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A BSC method for supplier selection strategy using TOPSIS and VIKOR: A case study of part maker industry

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A B S T R A C T

In recent decades, provision-chain management has been one of the major concepts. The main reason that attracts attention to the concept is the increase in competition and struggle for the survival. There are different ways to increase the competition in organizations such as increasing productivity by acquiring information technology.
In this paper, we present an integrated model with the balanced score card framework for supplier selection strategy. The proposed model of this paper gathers 161 important factors suggested in the literature and selects the six most important ones using different multi criteria techniques. We also propose a goal programming techniques with some hard constraints and implement the mathematical model for real-world case study of auto industry. The proposed model is solved in four different forms using TOPSIS, VIKOR and the combination of these 2 factors with factor analysis. The preliminary results indicate that a combination of VIKOR and factor analysis presented better results with 9% reduction in costs, 38% increase of quality, and 3.2% increase in acceptability.

1. Introduction

Competition is a well-known concept in the present complicated world. There are some necessary factors for any product or service to survive. There are different was to increase competition such as cost reduction programs, better customer services, increase in quality of products, etc. Supply chain management (SCM), as a tool, is one of the most important techniques to join different product components in a system from the raw materials stage to final production delivery stage. A good SCM program plays an important role in product development for any organization. One of the necessary steps on having a good SCM plan is to choose appropriate suppliers (Dulmin & Mininno, 2009). There are normally different criteria involved for choosing appropriate suppliers, which make decision-making problem so complicated. On the other hand, traditional cost related items are also insufficient for decision-making problems. During the recent decade, decrease in product life cycle, globalization of product market and high celerity of technical skills development creates motivation for product promotion. Severe pressure in competition, has forced the companies to adopt strategies

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to reduce costs and time from the stages of supply chain. In such a competitive atmosphere, provision plays a crucial role. The suppliers have direct and crucial effects on costs, quality, technology and the time spent to deliver the product to the market. In this discussion, there are two significant views:
-Without any doubt, the main aspect of ordering is to establish strong relationships with some suppliers in order to reduce production costs and to maintain quality standards and to the customers.
-In decision making for ordering, there's a need for a systematic approach in which suppliers are recognized.
The main questions associated with SCM plan are to find out the order quantity and the appropriate suppliers. When the SCM plan is made we face with two types of systems of mono and multi product ordering. According to the first system, all of the suppliers pay close attention to the customer's order quantity, quality and on time delivery of goods. As a result, the only problem here is to know the best supplier. Based on the second system, the kind of service is non-obligatory, which means the supplier is not responsible for the product (price, quantity, delivery, discount, etc) and it depends on other strategies to maintain the competing market. In this paper, we present a balanced score card (BSC) (Kaplan & Norton, 1992) technique to chose appropriate supplier and implement our method for a case study of real-world problem. In BSC we consider non-financial elements along with financial figures to provide a better picture of decision making. The remaining of this paper is organized as follows. We first present the literature review in section 2. In section 3, we present the proposed model of this paper along with the details of our computations. Finally, concluding remarks are given in the last to summarize the contribution of the paper.

2. Literature Review

BSC was first developed in early 90s in Nolan Norton Institution (Kaplan & Norton, 1996). The method has been widely used in different works (Lamotte & Carter, 2000; Anderson et al., 2000; Wongrassamee et al., 2003). BSC provides comprehensive and quick insight of business to the managers. According to BSC technique, there is a fact that companies would not be able to maintain their competitive advantages by only establishing a developing objective finances. In better words, "invisible finances" or "Mental capital" would be the crucial factor for success to establish and preserve the competitive advantage (Sime & Koh, 2001, p11).
BSC includes financial criteria, which indicates previous activities' results, and also includes operational criteria associated with customer satisfaction, internal processes, creativity and learning. Such criteria are the incentives to financial functions in the future (Kaplan & Norton, 1992, p6). BSC also indicates some aspects of promotion and "invisible finances" (Sim & Koh, 2001, p8). Thus, the inefficiencies in traditional evaluating systems may be concealed by making values of "invisible finances" (Decoene & Gruggeman, 2006).
There is no doubt that the most important decisions in shopping are choosing and maintaining close relationships with a small number of trustworthy suppliers, which reduces product casts while preserving its quality after sale. Therefore, systematic approach would contribute to decision making to recognize appropriate suppliers.
The critical characteristics must be taken into account while we decide to choose a supplier (Aissaoui & et al., 2006). Chen and Lin (2004) introduced a holistic insight of literature and determined 183 characteristics for evaluating suppliers. These characteristics were classified into 8 aspects: 1) financial, 2) man source management, 3) industrial traits, 4) Knowledge management, 5) marketing, 6) compatibility, 7) product promotion and logistics management, 8) establishment and coordination of relationships (Chen & Lin, 2004). More than 50 percent of evaluations characteristic were based on two last items. Marvin et al. (2004) investigated the significance of supplier selection process in production, and looked for quality improvement in production process (Marvin et al., 2004). Razmi, et al. (2008) exploited a multi criteria decision making technique called TOPSIS and its combination with linear planning for choosing a supplier (Razmi et al., 2008). Mikhailov (2002) represented phase approach for choosing a supplier in virtual organizations (Mikhailov, 2002). He developed a technique, hierarchical analysis process (AHP), using staged data. Chen & Lin (2004) manipulated

phase decision making frame for choosing a convenient supplier (Chen & Lin, 2004). Some of the newest studies about and criteria for choosing a supplier are summarized in Table 1.

Table1
Studies and criteria used for choosing a supplier

Research and Researcher	Utilized Criteria
Wang, W. P., 2010	Quality, Performance, and Technology level, Ability to supply all the orders, Time ordering cycle, On time delivery, Ability to supply urgent orders, Precise documentation, Discounts, Price, Performance, cost reduction, financial abilities, Sale post services, Ease of communication, Ability and desire to participate in design processing, Back up and Coordination, Guarantee and warranty
Kesking et al., 2010	Equipment, Adequate staff, Safe production, Sufficient producing capacity, Evaluation and control systems, Design and improvement ability, Financial commitments, Price, Packing, Transportation, Location, Environmental effects and preventive abilities, Safety, World class Manufacturing
Sawik, 2010	Supplier capacity, Ordering cost, Price, Growth rate, Failure rate, Delay on delivery rate, Purchasing amount, Waste cost
Ustun & Demirtas (2008)	Profit (quality and services), Costs, Opportunities, Risks
Ha & Krishnan, 2008	Pleasure, Flexibility, Risk, Trust
(2010) Lam et al., 2010	Cost: Total cost, Price stability, Quality: Failure prevention cost, Evaluation activities, Quality Standards, Service: On time delivery, Technical cooperation and support, Communication and coordination, Buyer and supplier relationships: Costumers' Loyalty, Supplying guarantee, Abilities, Flexibilities and Trust, Payment Principles, Performance history, Credibility
Wu et al., 2009	Managerial, Technical, Operational, Fixed cost, Valuable cost
Liao & Kao, 2010	Quality, Price, Delivery, Services, Guarantee and warranty, Complaints handling
Guo et al., 2009	Quality, Price, Guarantee, Delivery, Catalog, After sale services, technical support, Instruction helping, Performance and Historical records, Ability in electronic commercials, Packing and Storing abilities, Reworking amount, Mutual agreements, products design, Finance and location status, Responsiveness, Operational Control, JIT capabilities, Environmental performance, Credibility, Communication systems, Production capabilities, Workforce relations, Technology and Innovation utilization
Önüt et al., 2009	Costs, Supplier's credibility and background, product's quality, Delivery, Organizational conditions, Coordination period
Hsu, C. W., & Hu, A. H., 2009	Supplying management, R&D, Management process, Quality control, System management
Wu, D., 2009	Inputs (Quality management systems and activities, Inspection, Producing process improvement, Management, R&D, Cost reduction abilities), Outputs (Quality, Price, Delivery, Price reduction performance)
Guneri et al. 2009	Credibility and Position in industry, Performance history, Conflicts solution, Delivery, Close relationships, Complaints handling
Luo et a., 2009	Managerial and technological capabilities, financial abilities, Resources available, Quality
Shen & Yu, 2009	Time cycle, Communication, Organization, Services, Quality
Lee, 2009	Opportunities (Enhancing shared opportunities and growing, technology), Risk (Supplier profile, Supplier and buyer limitations, Industry limitations), Costs (Communication and advertisement Costs, Production costs, Transportation costs), Profits (Delivery, Flexibility, Quality)

As mentioned before, in all past researches, choosing a supplier were based on restrained criteria, and therefore, it is necessary to represent a holistic model, which includes all significant aspects of choosing a supplier. In this model, BSC approach is used for such a purpose.

3. The proposed BSC model

In this paper, we first review all the existing criteria in the literature, discuss them in some brainstorming meeting, and then choose the most appropriate ones. For the literature review of our study, the following six factors have been chosen from 161 criteria for the case study of this paper, which is a major supplier of auto industry called Sapco.

1) Internal process
2) Product
3) Financial
4) Customer – market, social charge and relations with beneficiaries
5) Technology
6) Organizational, managerial and human sources.

Then, phase supposition test it used to determine the accuracy level of a hypothesis. A hypothesis may include certain or phase (stated) data. A hypothesis test creates a value in [0, 1] range, that indicates the accuracy level of a null hypothesis and alternative hypothesis (for sample data). Phase supposition test confirms H_0 hypothesis to the amount of μ, and alternative hypotheses to (1-μ). In general phase, supposition test does not intend to accept or refute a hypothesis as a whole, but to point out the accuracy level of each hypothesis. Therefore, test hypotheses were edited based on 7-item spectrum and for each of the proposed criteria. Accordingly, the criterion with a confirmation level more than 66.7 was chosen.

3.1. Evaluation of weights for indices

We need to know partial values of indexes in most of the multiple criteria decision making methods (MCDM) (Yoon & Hwang, 1981). In this study, Entropy approach was applied to evaluate the existing indexes weights. Entropy is a major concept in physics, sociology and information theory so that it indicates the amount of existent uncertainty in. informational expected content of a message (Yoon & Hwang, 1981). Criteria weights which were calculated using Entropy method are shown in Table 2.

Table 2

Final criterion for choosing Sapco supplier

View	Criteria	Confirmation Degree	Weights of Criteria
Internal Process	Supplier company's flexibility in changing the volume and date of delivery of the demanded product	0.74	0.0358
	Delay time of supplier company	0.79	0.0299
	Past performance advantage of P.C	0.73	0.0361
	The number of provided pieces by supplier	0.68	0.0319
Financial	Price Stability	0.73	0.0358
	Sale percentage of IK	0.69	0.0235
	Transportation cost of each unit	0.7	0.0279
	The situation & financial stability of the P.C	0.69	0.0357
	Non-IK sale percentage	0.74	0.0237
Product and R&D	Ability to design pieces	0.71	0.0365
	The time needed for producing new sample pieces	0.65	0.0357
	Supplier's flexibility to new requests	0.83	0.0356
	Reliability of pieces	0.79	0.0359
Information Technology	Satisfaction of users	0.69	0.0362
	Users' IT services coverage	0.71	.00761
	Information systems coverage with process	0.71	0.0362
Social, customer, and market responsibility	Pause cost	0.69	0.0221
	Level of relation and cooperation of P.C and Sapco company	0.69	0.0359
	PPM	0.71	0.0232
	IK customer's satisfaction	0.68	0.0355
	Non-IK customer satisfaction	0.74	0.0359
	Reputation of P.C	0.72	0.0359
Organizational, Managerial and Human Resource	Strategic adaptability of P.C to Sapco company	0.67	0.0358
	Organizational and managerial stability	0.69	0.0357
	Coordination History	0.78	0.0354
	Reputation of Supplier	0.71	0.0352
	Organizational Commitment	0.7	0.0359

3.2 Ranking Sapco suppliers using multi-criteria decision making methods

There are different MCDM techniques for ranking different alternatives such as AHP, VIKOR and TOPSIS. The proposed model of this paper uses VIKOR and TOPSIS for the case study of our proposed model.

3.2.1 Ranking by TOPSIS

In this method, decision matrix is normalized by Euclidean norms and then they the normalized matrix is multiplied in weight to make weight normalized vector to compute positive and/or negative ideals. Next, the distances between the choices are calculated based on Euclidean method out of positive/negative ideals, and finally, the relative closeness of each choice to the ideal solution is computed.

3.2.2 Ranking by VIKOR

In this method, we form decision making matrix, linear decaling, the best and the worst quantities. In a Q group, the choice is selected as the best if it can satisfy two conditions:
A) Let $A^{(1)}$ and $A^{(2)}$ be the first and the second best choices, respectively associated with Q and N groups. The following relationship holds,

$$Q(A^{(2)}) - Q(A^{(1)}) \geq \frac{1}{n-1}$$

B) The choice, $A^{(2)}$ must be recognized as the best choice in R or S groups.
When the first condition does not held, a set of choices are chosen as the best choices as follows:
The best choices - $A^{(1)}$, $A^{(2)}$, $A^{(M)}$
The highest quantity of M is calculated as the following,

$$Q(A^{(M)}) - Q(A^{(1)}) < \frac{1}{n-1}.$$

When the second condition does not held, $A^{(1)}$ and $A^{(2)}$ are chosen as the best choices. Table3. Shows the ranking of supplier companies based on TOPSIS and VIKOR:

Table 3
Ranking of supplier companies based on TOPSIS and VIKOR

Supplier Name	TOPSIS				VIKOR						
	d^+	d^-	CL	Rank	S	Rank	R	Rank	Q	Rank	Final Rank
Vasegh Forj	0.041	0.048	530.0	14	0.5055	16	0.0740	14	0.5908	13	13
Lola Khodro	0.041	0.052	0.559	11	0.3899	7	0.1542	24	0.3432	3	3
Peyvand Tose'e Automobile Industry	0.038	0.039	0.502	20	0.3887	6	0.0740	14	0.6861	19	19
Shayan Kav	0.043	0.041	0.486	21	0.4902	12	0.0555	5	0.6822	18	18
Electronic Power Supplyer	0.040	0.042	0.511	18	0.4385	9	0.1357	22	0.3825	6	6
Fara kloun	0.029	0.055	0.651	2	0.1977	2	0.0382	3	0.9946	24	24
Couban Mobaddel Fard Industry	0.036	0.057	0.615	4	0.5166	17	0.0740	14	0.5818	12	12
Tehran Technique	0.047	0.051	0.522	16	0.8107	24	0.0704	13	0.3573	4	4
Kosar Sanat Abzar	0.041	0.045	0.522	15	0.1308	1	0.1419	23	0.1993	1	1
Saze Pouyesh	0.025	0.057	0.698	1	0.2492	3	0.0591	6	0.8635	22	22
Tavana Nikan Ghaleb	0.058	0.034	0.369	24	0.5880	19	0.1172	21	0.3395	2	2
Sadr Paydaar Industry	0.038	0.054	0.0586	8	0.5012	13	0.0678	8	0.6206	16	16
Gharb Steel	0.032	0.056	0.637	3	0.4685	10	0.0864	18	0.5684	11	11
Sim Goon	0.047	0.048	0.505	19	0.7911	23	0.0740	14	0.3579	5	5
Shayan Clutch Industry	0.035	0.050	0.587	7	0.3803	5	0.0370	2	0.8508	21	21
Fadak Raah Ghate'e	0.039	0.049	0.558	12	0.4731	11	0.0678	8	0.6435	17	17
Automotive Parts Engineering	0.044	0.046	0.514	17	0.3130	4	0.0369	1	0.9060	23	23
Omid Ettehade Part Molding	0.037	0.048	0.568	9	0.5189	18	0.0678	8	0.6062	14	14
Gharb Arad Group of Industry	0.038	0.054	0.589	6	0.6146	20	0.0987	20	0.3966	7	7
Avam Industry	0.039	0.050	0.561	10	5020.0	14	0.0678	8	0.6200	15	15
Pars Ziba Faraz	0.049	0.040	0.448	23	0.7341	22	0.0695	12	0.420	8	8
Oskoo Azar Industry	0.045	0.043	0.484	22	0.7298	21	0.0668	7	0.4384	9	9
Toos Mahd Khodro	0.034	0.051	0.600	5	0.4066	8	0.0431	4	0.8031	20	20
Qom Milad	0.041	0.049	0.584	13	0.5025	15	0.0864	18	0.5407	10	10

According to Table 3, Saze Pouyesh company receives the highest rank based on TOPSIS technique and Kosar Sanat Abzar receives the highest rank according to VIKOR technique.

3.2.3 Supplier ranking by factor analysis composition and MCDM methods

One of the primary assumptions on our methods is that all criteria are mutually excluded. This simple assumption may not always hold. In this study, the matter of cohesion among the indexes was

excluded using factor analysis, and new independent factors were inserted in decision matrix as entries and ranking was done using multi-criterion methods.
The quantities associated with decision-making were indentified before factor analysis is implemented. In linear decaling the achieved quantities ranged between 0 & 1. This scale is linear, and makes all results equally linear; therefore, positions of the indexes and their results remain equal. The quantity of variance determined by initial variables, extractive components, and the item after rotation is shown in Table 4.

Table 4
The amount of variance, described by the factor before and after Rotation

Component	Initial Eigen values			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	12.606	43.468	43.468	12.606	43.468	43.468	11.547	39.816	39.816
2	3.020	10.415	53.883	3.020	10.415	53.883	2.747	9.472	49.288
3	2.762	9.525	63.408	2.762	9.525	63.408	2.601	8.968	58.256
4	1.790	6.171	69.579	1.790	6.171	69.579	2.501	8.623	66.879
5	1.446	4.985	74.564	1.446	4.985	74.564	1.898	6.546	73.425
6	1.246	4.298	78.862	1.246	4.298	78.862	1.577	5.437	78.862
7	.979	3.377	82.238						

According to Table 4 the information of initial Eigen values, the extraction sums of squared loadings and the rotation sums of squared loadings are reported. As we can observe, the principle component analysis (PCA) could determine six factors with 0.7862 percent of the variance (Kline, 1993). Next, we need to recognize the relative importance of new factors for ranking supplier companies. The weights of new factors (indexes) are calculated as follows,

$$W_j = \sqrt{\sum_{i=1}^{n} w_i \left(l_{ij}\right)^2}$$

where W_j is the weight of extractive factors using factor analysis and w_i is the weight of index and L_{ij} is the jth factor weight on ith index.
Having calculated W_j, the equated weight of the indexes is calculated as follows,

$$w_j' = \frac{w_j}{\sum_{j=1}^{F} w_j}$$

Factor weights make the cohesion of the factors with variables (Kline, 1993). When the factors are independent, factor weights show variable dependency on the factors as well, and it is also used as a weight to predict the variable out of the factors (Kline, 1993).
Here, the roots of factor weights are used for evaluating the amount of dependency of factor on former indexes. Factor weights accord with Table 5.

Table 5
Recognized new factor weights

Factor	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Weight	0.303	0.163	0.158	0.112	0.127	0.137

The ranks of supplier companies are re-computed by VIKOR and TOPSIS techniques. Table 6 shows the ranks of supplier companies of Sapco:

Table 6
Ranking of supplier companies based on factor analysis and multi-criterion decision techniques

Supplier Name	TOPSIS				VIKOR						
	d^+	d^-	CL	Rank	S	Rank	R	Rank	Q	Rank	Final Rank
Vasegh Forj	0.056	0.023	0.293	19	0.645	22	0.161	19	0.492	19	19
Lola Khodro	0.056	0.044	0.442	13	0.627	19	0.157	17	0.457	17	17
Peyvand Tose'e Automobile Industry	0.035	0.045	0.560	10	0.511	11	0.124	9	0.267	9	9
Shayan Kav	0.054	0.032	0.373	16	0.609	17	0.116	13	0.355	13	13
Electronic Power Supplyer	0.052	0.040	0.438	15	0.585	15	0.149	15	0.402	15	15
Fara kloun	0.023	0.090	0.797	1	0.319	1	0.124	1	0.050	1	1
Couban Mobaddel Fard Industry	0.041	0.067	0.622	6	0.477	8	0.137	8	0.258	8	8
Tehran Technique	0.069	0.023	0.253	21	0.626	18	0.267	23	0.704	23	23
Kosar Sanat Abzar	0.071	0.014	0.167	23	0.734	24	0.184	20	0.640	20	20
Saze Pouyesh	0.023	0.080	0.776	2	0.539	2	0.119	2	0.099	2	2
Tavana Nikan Ghaleb	0.049	0.029	0.368	17	0.606	16	0.134	14	0.392	14	14
Sadr Paydaar Industry	0.032	0.046	0.590	9	0.486	9	0.098	7	0.182	7	7
Gharb Steel	0.049	0.038	0.438	14	0.582	14	0.154	16	0.410	16	16
Sim Goon	0.088	0.016	0.152	24	0.716	23	0.303	24	0.881	24	24
Shayan Clutch Industry	0.042	0.037	0.471	12	0.527	12	0.136	11	0.311	11	11
Fadak Raah Ghate'e	0.026	0.057	0.689	3	0.425	4	0.101	3	0.122	3	3
Automotive Parts Engineering	0.039	0.042	0.522	11	0.509	10	0.149	12	0.319	12	12
Omid Ettehade Part Molding	0.027	0.049	0.646	4	0.432	5	0.107	5	0.145	5	5
Gharb Arad Group of Industry	0.036	0.056	0.611	8	0.445	6	0.158	10	0.270	10	10
Avam Industry	0.029	0.046	0.618	7	0.450	7	0.097	4	0.143	4	4
Pars Ziba Faraz	0.064	0.019	0.228	22	0.634	21	0.245	21	0.665	21	21
Oskoo Azar Industry	0.066	0.026	0.285	20	0.579	13	0.276	22	0.673	22	22
Toos Mahd Khodro	0.030	0.050	0.623	5	0.424	3	0.122	6	0.168	6	6
Qom Milad	0.056	0.025	0.312	18	0.627	20	0.165	18	0.482	18	18

According to the Table 6 Fara kloun company receives the highest rank based on VIKOR and TOPSIS techniques. Since there are differences between the ranking of various methods we perform Spearman test to study four methods used in this study. Table 7 summarizes the results of our Spearman test.

Table 7
Spearman's ranking interdependency coefficient for supplier companies in any of the ranking methods

			TOPSIS	VIKOR	PCA-TOPSIS	PCA-VIKOR
Spearman's rho	TOPSIS	Correlation Coefficient	1.000	-.431*	.711**	.625**
		Sig. (2-tailed)	.	.035	.000	.001
	VIKOR	Correlation Coefficient	-.431*	1.000	-.685**	-.714**
		Sig. (2-tailed)	.035	.	.000	.000
	PCA-TOPSIS	Correlation Coefficient	.711**	-.685**	1.000	.964**
		Sig. (2-tailed)	.000	.000	.	.000
	PCA-VIKOR	Correlation Coefficient	.625**	-.714**	.964**	1.000
		Sig. (2-tailed)	.001	.000	.000	.

*. Correlation is significant at the 0.05 level (2-tailed)

**. Correlation is significant at the 0.01 level (2-tailed)

The results show a close relationship in TOSIS method results with and without factor analysis. Similarly, TOSIS and VIKOR showed a high level of relationship, and their results are very similar.

3.2.4 Accumulated amount determination for allocation to each supplier (Goal programming model)

In this stage, with regard to the goals, parameters limitations, and also expressed suppositions, we propose a model to determine the amount of order allocated to each supplier.

3.2.5 Goal constraints

There are different criteria to be chosen for order allocation to suppliers. In this study, we choose the first set of goals as reducing purchase costs, which includes purchase and transportation costs and optimizing the quality of the purchased item. The second goal is "reducing the number of rejected items. Let x_{ij} and p_{ij} be the amount and the price of item i purchased from supplier j, respectively. Let a_{ij} be the expenses which is supposed to be paid for item i from supplier j. Let s_i be the advantage of supplier i. Let k, m and n be the maximum possible price, the minimum expected quality and the minimum expected utility, respectively. Therefore, we have three goal constraints as follow,

$$\sum_i \sum_j p_{ij} * x_{ij} + d^- - d^+ = k, \quad (1)$$

$$\sum_i \sum_j a_{ij} * x_{ij} + d^- - d^+ = m, \quad (2)$$

$$\sum_i \sum_j s_j * x_{ij} + d^- - d^+ = n, \quad (3)$$

where Eq. (1) to Eq. (3) are the goal constraints associated with the price, the amount of expenses and the advantage of different suppliers, respectively. The necessary input parameters of Eq. (1) to Eq. (3) are obtained from the implementation of TOPSIS and VIKOR approaches explained earlier.

3.2.6 Determining the parameters and structural limitations of the model

In addition to soft constraints given in Eq. (1) to Eq. (3) we need to consider some hard constraints. The first hard constraint is associated with demand of all products as follows,

$$\sum_j \mathrm{x_{ij}} = D_i \, . \qquad \forall_i \quad (4)$$

The second constraint is associated with the limitation on each supplier which is as follows,

$$x_{ij} \le C_{ij} \, , \quad (5)$$

where C_{ij} is the capacity of supplier j for part i.

There are normally some constraints associated with our strategic policy to maintain a minimum level of purchase from each supplier.

$$x_{ij} \ge v_j * \sum_j \mathrm{x_{ij}}, \quad (6)$$

where v_j is percentage of part i assigned to supplier j. Finally, all variable must remain nonnegative, i.e., $x_{ij} \ge 0$ and Integer $\forall_{i,j}$

3.3 The efficient results

The proposed model of this paper has been applied for the case study of our proposed model and the results using four MCDM techniques, with and without factor analysis, are summarized in Table 8.

Table 8

Results obtained from comparing model out puts to the present situation

Model 1 (using the results of TOPSIS technique)	14% reduction in cost 25% increase in quality 4% reduction in acceptability
Model 2 (using the results of VIKOR technique)	2% increase in cost 39% increase in quality 11% increase in acceptability
Model 3 (using a combination of the results of TOPSIS and factor analysis techniques)	3% reduction in cost 39.5% increase in quality 7% reduction in acceptability
Model 4 (using a combination of the results of VIKOR and factor analysis)	9% reduction in cost 38% increase in quality 3.2% increase in acceptability

Considering the results, it's clear that model 4 fulfilled all the regarded targets. The model, which is based on obtained weights of VIKOR and factor analysis methods, could reduce the costs up to 9%, and increase quality and perfection up to 38 and 3/2 percent, respectively. In general, we can conclude that the considered model is an ideal model, which can support the experts to achieve their goals.

4. Conclusion

In this paper, we have presented an integrated model with the balanced score card framework for supplier selection strategy. The proposed model of this paper has gathered 161 important factors suggested in the literature and selected the six most important ones using different multi criteria techniques. We have also proposed a goal programming techniques with some hard constraints and implemented the mathematical model for real-world case study of auto industry. The proposed model has been solved in four different forms using TOPSIS, VIKOR and the combination of these 2 factors with factor analysis. The results indicated that a combination of VIKOR and factor analysis presented better results with 9% reduction in costs, 38% increase of quality, and 3.2% increase in acceptability.

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