cl_{i^+} = \frac{d_{i^-}}{(d_{i^+} + d_{i^-})} ; 0 \ll cl_{i^+} \ll 1 ; i = 1,2, \ldots, m$$

(13)

Stage 8: Selecting the final Supplier

In this stage, the final ranking of suppliers is determined and the winner is visible based on the Supplier which obtained the most score.

5. Case Study:

The QFD-TOPSIS method is used for a supplier selection process at the IT department of a Private bank in Iran for purchasing the network routers. There are 5 decision makers, 6 main criteria (Whats) and 15 sub-criteria (Hows) in this case. The stages below are conducted:

5.1. Verification of Whats (Main Criteria)

In this study, the Whats (main criteria) of products purchased from suppliers are considered that include: **Supplier Performance**, **Quality**, **Delivery Time**, **Security Problems**, **Cost**, and **Service Level**.

5.2. Determination of Hows (Sub-Criteria)

In order to find suitable sub-criteria, after performing a four-round Delphi method, 15 sub-criteria are obtained that include: 1. Previous supplier performance 2. Expertise of the supplier's staff 3. Quality of the product/Service (i.e. the level of technology and the errors rate) 4. Reliability 5. Previous delay of the supplier in time of delivery 6. Authenticity of products/ services 7. Delivery speed 8. Security of products/ services 9. The perception of security risks 10. The price of the product /service 11. Maintenance costs 12. Ease of communication with the supplier 13. After-sales service system of the supplier 14. The ability to respond quickly to customer requirements 15. Product warranty period

5.3. Determination of weights of Whats

In this stage, the team was asked to rate the main criteria in the scale of 0 to 100 based on What's impact. Afterward, the Geometric mean of the team's opinions was calculated per each main criterion to find the weight of Whats. The result is shown in table 1.

Table 1. Normalized Matrix of Whats

	Member1	Member2	Member3	Member4	Member5	Geometric Mean	Normalized Weights
Supplier Performance	60	80	100	95	85	82.73	0.169
Quality	100	80	100	95	99	94.47	0.192
Delivery Time	80	90	80	50	98	77.65	0.159
Security Problems	100	90	70	60	95	81.48	0.166
Cost	70	60	100	50	95	72.44	0.148
Service Level	100	70	80	70	95	82.07	0.167

5.4. Formation of the correlation Matrix

In the fourth step, the team was asked to rate the sub-criteria based on the impact on the main criteria in high (H), medium (M) and low (L) levels and the numerical values of 9, 3 and 1 were assigned. Then, the consequent is calculated by using Geometric mean of the DM's opinions.

5.5. Calculation of weights of the Hows

The weights vector of Whats are multiplied with the DM's opinion about the effect of sub-criteria on main criteria.So, the weights of the How's are calculated from the constructed HOQ. The scores indicate that Authenticity of products/ services, Delivery speed, Expertise of the supplier's staff, Reliability, Quality of the product/Service (i.e. the level of technology and the errors rate) are the major sub-criteria.

5.6. Rating the Suppliers

In this stage, the team was asked to rate four suppliers of Router for the IT department of the bank. Then the Geometric mean is calculated and the SM matrix is formed that is the supplier matrix which has sub-criteria in columns and alternatives in rows.

5.7. Ranking the suppliers by using TOPSIS method

The matrix of the supplier's scores (SM) and the weights of Hows are the inputs of the TOPSIS method. The result of ranking in the TOPSIS phase is shown in table 2.

Table 2. Ranking results of the QFD-TOPSIS method

Supplier's Nom.	Calculated Score	Supplier's Rank
Supplier 1	0.5305	3
Supplier 2	0.5349	1
Supplier 3	0.5308	2
Supplier 4	0.5275	4

5.8. Selecting the final Supplier

After performing the TOPSIS phase completely and calculating the *cl*, the winner is Supplier 2 that has the most calculated score.

6. Model Validation

The final result of the proposed hybrid model is compared with the individual TOPSIS method. In the hybrid model, the weight vector resulted from the QFD phase is the input of the TOPSIS phase. Then the weight vector is entered the TOPSIS method and the suppliers are ranked again (table

3).

Table 3. Ranking results of the TOPSIS method

Supplier's Nom.	Calculated Score	Supplier's Rank
Supplier 1	0.5317	3
Supplier 2	0.5364	1
Supplier 3	0.5320	2
Supplier 4	0.5285	4

The results showed the same ranking for both methods that indicates the accuracy of the proposed method. At last, as shown in the table 4 SSE [18]and MSE [19]are calculated.

Table 4. SSE & MSE

Calculated Score for the proposed method	Calculated Score for the TOPSIS method	SSE	MSE
0.5305	0.5317	0/00000613	0/0000015325
0.5349	0.5364		
0.5308	0.532		
0.5275	0.5285		

7. Sensitivity Analysis

As indicated before, the sub-criteria including *Authenticity of products/ services, Delivery speed, Expertise of the supplier's staff, Reliability, Quality of the product/Service (i.e. the level of technology and the errors rate)* are the most significant ones in effect on the main criteria. In order to measure the sensitivity analysis, the steps below are performed per each 5 most weighted sub-criteria:

Step1.10-percent increase in the weight of one of the most weighted sub-criteria

Step2. 2.5-percent decrease in the weight of 4 other most weighted sub-criteria

Step3. Ranking the suppliers in the TOPSIS phase of the proposed method

Step4.Observing the change rate of the supplier's ranking.

As shown in the table 5 the result indicates that among the 5 most significant sub-criteria, the ones including *Delivery speed* and *Expertise of the supplier's staff* have the most rate of sensitivity and if their weights change, the ranking result will be different.

Table 5. Summarized result of the supplier ranking before and after the sensitivity analysis

Final ranking before the sensitivity analysis	S2>S3>S1>S4
Ranking after the change of the first sub-criterion (*Authenticity of products/ services*)	S2>S1>S3>S4
Ranking after the change of the second sub-criterion (*Delivery speed*)	S3>S1>S4>S2
Ranking after the change of the third sub-criterion (*Expertise of the supplier's staff*)	S3>S2>S1>S4
Ranking after the change of the fourth sub-criterion (*Reliability*)	S2>S1>S4>S3
Ranking after the change of the fifth sub-criterion (*Quality of the product/Service (i.e. the level of technology and the errors rate)*)	S2>S4>S3>S1

8. Conclusion

The objectives of the proposed model are finding the suitable criteria of supplier selection in the IT department of financial institutions and also ranking the suppliers with a novel hybrid QFD-TOPSIS method. In the provided model, first of all after finding the main criteria of the QFD phase, a four-round Delphi method is performed in order to find the sub-criteria and by an 8-step procedure the winner supplier is determined. Afterward, in a case study with 4 suppliers that is performed in the IT department of a private bank in Iran, the proposed QFD-TOPSIS model is run. The ranking is S2>S3>S1>S4. Then, by comparing the result of the proposed method with the individual TOPSIS method and then calculating the SSE=0/00000613 and MSE=0/0000015325, very close consequents are obtained that shows high accuracy of the QFD-TOPSIS method. At last, a sensitivity analysis was performed that indicated that two of sub-criteria including *Delivery speed* and *Expertise of the supplier's staff* are the most sensitive ones and will change the ranking result in case of alternation. This method is applicable to supplier selection process of the IT department in financial institutions.

For future studies, soft operational research methods such as soft system methodology ,Strategic Options Development and Analysis methodology and Interpretive Structural modeling [20] are also recommended[21].

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