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Development of Criteria of Selecting the Supplier by Using the Fuzzy DEMATEL Method

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Abstract

Selection of the suppliers shall always be considered by managers because the suppliers can have very positive or very harmful and negative impacts on the general performance of an organization. Thus, in this research, firstly, 43 important criteria were recognized in selecting the suppliers through library studies which included Persian and English texts and also through reviewing various articles associated with this issue. Then a number of 14 criteria was confirmed by using fuzzy Delphi method and were turned into the DEMATEL questionnaire and it was distributed among 11 of the experts and members of the universities. The information of the questionnaire were turned to fuzzy and the CFCS algorithm was written in codes by using MATLAB software and by using the fuzzy DEMATEL method, it has been attempted to review the relationships between indexes and the rate that the criteria of selecting suppliers are influential and influenced. Ultimately, the research results show that the financial stability index has had the highest impact on the execution of the project of reviewing the relationship associated with the optimal selection of the suppliers of the universities of Yazd according to the opinion of experts, specialists and, CFCS algorithm and fuzzy DEMATEL technique.

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1. Introduction

In current world, the change rate of information and knowledge is so that large organizations are going out of the competition quickly, and this has been led to find a solution for this problem. One of the ways to save these companies is outsourcing and downsizing of organizations so that they can change quickly. Manufacturing companies are trying to reduce the costs and increase the efficiency in the competitive market and stabilize and improve their position with high focus on activities considered as an advantage compared to their competitors through correct outsourcing of manufacturing activities that are not among the core competencies of organization (Ahmadi Dastjerdi and Shahande, 2012). When an organization outsources some part of its activities and assigns them to suppliers, it depends largely on them and it can be said that organization performance will be dependent on its suppliers in such case. As wrong decision in this selection will have irreparable consequences for organization, evaluation, management, and selection of the best supplier among the potential suppliers seem to be necessary. Some companies and organizations use the lowest cost criterion for selection, while this criterion alone cannot ensure the quality and success of the project. In fact, criteria are factors that evaluators can use them to examine suppliers and their performance in different projects (Elahi et al., 2010). Supplier selection process is complex due to the possibility of a conflict in criteria. Many researchers have tried to help managers in taking relevant decisions by identifying the important criteria for selecting suitable suppliers. Some important criteria examined for making decisions include economic conditions, resources, strategies, risks, and quality management. According to Hafeez et al, physical assets, intellectual capital, and cultural capital are the most important criteria to select contractor. Nine criteria have been provided by Khalfan and Gough to select contractor in public and private sectors including creditability / excellence, quality, price, flexible contract, capability of adding value added, good communications, cultural and regional resources adaptability. Criteria specified by Montazer et al (2009) to select seller include six sets of variables that include price, after sale service, delivery time, flexibility of seller, quality and political factors (Kalantari and Shayan, 2011). Various methods are used for selecting the best suppliers in the outsourcing activities of an organization. Some of these methods include hierarchical analysis, network analysis process, methods based on the non-ordinal relations concept, multi-attribute utility theory, mathematical programming model, and fuzzy sets.

2. Problem statement

Although outsourcing of activities creates many opportunities for the organization, but it cannot work properly, it will face with problems. If they make a mistake in selecting suppliers and deep gap occurs between them and suppliers, internal cooperation and collaboration will be eliminated, and therefore efficiency and productivity of works will decrease. The disadvantages of outsourcing could create serious risks and problems to organization. According to what was said and outsourcing and supplier selection can have positive or negative consequences, organizations need an efficient and strong method for supplier selection. This method must consider the various benefits and risks of outsourcing and provide tools e to them so that they can make decisions by considering different criteria about outsourcing and supplier selection. However, to make decisions and evaluate suppliers, there are many criteria that they can create problems for organizations to make decision. Therefore, decision makers must identify appropriate supplier selection criteria. For example, some companies and organizations use the lowest cost criterion to select contractor in tenders, while this criterion alone cannot ensure the quality and success of the project. In fact, criteria are factors that evaluators can use these criteria to examine contractors and their performance in different projects (Elahi et al., 2010). Given that a producer needs several suppliers, they follow different and sometimes contradictory objectives such as minimizing cost, maximizing timely delivery, and increased quality. Providing all these objectives in a trial and error way is practically impossible and imposes high costs to system. Therefore, using mathematical techniques such as decision-making methods can help a lot in this regard to the decision makers. As various factors are involved in selection of suppliers of activities that university managers intend to outsource them, this research aims to find the factors that has the highest impact, so that we can help training centers in order in finding the best suppliers. Thus, according to the above-mentioned cases, we aim to answer the question that which factors have impact on outsourcing and how they affect and affected.

3. Literature review

Hushmandi Maher et al (2012) provided a mixed model of Dematel and network analysis process to consider the correlation between criteria effective in supplier selection and ranking suppliers. The results indicate criteria of cost and financing, delivery, and capabilities of information technology are the most important criteria. In a study entitled studying and prioritizing risks of outsourcing in information technology and communication projects. Bailey et al (2002) conducted a study entitled "Outsourcing in Edinburgh and Lothian". In their studying on organizations and factories in Edinburgh and Lothian region, they stated that 70% of organizations outsource activities such as maintenance, cleaning, and procurement of materials to reduce costs and improve quality.

3.1. Fuzzy Delphi method

Delphi method seeks to achieve consensus on the views of experts. In general, this method suffers from weaknesses such as high cost, long time to collect data, etc (Feizi and Dehghan Dehnavi, 2009). Fuzzy Delphi method was developed by Kaufman and Gupta in the 1980s (Cheng and Lin, 2002). Application of this method for decision-making and consensus on problems in which objectives and parameters are not explicitly specified will lead to valuable results.

3.2. Fuzzy Dematel method

Dematel is a developed method for analyzing a structural model to analyze the relationship among complex criteria. However, decision-making in a fuzzy environment for factors of complex section is very difficult (Shakerian, 2015). The present study uses fuzzy Dematel method to obtain a more accurate analysis. The theory of fuzzy introduces a concept of membership function in order to deal with various linguistic variables (Chang et al, 2011).We used CFCS algorithm in this study to evaluate the relationship between indexes. This procedure (CFCS algorithm, fuzzy data conversion to definite numbers) includes a five-step algorithm explained in the relevant section:

4. Population and sample of study

Since the goal of this study was to identify factors affecting the selection of supplier in Islamic Azad University of Yazd, to collect data, opinions of academic experts that had the following features were used: a) having a Ph.D. in the fields of management, economics and accounting b) having at least 5 years of teaching experience at Azad University.

5. Procedure

In this study, the necessary steps for research are as follows. Step 1) preparing a list of factors affecting I evaluation and selection of suppliers: based on investigation conducted from literature review of study and using various papers, 43 indices were identified that will be discussed in detail. Step 2) preparing Delphi questionnaire to identify effective factors: according to indices identified in the first step, a questionnaire based on Delphi method was developed and it was distributed among 21 academic experts. Step 3) using Fuzzy Delphi method to identify effective factors: after distribution of initial questionnaire among professors and managers, to identify the most important indices, the Fuzzy Delphi technique was used. Step 4) Preparation of Dematel questionnaire: According to a survey conducted in Step 3 and identifying indices, 14 indices were confirmed and Dematel questionnaire was developed to examine the relationship between indices and their impact. Step 5) collecting the data needed to identify the relationship between variables: a questionnaire was distributed among 21 of the statistical population (professors and academic experts). As it is time-consuming to complement this questionnaire, despite repeated follow-ups, a number of questionnaires were not completed and only 11 experts responded to the questionnaire. Step 6) data obtained was fuzzed and CFCS algorithm was then used to identify relationships between factors: In this

step, obtained data were fuzzed and considered algorithm was described. Then, using obtained data, we solved the problem using this algorithm. Then, Dematel technique was explained, and we examined and evaluated the level of relationship and intensity of this relationship among factors affecting selection supplier, based on obtained data of solving algorithm. Step 7) Conclusions and recommendations: The table below shows the extracted indices using fuzzy Delphi method.

Table 1. Effective criteria of outsourcing

Row	Criteria (indices)	Row	Criteria (indices)
1	Cost	8	Respond to customers
2	Timely delivery	9	Credibility
3	Quality	10	Good communications
4	Flexibility	11	Rate of proving service
5	Financial stability	12	Trust and confidence
6	Allocation in doing tasks	13	Security
7	Innovation	14	Performance evaluation

After identifying effective indices, to examine the relevance and effectiveness among the important criteria in the evaluation and selection of suppliers, Dematel technique was used. In this regard, a second questionnaire, Dematel questionnaire, was developed. It was redistributed among the population, and questionnaires were fuzzed (Shakerian, 2014). After we converted the numbers in the table of second questionnaire (Dematel) into fuzzy numbers, using the steps of CFCS algorithm formulated in MATLAB software environment, we examined the relationship and effectiveness of the indices. In this section, fuzzy Dematel stages and its relationships as well as coding CFCS algorithm in MATLAB software are provided.

5.1. Solving CFCS algorithm steps

CFCS method steps are as follows:

Step 1) normalization

$$xr_{ij}^{n} = \frac{\left(r_{ij}^{n} - \min \; l_{ij}^{n}\right)}{\Delta_{min}^{max}} \tag{1}$$

$$xm_{ij}^{n} = \frac{\left(m_{ij}^{n} - \min \; l_{ij}^{n}\right)}{\Delta_{min}^{max}} \tag{2}$$

$$xl_{ij}^{n} = \frac{\left(l_{ij}^{n} - \min \; l_{ij}^{n}\right)}{\Delta_{min}^{max}} \tag{3}$$

where $\Delta_{min}^{max} = \max r_{ij}^{n} - \min l_{ij*}^{n}$

$\Delta_{min}^{max} = 1$

Step 2) calculation of normalized values 1s and rs

$$xrs_{ij}^{n} = \frac{xr_{ij}^{n}}{\left(1 + xr_{ij}^{n} - xm_{ij}^{n}\right)} \tag{4}$$

$$xls_{ij}^{n} = \frac{xm_{ij}^{n}}{\left(1 + xm_{ij}^{n} - xl_{ij}^{n}\right)} \tag{5}$$

Step 3) calculation of total normalized values separately

$$x_{ij}^{n} = \frac{\left[xls_{ij}^{n}\left(1 - xls_{ij}^{n}\right) + xrs_{ij}^{n} \times xrs_{ij}^{n}\right]}{\left[1 - xls_{ij}^{n} + xrs_{ij}^{n}\right]} \tag{6}$$

Step 4) calculation of separated values

$$Z_{ij}^{n} = \min \; l_{ij}^{n} + x_{ij}^{n} \times \Delta_{min}^{max} \tag{7}$$

Step 5) merging separated values

$$Z_{ij}^{n} = \frac{1}{h\left(Z_{ij}^{1} + Z_{ij}^{2} + \cdots + Z_{ij}^{h}\right)} \tag{8}$$

8-1:CFCS algorithm coding in Matlab 2012 software

Using *CFCS algorithm* coding, we implement algorithm steps.
The final Zs table obtained from coding MATLAB in based on the table of next page.

Table 2. Final z table

C_1	0	0.6697	0.7375	0.6966	0.6697	0.5000	0.3939	0.6761	0.7488	0.5212	0.5212	0.6273	0.5943	0.6909
C_2	0.7333	0	0.7375	0.6352	0.5848	0.7545	0.5848	0.3939	0.4788	0.4788	0.5000	0.3939	0.6352	0.5212
C_3	0.7170	0.5424	0	0.6273	0.4576	0.5739	0.5212	0.6485	0.5424	0.6061	0.4576	0.5000	0.4152	0.5636
C_4	0.6061	0.5212	0.4364	0	0.4576	0.4152	0.6485	0.6485	0.7758	0.6557	0.5212	0.6909	0.5212	0.6485
C_5	0.7333	0.6061	0.6273	0.6697	0	0.8606	0.8394	0.7970	0.8193	0.7970	0.7580	0.8602	0.7758	0.7784
C_6	0.5929	0.5212	0.4152	0.5424	0.4152	0	0.5212	0.5212	0.5212	0.5848	0.5424	0.3303	0.5212	0.5636
C_7	0.3939	0.4788	0.5424	0.4788	0.5212	0.5534	0	0.5212	0.5044	0.7170	0.5424	0.3034	0.5848	0.5636
C_8	0.6273	0.5848	0.5212	0.6485	0.5636	0.7121	0.6273	0	0.3939	0.5636	0.5848	0.4576	0.4576	0.4364
C_9	0.5212	0.6697	0.3515	0.4152	0.6148	0.5000	0.5424	0.6061	0	0.5424	0.5000	0.5000	0.5424	0.5000
C_{10}	0.6148	0.5424	0.4788	0.6352	0.5000	0.6148	0.6273	0.7375	0.5424	0	0.7784	0.7333	0.7758	0.7758
C_{11}	0.6352	0.6061	0.5000	0.6352	0.5848	0.7375	0.4788	0.5424	0.5000	0.4576	0	0.6909	0.5848	0.6966
C_{12}	0.5636	0.5424	0.6273	0.5424	0.6273	0.5943	0.7121	0.5534	0.7580	0.5762	0.5424	0	0.6697	0.7989
C_{13}	0.3239	0.4364	0.5000	0.5212	0.4364	0.6273	0.4152	0.5636	0.3485	0.3727	0.6061	0.4364	0	0.5000
C_{14}	0.4788	0.5636	0.5848	0.5848	0.6909	0.4576	0.4152	0.6273	0.5212	0.5848	0.4364	0.6557	0.4152	0

After calculating the Z, now we solve Dematel technique.

5.2. Dematel method solving steps:

Step 1) Calculation of K

$$K = \frac{1}{\max_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}} \quad (9)$$

Table 3. Sum of rows table

	Calculation sum of each row		
ROW 1	8.0472		
ROW 2	7.4319		
ROW 3	7.1728		
ROW 4	7.5468		
ROW 5	9.9221	MAX	$K = \frac{1}{9.9221} = 0.10078$
ROW 6	6.5928		
ROW 7	6.7053		
ROW 8	7.1787		
ROW 9	6.8057		
ROW 10	8.3565		
ROW 11	7.6499		
ROW 12	8.018		
ROW 13	6.0877		
ROW 14	7.0163		

Step 2) calculation of S

$$S = K \times T \quad (10)$$

Table 4. Table S

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}
C_1	0	0.0675	0.0743	0.0702	0.0675	0.0504	0.0397	0.0681	0.0755	0.0525	0.0525	0.0632	0.0599	0.0696
C_2	0.0739	0	0.0743	0.0640	0.0589	0.0760	0.0589	0.0397	0.0483	0.0483	0.0504	0.0397	0.0640	0.0525
C_3	0.0723	0.0547	0	0.0632	0.0461	0.0578	0.0525	0.0654	0.0547	0.0611	0.0461	0.0504	0.0418	0.0568
C_4	0.0611	0.0525	0.0440	0	0.0461	0.0418	0.0654	0.0654	0.0782	0.0661	0.0525	0.0696	0.0525	0.0654
C_5	0.0739	0.0611	0.0632	0.0675	0	0.0867	0.0846	0.0803	0.0826	0.0803	0.0764	0.0867	0.0782	0.0784
C_6	0.0598	0.0525	0.0418	0.0547	0.0418	0	0.0525	0.0525	0.0525	0.0589	0.0547	0.0333	0.0525	0.0568
C_7	0.0397	0.0483	0.0547	0.0483	0.0525	0.0558	0	0.0525	0.0508	0.0723	0.0547	0.0306	0.0589	0.0568
C_8	0.0632	0.0589	0.0525	0.0654	0.0568	0.0718	0.0632	0	0.0397	0.0568	0.0589	0.0461	0.0461	0.0440
C_9	0.0525	0.0675	0.0354	0.0418	0.0620	0.0504	0.0547	0.0611	0	0.0547	0.0504	0.0504	0.0547	0.0504
C_{10}	0.0620	0.0547	0.0483	0.0640	0.0504	0.0620	0.0632	0.0743	0.0547	0	0.0784	0.0739	0.0782	0.0782
C_{11}	0.0640	0.0611	0.0504	0.0640	0.0589	0.0743	0.0483	0.0547	0.0504	0.0461	0	0.0696	0.0589	0.0702
C_{12}	0.0568	0.0547	0.0632	0.0456	0.0632	0.0599	0.0718	0.0558	0.0764	0.0581	0.0547	0	0.0675	0.0805
C_{13}	0.0326	0.0440	0.0504	0.0525	0.0440	0.0632	0.0418	0.0568	0.0351	0.0376	0.0611	0.0440	0	0.0504
C_{14}	0.0483	0.0568	0.0589	0.0589	0.0696	0.0461	0.0418	0.0632	0.0525	0.0589	0.0440	0.0661	0.0418	0

Step 3) calculation of M

$$M = X\,(I - X)^{-1} \tag{11}$$

Table 5. Table M

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}
C_1	0.1802	0.2374	0.2372	0.2454	0.2336	0.2350	0.2139	0.2498	0.2480	0.2282	0.2241	0.2313	0.2347	0.2559
C_2	0.2353	0.1609	0.2247	0.2267	0.2128	0.2438	0.2168	0.2108	0.2103	0.2104	0.2083	0.1969	0.2249	0.2264
C_3	0.2288	0.2086	0.1509	0.2209	0.1971	0.2224	0.2071	0.2280	0.2118	0.2172	0.2000	0.2015	0.2004	0.2248
C_4	0.2258	0.2143	0.2000	0.1685	0.2049	0.2161	0.2255	0.2356	0.2397	0.2291	0.2138	0.2268	0.2182	0.2402
C_5	0.2863	0.2687	0.2627	0.2805	0.2069	0.3076	0.2908	0.2995	0.2922	0.2901	0.2820	0.2881	0.2891	0.3038
C_6	0.2054	0.1948	0.1796	0.2014	0.1818	0.1551	0.1947	0.2045	0.1972	0.2029	0.1964	0.1745	0.1982	0.2117
C_7	0.1899	0.1923	0.1931	0.1974	0.1935	0.2110	0.1471	0.2073	0.1973	0.2171	0.1991	0.1751	0.2060	0.2142
C_8	0.2213	0.2123	0.2017	0.2232	0.2069	0.2360	0.2167	0.1671	0.1987	0.2142	0.2124	0.1981	0.2047	0.2139
C_9	0.2039	0.2118	0.1783	0.1942	0.2043	0.2085	0.2018	0.2161	0.1515	0.2040	0.1967	0.1940	0.2051	0.2104
C_{10}	0.2427	0.2313	0.2189	0.2452	0.2234	0.2512	0.2388	0.2600	0.2345	0.1826	0.2517	0.2456	0.2561	0.2688
C_{11}	0.2312	0.2233	0.2079	0.2313	0.2181	0.2473	0.2122	0.2287	0.2171	0.2133	0.1653	0.2288	0.2254	0.2471
C_{12}	0.2318	0.2252	0.2260	0.2223	0.2289	0.2425	0.2407	0.2283	0.2470	0.2316	0.2248	0.1700	0.2399	0.2643
C_{13}	0.1698	0.1751	0.1758	0.1879	0.1721	0.2028	0.1740	0.1957	0.1694	0.1726	0.1904	0.1730	0.1359	0.1930
C_{14}	0.2060	0.2087	0.2051	0.2154	0.2170	0.2107	0.1966	0.2245	0.2087	0.2140	0.1969	0.2150	0.1991	0.1695

Step 3) calculation of M

$$M = M_{IJ} \qquad I, J = 1,2, \dots, N \tag{12}$$

Table 6. sum of rows and columns of table

COL 1	3.0584	ROW 1	3.2547
COL 2	2.9647	ROW 2	3.009
COL 3	2.8619	ROW 3	2.9195
COL 4	3.0603	ROW 4	3.0585
COL 5	2.9013	ROW 5	3.9483
COL 6	3.19	ROW 6	2.6982
COL 7	2.9767	ROW 7	2.7404
COL 8	3.1559	ROW 8	2.9272
COL 9	3.0234	ROW 9	2.7806
COL 10	3.0273	ROW 10	3.3508
COL 11	2.9619	ROW 11	3.097
COL 12	2.9187	ROW 12	3.2233
COL 13	3.0377	ROW 13	2.4875
COL 14	3.244	ROW 14	2.8872

Step 5 and 6) calculation of R + D and R – D

$$D = \left[\sum_{J=1}^{N} M_{IJ}\right]_{N \times 1} \tag{13}$$

$$(R = \left[\sum_{I=1}^{N} M_{IJ}\right]_{1 \times N} \tag{14}$$

Table 7. row +column and row-column

	ROW + COL	ROW - COL
1	6.3131	0.1963
2	5.9737	0.0443
3	5.7814	0.0576
4	6.1188	-0.0018
5	6.8496	1.047
6	5.8882	-0.4918
7	5.7171	-0.2363
8	6.0831	-0.2287
9	5.804	-0.2428
10	6.3781	0.3235
11	6.0589	0.1351
12	6.142	0.3046
13	5.5252	-0.5502
14	6.1312	-0.3568

Step 7) drawing cause and effect diagram with respect to the coordinates obtained in the previous step

After calculating the final step, the following diagram is obtained. It represents the impact and effectiveness of indices (important indices in supplier selection) is in a two-dimensional space.

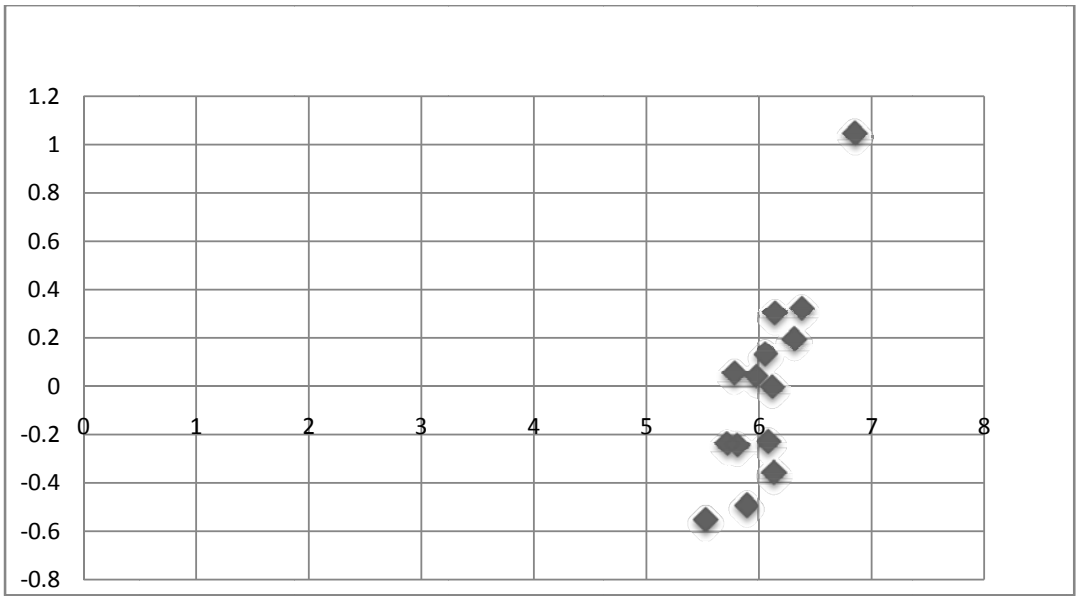

Figure1. the impact and effectiveness of indices

6. Conclusion and Recommendations

The aim of conclusion in research works is highlighting the value of research, in a way that lack of a general conclusion may reduce research work value or make it valueless. In this research, using initial questionnaire, we firstly extracted the factors influencing supplier selection. Then, we investigated the impact and effectiveness of indices using CFCS algorithm. The main objective of this study is to provide a model to examine the relationship and the impact of indices related to the selection of suppliers at Islamic Azad University of Yazd. In this study, according CFCS algorithms and fuzzy Dematel techniques and cause – effect diagrams, the role or importance of each index was determined. Financial stability index (C_5) had the most impact in implementing the project examining the optimal selection of supplier at Yazd universities, according to views of experts, fuzzy Dematel technique, and CFCS technique. Security index (C_{13}) had the lowest impact and effectiveness, while financial stability (C_5) is affected higher than other other indices in this project, and security index is less affected than other indices.

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