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Research Article

Determining the Best Combination of Perspective indicators of Balanced Scorecard using the Game Theory

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Abstract

Manufacturing performance measurement offers an appropriate program for future planning, controlling, and decision-making of organizations as well as determination of their present status. This paper aimed to assess a firm's manufacturing performance using a reasonably comprehensive integrated BSC- Game model to empirically determine the importance of the perspectives and indicators under evaluation and the best combination of indicators A mathematical model was employed to determine the equilibrium among the four perspectives of the balanced scorecard (BSC) as four players in a cooperative game to specify the relationship among indicators in the strategy map of Esfahan Steel Complex Company. The GAMS optimization package was used to solve the model. The results suggest that the decision-makers of Esfahan Steel Company consider innovation, modern technologies, customer satisfaction, and equity profitability as the best combination of strategies and equilibrium point in the BSC. In fact, the proposed mathematical model successfully provided an equilibrium to minimize the costs and maximize the perspectives' payoff of the BSC. The main contribution of this paper lies to the adaption of a game theory approach to performance measurement in the industrial sector that makes balancing in the BSC become more real.

Keywords: Balanced scorecard; Game theory; Nash equilibrium; Performance evaluation

1. Introduction

Initially developed by Kaplan and Norton (1992a,b, 1996a), the balanced scorecard (BSC) seeks to offer managers a system to help them turn strategy into action, manage new changes, and increase the effectiveness, productivity, and competitive advantage of a company (Keyes, 2005). Kaplan and Norton introduced the idea of BSC as a new method for measuring the performance by integrating both financial and non-financial items affecting the efficiency of an organization. In the past, financial factors were only considered for performance evaluation. However, BSC developed the indices toward four outlooks of growth and learning, internal processes, customer and finance in a logical way. All these perspectives need to be consistent with the organizational vision and strategy to ensure that the development of the organization aligns with the internal and external performance. In organizational management, a critical challenge is when the number the potential combination of indicators is too large. In such cases, it is crucial to select the most appropriate combination of these indicators as an equilibrium point. Considering each perspective of BSC as a player in a four-person cooperative game, it is possible to achieve the payoff coalition of players in performing strategies and developing a mathematical model of a finite-discrete game in the normal form to achieve the equilibrium point. Therefore, this paper provides a method through which the players (perspectives) can maximize their benefits and create a balance by choosing different strategies. In other words, this paper shows that if each perspective of BSC is considered a player, it is possible to achieve the best combination of indicators in a strategic plan by developing a Nash model (1951). The application of the game theory for obtaining an equilibrium among the perspectives of the BSC has received very little attention in previous studies. The mixed performance measurement system was used in most of the previous studies to select the best strategies for the performance and to maximize the payoff of the players (Eskafi et al., 2015, Naini et al., 2011). Therefore, it seems necessary to consider other factors, such as minimizing total allocated costs in the performance measurement system. Furthermore, the mathematical equations used in previous studies to determine a balanced point in the decision making process are very complicated, especially when the number of players and indicators increase in real situations.

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Although the game theory has provided numerous insights in different sciences, it has not yet been applied widely in the context of strategic management due to the presence of three main obstacles or limitations of the game theory, as described below. (1) The problem of equilibrium selection: every game cannot be seen in the context of a Nash equilibrium, which makes solving games more difficult, (2) the problem of hyper-rational agents, and (3) lack of game theory dynamics, which is a very important feature in organizations. Therefore, one of the contributions of this paper is to apply the game theory in the strategic management. Another significance of the present study is that the proposed model is not very complicated and does not involve complex mathematical computations of some existing models (Naini et al., 2011). Thus, it can be easily applied even in situations that increased number of BSC indicators or perspectives (become more than four). Furthermore, the proposed model takes into account the cost and budget of a company and can easily turn into a linear model by changing the variables.

The rest of this article is organized as follows. In Section 2, a literature review is provided on BSC and cooperative game theory. Section 3 discusses the proposed mathematical model of finite-discrete game with multiple players and multiple indicators. Section 4 provides a case study, and finally, Section 5 presents the conclusions and suggestions of this study.

2. Literature Review

Total quality management (TQM), business process re-engineering (BPR), business process management (BPM), enterprise resource planning (ERP), customer relationship management (CRM), and value based management (VBM) are among various performance measurement tools and approaches that were theorized and studied over the last years (Ten Have et al., 2003). However, the BSC, originally created in 1992 and later developed by Robert Kaplan and David Norton, acquired a unique position as a multidimensional performance measurement system for strategic management evaluations. The BSC framework has been applied in many studies and various management fields, such as supply chain management (Aliakbari Nouri et al., 2019), research and development projects (Purnomo and Sutanto, 2019), commerce (Rickards, 2007, Shan et al., 2019), enterprise resource planning (Kajtazi and Holmberg, 2019, You and Wu, 2019), business (Bénet et al., 2019, Hamamura, 2019), and quality function deployment (Dincer et al., 2019).

It is a holistic performance measurement system that takes into account the non-financial measures and the financial measures simultaneously (Kaplan and Norton, 1996) to improve managers' decision making and problem solving. BSC is among few measures or performance indicators that need to be examined periodically (Neely and Hii, 1998). BSC draws on causal loop diagrams for improving strategic plans (Li et al., 2009). As a strategic management system, BSC improves the management of information in organizations (Huang, 2009). However, it is important to note that there are some limitations to this approach. The use of causal-loops alone is seen as problematic (Richmond, 2001). BSC is not dynamic enough for the online control (Akkermans and Van Oorschot, 2002) and does not take into account the complexity of the set of strategic decisions and their temporal dynamics in constructing the strategy map (Othman, 2006). It does not provide mechanisms for selecting the best measures of performance (Cebeci, 2009). Unidirectional causality of the BSC is very simplistic; in other words, it does not separate cause and effect over time, i.e., the time dimension is not a part of the BSC (Cebeci, 2009, Lee et al., 2008). The balanced scorecard approach was employed to evaluate the effectiveness of implementation Quality Management System (ISO 9001:2000) in gas processing plants of National Iranian Gas Company (Alinezhad et al., 2010). The results indicated that the BSC could be used as a holistic approach to measure the performance of quality systems in the gas processing plants of NIGC. However, the customer and learning perspectives are usually neglected in the target companies. BSC does not select value chains for organizations, cannot define value chains in strategic operations (Yüksel and Dağdeviren, 2010), and indicates that all strategic objectives have the same importance and weighted similarly, which may not be true in real contexts (Chytas et al., 2011). The selection process of indicators from all the possible important ones, which can exist in an organization, has not received enough attention (Quezada and López-Ospina, 2014). A knowledge-based system (KBS) using the analytic hierarchy process (AHP) method and an intellectual BSCKBS was designed to produce in an improved approach to strategy planning and decision making (Huang, H., 2009). The integrated use of Control Objectives for Information Technology (COBIT) and BSC frameworks for strategic Information Security Management (ISM) were explored (Goldman and Ahuja, 2009). The goal was to investigate the strengths, weaknesses, implementation techniques, and potential benefits of such an integrated framework. The integration of ANP (Analytic Network Process) and BSC methods (Yuksel, I. & Dagdeviren, M., 2010) was proposed to assist the implementation and modernization of the BSC framework. The development of a "dynamic BSC" was carried out to demonstrate that matching the traditional BSC architecture with system dynamics principles would offer better support for strategic management decisions (Barnabè and Busco, 2012). The lean BSC approach was implemented for determining the lean performance measurement through the lean strategy map of a company. The main objective of this approach was to reduce costs and enhance the quality control and human aspects (Seyedhosseini et al., 2011). A systematic approach was developed for the evaluation of e-learning systems that integrates two well-established managerial methodologies, namely BSC and Fuzzy AHP (Jami pour et al 2017). They considered pedagogical, organizational, and technological aspects synchronously. A hybrid of BSC and NP has been proposed for the selection of the

best outsourcing strategy for operational activities of a coal mining company in India (Modaka et al 2018). They utilized ANP to study the interactions of the BSC indicators, assigning and prioritizing weights, and determining the best outsourcing alternative.
The game theory is an applied branch of mathematics used in many domains, such as economics (Mendoza-Alonzo et al., 2019; Zameer et al., 2018), politics, management (Prasad et al., 2019), mathematics, engineering (Mendoza-Alonzo et al., 2019; Ahmadi-Javid and Hoseinpour, 2018; Xiaohui et al., 2014), organizations, etc. (Ahmadi-Javid and Hoseinpour, 2018; Barari et al., 2012; Hernández et al., 2014; Mendoza-Alonzo et al., 2019; Prasad et al., 2019; Zameer et al., 2018). It concerns the mathematical study of the decision-making process and mathematical models of conflict and cooperation, meaning that it can model the possible behaviours of individuals in specific circumstances that resemble simple types of games; this allows an examination of the relationship between decisions and outcomes. Game theory includes the concept of utility, which concerns a mathematical measure of player satisfaction (Neumann and Morgenstern, 1944). In games that involve a deterministic relation between decision and outcome, a utility value can be assigned to the outcome of each decision. The game theory and Nash bargaining solution have been used in many studies. Nash bargaining game DEA model was applied to supplier evaluation, since the traditional DEA method adopts varying weights in the evaluation and fails to consider the competition among the suppliers (Wang and Li, 2014). Game theory was utilized in combination with Monte Carlo simulation modelling to support the analyses of different retail marketing strategies (Taylor et al., 2019). Nash bargaining model has been applied to find a compromise solution among agents, and linear programming, and interval coefficients have been used to find the best and the worst Nash bargaining solutions (Safari et al., 2018). An optimization fuzzy game model of three-player payoff affected by customer demands has been proposed in a green supply and a practical solution has been obtained to increase the players' confidence to choose green strategies (Chavoshlou et al 2019). Della Vecchia et al. (2019) combined the game theory with the fuzzy sets theory and used Nash equilibrium and evolutionary algorithm to optimize the player's payoff function in uncertain conditions of customer demands. They followed a multi-objective optimization approach, paying attention to the variables that mainly influence the objective functions, with the aim of comparing different optimization strategies in the aircraft design field. Jalali Naini et al. (2011) posit the problem of equilibrium selection, the problem of hyper-rational agents, and the lack of a dynamic theory in the traditional theory of games as the three main obstacles for the application of the game theory in the context of management. Gandolfo Dominici (2011) believes that, as the number of players increase in the actual business, the game theory becomes more difficult and it can simply provide a general rule of logic not the winning strategy. A mathematical optimization framework in the context of a Stackelberg game was utilised to study government-agriculture interactions with the aim of redressing market failures (Shafia et al., 2018). A Stackelberg game model seeking the equilibrium solutions was formulated as an approach to optimize policies of government under the cartel of two green and non-green supply chains (Yazdanpanah et al., 2018). The results indicated that the investment's encouraging tax rate in green technology has no impact on the optimal production of the green and ordinary manufacturers, and cannot be considered as an affective variable on the product market, but it is an important variable for the state utility function.
In spite of a rich literature on elucidating the advantages of the BSC approach, the application of this approach in combination with game theory has rarely been considered in previous studies. An interaction method among different strategic agents of scorecard as players was proposed to provide a methodology for the collaboration among different players to reduce the (Eskandari et al., 2010) proposed. It was shown that the payoff of a player in a special continuous-strategy collaboration game could be used to describe the payoff of the player in a dynamic game. A combination of the evolutionary game theory and a knowledge-based BSC in environmental supply chain management (ESCM) was employed (Jalali Naini et al., 2011) to address some hurdles (Brewer & Speh, 2001) in applying performance measurement tools and systems across the supply chain. The BSC, path analysis, cooperative game theory, and the evolutionary game theory was used as a performance measurement system for supply chains to demonstrate that these perspectives complement each other to increase the efficiency and to select the best strategy in emergency situations (Eskafia et al., 2015).
However, it is observed that the mathematical equations used in these studies to determine a balanced point in the decision-making process are very complicated, especially when the number of players and indicators increase in actual situations. To address this gap, this research tries to contribute to a mathematical model incorporating the game theory and the BSC for deciding the best strategy in competitive and conflicting situations and to determine the equilibrium between financial and non-financial perspectives with respect to the organizational costs and budget.

3. Methodology

An integrated approach based on the balanced scorecard and game theory has been developed for evaluating the performance of an Iranian company to determine the most appropriate combination of BSC indicators and to build an equilibrium point between financial and non-financial performance measures in the present study. It considers the four perspectives of BSC as the players of a four-player cooperative game. It is supposed that a combination of the BSC and game theory may be used to determine the equilibrium in the decision-making process.

The overall algorithm of the research framework is shown in Figure 1. In this study, each player has three pure strategies, which are mutually exclusive; therefore, there will be 81 possibilities of interaction (3 × 3 × 3 × 3). This model also defines the best combination of indicators in different perspectives to reach an equilibrium and control allocated costs and the total budget of an organization.

In this paper, the proposed model is based on a general finite-discrete game model with multiple players and multiple strategies, for which a common equilibrium point is obtained consisting of one payoff vector of Pareto-Optimal solution. All players should bargain and be provided with a security level of di. Nash Bargaining theory is a central topic in game theory studies (Chakrabarty et al., 2008) and Nash Bargaining game, proposed by Nash (1950), adopts a cooperative approach to the bargaining problem. I n cooperative games, agents bargain before playing the game. If an agreement is reached, agents act according to this agreement; otherwise, they act non-cooperatively. Nash Bargaining game aims to analyze the way agents should cooperate when non-cooperation leads to Pareto-inefficient results, i.e., the case where the results are dominated by other alternatives. A Nash equilibrium concerns a situation where the game players cannot improve their payoff by independently and unilaterally changing their strategy (Nash, 1950). This means that it is the best strategy, assuming that the other game player has chosen a strategy and will not change it (Froschauer, Arends, Goldfarb, & Merkl, 2012). The Nash equilibrium will be reached when the best rewards are obtained after playing the game (Neslin & Greenhalgh, 1983; Sánchez Torres, Rivera González, & Jorba, 2018). For the bargaining problem, Nash (1950) presented a solution characterized by four properties: Pareto efficiency (PE), invariance with respect to affine transformation (IAT), independence of irrelevant alternatives (IIA), and symmetry (SYM). Harsanyi (1959) used Nash solution for an n-player game that can be presented as follows:

$$max: \prod_{i=1}^{N} (f_i - d_i) \qquad (1)$$

Subject to

$$f_i \geq d_i \qquad \forall i \in \{1, \dots, n\} \qquad (2)$$

$$f_i \in F_i \qquad \forall i \in \{1, \dots, n\} \qquad (3)$$

The following model is proposed based on the above model and discussion. To facilitate the understanding of the mathematical model, the sets, parameters, and the decision variables are introduced in this section.

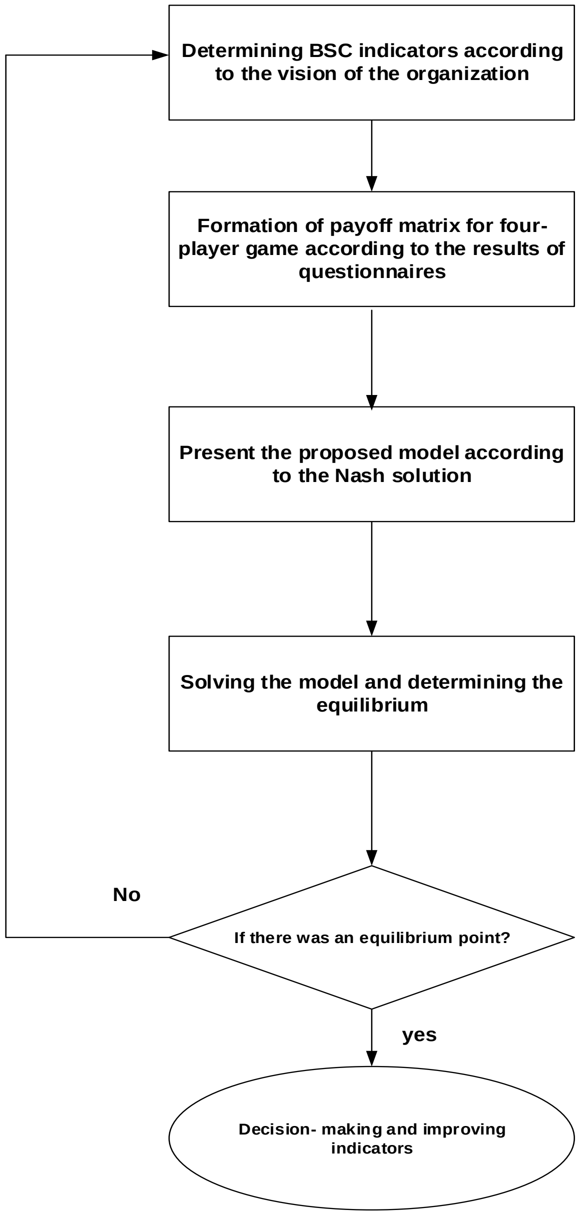

Fig 1. The research framework

Assumptions

The model of this study has been proposed on the basis of some assumptions that seem necessary to be specified to run the model in the real-word situation. These assumptions are presented here:

1- All the parameters are deterministic.
2- The number of perspectives and indicators are finite in the company.
3- Budget and costs must be available to run the model.
4- All players act rationally and intelligently.
5- There is conflict of interest between the players.
6- The rules of play are known to all the players.

Sets and Indexes

$i \in \{1,2,\cdots,n\}$	Index of players (perspectives)
$j \in \{1,2,\cdots,m\}$	Index of all pure strategies
$j_i \in \{1,2,\cdots,m_i\}$	Index of strategies available to player (perspective) i

Parameters

d_i	Security level (disagreement utility) for player (perspective) i
$A_{i,j_1,j_2,\ldots,j_n}$	Utility of player (perspective) i if the players $1,2,\cdots,n$ choose their strategies as $j_1,j_2,\ldots,j_n$
c_{ij}	The cost of indicator j for player (perspective) i
B	The total available budget

Variables

f_i	The payoff for player (perspective) i
x_{ij}	Is 1 if player (perspective) i chooses indicator j
$t_{j_1,j_2,\ldots,j_n}$	Is 1 if the players $1,2,\cdots,n$ choose their strategies as $j_1,j_2,\ldots,j_n$
B	The total available budget

Mathematical model

$$max\ Z_1 = \sum_i \ln(f_i - d_i) \quad (4)$$

$$\min Z_2 = \sum_i \sum_j c_{ij} x_{ij} \quad (5)$$

Subject to

$$f_i \geq d_i \qquad \forall i \in \{1,\ldots,n\} \quad (6)$$

$$f_i - M * \left(1 - t_{j_1,j_2,\ldots,j_n}\right) \leq A_{i,j_1,j_2,\ldots,j_n} \qquad \forall i \in \{1,\ldots,n\}, \forall\, j_i \in \{1,2,\cdots,m_i\} \quad (7)$$

$$f_i + M * \left(1 - t_{j_1,j_2,\ldots,j_n}\right) \geq A_{i,j_1,j_2,\ldots,j_n} \qquad \forall i \in \{1,\ldots,n\}, \forall\, j_i \in \{1,2,\cdots,m_i\} \quad (8)$$

$$\sum_{j_1} \sum_{j_2} \cdots \sum_{j_n} t_{j_1,j_2,\ldots,j_n} = 1 \quad (9)$$

$$x_{ij} = \sum_{j_2} \cdots \sum_{j_n} t_{j_i,j_2,\ldots,j_n} \qquad \forall i \in \{1,\ldots,n\}, \forall j \in \{1,2,\cdots,m\} \quad (10)$$

$$\sum_i \sum_j c_{ij} x_{ij} \leq B \quad (11)$$

$$t_{j_1,j_2,\ldots,j_n}, x_{ij} \in \{0,1\} \qquad \forall i \in \{1,\ldots,n\}, \forall j \in \{1,2,\cdots,m\}, \forall\, j_i \in \{1,2,\cdots,m_i\} \quad (12)$$

In this model, the first objective function is to maximize the total payoff, while the second objective function is for minimizing the total cost allocated to the indicators. Constraint (6) states that the payoff of each player (perspective) must be greater than the corresponding security level. Constraints (7) and (8) determine the payoff for each perspective considering the strategies of all perspectives. Constraint (9) imposes the fact that only one combination of indicators must be selected. Constraint (10) determines the indicator (strategy) selected for each perspective. Constraint (11) indicates that the total allocated costs to indicators (the second objective function) should not exceed company's budget. Finally, Constraint (12) determines the type of the variables.

The LP-metric method belongs to the first category of multi-objective decision making (MODM) problems, i.e., the case where a decision maker gives all required information before solving the problem (Saraj&Safaei 2012). In this paper, LP-metric was applied as a method for the bi-objective optimization, considered for two main reasons. The first one is that this method requires little information from a decision maker, and the second one is its ease of implication in practice. The deviation of the objectives from their optimum values is minimized in this method. Based on this conception, the optimum value of each function should be measured for a model with n objectives, regardless of n-1 remaining objectives and considering all the constraints. The best state happens when all the objectives approach to their optimum values (Chou et al., 2008).

4. Case Study

Esfahan Steel Complex Company is the first and largest constructional steel and rail producer in Iran and the biggest producer of long products in the Middle East, with 3 Million tons capacity per year, producing various constructional and industrial steel sections. Esfahan Steel Plant started operation in 1971 and is located in the Southwest of Esfahan. This factory has an important role in the formation of other steel industries. The proposed model was applied to this company. The required data were collected in during 2018-2019. The BSC was previously applied in this company at the business level. The required data are presented in Figure 2.

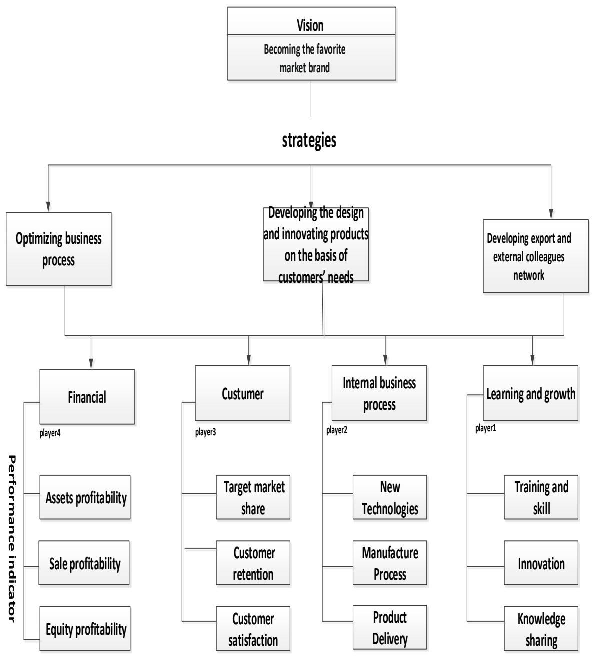

Fig 2. The hierarchical model for BSC instead company

4.1. Data collection and analysis procedure

Based on the research objectives specified above, a two-part questionnaire was used as an instrument to collect data. The first part uses a nominal scale, while the rest use a 5-point Likert scale. The first part of the questionnaire was designed to collect information about the respondent's characteristics, including education, age, work experience, and position. The second part of the questionnaire was designed to measure the four BSC performance perspectives, finance, customer, internal process, and learning and growth. The four performance perspectives were first identified in terms of their indicators based on the hierarchical structure of Figure 2. The measurement items for these 12 indicators were then developed from an extensive review of relevant studies (Yuksel, I. & Dagdeviren, M., 2010). As a result, all finance, customer, internal process, and learning and growth constructs contain three items. The questionnaire contained 27 questions about the relationship between indicators of BSC and the rate of pay-off between indicators (Eskafi et al., 2015). Top managers, including chief executives, finance executives, and operational executives, are the persons more likely to be familiar with the company performance, since they are considered as responders. The questionnaire was validated through reviewing by several researchers and experts, and their recommendations were incorporated into the questionnaire before and after pre-testing. Necessary corrections and adjustments were made before they were used in the actual collection of data in the field. Cronbach's alpha coefficient was used to examine the reliability of the questionnaire. The results show that the calculated alpha coefficient was 0.82 for the whole questionnaire. Considering that the calculated reliability coefficients are more than 0.70, it can be concluded that the questionnaire has the necessary research reliability. Of 80 questionnaires given to the company's specialists, 72 (90%) cases were completed and analyzed here. Data on the indicators were collected for a 12-month period. In the questionnaire, 27 questions were used to develop 27 hypothesis tests by a two-sided correlation t-test. The SPSS software was used to test the hypothesis. The payoff matrix of the four players is obtained as follows:

Table 1: Payoff matrix of the four-person game theory

player 1(Learning and growth)	≡			=			−			player 4 (Financial)	player 2(Internal processes)
player 3(Customer)											
	(2,5,1,2)	(3,3,4,2)	(4,3,4,0)	(5,2,4,0)	(1,3,3,3)	(5,3,1,2)	(3,0,3,3)	(0,2,4,4)	(4,1,5,3)	−	
	(4,1,4,2)	(4,1,4,1)	(2,4,1,3)	(1,3,4,2)	(4,1,2,5)	(3,3,2,1)	(3,5,4,2)	(4,1,1,4)	(2,1,4,1)		
	(4,5,1,1)	(1,2,5,3)	(0,2,5,3)	(5,2,4,3)	(1,4,3,3)	(2,5,4,1)	(2,4,1,3)	(1,4,2,4)	(4,2,4,5)		
	(3,5,5,5)	(1,0,3,3)	(0,1,4,0)	(4,2,4,1)	(0,1,0,2)	(1,1,2,4)	(2,3,1,4)	(4,4,2,1)	(1,0,3,4)	=	
	(5,5,5,4)	(3,0,2,3)	(1,2,0,5)	(2,3,1,2)	(5,3,2,4)	(4,1,3,2)	(3,5,3,1)	(0,1,2,1)	(3,5,4,1)		
	(4,3,5,3)	(3,5,4,3)	(3,1,3,2)	(1,1,3,0)	(2,3,1,3)	(3,5,4,2)	(2,2,5,4)	(4,3,2,2)	(5,3,3,1)		
	(3,0,3,2)	(0,3,3,3)	(3,0,2,3)	(3,5,4,1)	(3,0,1,5)	(4,1,1,2)	(1,3,0,2)	(4,5,3,0)	(2,1,2,3)	≡	
	(2,3,4,1)	(3,4,3,4)	(2,5,1,1)	(0,1,5,3)	(3,2,5,5)	(1,5,4,4)	(5,4,3,2)	(0,4,3,2)	(0,1,1,1)		
	(1,3,5,1)	(4,4,3,5)	(4,4,2,3)	(1,3,5,4)	(4,3,5,3)	(4,2,4,3)	(2,5,3,5)	(2,2,3,2)	(5,5,,1,3)		

The top financial manager of Esfahan Steel Company specified the costs and total available budget of the company for a one-year period (Table 2). A reduction in the cost of this company is an important outcome of the proposed model.

Table 2
Cost of perspectives and budget of the company

Perspective	Cost (USD)			Total available budget (USD)
	Indicator 1	Indicator 2	Indicator 3	
Financial	21400	7053	14266	10000
Customer	828	10624	1409	
Internal processes	328	410	694	
Learning and growth	400	410	694	

4.2. Result

Using the above payoff matrix and the company's reported budget and costs, the proposed model with four players and three strategies for each player was run using the GAMS software package. To explain Table 1, the combination (4, 1, 5, and 3) is the pay-off acquired when the players 1, 2, 3, and 4 of the BSC select the first strategy to play the game. The proposed model for this company consists of 180 constraints, 85 independent variables, and 12 dependent variables. The GAMS optimization package was used to solve the model in three steps. In the first step, the proposed model was solved without considering the organization costs and budget. The equilibrium point of this step was (5,5,5,4). In the second step, the model was solved considering the allocated costs to indicators without considering the organization budget. The equilibrium point of this step was (3,2,5,5). In the third step, the model was solved considering the organization costs and budget. The equilibrium point of this step was (5,2,4,3). The decision-makers consider the third equilibrium point as an optimal and appropriate one, i.e. when players 1, 2, 3, and 4 select the second indicator (innovation), the first indicator (new technology), the third indicator (customer satisfaction), and the third indicator (equity profitability), respectively. The best combination of indicators and a relevant real equilibrium point are acquired to play the game. However, one of the limitations encountered in this case is in determining alternative payoffs, especially when the problems are dominated by qualitative considerations, such as what usually happens in strategic problems. Qualitative inputs cannot be processed directly by the game theory. They should first be translated into quantitative inputs (pay-offs).

5. Conclusion

The main contribution of a performance measurement framework is to enhance the quality and effectiveness of planning, controlling, and decision-making in critical situations. In this study, an innovative method has been presented for performance measurement of an Iranian manufacturing firm. In this method, a combination of balanced scorecard and cooperative game theory was employed to obtain the best combination of indicators. After determining strategies in each aspect of BSC, we determine cause and effect relationships between the strategies defined. Then the best strategic path were determined by using cooperative game theory. The results indicated that the best combination of indicators in Esfahan Steel company were innovation, modern technologies, customer satisfaction, and equity profitability. These indicators should be considered by the managers to improve the performance of the company within the BSC framework. In fact, the proposed mathematical model was shown to be able to successfully minimize costs and maximize perspectives' payoff of the BSC to achieve the equilibrium point. One of the reported limitations of the BSC is the unreal balancing (Pfeffer and Sutton, 2000). The main contribution of this paper lies in the adaption of a game theory approach to the performance measurement to make more real balancing in the BSC. The proposed model has some advantages in comparison with other models. As a practical application of the game theory in strategic management, this model gives managers better opportunity for logical decision making, and can be applied with increased number of players or perspectives, i.e. more than four (Aliakbari Nouri et al., 2019, Kalender and Vayvay, 2016, Monteiro and Ribeiro, 2017). This model can be easily applied since the number of indicators in most of organizations are more than three. This model can be used to determine the equilibrium point in the strategic map of an organization and to invest limited resources in the areas that need utmost improvements.

Considering the influence of outside factors and challenges and requirement of a manufacturing company, it is very important to keep in mind, that the manufacturing indicators by themselves can't be considered as final solution of a company's performance measurement. They can only show the right direction of an action in the process of its development. Although game theory provides a systematic quantitative approach for deciding the best strategy in competitive and conflicting situations and makes managers more flexible in their choices, the existence of some degree of uncertainty in actual field of business performance and the influence of outside factors and challenges cannot be considered in game theory. On the other hand, businessmen and managers do not have adequate knowledge for the game theory, and they usually resist any new changes. The data set of a single organization in the manufacturing industry employed to show the performance of the proposed mathematical model cannot be generalization. This framework is based on Iranian community and experts' viewpoints; therefore, different results may be obtained if it is applied elsewhere, and the importance of perspectives and their indicators might show different results in other populations, other countries, and other periods of time.

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References

Ahmadi-Javid, A. and Hoseinpour, P. (2018) "Cooperative advertising in a capacitated manufacturer–retailer supply chain: a game-theoretic approach," *International Transactions in Operational Research*. Wiley Online Library, 25(5), pp. 1677–1694.

Akkermans, H. and Van Oorschot, K. (2002) "Developing a balanced scorecard with system dynamics," *Journal of the operational research society*, 40(56), pp. 931–941.

Aliakbari Nouri, F., Shafiei Nikabadi, M. and Olfat, L. (2019) "Developing the framework of sustainable service supply chain balanced scorecard (SSSC BSC)," *International Journal of Productivity and Performance Management*. Emerald Publishing Limited, 68(1), pp. 148–170.

Alinezhad, A. et al. (2010) "Evaluation of effectiveness of implementing quality management system (ISO9001: 2000) Using BSC Approach in NIGC," *Journal of Optimization in Industrial Engineering*. QIAU, (6), pp. 33–42.

Barari, S. et al. (2012) "A decision framework for the analysis of green supply chain contracts: An evolutionary game approach," *Expert systems with applications*. Elsevier, 39(3), pp. 2965–2976.

Bénet, N., Deville, A. and Naro, G. (2019) "BSC inside a strategic management control package," *Journal of Applied Accounting Research*. Emerald Publishing Limited, 20(1), pp. 120–132.

Brewer, P. C. and Speh, T. W. (2001) "Adapting the balanced scorecard to supply chain management.," *SUPPLY CHAIN MANAGEMENT REVIEW, V. 5, NO. 2 (MAR./APR. 2001), P. 48-56: ILL*.

Cebeci, U. (2009) "Fuzzy AHP-based decision support system for selecting ERP systems in textile industry by using balanced scorecard," *Expert Systems with Applications*. Elsevier, 36(5), pp. 8900–8909.

Chakrabarty, D. et al. (2008) "Efficiency, Fairness and Competitiveness in Nash Bargaining Games," in *International Workshop on Internet and Network Economics*. Springer, pp. 498–505.

Chavoshlou, A. S., Khamseh, A. A. and Naderi, B. (2019) "An optimization model of three-player payoff based on fuzzy game theory in green supply chain," *Computers & Industrial Engineering*. Elsevier, 128, pp. 782–794.

Chou, S.-Y., Chang, Y.-H. and Shen, C.-Y. (2008) "A fuzzy simple additive weighting system under group decision-making for facility location selection with objective/subjective attributes," *European Journal of Operational Research*. Elsevier, 189(1), pp. 132–145.

Chytas, P., Glykas, M. and Valiris, G. (2011) "A proactive balanced scorecard," *International Journal of Information Management*. Elsevier, 31(5), pp. 460–468.

Dincer, H., Yüksel, S. and Martinez, L. (2019) "Balanced scorecard-based Analysis about European Energy Investment Policies: A hybrid hesitant fuzzy decision-making approach with Quality Function Deployment," *Expert Systems with Applications*. Elsevier, 115, pp. 152–171.

Dominici, G. (2011) "Game theory as a marketing tool: uses and limitations," *Gandolfo Dominici/Elixir Marketing*, 36, pp. 3524–3528.

Eskafi, S., Roghanian, E. and Jafari-Eskandari, M. (2015) "Designing a performance measurement system for supply chain using balanced scorecard, path analysis, cooperative game theory and evolutionary game theory: A Case Study," *International Journal of Industrial Engineering Computations*, 6(2), pp. 157–172.

Froschauer, J. et al. (2012) "A serious heritage game for art history: Design and evaluation of ThIATRO," in *2012 18th International Conference on Virtual Systems and Multimedia*. IEEE, pp. 283–290.

Goldman, J. E. and Ahuja, S. (2009) "Integration of COBIT, balanced scorecard & SSE-CMM as a strategic information security management (ISM) framework," in *Proceedings of the 10th Annual Information Security Symposium*. CERIAS-Purdue University, p. 19.

Gumbus, A. (2005) "Introducing the balanced scorecard: creating metrics to measure performance," *Journal of management education*. Sage Publications Sage CA: Thousand Oaks, CA, 29(4), pp. 617–630.

Harsanyi, J. (1959) "C.,(1959), A bargaining model for the cooperative n-person games," *Contributions to the theory of Games IV. Princeton University Press, Princeton*, pp. 325–355.

Hamamura, J. (2019) "Unobservable transfer price exceeds marginal cost when the manager is evaluated using a balanced scorecard," *Advances in accounting*. Elsevier, 44, pp. 22–28.

Ten Have, S. et al. (2003) Key management models: The management tools and practices that will improve your business. Pearson Education.

Hernández, E., Barrientos, A. and Del Cerro, J. (2014) "Selective Smooth Fictitious Play: An approach based on game theory for patrolling infrastructures with a multi-robot system," *Expert Systems with Applications*. Elsevier, 41(6), pp. 2897–2913.

Hoque, Z., Barnabè, F. and Busco, C. (2012) "The causal relationships between performance drivers and outcomes," *Journal of Accounting & Organizational Change*. Emerald Group Publishing Limited.

Huang, H.-C. (2009) "Designing a knowledge-based system for strategic planning: A balanced scorecard perspective," *Expert Systems with Applications*. Elsevier, 36(1), pp. 209–218.

Jami Pour, M. et al. (2017) "Developing a new framework for evaluating e-learning systems: integrating BSC and FAHP," *Kybernetes*. Emerald Publishing Limited, 46(8), pp. 1303–1324.

Kajtazi, M. and Holmberg, N. (2019) "IS Education Revisited: Reflections on a BSc Program in Business Information Systems Design," in *2019 5th International Conference on Information Management (ICIM)*. IEEE, pp. 144–149.

Kalender, Z. T. and Vayvay, Ö. (2016) "The fifth pillar of the balanced scorecard: Sustainability," *Procedia-Social and Behavioral Sciences*. Elsevier, 235, pp. 76–83.

Kaplan, R. S. and Norton, D. P. (1996) "Strategic learning & the balanced scorecard," *Strategy & Leadership*. MCB UP Ltd, 24(5), pp. 18–24.

Keyes, C. L. M. (2005) "Mental illness and/or mental health? Investigating axioms of the complete state model of health.," *Journal of consulting and clinical psychology*. American Psychological Association, 73(3), p. 539.

Lee, A. H. I., Chen, W.-C. and Chang, C.-J. (2008) "A fuzzy AHP and BSC approach for evaluating performance of IT department in the manufacturing industry in Taiwan," *Expert systems with applications*. Elsevier, 34(1), pp. 96–107.

Li, X., Gu, X. J. and Liu, Z. G. (2009) "A strategic performance measurement system for firms across supply and demand chains on the analogy of ecological succession," *Ecological Economics*. Elsevier, 68(12), pp. 2918–2929.

Mendoza-Alonzo, J., Zayas-Castro, J. and Charkhgard, H. (2019) "Office-based and home-care for older adults in primary care: A comparative analysis using the Nash bargaining solution," *Socio-Economic Planning Sciences*. Elsevier.

Modak, M., Ghosh, K. K. and Pathak, K. (2018) "A BSC-ANP approach to organizational outsourcing decision support-A case study," *Journal of Business Research*. Elsevier.

Monteiro, S. and Ribeiro, V. (2017) "The balanced scorecard as a tool for environmental management: Approaching the business context to the public sector," *Management of Environmental Quality: An International Journal*. Emerald Publishing Limited, 28(3), pp. 332–349.

Naini, S. G. J., Aliahmadi, A. R. and Jafari-Eskandari, M. (2011) "Designing a mixed performance measurement system for environmental supply chain management using evolutionary game theory and balanced scorecard: A case study of an auto industry supply chain," *Resources, conservation and recycling*. Elsevier, 55(6), pp. 593–603.

Nash, J. (1951) "19.96. Essays on Game Theory." Cheltenham, United Kingdom: Edward Elgar.

Neely, A. and Hii, J. (1998) "Innovation and business performance: a literature review," *The Judge Institute of Management Studies, University of Cambridge*, pp. 0–65.

Neslin, S. A. and Greenhalgh, L. (1983) "Nash's theory of cooperative games as a predictor of the outcomes of buyer-seller negotiations: An experiment in media purchasing," *Journal of Marketing Research*. SAGE Publications Sage CA: Los Angeles, CA, 20(4), pp. 368–379.

von Neumann, J. and Morgenstern, O. (1944) "Theory of games and economic behavior, Science Editions, 1964." New York: John Wiley & Sons, Inc.

Othman, R. (2006) "Balanced scorecard and causal model development: preliminary findings," *Management Decision*. Emerald Group Publishing Limited, 44(5), pp. 690–702.

Pfeffer, J. and Sutton, R. I. (2000) The knowing-doing gap: How smart companies turn knowledge into action. Harvard business press.

Prasad, S., Shankar, R. and Roy, S. (2019) "Impact of bargaining power on supply chain profit allocation: a game-theoretic study," *Journal of Advances in Management Research*. Emerald Publishing Limited.

Quezada, L. E. and López-Ospina, H. A. (2014) "A method for designing a strategy map using AHP and linear programming," *International Journal of Production Economics*. Elsevier, 158, pp. 244–255.

Richmond, B. (2001) "A new language for leveraging scorecard-driven learning," Harvard Business School Publishing. Balanced Scorecard Report.

Rickards, R. C. (2003) "Setting benchmarks and evaluating balanced scorecards with data envelopment analysis," *Benchmarking: An International Journal*. MCB UP Ltd.

Safari, G., Hafezalkotob, A. and Khalilzadeh, M. (2018) "A Nash bargaining model for flow shop scheduling problem under uncertainty: a case study from tire manufacturing in Iran," *The International Journal of Advanced Manufacturing Technology*. Springer, 96(1–4), pp. 531–546.

Sánchez Torres, J. A., Rivera González, J. A. and Jorba, L. (2018) "What kind of e-mail information is more effective in communicating with the client? Application of game theory," *Harvard Deusto Business Research, 2018, vol. 7, num. 1, p. 2-18*. Harvard Deusto Business Review y EAE Business School.

Saraj, M. and Safaei, N. (2012) "Solving bi-level programming problems on using global criterion method with an interval approach," *Applied Mathematical Sciences*, 6(23), pp. 1135–1141.

Seyedhosseini, S. M. et al. (2011) "Extracting leanness criteria by employing the concept of Balanced Scorecard," *Expert Systems with Applications*. Elsevier, 38(8), pp. 10454–10461.

Shan, H., Yang, K. and Shi, J. (2019) "A Strategic Perspective Analysis for Improving Operational Inefficiency of E-commerce Based on Integrated BSC and Super-SBM Model," in *Proceedings of the 2019 3rd International Conference on Management Engineering, Software Engineering and Service Sciences*. ACM, pp. 128–134.

Shafia, M. A. et al. (2018) "A Novel Model for the Analysis of Interactions Between Governments and

Agricultures in a Study of Social Beneficial Externalities Based on the Stackelberg Game: A Case Study on Cotton Production," *Journal of Optimization in Industrial Engineering*. QIAU, 11(2), pp. 119–127.

Sohn, M. H. et al. (2003) "Corporate strategies, environmental forces, and performance measures: a weighting decision support system using the k-nearest neighbor technique," *Expert Systems with Applications*. Elsevier, 25(3), pp. 279–292.

Taylor, M. et al. (2019) "Game theory modelling of retail marketing discount strategies," Marketing Intelligence & Planning. Emerald Publishing Limited.

Della Vecchia, P. et al. (2019) "Application of Game Theory and Evolutionary Algorithm to the Regional Turboprop Aircraft Wing Optimization," in *Evolutionary and Deterministic Methods for Design Optimization and Control With Applications to Industrial and Societal Problems*. Springer, pp. 403–418.

Wang, M. and Li, Y. (2014) "Supplier evaluation based on Nash bargaining game model," *Expert Systems with Applications*. Elsevier, 41(9), pp. 4181–4185.

Xiaohui, N. et al. (2014) "Predicting the protein solubility by integrating chaos games representation and entropy in information theory," *Expert Systems with Applications*. Elsevier, 41(4), pp. 1672–1679.

Yazdanpanah, A. H., Akbari, A. A. and Mozafari, M. (2019) "A Game Theoretical Approach to Optimize Policies of Government Under the Cartel of Two Green and Non-green Supply Chains," *Journal of Optimization in Industrial Engineering*. QIAU, 12(2), pp. 189–197.

Yüksel, İ. and Dağdeviren, M. (2010) "Using the fuzzy analytic network process (ANP) for Balanced Scorecard (BSC): A case study for a manufacturing firm," *Expert Systems with Applications*. Elsevier, 37(2), pp. 1270–1278.

Zameer, H. et al. (2018) "A game-theoretic strategic mechanism to control brand counterfeiting," *Marketing Intelligence & Planning*. Emerald Publishing Limited, 36(5), pp. 585–600.

abedian, M., amindoust, A., madahi, R., jouzdani, J. (2021). Determining the Best Combination of Perspective indicators of Balanced Scorecard by using Game Theory.
Journal of Optimization in Industrial Engineering, 14(1), 185-194.

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