

SUPPLIER SELECTION IN PROCUREMENT LOGISTICS USING AHP-QFD AND ANP-QFD APPROACH

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Abstract: Procurement logistics stands out as one of the basic sectors in a logistics company. The other sectors in a company depend on procurement as it can cause downtime and delays that affect the entire company. In addition to the impact on the company itself, procurement can also have an impact on end-users, given that efficient procurement is one of the factors of competitiveness. One of the basic tasks of procurement logistics is the selection of suppliers. For this reason, the aim of this paper was to propose approaches based on AHP-QFD and ANP-QFD methodology in order to select suppliers. On that occasion, the evaluation of three suppliers was performed by applying eight criteria (price, product quality, on-time delivery, location, communication, reliability, flexibility, and reputation). The results of the application of the described methodologies also showed a different ranking of suppliers depending on the chosen methodology.

Keywords: procurement logistics, supplier selection, AHP, ANP, QFD.

1. Introduction

Supplier selection directly affects the efficiency of all processes in the field of procurement, production, distribution, and delivery of products. In addition, the supplier selection has an impact on the efficiency of the entire supply chain, given that cooperation with adequate suppliers can result in reduced costs but also reduced time required for delivery of raw materials (products). The importance of managing the procurement process is shown by the fact that procurement costs can be up to 70% of the costs of the final product (Bottani *et al.*, 2018). Also, in industrial companies, the share of procurement in the total turnover ranges from 50-90% (Taghizadeh

and Ershadi, 2013). Based on this, it can be concluded that significant procurement can achieve significant savings and can affect the company's profitability. For this reason, the issue of supplier selection has been recognized both in the literature and in practice, where more and more attention is being paid to this process.

As the issue of choosing an adequate supplier is very complex, multi-criteria decision-making (MCDM) methods are often being used in the literature to solve this problem. Another reason for the implementation of these methods is that when choosing a supplier, it is necessary to consider several criteria at the same time. Given that the issue of supplier selection is so complex, one of

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the most commonly MCDM methods used on this occasion is the Analytic Hierarchy Process (AHP). The reason for this is the fact that when applying this method, the problem can be broken down into a hierarchical structure. In addition to AHP, the Analytic Network Process (ANP) method is often used, which is an upgrade to AHP, since it also observes the interrelationships between elements at different hierarchical levels, while AHP observes only the interrelationships between elements in relation to a hierarchically higher level. Precisely for these reasons, a methodology based on the mentioned methods together with the quality function deployment (QFD) method was applied in this paper. The QFD method was used in this paper to obtain the weights of the criteria which were then used to obtain the final supplier rank. In addition to AHP and ANP, TOPSIS, DEA, ELECTRE, and other methods are used to select suppliers.

The paper is organized as follows. In addition to the introduction, the second chapter describes the problem and provides a review of the literature on the application of the methods used in this paper. The third chapter describes the methodology of the paper, while the fourth chapter presents the results of the research and the application of the described methodology. Also, within this chapter, the criteria used for evaluating suppliers in this paper are defined. Finally, concluding remarks are given as well as directions for future research.

2. Problem Description and Literature Review

Interruption of the production process or unsatisfied demand can have major consequences for the company's profitability.

For this reason, it is necessary to choose a supplier who can support the existing demand but also who can provide the necessary flexibility in the event of sudden changes in demand. Non-compliance with the delivery deadline by the supplier directly affects the delay in delivery and the dissatisfaction of end-users. In practice, the process of procurement and selection of suppliers is often done through tenders. However, in order for companies to differentiate between different suppliers, it is necessary to use certain tools. In addition to business indicators (such as financial stability, business in previous years, experience, etc.), it is possible to apply some of the MCDM methods. The aim of this paper is to propose a methodology based on AHP-QFD and ANP-QFD approaches that can be used and assist in the supplier selection process.

A review of the literature revealed that there are numerous approaches (techniques) that can be used alone or in combination with others in order to select suppliers such as AHP, ANP, QFD and other MCDM methods in classic and fuzzy form. Although the application of MCDM methods independently in order to select suppliers is more popular in the literature, there are a large number of papers that have implemented a combination of methods. The reason for this lies in the fact that the use of a combination of methods allows the consideration of multiple aspects that can be considered simultaneously when evaluating alternatives (in this case suppliers), including quantitative and qualitative factors. The application of a combination of methods also enables the selection of the optimal supplier in terms of various aspects such as cost, quality, delivery, flexibility, reliability, etc. (Bottani *et al.*, 2018). Bevilacqua *et al.* (2006)

presented the first example of the application of the QFD method for supplier selection. In their approach, they first identified the characteristics that the product should have (WHATs) to meet the company's needs and then determined the supplier evaluation criteria (HOWs) in order to perform the final supplier ranking. A review of the literature showed that the QFD method is often combined with MCDM methods. The application of the QFD method with AHP and ANP methods is particularly suitable for decision-makers (Rajesh and Malliga, 2013). Bhattacharya *et al.* (2010) applied the fuzzy QFD methodology for supplier selection in their paper, combining it with the AHP method to determine the cost of the supplier selection process using a specific cost factor measure (CFM). In the papers (Rajesh and Malliga, 2013; Dai and Blackhurst, 2012) the AHP-QFD methodology for supplier selection was applied. Ho *et al.* (2011) developed a three-phase AHP-QFD approach to increase decision-making efficiency. The goal of this approach was to identify stakeholders and then identify the best suppliers. Scott *et al.* (2015) developed an AHP-QFD approach for supplier selection and order allocation. An integrated approach based on AHP and QFD methods was developed by Dai and Blackhurst (2012), which consists of four steps (phases), connecting customer requirements with the company's strategy, determining sustainable purchasing competitive priority, determining sustainable selection criteria and ranking suppliers. Polat *et al.* (2017) presented an integrated fuzzy approach for supplier selection combining fuzzy AHP and fuzzy TOPSIS methods. In the presented methodology, the fuzzy AHP was used to analyze the structure of the supplier selection problem and to determine the weighting coefficients of the criteria

while the fuzzy TOPSIS method was used to rank the suppliers. In the papers (Shaw *et al.*, 2012; Shaw *et al.*, 2013), the authors proposed a method based on fuzzy AHP and fuzzy multi-objective programming to select suppliers in the supply chain taking into account carbon emissions.

In addition to the AHP-QFD, a combination of ANP-QFD methods is often used in the literature for supplier selection. In the paper (Wu *et al.*, 2013), they applied ANP in combination with fuzzy Delphi-TOPSIS methods to select the optimal supplier. The fuzzy Delphi method was used to select the evaluation criteria. Given the correlation of the selected criteria with each other, the ANP method was used to determine their weights. Finally, the TOPSIS method was used to rank alternatives. Galankashi *et al.* (2015) applied the nominal group technique (NGT) used to determine the most critical KPIs. After that, a fuzzy ANP was applied to determine the weights of the criteria for selecting a green supplier. Palanisamy and Zubar (2013) applied a combination of fuzzy QFD and ANP in their paper to perform supplier (seller) ranking. Namely, the fuzzy QFD method was first used to reduce the number of potential suppliers and to convert linguistic statements into quantitative values, after which the ANP method was applied to rank the selected suppliers. Bottani *et al.* (2018) in their paper developed the ANP-QFD method for supplier selection taking into account the BOCR (Benefits, Opportunities, Costs and Risks) model. Taghizadeh and Ershadi (2013) applied the ANP-QFD methodology for supplier selection for strategic items, leverage items and average items. By applying the mentioned methodology, they came to the conclusion that quality is the most important selection criterion.

Based on the review of relevant literature and scientific approaches used in solving this very important and current issue, the authors decided to apply AHP-QFD and ANP-QFD methodology, which is presented in the next section.

3. AHP-QFD and ANP-QFD Methodology

AHP-QFD and ANP-QFD methodology contains the following steps: identification of requirements (WHATs), determination of supplier attributes (HOWs), determination of WHATs weights using AHP method, the formation of relationship matrix, calculation of HOWs weights, evaluation of suppliers using AHP and supplier ranking. The described methodology is shown in Figure 1. The identification of requirements as well as the determination of supplier attributes was performed using a QFD matrix. House of Quality (HoQ) differs from the standard in this methodology, as here the company determines what it takes for the product/service to have in order to meet certain requirements of the company and then identifies the supplier's attributes that have the greatest impact on the achievement of set goals. In order to perform the evaluation within the relationship matrix, it was necessary to determine the weights of requirements (WHATs), which was done in this paper using AHP/ANP methods (using Saaty's scale). After that, the formation of the relationship matrix and calculation of weights of the supplier attributes (HOWs) was done. Determined criterion weights were then used in the AHP and ANP models to perform supplier evaluation and ranking.

In the literature, the AHP method is mainly used for decision-making that depends on

several factors, and when it is possible to differentiate the decision-making process into a hierarchical structure (Owida *et al.*, 2010). This is especially applied when choosing a supplier or a provider. Also, due to its nature, AHP allows the breakdown of complex problems into smaller levels (thanks to the hierarchical structure of the model). As the supplier selection process is a complex process, the authors considered that the application of the AHP method is the most suitable and for that reason, it is applied in this paper.

The ANP method is a more advanced version of the AHP method that is based on the network structure and more precisely defines the relationships within complex models as well as the interdependence of the criteria themselves. This method, which contains a feedback structure, enables network definition of problems, differing from the AHP method because it does not represent a linear hierarchy but examines the influences between network elements (compared to the AHP method where the comparison is made according to hierarchically higher levels). The ANP-QFD methodology is identical to the previously described AHP-QFD, where the difference is only reflected in the model. The combination of ANP-QFD methods was used in this paper to compare the results obtained using these methods with the results obtained using AHP and QFD methods. Also, another reason for application is to determine whether there will be a difference in the results when the interrelationships of the elements at different hierarchical levels are taken into account (which is the main difference of the ANP method in relation to AHP).

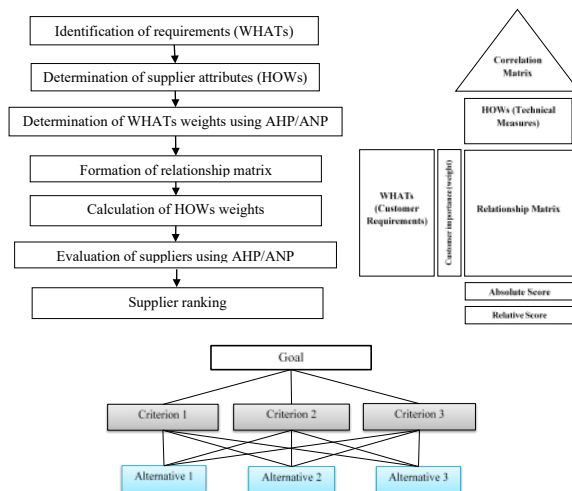


Fig. 1.
Methodology

4. Results

The developed methodology was tested and applied to a specific example of supplier selection by procurement logistics in a trading company operating in the Serbian market. The task was to select the most favorable of the three potential suppliers, having in mind the real requirements in the process of supplying the company and the key criteria for selecting suppliers. The research and selection of suppliers were based on the expert assessment of 10 managers with many years of experience in product procurement. In this paper, an affordable product, an adequate quality of the product, and timely delivery were considered as company requirements (WHATs in HoQ), while price, product quality, on-time delivery, location, communication, reliability, flexibility, and reputation were observed as attributes of suppliers (HOWs). In the next part of the paper, the results obtained

through the basic phases and steps of the research are presented, according to the described methodology.

4.1. Results of AHP-QFD Methodology Application

As already mentioned, an affordable product, adequate quality of the product and timely delivery were observed as company requirements (WHATs). In order to determine the weights of these requirements, the Saaty scale was used, which is used when applying the AHP method. Based on conversations with experts in the field of procurement, it was determined that an affordable product is the most important requirement. For this reason, it was estimated that this requirement is moderately dominant in relation to an adequate quality of the product (and for that reason, a value of 3 was assigned), Table 1. In relation to timely delivery, this

requirement is very strongly dominant (and for that reason, a value of 7 has been assigned). As the second requirement in terms of significance, adequate quality of

product stood out, which when compared to timely delivery has a strong to very strong dominance, and for that reason, a value of 6 was assigned.

Table 1
Requirements Weights

Requirement	Affordable Product	Adequate Quality of the Product	Timely Delivery		
Affordable Product	1	3	7		
Adequate Quality of the Product	0.33	1	6		
Timely Delivery	0.14	0.17	1		
Sum	1.47	4.17	14		
	Normalized Matrix			Sum	Priority Vector
Affordable Product	0.68	0.72	0.50	1.90	0.63
Adequate Quality of the Product	0.22	0.24	0.43	0.89	0.30
Timely Delivery	0.10	0.04	0.07	0.21	0.07
Sum	1.00	1.00	1.00	3.00	

After determining the weights of the requirements, which will then be used in the QFD matrix, the next step was the formation of the matrix within HoQ, Table 2. Given that the price of the product, as well as the quality, directly affect whether the product will be affordable, a strong relationship was estimated (9). On-time delivery and reputation can also have an impact on the affordability of a product, but this impact is not as pronounced and for this reason, the medium strong relationship was estimated (3). The location has a weaker impact in the following way, the closer the supplier's

location is to the distribution center (DC) of the trader, the lower the price will be (since the transport distance is shorter), and for that reason, a weak relationship was estimated (1). On the other hand, the price and quality of the product directly affect the adequacy of the quality of the product being procured, and for that reason, a strong relationship has been estimated (9). Adequate quality of the product is also influenced by communication (better communication results in a better product), reliability (if the supplier is reliable in the past, it is more likely that it will remain so) and flexibility (primarily

reflected in the ability to adapt to customer requirements). These are the reasons why a medium strong relationship was estimated (3). In addition, reputation can also have an impact on the adequate quality of the product (stronger brands usually have better quality products, although not necessarily) which is why a weak relationship was estimated (1). Finally, when timely delivery is observed, it

can be concluded that this request is most influenced by on-time delivery, location, communication (refers to determining time window for receipt and unloading) and flexibility, and for these reasons, a strong relationship was estimated (9). In addition, this requirement is also influenced by quality and reliability, where the medium strong relationship was estimated (3).

Table 2
QFD Matrix

WHATs	Weight by AHP	HOWs								Total Weight
		Price	P. quality	On-time Delivery	Location	Communication	Reliability	Flexibility	Reputation	
Affordable Product	0.63	9 5.67	9 5.67	3 1.89	1 0.63				3 1.89	15.75
Adequate Quality of the Product	0.30	9 2.7	9 2.7			3 0.9	3 0.9	3 0.9	1 0.30	8.4
Timely Delivery	0.07		3 0.21	9 0.63	9 0.63	9 0.63	3 0.21	9 0.63		2.94
Total Weight		8.37	8.58	2.52	1.26	1.53	1.11	1.53	2.19	27.09
Relative Weight		0.31	0.32	0.09	0.05	0.06	0.04	0.06	0.08	

Based on the presented Table 2, it can be concluded that the three most important attributes of suppliers were product quality, price and on-time delivery. After determining the weights of the attributes using the QFD method, the analysis of suppliers was carried out which were then observed as alternatives in AHP and ANP methods. Based on the data of one trading company, 3 suppliers were evaluated according to 8 observed criteria. The selection of criteria was made

on the basis of a literature review and on the basis of interviews with experts in the field of procurement logistics. Of the potential 12 criteria presented to the experts, based on their evaluation and literature review (number of papers in which these criteria were used), 8 key ones were defined which were then considered and used in the supplier evaluation process: price, product quality, on-time delivery, location, communication, reliability, flexibility, and reputation (Table 3).

Table 3
Supplier Selection Criteria

Criterion	Description	Reference
Price	Unit price, payment terms and discounts that can be granted (when it comes to a larger quantity) where considered under this criterion	Watt <i>et al.</i> (2010); Bansal <i>et al.</i> (2013); Akman and Baynal (2014); Jothimani and Sarmah (2014); Hwang <i>et al.</i> (2016)
Product Quality	Quality level implies the ability of the supplier to meet the required level of quality related to the quality of products, production, packaging, etc.	Jharkharia and Shankar (2007); Hsu and Hu (2009); Kumar <i>et al.</i> (2012); Jothimani and Sarmah (2014); Hwang <i>et al.</i> (2016); Suraraksa and Shin (2019)
On-time Delivery	On-time delivery represents delivery that has been made by the agreed time and in full (right goods, at the right time at the right place)	Ustun and Demirtas (2008); Hruška <i>et al.</i> (2014); Ozbek (2015); Hwang <i>et al.</i> (2016)
Location	The distance of the supplier from the DC of the retailer as well as the geographical coverage of Serbia in terms of delivery possibilities were observed within the location criteria	Sarkar and Mohapatra (2006); Daim <i>et al.</i> (2012); Kumar and Singh (2012)
Communication	Real-time information sharing and quality communication can lead to savings in both time and cost	Sarkar and Mohapatra (2006); Uygun (2013); Ozbek (2015); Suraraksa and Shin (2019)
Reliability	Supplier reliability is primarily reflected in financial stability, business history in previous years and revenue generated in the previous year	Jamil <i>et al.</i> (2013); Hruška <i>et al.</i> (2014); Suraraksa and Shin (2019)
Flexibility	The ability of the supplier to adapt to changes in demand as well as the ability to adapt to sudden changes in terms of delivery time	Jamil <i>et al.</i> (2013); Uygun (2013); Suraraksa and Shin (2019)
Reputation	The reputation of the brand and reputation of the supplier on the market (observed in relation to the realized sales in the last year)	Watt <i>et al.</i> (2010); Kilic (2013); Akman and Baynal (2014); Ozbek (2015)

The evaluation of suppliers was performed using a scale of 1-3, where the value of 1 represents the worst result according to criteria while the value of 3 represents the best result, Table 4.

Table 4
Evaluation of Suppliers according to Criteria

Criterion	Supplier 1 (V1)	Supplier 2 (V2)	Supplier 3 (V3)
Price (C1)	1	2	3
Product Quality (C2)	2	1	3
On-time Delivery (C3)	1	3	2
Location (C4)	2	1	3
Communication (C5)	3	2	1
Reliability (C6)	3	2	1
Flexibility (C7)	2	3	1
Reputation (C8)	3	2	1

The evaluation of suppliers according to criteria was done based on the following. In terms of price, supplier 1 is the worst since

it is not able to provide as many discounts as the other two suppliers and is therefore rated the worst (1). When looking at product

quality then it can be concluded that the supplier in terms of quality is between the other two suppliers and for this reason is rated 2 according to this criterion. Service level for the previous 8 months was observed when estimating on-time delivery and as it was 83.95% in the case of this supplier compared to other suppliers is the worst result and therefore rated the worst (1). When estimating the location, the distance between the DC of the retailer and the supplier's location was observed, which in the case of the first supplier is 95 km. In terms of communication, reliability and reputation, this supplier is better compared to other suppliers, which is why it is rated with 3. When it comes to flexibility, this supplier is rated with 2 since it is better than supplier 3 and worse than supplier 2 (Table 4).

In terms of price, the second supplier is between the other two suppliers. When the level of quality is observed, then this supplier is the worst and for that reason, it was evaluated with 1. The service level of this supplier was 101.26% which is also the best result according to this criterion. In terms of location, this supplier is the furthest from the

DC of the retailer (182 km) and is therefore rated the worst (1). According to the criteria of communication, reliability and reputation, this supplier is between the other two and is therefore rated with 2. From the aspect of flexibility, this supplier is best rated as it is the most flexible in terms of adapting to customer requirements (Table 4).

In terms of price, the third supplier is the best as it can provide significant discounts on a larger quantity of requested products. The same situation is in terms of product quality, where this supplier can deliver the highest level of quality. The service level of this supplier was 87.49% which is why it is rated with 2. In terms of location, this supplier is the closest to the DC (32 km), which is why it is rated with 3 according to this criterion. In terms of communication, reliability, flexibility and reputation, this supplier is the worst compared to the other two suppliers (Table 4).

The data in Table 4 were then used in the AHP model to evaluate each supplier. The layout of the AHP model used in this paper is shown in Figure 2.

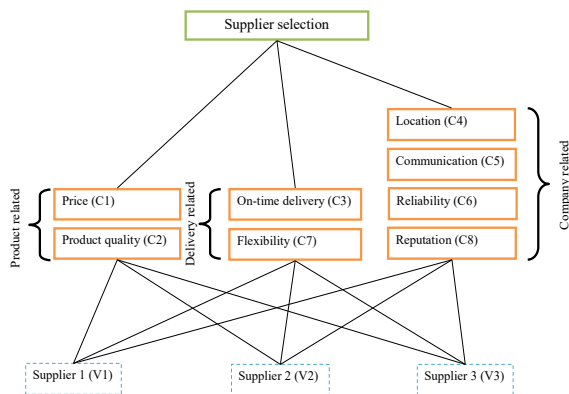


Fig. 2.
AHP Model

SuperDecisions software was used to calculate the results using the AHP and ANP methods. After entering the input data into this software, an unweighted supermatrix shown in Table 5 was obtained.

Table 5
Unweighted AHP Supermatrix

		Goal	Criteria								Alternatives		
		Goal	C1	C2	C3	C4	C5	C6	C7	C8	V1	V2	V3
Goal	1GoalNode	0	0	0	0	0	0	0	0	0	0	0	0
Criteria	Price	0.125	0	0	0	0	0	0	0	0	0	0	0
	Product Quality	0.125	0	0	0	0	0	0	0	0	0	0	0
	On-time Delivery	0.125	0	0	0	0	0	0	0	0	0	0	0
	Location	0.125	0	0	0	0	0	0	0	0	0	0	0
	Communication	0.125	0	0	0	0	0	0	0	0	0	0	0
	Reliability	0.125	0	0	0	0	0	0	0	0	0	0	0
	Flexibility	0.125	0	0	0	0	0	0	0	0	0	0	0
Reputation	0.125	0	0	0	0	0	0	0	0	0	0	0	
Alternatives	Supplier1	0	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0	0	0
	Supplier2	0	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0	0	0
	Supplier3	0	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0	0	0

Then the evaluation of attributes in relation to the goal and alternatives in relation to attributes was performed. During the evaluation, the condition of the AHP method which refers to

the inconsistency index was fulfilled considering that the value of CR was 0.09739 which is less than 10%. After evaluation, the weighted supermatrix shown in Table 6 was obtained.

Table 6
Weighted AHP Supermatrix

		Goal	Criteria								Alternatives		
		Goal	C1	C2	C3	C4	C5	C6	C7	C8	V1	V2	V3
Goal	GoalNode	0	0	0	0	0	0	0	0	0	0	0	0
Criteria	C1	0.334	0	0	0	0	0	0	0	0	0	0	0
	C2	0.287	0	0	0	0	0	0	0	0	0	0	0
	C3	0.159	0	0	0	0	0	0	0	0	0	0	0
	C4	0.024	0	0	0	0	0	0	0	0	0	0	0
	C5	0.032	0	0	0	0	0	0	0	0	0	0	0
	C6	0.081	0	0	0	0	0	0	0	0	0	0	0
	C7	0.050	0	0	0	0	0	0	0	0	0	0	0
	C8	0.033	0	0	0	0	0	0	0	0	0	0	0
Alternatives	V1	0	0.17	0.33	0.17	0.33	0.50	0.50	0.33	0.50	0	0	0
	V2	0	0.33	0.16	0.50	0.17	0.33	0.33	0.50	0.33	0	0	0
	V3	0	0.50	0.50	0.33	0.50	0.17	0.17	0.17	0.17	0	0	0

In order to obtain the final supplier rank, based on Table 6, the values of the alternatives by attributes were extracted and then

multiplied by the values (relative weights) of the attributes obtained using the QFD method, which is shown in equation (1) below.

$$\begin{pmatrix} 0,167 & 0,333 & 0,167 & 0,333 & 0,500 & 0,500 & 0,333 & 0,500 \\ 0,333 & 0,167 & 0,500 & 0,167 & 0,333 & 0,333 & 0,500 & 0,333 \\ 0,500 & 0,500 & 0,333 & 0,500 & 0,167 & 0,167 & 0,167 & 0,167 \end{pmatrix} \times \begin{pmatrix} 0,31 \\ 0,32 \\ 0,09 \\ 0,05 \\ 0,06 \\ 0,04 \\ 0,06 \\ 0,08 \end{pmatrix} = \begin{pmatrix} 0,29999 \\ 0,29996 \\ 0,41005 \end{pmatrix} \tag{1}$$

Based on these results, it can be concluded that according to the applied AHP-QFD methodology, the final supplier rank is as follows: S3>S1>S2. So according to this methodology, the supplier S3 achieved the best results and it should be chosen.

4.2. Results of ANP-QFD Methodology Application

ANP-QFD methodology is identical to the AHP-QFD methodology, so the input data used in the AHP method is now used in the ANP method. The only difference between these methodologies is reflected in the model since the ANP model considers

the interrelationship of criteria and alternatives.

In addition to the evaluation of the alternatives in relation to the attributes (with the AHP method), the ANP method also evaluated the attributes in relation to the alternatives. After the evaluation and application of the ANP method, a weighted supermatrix was obtained. On that occasion, the condition regarding the coefficient of inconsistency was met since it did not exceed 0.1 and was 0.09738; 0.09963 and 0.09769 when attributes were compared to alternatives. The values of the weighted supermatrix are shown in Table 7.

Table 7
Weighted ANP Supermatrix

		Criteria								Alternatives		
		C1	C2	C3	C4	C5	C6	C7	C8	V1	V2	V3
Criteria	Price	0	0	0	0	0	0	0	0	0.40	0.37	0.33
	Product quality	0	0	0	0	0	0	0	0	0.25	0.27	0.29
	On-time Delivery	0	0	0	0	0	0	0	0	0.15	0.15	0.16
	Location	0	0	0	0	0	0	0	0	0.02	0.02	0.03
	Communication	0	0	0	0	0	0	0	0	0.03	0.03	0.03
	Reliability	0	0	0	0	0	0	0	0	0.07	0.07	0.08
	Flexibility	0	0	0	0	0	0	0	0	0.05	0.06	0.06
Reputation	0	0	0	0	0	0	0	0	0.03	0.03	0.02	
Alternatives	Supplier1	0.17	0.33	0.17	0.33	0.50	0.50	0.33	0.50	0	0	0
	Supplier2	0.33	0.17	0.50	0.17	0.33	0.33	0.50	0.33	0	0	0
	Supplier3	0.50	0.50	0.33	0.50	0.17	0.17	0.17	0.17	0	0	0

In order to obtain the final ranking of suppliers, as in the case of applying the AHP-QFD methodology, the values of alternatives in accordance to attributes were extracted

from Table 7, which were then multiplied by the values (relative weight) of attributes obtained using the QFD method, as shown in equation (2) below.

$$\begin{pmatrix} 0,40 & 0,25 & 0,15 & 0,02 & 0,03 & 0,07 & 0,05 & 0,03 \\ 0,37 & 0,27 & 0,15 & 0,02 & 0,03 & 0,07 & 0,06 & 0,03 \\ 0,33 & 0,29 & 0,16 & 0,03 & 0,03 & 0,08 & 0,06 & 0,02 \end{pmatrix} \times \begin{pmatrix} 0,31 \\ 0,32 \\ 0,09 \\ 0,05 \\ 0,06 \\ 0,04 \\ 0,06 \\ 0,08 \end{pmatrix} = \begin{pmatrix} 0,2285 \\ 0,2262 \\ 0,2212 \end{pmatrix} \quad (2)$$

Based on these results, it can be concluded that according to the applied ANP-QFD methodology, the final rank of the suppliers is as follows: S1>S2>S3. So, according to this methodology, unlike the AHP-QFD methodology, supplier S1 achieved the best results and it should be chosen. Based on these results, it can be concluded that when considering the interrelationships between attributes and alternatives, there was a change in the final rank of the supplier.

5. Conclusion

The issue of supplier selection is one of the basic ones in procurement logistics. Also, this issue is recognized both in the literature and in practice. The reason for this lies in the fact that the process of selecting suppliers can have a significant impact on a number of other activities in one company. This primarily refers to achieving savings, increasing efficiency, increasing flexibility, meeting user requirements, etc. For this reason, companies are paying more and more attention to the supplier selection process. In order to differentiate between certain suppliers, companies observe the issue of supplier selection from the aspect of several criteria, given that this process

is very complex. On that occasion, in order to facilitate the decision-makers, it is often suggested to implement some of the methods of MCDM.

The aim of this paper was to propose one such methodology which, in addition to the method of multi-criteria decision-making, also relies on the QFD method, as one of the quality methods. In addition to AHP-QFD, the ANP-QFD methodology was applied in this paper to determine whether there is a difference in the final supplier rank. Three suppliers were analyzed using 8 criteria: price, product quality, on-time delivery, location, communication, reliability, flexibility, and reputation. Using the AHP-QFD methodology, it was obtained that supplier S3 proved to be the best, while the application of the ANP-QFD methodology showed that supplier S1 proved to be the best solution. Based on these results, it can be concluded that the supplier selection process is a significant and complex issue that needs to be considered from several aspects. The application of the described methodology in order to determine from which DC it is necessary to ship goods stands out as one of the directions of future research. In addition, the development and application of other

methods in order to select suppliers whose results would be compared with the results of this research is also one of the directions of future research.

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