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An Aggregated Supplier Selection Method Based on QFD and TOPSIS (Case Study: a Financial Institution)

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Abstract

With daily development of information technology supply chain of service-based organizations such as financial institutions and the increased value of outsourced activities along with the importance of customer satisfaction, outsourced affairs must have been done by the suppliers who have the ability to fulfill the organizational demands. To mitigate the risk of invalid supplier selections, verification and selection of the suppliers should be performed with an optimized and systematic solution. In order to help the selection of suppliers in the IT department of financial organizations, a different model by using a hybrid QFD-TOPSIS solution in MCDM methods is suggested In this study, The first goal of the provided model is to find the most related criteria and the second one is to offer an optimized solution to the supplier selection problem. To begin the QFD part in the mentioned method, two categories of criteria are needed. Then, after the formation of the House of Quality, in a real case study that was performed in a private bank in Iran, the suppliers are ranked by using the proposed method. The greatest efficiencies of this method are not only finding the best supplier by measuring the nearest distance to the ideal and the farthest one to the negative-ideal solution but also closing the opinions of employers to the technical requirements(sub-criteria) of information technology of supplier qualifications. Finally, a model reliability part is designed to indicate the validation of the proposed method and a sensitivity analysis is implemented to find the most sensitive sub-criteria. That is the results of ranking alter if sensitive sub-criteria change.

Keywords: Supply selection; Multiple criteria decision making; Information technology; Quality function deployment; TOPSIS and Financial institution.

1. Introduction & Research Literature

The main objectives of the supply chain management are reduction of the chain risks, improvement of customer servicing, and optimization of the business processes. Service-based companies, such as banks for their IT outsourced activities, need to find valid suppliers to submit the best services at the least time. Not having the ability to service the customers in a just-in-time procedure may lead to great financial losses.
Nowadays, the supplier selection methods are in the spotlight of the supply chain management. It is clear that determined criteria in combination with an optimized model for selecting the right suppliers are required to complete an effective supply chain management.
Suppliers are defined as one of the vital parts of an organization who deliver all the requirement for producing complete product from raw materials, components, and services and a suitable supplier is the one who meets these requirements at the right time, acceptable quality, and standards (Yazdani et al, 2017).
The main categories of criteria in supplier selection problems include cost, quality, and time. A variation of criteria is also used indifferent studies. With the consideration of many studies in supplier selection the current study that will be explained in detail at the next sessions.
Quality Function Deployment[i] is one of total quality management[ii] methods. It is a systematic approach to product design, engineering and production and it also provides detailed possibility of a product assessment (Bester field et al , 2008). House of Quality[iii], the main body of QFD, shows the relationship between the voice of customers and the engineering characteristics (Karsak et al., 2003). QFD in service-based companies behaves differently. However, the supplier selection process based on QFD is characterized by the fallowing steps:
1. Identifying the Whats (customer requirements)
2. Identifying the HOWs (Technical requirements)
3. Determining the relative importance of Whats
4. Determining the What-How correlation scores and constructing the HOQ
5. Determining the weights of Hows
6. Preparing the matrix for correlating the Hows
7. Determining the potential suppliers impact on Hows
8. Drawing up the final ranking on suppliers (Bevilacqua et al. 2006)
The Technique for Order Preference by Similarity to an Ideal Solution[iv]is one of the Multiple Criteria Decision Making[v] methods that calculate the nearest distance to the ideal solution and the farthest one to the negative-ideal

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solution (Hwang and Yoon, 1981) . TOPSIS was first developed by Hwang & Yoon (1981). In this method, two artificial alternatives are defined as positive-ideal and negative-ideal solutions. 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 (Wang & Elhag, 2006). In fact, 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 the negative ideal solution (Jahanshahloo et al.,2006).

In the proposed research, in order to optimize the QFD method, TOPSIS is presented in combination at a deterministic environment. Among extensive studies conducted in the last issues, the following recent studies can be mentioned here.

Jose A. Carnevalli, Paulo Cauchick Miguel (2008) presented a review, analysis and classification of the literature on quality function deployment (QFD) produced between 2002 and 2006. This review showed that the majority of cases are conceptual and descriptive and used mainly bibliographical data sources. In most of the cases, the work goals were about adapting QFD to a specific application. There were also several studies of intended improvements to the method that introduced other tools and techniques . Bevilacqua et al. (2006) developed a fuzzy-QFD approach to supplier selection problem. This study determined the features of the purchased products (Whats)and also related criteria (Hows) to assess the suppliers, and then ranked the suppliers by fuzzy numbers. The formation of HOQ in their paper made the two classes of criteria be correlated in order to help the researchers understand how each feature of the supplier (Hows) succeeded in meeting the requirements established for the product being purchased outside the company . Rong-Tsu Wang (2007) employed QFD to integrate inside-quality technology and the voice of outside consumers in order to examine the performance of China Airlines, and illustrated the company's performance in terms of service and offered suggestions for improvement by using ''House of Quality'' charts. Fatih Emre Boran et al. (2009) presented a study with TOPSIS method combined with intuitionistic fuzzy set proposed to select an appropriate supplier in group decision making environment. In the evaluation process, the ratings of each alternative with respect to each criterion and the weights of each criterion were given as linguistic terms characterized by intuitionistic fuzzy numbers. Also, intuitionistic fuzzy averaging operator was utilized to aggregate opinions of decision-makers. After intuitionistic fuzzy positive-ideal solution and intuitionistic fuzzy negative-ideal solution were calculated based on the Euclidean distance, the relative closeness coefficients of alternatives were obtained and alternatives were ranked. Jia -Wen Wang et al. simplified the complicated metric distance method [L.S. Chen, C.H. Cheng, Selecting IS personnel using ranking fuzzy number by metric distance method, Eur. J. Operational Res. 160 (3) 2005803–820], and proposed an algorithm to modify Chen's Fuzzy TOPSIS (Technique for Order Preference by Similarity to the Ideal Solution). Gumus (2009) employed the AHP and TOPSIS methods for hazardous waste transportation. The TOPSIS viewed a MADM problem with m alternatives as a geometric system with m points in the n-dimensional space of criteria.

Amiri (2010) used AHP and fuzzy TOPSIS methods in order to perform a project selection for oil fields development. After criteria verification and AHP usage for weighing them, he used the fuzzy TOPSIS method to rank the projects at last[12]. Kumaraswamy et al. (2011) presented an integrated QFD-TOPSIS method for supplier selection in small- and medium-sized enterprises.They identified the Customer Requirements[vi] and then they used AHP method to obtain weights of customer requirements. Next, they constructed the correlation matrix of QFD. Then, they ranked the suppliers by TOPSIS method. Akram Zouggari, Lyes Ben youcef (2012) presented a new decision making approach for group multi-criteria supplier selection problem, which clubbed supplier selection process with order allocation for dynamic supply chains to cope with market variations. The developed approach imitated the knowledge acquisition and manipulation in a manner similar to the decision maker who gathered considerable knowledge and expertise in procurement domain. Fuzzy-AHP was used first for supplier selection through four classes (performance strategy, quality of service, innovation, and risk).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 created a relationship between the products characteristics and the suppliers' features by the formation of the HOQ. After extracting the supplier weights from the relational matrix, the suppliers were compared by an AHP method [15]. 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 these factors: adequacy of changes of alternatives or criteria, agility in the decision process, computational complexity, adequacy of supporting group decision making, the number of alternative suppliers and criteria, and modeling of uncertainty. The research showed that Fuzzy TOPSIS exceeded Fuzzy AHP in most of criteria except when there had been few criteria and suppliers concerning the agility in the decision process. Ahmad Dargi et al. (2014) developed a framework to support the supplier selection process in an Iranian automotive industry. That paper aimed to attain the collection of criteria which had impacts on selecting a reliable supplier. As a result, Nominated Group Technique[vii]had been used to summarize the most critical factors. A fuzzy analysis network process[viii]was deployed to weight the selected criteria. Ming Li et al. (2014) provided a combined QFD-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' [ix]opinions and next transforming them into intuitionistic fuzzy numbers, they calculated the overall relationship between customer requirements and engineering characteristics. In the next step, they extracted the related weights and, finally, they determined the priority of alternatives by TOPSIS method. Yıldız and Yayla (2015) reviewed 91 studies 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. Arpan Kumar Kar (2015) presented a hybrid group decision support system for supplier selection using analytic hierarchy process[x], fuzzy set theory, and neural network. These three methods were integrated to provide group decision support under consensus achievement. Discriminant analysis was used for the purpose of supplier base rationalization, through which suppliers were mapped onto highly suitable and less suitable supplier classes. The proposed integrated approach was further studied through two case studies and the proposed approach was compared with another approach for group decision making under consensus and other approaches for prioritization using AHP .Tavana et al. (2016) provided an integrated ANP[xi]-QFD approach to sustainable supplier selection problems. They proposed the method in five phases where ANP is integrated with QFD to weight customer factors and decision criteria, while MOORA [xii]and WASPAS [xiii]are used to rank the suppliers. Yazdani et al. (2016) delivered an integrated model of supplier selection problem using SWARA[xiv], QFD and the new MCDM tool called WASPAS. Their work considered customer attitudes in the process of supplier evaluation. To give more weight to customer requirements, a new SWARA method was designed; additionally, QFD and the house of quality matrix were used to transform customer requirements into the supplier evaluation index. Finally, WASPAS was used to rate the performance of suppliers and present supplier ranking scores.

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[xv] 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 financial institutions and then in opening a new angle in optimized and quick solutions for selecting the suppliers in deterministic space.

Problem definition of this model is provided in section 2. Section 3 is mathematical formulation & conceptual method of the research. Case study of the research is presented in section 4 to demonstrate the applicability of the proposed method in an actual environment. Model reliability and sensitivity analysis are given in sections 5 and 6, respectively. Finally, the conclusion is given in section 7.

2. Problem Definition

In this study, a novel hybrid approach based on QFD-TOPSIS method is proposed. The objectives of this method are finding supplier selection criteria in IT department of financial institutions and also providing a framework for supplier selection in such service-based organizations. The following assumptions are used for formulating the problem:

1.*p* is the number of suppliers.
2. *m* is the number of decision-makers.
3. *l* is the number of sub-criteria.
4.b is the number of criteria.
5. Each opinion is expressed independently by the DMs.
6. The opinions are expressed verbally in high (H), medium (M), and low (L) levels.
7. The scores are calculated in deterministic environment.
8. Criteria selection is based on classic Delphi method in four rounds.

3. Mathematical Formulation & Conceptual Model

3.1. 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
${cl_i}^{+}$: The alternative final score
d^{+}: The distance of Alternative I from the ideal solution
d^{-}: The distance of Alternative I from the negative ideal solution

3.2. Design of A novel hybrid approach based on QFD-TOPSIS method

The following steps of the proposed method are here:
Step 1. Verification of Whats (Main Criteria)
The main criteria (Whats) are determined based on the expert's opinions by a brainstorming method.
Step 2: Determination of Hows (Sub-Criteria)
Then, after selecting the DMs, a classic Delphi method in four rounds is applied. Therefore, by gathering the opinions in an expert survey procedure, the sub-criteria (Hows) are found. A strong consensus of opinion supports the found sub-criteria.

Step 3: Determination of the weights of Whats

In this step, according to the number of main criteria and considering all of decision-makers' 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 is turned into a constant percent for that criterion by using Geometric mean (Eq.2).

$$DC = \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{pmatrix};\ a_{ij} = The\ DM\ i\ opinion\ about\ the\ criterion\ j \quad (1)$$

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

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 for every criterion. Now, the weight of each main criterion is obtained by using normalization with Eq.3 (Eshlaghy et al., 2011)

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

Step 4: Formation of the correlation Matrix

In this step, Panel members express 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 are assigned (Eq.4).

$$DS_k = \begin{pmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{pmatrix};$$
$$r_{ij} = The\ DM\ k\ opinion\ about\ the\ effect\ of\ sub\ criterion\ i\ on\ criterion\ j\ ;\ \mathrm{k} = 1,2,\ldots,\mathrm{m} \quad (4)$$

Step 5: Calculation of the weights of Hows

The consequent of the last step is calculated by using Geometric mean in a unit form. Then, the weight of each main criterion is multiplied bythe 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.

Step 6: Scoring the Suppliers

In this stage, the DMs 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).

$$SM = \begin{pmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{pmatrix};\ r_{ij} = The\ DM\ i\ opinion\ about\ the\ criterion\ j \quad (6)$$

Step 7: Ranking suppliers by 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 (ND Matrix). Then, the ND matrix is multiplied by the weight vector of Hows (Eqs.7 & 8).

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

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

Next, the ideal solution and the negative ideal solution are calculated by Eqs.9 &10.

$$A^+ = \left\{ \left(max_i\, v_{ij} \mid j \epsilon J \right), \left(min_i\, v_{ij} \mid j \epsilon J' \right) \mid i = 1,2,\ldots m \right\} \text{Ideal Solution}$$
$$= \left\{ V_1^+, V_2^+, \ldots V_j^+, \ldots, V_n^+ \right\} \quad (9)$$

$$A^- = \left\{\left(min_i v_{ij} \middle| j\epsilon J\right), \left(max_i v_{ij} \middle| j\epsilon J'\right) \middle| i = 1,2, \dots m\right\} \text{Negative Ideal Solution} \quad (10)$$
$$=\{V_1^-, V_2^-, \dots V_j^-, \dots, V_n^-\}$$

The separation of each alternative from the ideal solution is given as Eq.11 and, similarly, the separation from the negative ideal solution is given as Eq. 12.

$$d_{i^+} = \left\{\sum_{j=1}^{n}(V_{ij} - V_j^+)^2\right\}^{0.5} ; i = 1,2, \dots, m \quad (11)$$

$$d_{i^-} = \left\{\sum_{j=1}^{n}(V_{ij} - V_j^-)^2\right\}^{0.5} ; i = 1,2, \dots, m \quad (12)$$

Step 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 obtains the most score.

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

$$cl_{i^+} = \frac{d_{i^-}}{(d_{i^+} + d_{i^-})} ; 0 \ll cl_{i^+} \ll 1 ; i = 1,2, \dots, m \quad (13)$$

All the mentioned steps are configurable in a conceptual model as shown in fig. 1.

4. Case Study

The mentioned proposed method was used for a supplier selection process at IT department of a financial institution in Iran for purchasing switch devices. There were5 decision-makers, 6 main criteria (Whats), and 15 sub-criteria (Hows) in this case. According to the conceptual model, the stages below were conducted:

4.1. Verification of Whats (Main Criteria)

In this study, the Whats (main criteria) of products purchased from suppliers are presented in table 1.

Table 1
Main Criteria

Main Criteria	Abbreviations
Supplier Performance	C1
Quality	C2
Delivery Time	C3
Security Problems	C4
Cost	C5
Service Level	C6

4.2. Determination of hows (Sub-Criteria)

In this stage, in order to find the most related sub-criteria, a four-round classic Delphi method was performed and 5decision-makers (all from IT banking experts) voted the top15 sub-criteria (Table 2) among 80 sub-criteria adopted from 91 studies that were performed between 2001 and 2014 on the multi-criteria supplier selection methods[19] and the panel members' opinions.

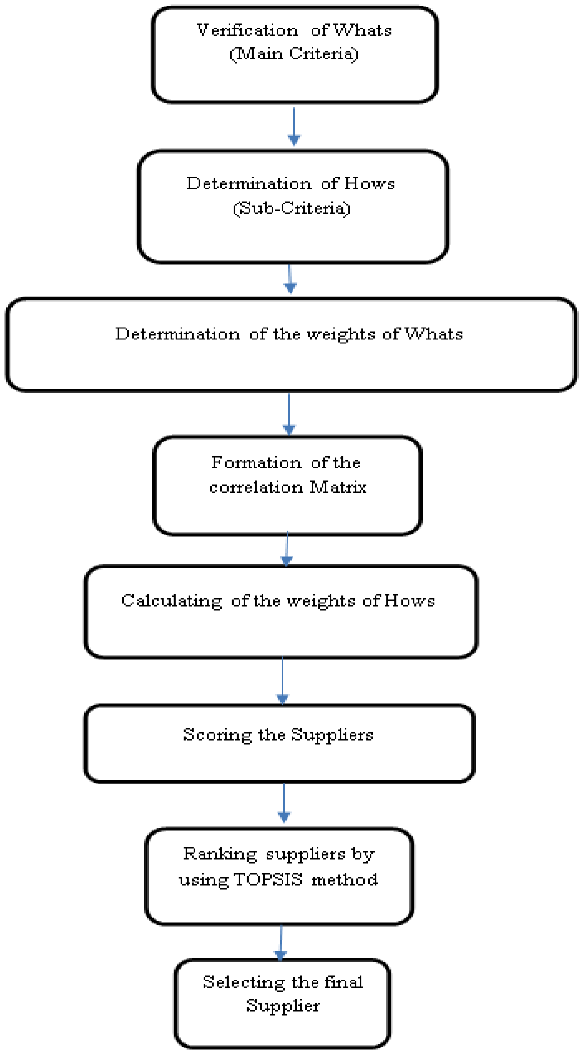

Fig. 1. The conceptual model of QFD-TOPSIS method

Table 2
Sub-Criteria

Sub-Criteria	Abbreviations
Previous supplier performance	SC1
Expertise of the supplier's staff	SC2
Quality of the product/Service (i.e., the level of technology and the errors rate)	SC3
Reliability	SC4
Previous delay of the supplier in time of delivery	SC5
Authenticity of products/ services	SC6
Delivery speed	SC7
Security of products/ services	SC8
The perception of security risks	SC9
The price of the product /service	SC10
Maintenance costs	SC11
Ease of communication with the supplier	SC12
After-sales service system of the supplier	SC13
The ability to respond quickly to customer requirements	SC14
Product warranty period	SC15

4.3. Determination of the weights of whats

Then, the DM team was asked to score the main criteria in the scale of 0 to 100 based on Whats' impacts. Afterward, the Geometric mean of the team's opinions was calculated per each main criterion to find the weight of Whats. The result wasa weight vector for the main criteria.

4.4.Formation of the correlation matrix

In the fourth step,theDM 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 merged consequent wascalculated by using Geometric mean of the DM's opinions (Table 3).

Table 3
The merged consequent of the DMs' verbal opinions

	SC1	SC2	SC3	SC4	SC5	SC6	SC7	SC8	SC9	SC10	SC11	SC12	SC13	SC14	SC15
C1	5.79	9	*	*	3	2.4	3.73	*	*	1	2.4	3.73	2.4	*	*
C2	*	3	9	9	*	4.65	*	1	*	2.4	1	*	1	1	3.73
C3	*	1.24	*	*	9	9	9	*	*	*	*	*	*	1	*
C4	*	*	1.93	3	*	1	*	9	9	*	*	*	*	*	*
C5	*	1.24	2.4	1.55	*	*	1.55	1	*	9	9	*	1	1	1.24
C6	1	1.55	*	1	2.4	3.73	3	*	*	*	*	9	9	9	7.22

4.5. Calculation of weights of Hows

The weights of the How's were calculated from the constructed HOQ. As shown in table 4, the scores indicate that *Authenticity of products/ services*, *Delivery speed*, *Expertise of the supplier's staff* are the major sub-criteria due to having the most weights among the other criteria.

Table 4
HOQ (Weights of Hows)

	The weights of Whats	SC1	SC2	SC3	SC4	SC5	SC6	SC7	SC8	SC9	SC10	SC11	SC12	SC13	SC14	SC15	Total
C1	0/169	0/97851	1/521	*	*	0/507	0/4056	0/63037	*	*	0/169	0/4056	0/63037	0/4056	*	*	5/82205
C2	0/192	*	0/576	1/728	1/728	*	0/8928	*	0/192	*	0/4608	0/192	*	0/192	0/192	0/71616	7/06176
C3	0/159	*	0/19716	*	*	1/431	1/431	1/431	*	*	*	*	*	*	0/159	*	4/80816
C4	0/166	*	*	0/32038	0/498	*	0/166	*	1/494	1/494	*	*	*	*	*	*	4/13838
C5	0/148	*	0/18352	0/3552	0/2294	*	*	0/2294	0/148	*	1/332	1/332	*	0/148	0/148	0/18352	4/43704
C6	0/167	0/167	0/25885	*	0/167	0/4008	0/62291	0/501	*	*	*	*	1/503	1/503	1/503	1/20574	7/9993
Total		1/14551	2/73653	2/40358	2/6224	2/3388	3/51831	2/79177	1/834	1/494	1/9618	1/9296	2/13337	2/2486	2/002	2/10542	34/26669
The weights of Hows		3/34%	7/99%	7/01%	7/65%	6/83%	10/27%	8/15%	5/35%	4/36%	5/73%	5/63%	6/23%	6/56%	5/84%	6/14%	

4.6. Scoring the Suppliers

In this stage, the DM team was asked to score four suppliers of Switch devices for the IT department in the bank. Then the Geometric mean was calculated, and the result is shown in table5.

Table 5
Suppliers Scores for each criterion

	SC1	SC2	SC3	SC4	SC5	SC6	SC7	SC8	SC9	SC10	SC11	SC12	SC13	SC14	SC15
Supplier 1	70.47	70.68	78.97	66.73	52.27	72.47	59.23	60.93	65.38	69.33	31.89	60.49	64.85	50.34	61.73
Supplier 2	73.84	68.42	66.08	56.81	62.27	59.58	70.56	70.84	71.82	66.60	28.71	62.40	60.49	67.89	66.73
Supplier 3	63.39	61.38	72.89	72.07	61.97	74.41	59.18	75.34	64.07	61.88	37.28	63.75	55.76	68.69	64.49
Supplier 4	70.90	79.17	68.71	70.84	72.89	76.42	67.87	71.04	60.22	58.24	36.88	63.08	55.53	72.75	57.45

4.7. Ranking the suppliers by using TOPSIS method

The matrix of the supplier's scores (table5) and the weights of How s (table4) were the inputs of the TOPSIS method. The result of ranking by the TOPSIS method is shown in Fig 2.

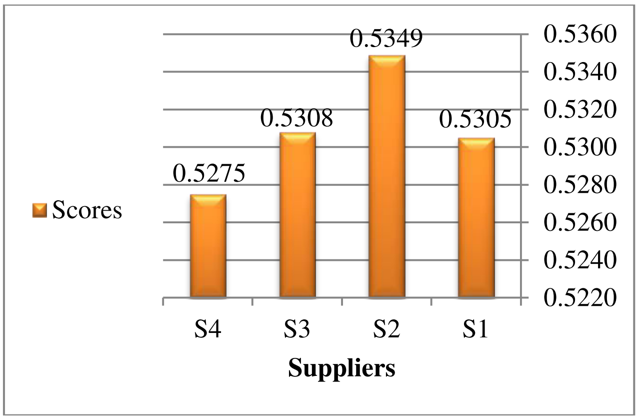

Fig. 2. Ranking results of the QFD-TOPSIS method

4.8. Selecting the final Supplier

As shown in Fig 2, the winner is the one with the most of cl_i+. At this case, Supplier 2 is the winner.

5. Method Reliability

The final result of the proposed hybrid model is compared with that of the individual TOPSIS method. In the hybrid model, the weight vector resulting from the QFD phase is the input of the TOPSIS phase. So, the weight vector enters the TOPSIS method and the suppliers are ranked. Then, the weighted vector of Hows derived from a pair-wise comparison process enters the individual TOPSIS method and the suppliers are ranked again (Fig 3).
The results showed the same ranking for both methods that indicate the accuracy of the proposed method. At last, as shown in table 6, SSE [xvi] was calculated.

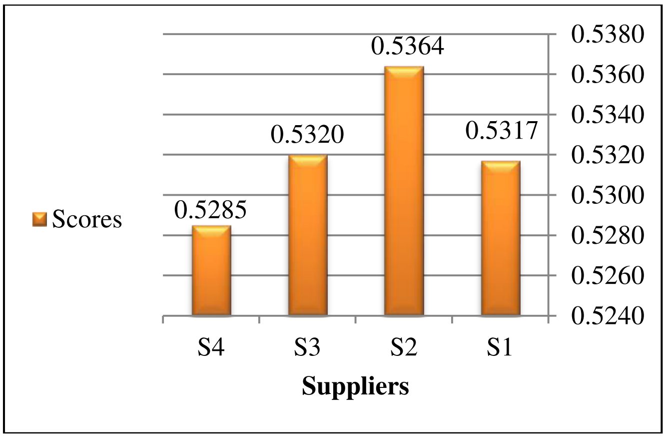

Fig. 3. Ranking results of the TOPSIS method

Table 6
SSE

Calculated Score for the proposed method	Calculated Score for the TOPSIS method	SSE
0.5305	0.5317	0.0000061
0.5349	0.5364	
0.5308	0.532	
0.5275	0.5285	

6. Sensitivity Analysis

As indicated in table2, the sub-criteria, including *Authenticity of products/ services, Delivery speed, Expertise of the supplier's staff*, were the most significant ones in effect on the main criteria. In order to measure the sensitivity analysis, the steps below were performed per each 3 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 2 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 Table7, the result indicates that among the 3 most significant sub-criteria, the ones, including *Delivery speed* and *Expertise of the supplier's staff*, have the highest rate of sensitivity; if their weights changed, the ranking result would be different.

7. Conclusion

The objectives of the proposed model are finding the most precise criteria of supplier selection in the IT department of financial institutions and also ranking the suppliers by a quick hybrid QFD-TOPSIS method. In the provided model, first of all, after finding the main criteria of the QFD phase, a four-round classic Delphi method was performed in order to find the most suitable sub-criteria and the winner supplier was determined by an 8-step procedure. Afterward, in a case study with 4 suppliers that was performed in the IT department of a private bank in Iran, the proposed QFD-TOPSIS model was run. The ranking was S2>S3>S1>S4. Then, by comparing the result of the proposed method with that of the individual TOPSIS method and then calculating the SSE=0/0000061, very close consequents were obtained that showed 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* ,were the most sensitive ones and would change the ranking result in case of alternation.

Table 7
Ranking results of the suppliers before and after the sensitivity analysis

Final ranking before the sensitivity analysis	S2>S3>S1>S4
Ranking after the change of the first sub-criteria (*Authenticity of products/ services*)	S2>S1>S3>S4
Ranking after the change of the second sub-criteria (*Delivery speed*)	S3>S1>S4>S2
Ranking after the change of the third sub-criteria (*Expertise of the supplier's staff*)	S3>S2>S1>S4

Finally, Lack of the most related criteria in the supplier selection process of the IT departments in banks may cause great losses in most cases. Additionally, the selection procedure is often done with subjective opinions of managers without considering the security risks and a fair attitude to the suppliers. Therefore, the presented conceptual model can minimize the chaos of supplier selection in the information technology affairs of financial institutions.
For future studies, soft operational research methods, such as soft system methodology, Strategic Options Development and Analysis methodology, and Interpretive Structural modeling [xvii], are also recommended[xviii]. This study has been carried out in a service-based institution, and it mightlead to different results if performed for product-based organizations.

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