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ORIGINAL ARTICLE

Supplier selection in automobile industry: A mixed balanced scorecard–fuzzy AHP approach

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Abstract This study proposed an integrated Balanced Scorecard–Fuzzy Analytic Hierarchical Process (BSC–FAHP) model to select suppliers in the automotive industry. In spite of the vast amount of studies on supplier selection, the evaluation and selection of suppliers using the specific measures of the automotive industry are less investigated. In order to fill this gap, this research proposed a new BSC for supplier selection of automobile industry. Measures were gathered using a literature survey and accredited using Nominal Group Technique (NGT). Finally, a fuzzy AHP was used to select the best supplier.

1. Introduction

In today's competitive markets, companies have realized the importance of selecting proper suppliers who can supply their requirement with their desired quality and in a scheduled time. With the advent of Supply Chain Management (SCM), performance measurement can be considered as the best strategy for manufacturers to evaluate and select the best supplier to achieve supply chain surplus. Although the concepts of supplier evaluation and selection have been discussed by many researchers [1–6] only a very few attempts have been made to propose specific supplier selection frameworks for automotive industries [43]. In this context, proposing, incorporating, merging, quantifying, and deploying the exact variables and measures to proficiently and efficiently observe and assess the performance of suppliers are a confront for many practitioners, managers, and researchers [7–10]. While managers know about the importance of evaluating suppliers from different perspectives, this is less happening in the real world. This is partially due to the availability and complexity of many measures for the aim of supplier evaluation, which make the process of selecting measures very complicated and time consuming. In addition, BSCs should be fitted to the characteristics of specific industries to be efficient. However, considering specific performance measures for the supplier selection of automotive companies can be beneficial due to following reasons:

1. In real world life, managers aim to consider the most important measures for the aim of evaluating their suppliers and considering the economic issues (e.g. waste of time and human resource).

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2. Performance measures must be categorized in specific perspectives. This helps managers to assign different importance to some perspectives (e.g. assigning a higher weight to financial issues comparing to customer related concerns).
3. Mathematical models are precise tools to combine all the supplier evaluation results together and select the best one. This will be more precise when the decision maker has the option of making his/her decision in fuzzy environments.

Therefore, developing a BSC–FAHP model to evaluate the performance of different suppliers of automobile industries is the main objective of this study. By doing this, it attempts to address the following research questions:

1. How a specific framework can be proposed for the aim of choosing suppliers in automobile industries?
2. How different suppliers can be evaluated using the proposed framework?
3. How a fuzzy AHP can be used to combine the proposed framework to supplier selection process?

The scope of this study is limited to Iran's automotive industry. However, the research structure, methodology, and framework can be helpful to researchers and practitioners who are interested in evaluating and selecting suppliers for specific industries. This study contributes to proposing a new BSC framework for the aim of evaluating and selecting suppliers for manufacturers in automotive industries along with using a fuzzy AHP in order to combine all the performance measures concurrently. It introduces a new idea for the integration of specific measures used for the process of supplier selection in automotive industries when there are so many performance measures which may make the decision makers confused. From the hypothetical and methodological point of view, to the best of our knowledge, this study also contributes to offer a new approach for automotive manufacturers to select their suppliers based on the specific measures since very few researches have been conducted before. The rest of this paper is organized as follows. Section 2 is a review of recent works on supplier evaluation and selection. A summary of research methodology is discussed in Section 3. Section 4 presents the proposed BSC. Section 5 shows the supplier performance measurement and section 6 concerns the supplier selection process.

2. Literature review

2.1. Supplier selection

Since 1980s, company's procurement processes have changed from fundamental supplies and raw materials to a network of joint enterprises. Consequently, supplier selection is a significant player of the procurement process [1,2]. Basically, selecting a proper supplier is considered as a non-trivial task. To achieve this goal, the majority of the decision makers empirically choose suppliers [3,4]. Fundamentally, supplier selection is a decision procedure with the goal of decreasing the preliminary group of prospective suppliers to the ultimate choices [5–9]. Supplier selection has been discussed by many researchers within the available literature [10–14].

2.2. Performance measurement

Performance measurement is a subject which is frequently argued, but seldom described. Based on the marketing perspective, organizations attain their objectives by fulfilling their clients with superior efficiency in comparison with their competitors. Performance measurement is a fundamental approach to achieve this progress. In other words, progress will not happen except the proper metrics are created, evaluated, measured and tracked. A performance measure can be described as a metric deployed to quantify the efficiency and/or effectiveness of an action. A performance measurement system can be described as the set of metrics deployed to quantify both the efficiency and effectiveness of actions [15,44,45].

With the advent of technology and increasing market competitiveness, companies understood about the significance of assessing their performance not only based on financial perceptions, but also based on other perspectives such as customer satisfaction and innovation [46–50]. BSC framework was developed in order to assist companies to balance the financial perspectives. Financial perspectives are appropriate to explain the past occurrences which are mostly long-term categories and not appropriate for critical success [16,17]. BSC was proposed to assist managers to assess the performance of their enterprise based on financial, customer, internal business, and learning and growth perspectives.

2.3. BSC–FAHP integration

Sharma and Bhagwat [18] suggested an incorporated BSC–AHP method for supply chain assessment. This paper suggested a balanced performance assessment structure for supply chain. While offering BSC, diverse SCM performance measures were allocated into four viewpoints. Lee et al. [19] proposed a fuzzy AHP and BSC method for assessing the performance of IT department in the manufacturing business of Taiwan. The BSC idea was used to identify the hierarchy with four major perspectives and performance. A FAHP approach was then developed to tolerate vagueness and ambiguity of information.

Cebeci [20] offered a method to choose an appropriate ERP system for textile industry. The developed methodology provides suggestion prior to ERP selection. The criteria were concluded and subsequently compared in relation to their significance. Wu et al. [6] suggested a fuzzy MCDM method for assessing banking performance based on BSC. The research developed a Fuzzy Multiple Criteria Decision Making (FMCDM) method for banking performance assessment. Considering the four perspectives of a BSC, this study first reviewed the assessment indexes created from the literature connecting to banking performance. Then, for viewing these indexes, 23 indexes proper for banking performance assessment were chosen through expert questionnaires. In a similar study, Tseng [21] developed four BSC aspects and 22 criteria for a private university of science and technology in Taiwan.

Yüksel and Dağdeviren [22] did a case study analysis for a manufacturing firm using the FANP–BSC. This research revealed that BSC framework can be merged with fuzzy ANP method. Wang et al. [23] used a non-additive fuzzy set function and algorithm method to solve the BSC, hard to count and cause-and-effect relationship between different perspectives. This research facilitated investigators and administrators to appreciate the interface of features will affect the performance assessment results. Research by Chang et al. [24] used the BSC in constructing a framework of wealth management (WM). The suggested model helped the banking sector in evaluating the organizational performance of WM banks, making it extremely appropriate for bank administrators. Bentes et al. [25] incorporated BSC and AHP for the goal of multidimensional evaluation of organizational performance. This research showed that the BSC and AHP can be integrated for the aim of performance measurement.

Briefly, an efficient supplier selection framework to propose specific measures of automotive industries has not been developed. Besides, there are so many performance measures in the literature which make the supplier selection task confusing and expensive. A fit supplier selection framework is needed to use a specific performance measurement approach for the aim of evaluating suppliers. Trying to fill the gap in the literature, this study proposed an integrated BSC–FAHP model for evaluating and selecting suppliers by considering the characteristics of automotive industries, in order to assist managers and researchers to efficiently handle their supplier selection decision.

3. Research methodology

A literature review was conducted and an initial list of measures was gathered (see Table 1). The output of this phase was an initial list of measures proper to be used for supplier selection. Next, using NGT, a new BSC was proposed for the aim of assessing suppliers in the automotive industry. Following, a group of managers, researchers and practitioners with more than 10 years of working experience were asked to finalize the metrics of new BSC. Afterward, the proposed BSC was used to assist a manufacturing company to select its supplier. To achieve this goal, measures of BSC were used to assess the performance of each supplier and the results were used for the next step. Subsequently, a fuzzy AHP was applied to select the best supplier. The justification of using FAHP was its ability to consider different perspectives of BSC simultaneously.

4. Proposed BSC

Using literature survey and NGT, a new BSC was proposed for the aim of assessing suppliers in the automotive industry. A group of managers, researchers and practitioners with more than 10 years experience in this industry were asked to propose the new BSC. Table 2 shows the proposed BSC.

5. Suppliers performance measurement

The proposed BSC was used to assist a manufacturing company to select its supplier from a pool of suppliers including three national and one foreign supplier. Fig. 1 presents the supplier performance evaluation by applying the proposed BSC. The result is divided into four different sections showing BSC's perspective. Quantities shown at the top of each column display the score achieved by each supplier. The scores were calculated using related equations, manufacturer's staff and management comments.

6. Supplier selection using FAHP

Supplier selection is categorized as an MCDM problem. Many researches used MCDM techniques with the objective of solving supplier selection problem such as AHP, TOPSIS, and ANP [10,11,35].

AHP was primarily introduced by Saaty in 1971 [36]. It abridges decision making by systematizing opinions, emotions, decisions, and memories into a structured environment. Once the hierarchy has been created, the decision-maker starts the prioritization process to decide the relative significance of the components in each level. The scale deployed for judgments in AHP allows the decision maker to integrate the knowledge and experience instinctively and specify how many times an element dominates another with respect to the criterion [37]. Within the literature, AHP has been largely used to discover answers for many complex decision-making problems.

Fuzzy sets were commenced by Zadeh in 1965 as a development of the conventional notion of set [38]. Concurrently, Salii [39] explained a more extensive kind of arrangements named L-relations, which were examined in an abstract algebraic context. Fuzzy relations are applicable in many areas such as linguistics, decision-making and clustering [40,41].

One of the important steps of AHP technique is to place the comparison matrices. When the number of attributes (or alternatives) in the hierarchy increases, more judgments between features (or alternatives) require to be made. This could simply cause bewilderment, because of the overload of questions and therefore the inefficiency of the model. So a consistency check is needed for the pairwise comparison matrix. When the comparison matrices are not consistent, we should adjust the elements in the matrices and carry out a consistency test until they are consistent. Kong and Liu [42] introduced a FAHP in which they replaced membership scales for Saaty's 1–9 scales to decrease adjusting times required. The following shows the related equations.

The comparison matrix described by Saaty deploys 1–9 scales. The 1–9 scales are shown with the subsequent comparison matrix in Table 3.

$$A = \begin{pmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & \frac{w_n}{w_n} \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix} \tag{1}$$

New fuzzy comparison matrix by Kong and Liu [42] is different from Saaty's and they employ membership scales, in place of the 1–9 scales, as the values of the elements.

$$A = \begin{pmatrix} \frac{w_1}{w_1+w_2} & \frac{w_1}{w_1+w_2} & \cdots & \frac{w_1}{w_1+w_n} \\ \frac{w_2}{w_2+w_1} & \frac{w_2}{w_2+w_2} & \cdots & \frac{w_2}{w_2+w_n} \\ \vdots & \vdots & & \vdots \\ \frac{w_n}{w_n+w_1} & \frac{w_n}{w_n+w_2} & \cdots & \frac{w_n}{w_n+w_n} \end{pmatrix} = \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{23} \\ \vdots & \vdots & & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nn} \end{pmatrix} \tag{2}$$

If this comparison matrix is consistent, it should satisfy the following:

Table 1 Partial list of BSC performance measures found in the literature.

Author	Year	Financial	Customer	Internal	Learning
[26]	2005	Waste reduction Level	Convenience	IT	Competitiveness
		Cost saving level	Customer service	Product recovery Option	Monitoring of suppliers
		Recapturing value	Green products	Commitment by top management	Formation of strategic Alliances
			Customer satisfaction	New technologies	Knowledge management
[27]	2010	Profitability	Market share	Ratio of new products to total products	Employee satisfaction
		Revenue growth	customer satisfaction	Inventory turn over	Training hours
		EVA	Customer loyalty	Productivity	Knowledge sharing
			Brand recognition	Risk minimization	Corporate values adoption
[28]	2011	Cost reduction level	Supply chain collaboration level	Quality of products	Flexibility to change
		Waste reusing level	Information sharing	Reduction of packaging waste	Standards consideration
					Eco-efficiency level
		Improved sales revenue	Customer satisfaction	Manufacturing efficiency	Development of new product
[29]	2012	Sales growth	Retention	Quality	New pattern
		Net profit	Response time	Defect rate	Quality of leadership
		Gross profit	Loyalty	Cycle time for continually improving the internal process	New market
		Operating income	Market share		New technology
		Return on investment	On time delivery		Improvement level of employee skill
		Economic value-added (EVA)			Health and safety
					Absenteeism
[30]	2009	Annual profit and growth	No. of customers	Cost reduction activity	Development activity
		Annual revenue and growth	Customer reliance	On time delivery	Training activity
		Financial stability	Response to change	Flexibility of production system	State reliance
		Fiscal outlook	Satisfaction on claims	Design capability	Information sharing
		Market share	Satisfaction on service	Responsibility to market demand	
[31]	2009	Process cost optimization level	Customer satisfaction	Order handling	Process knowledge
		Improvement of cash flow	Sales volume	Delivery ability	Joint learning
				Quality of replenishment process	
				Price consistency	
[32]	2008	Account receivable turnover	Customer complaints	Capacity usage rate	Employee productivity
		Economic value added	Customer loyalty	Quantity of defected units	Employee satisfaction
		Return on equity	Customer satisfaction	Setup times	Employee suggestions accepted and implemented
		Return on total assets	Rate of sales returns	Ratio of new products	Quality of work environment
[33]	2011	Price Stability	Level of relation and cooperation	Supplier company's flexibility	Organizational and managerial stability
		Sale percentage	Customer's satisfaction	Delay time of supplier company	Organizational commitment
		Transportation cost of each unit	Reputation	Past performance advantage	Organizational and managerial stability
		The situation and financial stability		The number of provided pieces by supplier	Coordination history
[34]	2006	Unit value added of internal logistics	% of incomplete processes	Nonconformity on the line	Accidents
			Range of quantity of inventories	Forecast and realized inventories	Individual competence measures
				Check 100% of large and small packages	
				Compliance with movement deployment	

Table 2 Proposed BSC for Automotive Industry.

Financial	Customer
Price of product	Service and delivery
Quality of product	Reputation
Distance to manufacturer	Supply chain collaboration level
Economic value added	Market share
Economic value-added (EVA)	Rate of sales return
Internal business	**Learning and growth**
Technical capability	Competitiveness
Production capacity	Employee satisfaction
Flexibility (design, make, delivery)	Knowledge sharing
Inventory turnover	Health and safety issues level
Productivity	Standards consideration

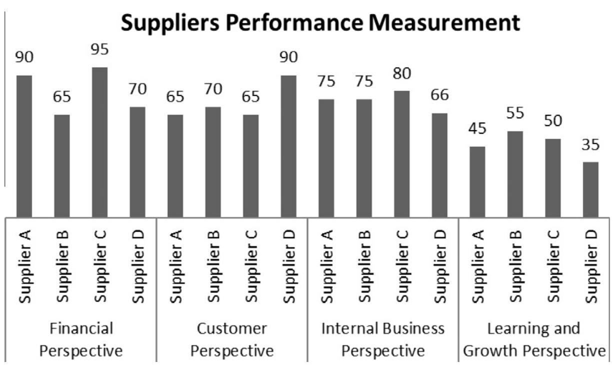

Figure 1 Suppliers performance measurement using proposed BSC.

Table 3 Saaty's scale for pairwise comparison.

AHP scale	The relative importance of the two sub-elements
1	Equally important
3	Moderately important with one over another
5	Strongly important
7	Very strongly important
9	Extremely important
2,4,6,8	Intermediate values

$$r_{ii} = 0.5, r_{ij+}r_{ji} = 1, \frac{1}{r_{ij}} - 1 = \left(\frac{1}{r_{ik}} - 1\right) \times \left(\frac{1}{r_{ki}} - 1\right) \quad (3)$$

This approach evaluates weights in pairs and is more simple and easier to be deployed by the decision-makers. The senses of this membership scales can also be stated in the similar method as Saaty's scale (see Table 4).

Hypothetically, the membership scales put forward in this study and Saaty's scales should satisfy the following:

$$r_{ij} = \frac{a_{ij}}{a_{ij+1}} \quad (4)$$

The dissimilarity of membership scales with Saaty's lies in the values of membership scales placed within the range of [0,1]. To compute the priority weights. Let:

Table 4 Scale for fuzzy pairwise comparison.

Scale values	The relative importance of the two sub-elements
0.5	Equally important
0.55 (or 0.5 0.6	Slightly important
0.65 (or 0.6 0.7)	Important
0.75 (or 0.7 0.8)	Strongly important
0.85 (or 0.8 0.9)	Very strongly important
0.95 (or 0.9 1.0)	Extremely important

Table 5 Values of RI.

Size of matrix	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 6 Fuzzy criteria pairwise comparison matrix.

Criteria	C1	C2	C3	C4
C1	0.5	0.6	0.7	0.9
C2	0.4	0.5	0.5	0.8
C3	0.3	0.5	0.5	0.7
C4	0.1	0.2	0.3	0.5

Table 7 Pairwise comparison matrix under financial criterion.

C1 = financial	Supplier A	Supplier B	Supplier C	Supplier D
Supplier A	0.5	0.7	0.45	0.65
Supplier B	0.3	0.5	0.15	0.45
Supplier C	0.55	0.85	0.5	0.8
Supplier D	0.35	0.55	0.2	0.5

$$W = w_1, w_2, \ldots, w_n \quad (5)$$

$$w_i = \frac{b_i}{\sum_{i=1}^{n} b_i} \quad (6)$$

$$b_i = \frac{1}{[\sum_{j=1}^{n} \frac{1}{r_{ij}}] - n} \quad (7)$$

We can employ the subsequent equation to determine the consistency index:

$$CI = \frac{[\sum_{i=1}^{n} \frac{(AW)_i}{nw_i}]}{n-1} \quad (8)$$

in which the values of the components in matrix A could be obtained by using Eq. (3) to matrix R. The comparison matrix will be considered to be consistent if there exists $CR \frac{CI}{RI} = 0.1$. The different values of RI are shown in Table 5.

Now, we employ proposed BSC–FAHP model to select the best suppliers for a manufacturing company in the Iranian automotive industry. Initially, hierarchy model of supplier selection is shown as follows:

Then, we provide the fuzzy comparison matrices of the criterion level. For example, Tables 6 illustrates the original fuzzy pairwise comparison matrices for supplier selection.

Table 8 Pairwise comparison matrix under customer criterion.

C2 = customer	Supplier A	Supplier B	Supplier C	Supplier D
Supplier A	0.5	0.45	0.5	0.25
Supplier B	0.55	0.5	0.55	0.35
Supplier C	0.5	0.45	0.5	0.25
Supplier D	0.75	0.65	0.75	0.5

Table 9 Pairwise comparison matrix under internal business criterion.

C3 = internal business	Supplier A	Supplier B	Supplier C	Supplier D
Supplier A	0.5	0.5	0.45	0.6
Supplier B	0.5	0.5	0.45	0.6
Supplier C	0.55	0.55	0.5	0.7
Supplier D	0.4	0.4	0.3	0.5

Table 10 Pairwise comparison matrix under learning and growth criterion.

C4 = learning and growth	Supplier A	Supplier B	Supplier C	Supplier D
Supplier A	0.5	0.4	0.45	0.6
Supplier B	0.6	0.5	0.55	0.65
Supplier C	0.55	0.45	0.5	0.7
Supplier D	0.4	0.35	0.3	0.5

Each supplier should be evaluated and compared under each criterion. Table 7–10 show suppliers' fuzzy pairwise comparison matrices.

Based on Eqs. (1)–(8) and the result of pairwise comparison matrices shown in Table 6–10, Fig. 2 shows the supplier selection hierarchy. In addition, Fig. 3 shows the suppliers' rankings using the proposed FAHP–BSC framework.

When decision makers have to make lots of comparisons (i.e., three or more), the track of the preceding responses may get lost. It is necessary that the rankings are valid and consistent. A preference determined for a set of pairwise comparisons needs to be consistent with another set of comparisons. It is compulsory to perform a consistency test for all steps of AHP calculation since it illustrates the level of steadfastness between data. The data were analyzed and the consistency test condition is satisfied [10].

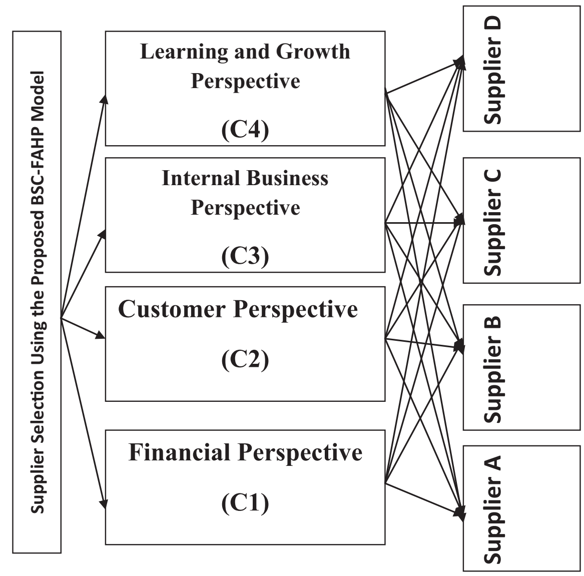

Figure 2 Supplier selection analytic hierarchy model.

7. Conclusion

This study developed an integrated Balanced Scorecard–Fuzzy Analytic Hierarchical Process (BSC–FAHP) model to select suppliers in the automotive industry. Despite the enormous quantity of researches on suppliers assessment, selection and related approaches, assessment and selection of suppliers with precise measures of this industry are less studied. To address this gap, this study was conducted to analytically recommend a new BSC framework for the mean of supplier evaluation. Principally, a BSC containing exact measures of automobile industry in each perspective (financial, customer, internal business and learning and growth) was proposed for the aim of suppliers' performance measurement. Measures in each perspective were collected with the aim of a literature survey and qualified using NGT. Finally, a fuzzy AHP was used to choose the best supplier. It initiated a novel idea for the incor-

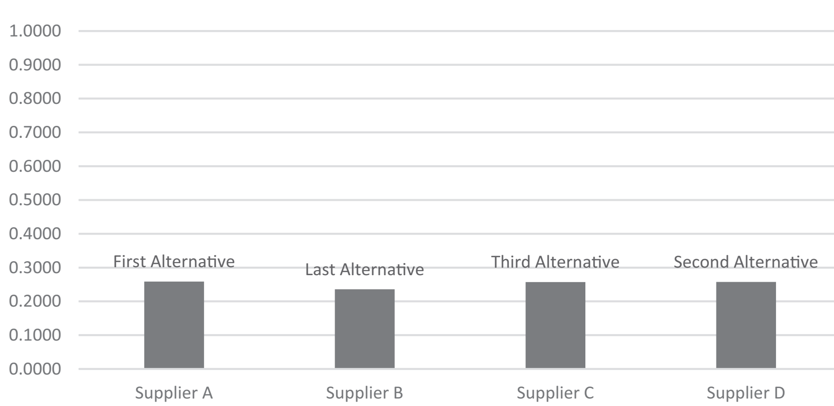

Figure 3 Suppliers ranking.

poration of explicit measures deployed in the process of supplier selection in automotive industries when there are a lot of performance measures which may make the decision makers bewildered. From the theoretical and methodological standpoint, to the best of our knowledge, this research also contributes to offer novel insight into automotive manufacturers for selecting their suppliers based on the exact measures since very few studies have been done before. In addition to the advantage of this study, FAHP considers the metrics of BSC separately and their interactions are neglected. This could be a good direction for future research. In addition, the proposed BCS of this study can be integrated with other MCDM tools such as ANP and DEA.

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