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Research Article

Optimization of Stakeholders' Interaction in the Lean Management Process via a Dynamic Game Theory Approach: A Case Study of the National Southern Oilfields Company

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Abstract. The aim of this paper is to assess and optimize the interaction of stakeholders in the lean management process via a dynamic game theory approach within the National Southern Oilfields Company. The present research is applied in terms of the purpose, and qualitative in terms of the data. Also, in terms of its nature and the implementation method, it is based on foundational data. To form the framework of the optimal stakeholder interaction management strategy and measure its effects on lean management (including the dimensions of components and indicators, etc.), scientific and legal documents were studied, experts who utilized the Delphi technique were interviewed, relevant data were summarized and, focus groups and brainstorming were held based on the data foundation method. The findings revealed that the organization in charge of the game selected Stackelberg's game instead of Nash's game, since compared to the latter, the former could produce more than twice when it came to total profit, production of suppliers and manufacturers, etc., thus showing a 100% improvement compared to the cooperative games. In fact, in this study, the manufacturer under consideration preferred Stackelberg's game with the manufacturer acting as the leader and making decisions independent of the suppliers, gaining more profit and consequently more acceptance among people because of optimal production. In this model, three types of parameters played a key role in obtaining the outputs, the first of which was the cost of production. The rise in this parameter indicated the level of competition in profit and production. The second effective parameter was the coefficient of sensitivity to the level of demand for goods. An increase in this parameter caused a decrease in the profit and production of all members of the supply chain. Finally, the last effective parameter was the share of the base goods.

Keywords. Optimization, Stakeholders' interaction, Lean management, Dynamic game theory, Southern Oilfields company

MSC. 26A33; 92B20; 34H10.

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1 Introduction

In the third millennium, the methods and procedures used for the management and administration of production organizations have substantially changed compared to the past [1]. In the contemporary arena, an organization is a set of processes aiming to create value for stakeholders, which entirely depends on value creation within the organization itself. Lean production is among the new perspectives on production that has emerged pursuant to mass production [9]. The fundamental concept of "pure thinking" lies in the eradication of waste and creation of value in the organization. Pure thinking is an attitude with the objectives of boosting productivity, continuous value creation and, minimizing expenditures and losses. The term lean was first coined in 1980. It is based on the utilization of less (raw materials, labor, time, etc.) compared to mass production [19].

Within this approach, customer satisfaction, the fruit of continuous improvement of production quality and services, is the primary foundation of the organization's function, and it is only through this approach that the organization can focus on the maximization of earnings [16]. At the heart of lean management is all-encompassing engagement. Participants can manage their success only via engaging. They are inclusive of the entire workforce of the company as well as the participation of third-party teams. The participants' partial mission [13] and the impact on the way participants behave have various effects on them [4, 14]. This system has two main goals. The first one is to eliminate waste from processes, and the second is to create value for the customer. In fact, the main focus of this management system is on the elimination of any activity that consumes resources and adds to costs, without adding value to the customer [10].

Game theory, on the other hand, seeks to achieve mathematical behavior in strategic or game situations, where one's success in selection depends on the choices of the others. Dependency means that each player is influenced by what the others do in the game, and a player's behavior also affects that of the others. The outcome of the game depends on everyone's decisions, and no one has full control over what happens. Individuals recognize these interdependencies and incorporate them into their decisions [12].

Businesses are affected by several stakeholders in the lean management process. Compliant with dynamic game theory, by constructing a three-stage game model, this research analyzed the mechanism of interaction between internal and external stakeholders affecting the implementation of lean management by an organization.

Nowadays, the phenomenon of lean thinking has been considered as a new strategy by all developed countries of the world. But our country is still in the early stages of considering this phenomenon. To be able to maintain themselves in the prevailing global competition and respond to the customer demands, organizations must adopt a system of lean thinking. Therefore, the use of lean thinking in the game theory of Iran's national petroleum industry is also a necessity. For this reason, the aim of the present study is to assess the interaction of stakeholders in the lean management process via a dynamic game theory approach in the National Southern Oilfields Company.

2 Theoretical Foundations of the Research

Due to increasing complexity, business management systems are required to use new decision-making procedures for their activities. The top executives of each company need to formulate a long-term strategy and policy in accordance with the internal logic of the organization and its specific characteristics. Decision-making has been studied in various situations by many researchers of the scientific and business communities. Hence, utilizing various decision-making techniques to evaluate the criteria that affect decision-making can lead to superior decisions. Therefore, choosing the right decision criteria is quite important [3].

Lean production is among the new perspectives on production emerging pursuant to mass production [9] It is also known as “smooth production” and “timely production”. Its underlying philosophies are to minimize the waste, enhance the product quality, and improve continuously. Lean production is not only concerned with the product, but also concerns customer satisfaction, the maximization of revenue and profit, and improvement of the workplace environment.

Lean management induces the acquisition and multiplication of customers, job satisfaction for both executives and personnel concerning their performance, enhanced productivity in materials, time, human resources and capital, extended life expectancy of organizations, significant improvement of the products, quality of services, significant reduction of organizational costs, and the increment of competitiveness in the current business world [16].

Game theory uses mathematics to assess behavior in strategic situations or games in which one’s success in making choices is based on the choices of the others. Dependency means that each player is influenced by what the others do in the game, and the player’s behavior also affects that of the others. The outcome of the game depends on everyone’s decisions, and no one has full control over what happens. Individuals recognize these interdependencies and incorporate them into their decisions [12].

A game consists of a set of players, a set of moves or strategies, and a specific outcome for each combination of the strategies. Winning a game is not just a matter of luck, rather, it has its own principles and rules, and each player tries to get closer to victory by using those principles during the game.

Based on dynamic game theory, by constructing a three-stage game model, this research investigated the mechanism of interaction between internal and external stakeholders that affect the implementation of the firm’s lean management.

Lean philosophy is a business approach focusing on the minimization of waste by increasing benefit utilization and reducing latency [21], and creates more value for customers by eliminating non-value-added activities [2]. Several academics have examined the effects of lean methods on performance. They believe that lean systems improve sustainability [20]. Lean systems have been considered as a determining factor in the improvement of overall sustainability [5]. Dos Santos and Gerson in 2018 examined the relationship between lean production and operating performance, in the four dimensions of cost, quality, delivery, and flexibility. They found a positive relationship between the purity of a production system and the operating performance [6].

Fullerton et al. in 2013 found the existence of a direct, positive relationship between lean manufacturing performance and simplified strategic reporting system, value-based costing, visual performance measurement information, and employee empowerment [8].

By examining the relationship between the philosophy of lean production and management accounting, [15] revealed the endeavor of the lean production method to minimize waste and maximize the efficiency of human resources, capital and capabilities. Also, by examining the management and accounting methods of lean manufacturing environment management, Khodami-Pour et al. in 2014 concluded the wide applicability of the lean strategy as the dominant paradigm in manufacturing companies [11]. According to Pouya and Soltani (2015), industries that pay more attention to timely production, suppliers and customers, have a higher performance in lean manufacturing [18]. In 2017, Faghhi-Farahmand and Poppendick used a combination of confirmatory factor analysis, clustering and LINMAP techniques to offer a model for the evaluation of lean manufacturing in small- and medium-sized industries [7, 17]. The research findings provided a model with eight structures for lean manufacturing, namely, *timely production, total quality management, repairs and maintenance, supplier relationships, customer relations, human resource management, process management, and factory-level improvement programs.*

Achieving optimal production is among topics worthy of serious consideration in all Iranian industries, and in particular, in the petroleum industry. Lean manufacturing provides a set of data and tools for senior and middle-ranked managers as well as employees that, if utilized properly, can reduce waste, minimize production time, cut down on costs, maximize employee participation, increase the lifespan of devices, standardize the production methods, etc. Although for some time, we have seen the use of lean management in some industrial projects, in this study, using a newer approach called lean thinking, we provide an optimal model in lean processes via a dynamic game theory approach within the National Iranian Oil Company.

3 Research Methodology

The present research is applied in terms of the purpose, and qualitative in terms of the data. Also, in terms of its nature and the implementation method, it is based on foundational data. In this paper, with the help of investigating scientific and legal documents, interviewing experts who utilized the Delphi technique, summarizing the relevant data, and holding focus groups and brainstorming based on the data method, the framework of stakeholder interaction management strategy, including the dimensions of components and indicators that have built the blueprint, is formed and its impact on lean management is measured.

Assessing the internal validity of the findings, comparing the results with theoretical foundations, confirming experts' opinions, verifying the accuracy of the data by the research members, and examining the validity of the interview form were conducted through content validity. In terms of data collection, the research can be considered as field research. The statistical population of this research consisted of twenty-five key experts in the field, including all senior managers, middle-ranked managers, and employees of the National Iranian Oil Company. Collection was made through a purposeful sampling method in three stages of developing a data theory model (structured interview), the Delphi method, panel of experts, brainstorming, required data from expert thinkers, etc.

Books, related articles, the internet, library resources, and the archives of the National Iranian Oil Company were utilized to collect the research data as well to inform the National Iranian Oil Company and its customers concerning advanced options and hypotheses based on each party's preferences and the ranking of those preferences as well as to evaluate the optimal interaction. In the process of implementing lean management, interviews were performed via a dynamic game theory approach.

3.1 Modeling

In this section, various issues on the relationship between the two levels of lean supply chain management, including the manufacturer and several non-suppliers, are presented. The offered supply rate is greater than the demand rate; hence, the sum of the demand rate ratio to the supply rate must be less than 1. Meanwhile, the demand for each product depends on its cost.

First, the assumptions governing the problem, variables and parameters utilized in the supplier and manufacturer models are analyzed as follows. Thereafter, the mathematical model of each chain member, including the objective function (service level), and its constraints are separately presented. In this paper, the interaction between suppliers and producers in the two modes of play (with and without cooperation) has been studied.

Uncooperative play is assessed in two different scenarios. (i) Simultaneous decision-making (ii) Stackelberg. In the first scenario, the weights of suppliers and manufacturers are the same in the chain, and they make decisions simultaneously. In the second one, which is a more common scenario, suppliers have more power in the chain and make decisions first, and then the producer makes his own decisions. In the game mode, with the cooperation of suppliers and manufacturers, they make their decisions in cooperation with each other and in a coordinated manner.

3.1.1 Assumptions

The proposed mathematical model considers several suppliers and one manufacturer, where production occurs in all categories of chain management. The planning horizon is unlimited. This means that the mathematical model is presented for one course only. The parameters, except demand, are definite and predetermined, and no uncertainties are considered. Also, the game is played with complete information, so that the members of the chain are aware of the parameters of each other. The demand for each commodity depends on the cost; whereas the cost increases, demand decreases. Here again, in order to make the model more practical, this relationship is considered nonlinear. There is no shortage because the production rate of petroleum products is higher than the demand rate, due to international sanctions imposed on the country. Of course, the supplier is dealing with budget constraints to offer the product. Since the producer market is in full competition, there must be at least two suppliers for each product to compete with each other. In addition, a supplier can supply more than one type of goods.

3.1.2 Producer's mathematical model

The producer's goal is to determine the optimal level of accumulated items needed (Q) the optimal cost of supplying petroleum products to exporting countries (ψ), and the optimal joint production cycle (T) enabling the maximization of production levels and earnings. Here, the model is considered in the form of several types of goods and with a limit on the amount of production. Hence, even if there is a demand for traction, the manufacturer cannot supply any product of any size. In other words, the producer has a limited supply capacity. The mathematical model of the producer entails a function of the variables of the producer's decision, referred to as the *net profit function*, described as follows. Moreover, the variable (F_{js}) is the cost of providing the products, determined by the suppliers, and the variable (ν_{js}) is the level of products provided by the suppliers.

$$\begin{aligned}
\max \quad \pi_M(\psi, T, Q_j) = & \textstyle\sum_{i=1}^{n}\left[\psi_i \sum_{r=1}^{R} D_{ir}\right] - \sum_{i=1}^{n}\left[Cm_i \sum_{r=1}^{R} D_{ir}\right] \\
& - \textstyle\sum_{j=1}^{J}\sum_{i=1}^{S} F_{js} V_{js} \frac{\sum_{i=1}^{n} AS_i}{T} \\
& - \textstyle\frac{T}{2}\sum_{i=1}^{n}\left[hm_i \sum_{r=1}^{R} D_{ir}\left(1 + \frac{1}{K_{ir}} - \frac{\sum_{r=1}^{R} D_{ir}}{P_i}\right)\right] \qquad (1) \\
s.t. \quad & \\
& T\textstyle\sum_{i=1}^{n}\left[Cm_i \sum_{r=1}^{R} D_{ir}\right] \leq B_m \\
& Q_j = u_{ji}\left(\textstyle\sum_{r=1}^{R} D_{ir}\right) \qquad j = 1, 2, 3, \cdots, J
\end{aligned}$$

The first constraint is the production budget, and the second is the level of required materials and equipment.

It must also generate the demand of the applicants, considering that the period of collecting T items is considered and all the products must be presented in this period. It is worth mentioning that the production time of the products is considered. Hence, the following constraints remain.

$$\begin{aligned}
& \sum_{i=1}^{n} \frac{T\sum_{r=1}^{R} D_r}{P_i} \leq T, \\
& \sum_{i=1}^{n} \frac{T\sum_{r=1}^{R} D_r}{P_i} \leq 1.
\end{aligned} \qquad (2)$$

Consequently, the producer's model should be as follows.

$$
\begin{aligned}
\max \quad & \pi_M(\psi_i, T, Q_{ij}) = \textstyle\sum_{i=1}^{n}\left[\psi_i \sum_{r=1}^{R} D_{ir}\right] - \sum_{i=1}^{n}\left[Cm_i \sum_{r=1}^{R} D_{ir}\right] \\
& \quad - \textstyle\sum_{j=1}^{J}\sum_{i=1}^{S} F_{js} V_{js} \frac{\sum_{i=1}^{n} AS_i}{T} \\
& \quad - \frac{T}{2}\textstyle\sum_{i=1}^{n}\left[hm_i \sum_{r=1}^{R} D_{ir}\left(\frac{\sum_{r=1}^{R} D_{ir}}{P_i}\right)\right] \\
s.t. & \\
& T\textstyle\sum_{i=1}^{n}\left[Cm_i \sum_{r=1}^{R} D_{ir}\right] \le B_m \\
& Q_{ij} = u_{ji}\left(\textstyle\sum_{r=1}^{R} D_{ir}\right) \qquad j = 1,2,3,\cdots,J \\
& \textstyle\sum_{j=1}^{j} Q_{ij} \le P_i \\
& \min_{ij}\left\{Q_{ij}\right\} < Q_{ij'} < \max_{ij}\left\{Q_{ij}\right\} \qquad \forall j' \in \{1,\cdots,j\}
\end{aligned}
\tag{3}
$$

3.1.3 The mathematical model of suppliers

The objective of suppliers is to determine the optimal product size of the manufacturer (ν_{js}) and the optimal supply per unit of product (F_{js}) to maximize the profit level of each supplier. Mathematically, this model includes a function of the suppliers' decision variables, presented as the production function and profit of the suppliers, as follows.

$$
\begin{aligned}
\max \quad & \pi_{S_s}(F_{ijs}, \nu_{ijs}) = \textstyle\sum_{j=1}^{J}\sum_{i=1}^{I} F_{ijs}\nu_{ijs} - \sum_{j=1}^{J}\sum_{i=1}^{I} Cs_{ijs}\nu_{ijs} \\
s.t. & \\
& \nu_{ijs} = Q_{ij} - \eta_{ijs}F_{ijs} + \textstyle\sum^{S} \theta_{ijs}F_{ijs} \\
& \textstyle\sum_{s=1}^{S} \nu_{ijs} = Q_{ij} \qquad j = 1,2,\cdots,J \\
& \nu_{ijs} \le Ca_{js} \qquad j = 1,2,\cdots,J
\end{aligned}
\tag{4}
$$

The first constraint is the limitation of competition on prices offered by the suppliers toward procuring materials. The second constraint guarantees the amounts of materials ordered, obtained from the total demand of applicants, that the suppliers are obliged to provide. Finally, the third constraint represents the production capacity of each producer (the ability to provide products).

3.1.4 Playing without simultaneous cooperation (The fair mode)

When suppliers and producers have the same decision-making power, they make decisions simultaneously and without cooperation. In this event, a Nash game takes place between the supplier and the manufacturer, and the solution to such a structure is to obtain the Nash equilibrium point of the game. The Nash Equilibrium Problem can be written as follows.

$$
\begin{aligned}
\max \quad & \pi_M(\psi_i, T, Q_{ij}) = \sum_{i=1}^{n}\left[\psi_i \sum_{r=1}^{R} D_{ir}\right] \\
& -\sum_{i=1}^{n}\left[Cm_i \sum_{r=1}^{R} D_{ir} - \sum_{j=1}^{J}\sum_{s=1}^{S} F_{ijs} V_{ijs} \frac{-\sum_{i=1}^{n} AS_i}{T}\right] \\
& -\frac{T}{2}\sum_{i=1}^{n}\left[hm_i \sum_{r=1}^{R} D_{ir}\left(\frac{\sum_{r=1}^{R} D_{ir}}{P_i}\right)\right] \\
s.t. \quad & \\
& T\sum_{i=1}^{n}\left[Cm_i \sum_{r=1}^{R} D_{ir}\right] \le B_m \\
& Q_i = u_{ji}\left(\sum_{r=1}^{R} D_{ir}\right) \qquad j = 1,2,3,\cdots,J.
\end{aligned} \tag{5}
$$

$$
\begin{aligned}
\max \quad & \pi_{S_s}(F_{js}, \nu_{js}) = \sum_{j=1}^{J} F_{js}\nu_{js} - \sum_{j=1}^{J} Cs_{js}\nu_{js} \\
& s.t. \\
& \quad \nu_{js} = Q_j - \eta_{js}F_{js} + \sum_{s=1}^{S}\theta_{js}F_{js} \\
& \quad \sum_{s=1}^{S}\nu_{js} = Q_j \qquad j = 1,2,\cdots,J \\
& \quad \nu_{js} \le Ca_{js} \qquad j = 1,2,\cdots,J.
\end{aligned}
$$

3.1.5 Playing without sequential cooperation

In this section, the confrontation between suppliers and producers is considered in the form of the Stackelberg game, where one of the players (members of the chain) plays the role of the leader and can impose his desired strategy on the other players (followers).

$$
\begin{aligned}
\max \quad & \pi_M(\psi_i, T, Q_{ij}) = \sum_{i=1}^{n}\left[\psi_i \sum_{r=1}^{R} D_{ir}\right] \\
& -\sum_{i=1}^{n}\left[Cm_i \sum_{r=1}^{R} D_{ir} - \sum_{j=1}^{J}\sum_{s=1}^{S} F_{ijs} V_{ijs} \frac{-\sum_{i=1}^{n} AS_i}{T}\right] \\
& -\frac{T}{2}\sum_{i=1}^{n}\left[hm_i \sum_{r=1}^{R} D_{ir}\left(\frac{\sum_{r=1}^{R} D_{ir}}{P_{ij}}\right)\right] \\
s.t. \quad & \\
& T\sum_{i=1}^{n}\left[Cm_i \sum_{r=1}^{R} D_{ir}\right] \le B_m \\
& Q_{ij} = u_{ji}\left(\sum_{r=1}^{R} D_{ir}\right) \qquad j = 1,2,3,\cdots,J \quad ,i = 1,2,\cdots,I \\
& (F_{ijs}, \nu_{ijs}) \in arg\max \pi_{S_s}(F_{ijs}, \nu_{ijs}) = \sum_{j=1}^{s} F_{ijs}\nu_{ijs} - \sum_{j=1}^{J} Cs_{ijs}\nu_{ijs} \\
& \nu_{ijs} = Q_{ij} - \eta_{ijs}F_{ijs} + \sum_{s=1}^{S}\theta_{ijs}F_{ijs} \\
& \sum_{s=1}^{S}\nu_{ijs} = Q_{ij} \qquad j = 1,2,\cdots,J \quad ,i = 1,2,\cdots,I \\
& \nu_{ijs} \le Ca_{js} \qquad j = 1,2,\cdots,J \quad ,i = 1,2,\cdots,I.
\end{aligned} \tag{6}
$$

To use the game without sequential cooperation (the Stackelberg game) in pure supply chain management with this model, we first try to solve the profit and production function of the suppliers, which are considered as followers in this model, and then determine the outputs. To do so, we enter the result obtained from the manufacturer model into the manufacturer (leader) model, execute the manufacturer's service function, and finally present the profit and decision variables obtained for each member of the supply chain.

3.1.6 The collaborative game

In this section, the collaborative game approach toward assisting the supply chain (involving suppliers and producers) is evaluated. Taking into account the constraints of suppliers and producers (meaning that, all suppliers are considered as one member), the mathematical model (with performed calculations) will be as follows.

$$
\begin{aligned}
\max \quad & \pi_M(\psi_i, T, Q_{ij}) = \sum_{i=1}^{n}\left[\psi_i \sum_{r=1}^{R} D_{ir}\right] \\
& \qquad - \sum_{i=1}^{n}\left[Cm_i \sum_{r=1}^{R} D_{ir}\right] - \frac{\sum_{i=1}^{n} AS_i}{T} \\
& \qquad - \frac{T}{2}\sum_{i=1}^{n}\left[hm_i \sum_{r=1}^{R} D_{ir}\left(\frac{\sum_{r=1}^{R} D_{ir}}{P_i}\right)\right] \\
s.t. \quad & \\
& T\sum_{i=1}^{n}\left[Cm_i \sum_{r=1}^{R} D_{ir}\right] \le B_m \\
& Q_{ij} = u_{ji}\left(\sum_{r=1}^{R} D_{ir}\right) \qquad j = 1, 2, 3, \cdots, J \\
& \nu_{ijs} = Q_{ij} - \eta_{ijs}F_{ijs} + \sum_{s=1}^{S} \theta_{ijs}F_{ijs} \\
& \sum_{s=1}^{S} \nu_{ijs} = Q_{ij} \qquad j = 1, 2, \cdots, J \quad, i = 1, 2, \cdots, I \\
& \nu_{ijs} \le Ca_{js} \qquad j = 1, 2, \cdots, J \quad, i = 1, 2, \cdots, I.
\end{aligned}
\tag{7}
$$

4 The Findings

Initially, the most important criteria and key sub-criteria affecting the supply chain were localized utilizing the Delphi hourly method. Next, using the fuzzy Dematel method and by the aid of experts in this field, the relationships between these factors were determined. The members of the decision-making team were three managers from the supply chain departments, and in all the stages alluded to in this paper, the experts were the members of this team.

In order to localize the variables, the criteria affecting production and profit were provided to the experts, and they were requested to comment on the primary factors under consideration. Based on the range from 1 to 10 (from insignificant to very important), each of the main numerical factors was assigned, and other effective factors and criteria consistent with the research objective were introduced, if necessary. Only those factors and criteria that had an average of more than 7 were considered. Thereafter, the questionnaire related to sub-factors (sub-criteria) was provided to the experts in order to be reviewed and completed as the previous questionnaire.

The criteria and sub-criteria extracted from the literature review (after localization) are shown in Table 1.

Table 1: The utilized criteria and sub-criteria and their abbreviations

Criterion	Financial Capability (FC)	Logistics Capability (LC)	Experience (HE)	Production Capacity (HC)
Sub-Criteria	Up-To-Date and Efficient Equipment (FC2)	Suitable Location (LC1)	Expert Human-Resources (HE2)	New Production Goods (HC2)
	Aviation Equipment (FC1)	Land Transportation (LC2)	Construction (HE3)	Production Staff (HC2)
		Production Speed (LC3)		

In order to assess the factors affecting the supply chain, four main criteria and nine sub-criteria were used. See Table 1 for more details. The following steps were undertaken to perform the fuzzy Dematel technique.

The first step was to calculate the average matrix of expert opinions. Each expert was asked to express their opinions on the effects of factor i on factor j, specifically, whether they were *ineffective, less effective, of medium effect, highly effective and of a very high effect.*

Their opinions as well as the corresponding triangular fuzzy numbers are shown in Table 2.

Table 2: The sub-criteria direct correlation matrix (Average of the three experts' opinions)

	FC_1			...	HC_2			HC_3			$\sum ui$
	l	m	u	...	l	m	u	l	m	u	
FC_1	0	0	1	...	1	3	4	2	3	4	36
FC_2	3	3	4	...	1.6667	2.6667	3.6667	2	3	4	31.3333
LC_1	0	1	2	...	2	3	4	2	3	4	33.6667
LC_2	2	3	4	...	2	3	4	2	3	4	37
LC_3	1	2	3	...	3	3	4	2	3	4	33
HE_1	2	3	4	...	2.6667	3	4	2	3	4	38.6667
HE_2	2.6667	3	4	...	2	3	4	2	3	4	40
HE_3	3	3	4	...	2	3	4	2	3	4	38
HC_1	1	2	3	...	2	3	4	1	2	3	34
HC_2	2	3	4	...	0	0	1	3	3	4	40
HC_3	2.6667	3	4	...	2.3333	2.6667	3.6667	0	0	1	37.6667
$\sum uj$		37		...		40.3333			40		

First, we acquired the opinions (average) of all the experts, and then we got the average of the experts' opinions by deleting the i_M expert. For the third, second and first expert questionnaires, the values obtained for reliability were 96.72, and 95.23 and 96.24, respectively. The second step was the normalization of the matrix as a direct fuzzy connection of the sub-criteria. The third step wasto calculate the complete fuzzy correlation matrix of the sub-criteria and criteria. The fourth step was to obtain the intensity and direction of the impact of factors and draw a causal diagram. To draw and analyze the graph, we required two indicators of impact intensity and, effectiveness and direction of impact, calculated using the above two indicators for each $i = j$ and in the form of Table 3.

Table 3: Calculation of the intensity index and the direction of impact of each sub-criterion (Fuzzy)

	$d'i$			$r'j$			$d'i + d'j$			$d'i - d'j$		
	I	m	u	I	m	u	I	m	u	I	m	u
FC1	0.7022	1.6925	9.2766	0.8585	1.7762	9.5921	1.5607	3.4687	18.8687	-8.8899	-0.0836	8.4181
FC2	0.6025	1.4072	8.1897	0.7244	1.6522	9.1205	1.3296	3.0594	17.3102	-8.5180	-0.2450	7.4653
LC1	0.5782	1.5708	8.7271	0.2753	1.0501	6.8247	0.8535	2.6209	15.5519	-6.2465	-0.5207	8.4519
LC2	0.7010	1.7533	9.5058	0.6705	1.6439	9.0274	1.3715	3.3972	18.5359	-8.3264	-0.1093	8.8380
LC3	0.5946	1.5017	8.5481	0.7190	1.6680	9.1795	1.3135	3.1697	17.7276	-8.5849	-0.1664	7.8292
HE	0.9037	1.8496	9.8743	0.8868	1.8462	9.8594	1.7905	3.6959	19.7337	-8.9557	-0.0034	8.9875
HE2	0.8926	1.9359	10.2036	0.6876	1.7139	9.3558	1.5802	3.6498	19.5594	-8.4632	0.2221	9.5160
HE3	0.8812	1.8130	9.7345	0.8710	1.8602	9.9128	1.7523	3.6732	19.6473	-9.0316	-0.0472	8.8635
HC1	0.5824	1.5724	9.8181	0.6775	1.7247	9.3958	1.2599	3.2971	18.2139	-8.8134	-0.1523	8.1406
HC2	0.9309	1.9359	10.2036	0.9276	1.9523	9.2641	1.8605	3.8882	20.4677	-8.3332	-0.0164	9.2740
HC3	0.7947	1.7878	9.6362	0.8641	1.9324	10.1881	1.6588	3.7201	19.8243	-8.3934	-0.1446	8.7721

Table 4: Calculation of the intensity index and the direction of impact of each criterion (Fuzzy)

	$\tilde{D}i$			$\tilde{R}j$			$\tilde{D}I + \tilde{R}j$			$\tilde{D}I + \tilde{R}j$		
	I	m	u	I	m	u	I	m	u	I	m	u
FC	0.2400	0.5598	3.1723	0.2864	0.6146	3.3800	0.5264	1.1743	6.5523	-3.1400	-0.0548	2.8859
LC	0.2234	0.5820	3.2441	0.1953	0.5211	3.0145	0.4186	1.1032	6.2585	-2.7911	-0.0609	3.0488
HE	0.3297	0.6820	3.6175	0.2968	0.6559	3.5156	0.6265	1.3379	7.1331	-3.1860	0.0261	3.3207
HC	0.2821	0.6444	3.4765	0.2966	0.6766	3.6003	0.5787	1.3209	7.0768	-3.3182	-0.0322	3.1799

Table 5: The definitive matrix of complete correlation of the sub-criteria (Ts)

	FC1	FC2	LC1	LC2	LC3	HE1	HE2	HE3	HC1	HC2	HC3
PC1	0.2655	0.3203	0.1985	0.2942	0.2990	0.3196	0.3196	0.3371	0.2970	0.3463	0.3441
PC2	0.3027	0.2217	0.1605	0.2336	0.2381	0.2779	0.2892	0.3090	0.2570	0.3032	0.3088
LC1	0.2653	0.2516	01704	0.2789	0.2847	0.3183	0.2872	0.3036	0.2975	0.3286	0.3257
LC2	0.3349	0.2979	0.2031	0.2528	0.3210	0.3417	0.3031	0.3433	0.3263	0.3540	0.3509
LC3	0.2829	0.2545	0.1840	0.2899	0.2299	0.3135	0.2521	0.2908	0.2913	0.3280	0.3196
HE1	0.3474	0.3240	0.2332	0.3336	0.3367	0.2915	0.3155	0.3623	0.3385	0.3718	0.3649
HE2	0.3610	0.3408	0.2397	0.3370	0.3418	0.3705	0.2831	0.3669	0.3478	0.3783	0.3750
HE3	0.3494	0.3309	0.2308	0.3017	0.3284	0.3559	0.3354	0.2891	0.3120	0.3632	0.3607
HC1	0.2915	0.2776	0.1889	0.2897	0.2790	0.3199	0.3045	0.3066	0.2422	0.3306	0.3060
HC2	0.3576	0.3409	0.24000	0.3373	0.3478	0.3691	0.3471	0.3672	0.3483	0.3152	0.3811
HC3	0.3425	0.3242	0.2510	0.2976	0.3024	0.3319	0.3309	0.3503	0.3229	0.3554	0.2925

Table 6: The definitive matrix of complete correlation of the criteria (Tc)

	FC	LC	HE	HC
FC	0.2776	0.2373	0.3087	0.3094
LC	0.2812	0.2461	0.3059	0.3247
HE	0.34227	0.2981	0.3300	0.3569
HC	0.3224	0.2815	0.3364	0.3216

Table 7: Calculation of the definite indicators of intensity and direction of impact

Criterion Type	(D-R) ^{def}	(D + R) ^{def}	Sub-Criteria	Criterion Type	(D-R)	(D + R)	
Impact (Causal)	-0.1598	6.8417	FC1	Impact (Effect)	-0.0909	2.3568	FC
Impact (Effect) (Causal)	-0.3857	6.1890	FC2				
Impact (Effect)	0.8117	5.4118	LC1	Impact (Causal)	0.0949	2.2209	LC
Impact (Effect)	0.1826	6.6755	LC2				
Impact (Causal)	-0.2721	6.3451	LC3				
Impact (Effect)	0.009	7.2290	HE1	Impact (Causal)	0.0467	2.6088	HE
Impact (Effect)	0.3742	7.1098	HE2				
Impact (Causal)	0.0656	7.1865	HE3				
Impact (Causal)	-0.2276	7.2308	HC1	Impact (Effect)	-0.0507	2.5744	HC
Impact (Causal)	-0.0230	7.5261	HC2				
Impact (Causal)	-0.2444	6.5170	HC3				

To draw a relationship map, the threshold value should be calculated. The value of the criteria threshold, the average of all the numbers in Table 6, is equal to

$$\text{Criteria Threshold Value} = \frac{0.2776 + 0.2373 + 0.3087 + \cdots + 0.3216}{16} = 0.3050.$$

Table 8: Impact or non-impact of the criteria

	FC	**LC**	**HE**	**HC**
FC		**0**	**1**	**1**
LC	**0**		**1**	**1**
HE	**1**	**0**		**1**
HC	**1**	**0**	**1**	

To map the internal relations of the criteria, we first calculate the value of the threshold. The value of this threshold can be obtained from the arithmetic mean of all the components listed in Table 5 (the Ts matrix):

$$\text{Sub-Criteria Threshold Value} = \frac{0.2655 + 0.3203 + 0.1985 + \cdots + 0.2925}{121} = 0.3069.$$

Table 9: Impact or non-impact of the sub-criteria

	FC_1	FC_2	LC_1	LC_2	LC_3	HE_1	HE_2	HE_3	HC_1	HC_2	HC_3
FC_1	0	0	1	0	0	1	1	1	0	1	1
FC_2	0	0	0	0	0	0	0	1	0	0	1
LC_1	0	0	0	0	0	1	0	1	0	1	1
LC_2	1	0	0	0	1	1	0	1	1	1	1
LC_3	0	0	0	0	0	1	0	1	1	1	1
HE_1	1	1	0	1	1	0	1	1	1	1	1
HE_2	1	1	0	1	1	1	0	1	1	1	1
HE_3	1	1	0	1	1	1	1	0	1	1	1
HC_1	0	0	0	0	0	1	0	0	0	1	0
HC_2	1	1	0	1	1	1	1	1	1	0	1
HC_3	1	1	0	0	0	1	1	1	1	1	0

Thereafter, the findings of the proposed algorithm in solving non-cooperative models of simultaneous and combined types and with cooperation in sample problems were discussed. The proposed algorithm provided the exact solution of each of the proposed models for different levels of the supply chain. First, the problem was modeled in a real state and then, it was compared in three scenarios: the Nash, Stackelberg and cooperative games.

4.1 Assessment in the event of a hypothetical case study

In this research, the provided services were, respectively, in two categories of services as well as supply and production of products. The first product was M2, and the other one was M3. The number of equipment and basic materials required to provide the both categories of services were both equal to 8. The equipment was procured from three different suppliers.

Table 10 presents the input parameters of the manufacturer. In this case, it is assumed that the manufacturer produces two different categories of services, primarily composed of eight raw materials. The unit considered in this research is *one thousand Rials* (for parameters cm_i, AS_i, ψ_i and hm_i). In addition, the unit of P_i is *number per second*, u_{ij} and Q_j are expressed in *numbers*, and finally, the unit of T is assumed to be *per second*.

Table 10: Government supplier's input parameters

U_{8i}	U_{7i}	U_{6i}	U_{5i}	U_{4i}	U_{3i}	U_{2i}	U_{1i}	p_i	hm_i	AS_i	Cm_1	Parameter / Product
3	2	4	6	3	2	5	3	300	3	100	60	1
3	1	4	2	1	5	4	4	250	4	150	70	1

Table 11 displays the input parameters of raw material suppliers. In this instance, three suppliers are considered for each raw material. The number of raw materials required to produce the two categories of services was 8, provided by the suppliers. In this section, the measurement unit of F_{js} and Cs_{js} is *one thousand Rials*, and the unit of V_{js} is *number per second*. Finally, η_{js} and θ_{js} do not have any measurement unit.

Table 12: General input parameters

γ_i	Base share of i in the market (materials and equipment required to be purchased by the supplier
α_i	Base share of commodity i
β_i	Coefficient of sensitivity to the offered product i

$$\beta_2 = 2,\ \beta_1 = 3,\ \alpha_2 = 170000,\ \alpha_1 = 150000$$

4.2 A case study of the outputs of the Nash game model

Table 13 shows the decision variables of the suppliers, namely, the costs of production services and the amount of raw material produced by the suppliers.

Table 11: The suppliers' input parameters

Supplier Parameter	Raw Material	1	2	3	Supplier Parameter	Raw Material	1	2	3
η_{js}	1	4	5	4	θ_{js}	1	2	2	1.5
η_{js}	2	5	6	6	θ_{js}	2	2.5	2	2.5
η_{js}	3	3	2	5	θ_{js}	3	1	1.5	2
η_{js}	4	6	5	2	θ_{js}	4	1.5	2	0.5
η_{js}	5	5	6	5	θ_{js}	5	1	2	1.5
η_{js}	6	7	5	6	θ_{js}	6	0.5	2.5	1
η_{js}	7	4	2	4	θ_{js}	7	1.5	2	1.5
η_{js}	8	3	1	4	θ_{js}	8	1.5	1.5	0.5
Cs $_{js}$	1	5	5	6	-	-	-	-	-
Cs $_{js}$	2	4	3	3	-	-	-	-	-
Cs $_{js}$	3	5	5	6	-	-	-	-	-
Cs $_{js}$	4	5	3	6	-	-	-	-	-
Cs $_{js}$	5	4	5	6	-	-	-	-	-
Cs $_{js}$	6	2	3	1	-	-	-	-	-
Cs $_{js}$	7	5	3	4	-	-	-	-	-
Cs $_{js}$	8	2	3	2	-	-	-	-	-

Table 13: Nash game model decision variables of suppliers

Supplier Parameter	Raw Material	1	2	3	Supplier Parameter	Raw Material	1	2	3
F_{JS}	1	27075.9	27075.9	23691.8	V_{js}	1	41292.3	28066.7	20717.9
F_{JS}	2	23014.4	23011	22014	V_{js}	2	11381.5	15171.6	11378.5
F_{JS}	3	35975.5	35857.5	35960	V_{js}	3	10739.9	2334.7	10741.6
F_{JS}	4	3199.68	3198.79	2300.12	V_{js}	4	28685.2	35040.3	28688.5
F_{JS}	5	7193.85	7194.3	7194.5	V_{js}	5	59751.2	72477.5	59756.6
F_{JS}	6	8851.44	8852	8850.96	V_{js}	6	55207.8	55911.1	55204.2
F_{JS}	7	5757.42	5756.58	5757	V_{js}	7	15567.4	18828.2	15562.1
F_{JS}	8	28767	2866	2580	V_{js}	8	77066.2	10273.2	77066.2

The decision variables of the manufacturers, namely, the wholesale price of each product, the joint production cycle of the products, and the required quantity of raw materials, are as follows.

$$\psi_1^* = 60311.5, \quad \psi_2^* = 70407.4, T^* = 0.015,$$
$$Q_1^* = 23937.5, \quad Q_2^* = 37931.6, \quad Q_3^* = 85057.2, \quad Q_4^* = 63618.3,$$
$$Q_5^* = 127236.6, \quad Q_6^* = 6997.1, \quad Q_7^* = 32683.8, \quad Q_8^* = 25686.7,$$
$$D_1^* = 0, \quad D_2^* = 29185.2.$$

The profit and production quantities of each chain member can be written as follows.

$$\pi_{s1}^* = 1.0349 * 10^9, \pi_{s2}^* = 1.11284 * 10^9, \pi_{s3}^* = 1.514492 * 10^9,$$
$$\pi_M^* = 4.03798 * 10^9, \pi_T^* = 7.75735 * 10^9.$$

Based on the obtained outputs, the cycle time in this game was 0.0015 seconds, and the costs of preparing each product were 6031.5 and 70407.4 thousand Rials, respectively. Next, the monetary figures for raw materials (required for each type of material) were 23937.5, 37931.6, 85057.3, 63618.3, 127236.6, 6997.1, 32683.8 and 25686.7. Finally, we obtained the demand for each of the final products, which were 0 and 29185.2, respectively. In this game, pursuant to the calculations and obtaining the decision variables of each member of the chain, we tried to separately obtain the level of service of each member (plus the service of the entire game), which were equal to 103490, 1112840, 1514492, 403798 and 775735 ththousand Rials, respectively.

4.3 The outputs of the Stackelberg game model

Table 14 presents the decision variables of the suppliers, namely, the production costs and the amount of raw material produced by the suppliers.

Table 14: The decision variables of the suppliers in the Stackelberg model

3	2	1	Raw Material	Supplier Parameter	3	2	1	Raw Material	Supplier Parameter
8027.7	255952.4	202117.4	1	V_{js}	31812.6	23855.2	23546	1	F_{JS}
231062.1	441416.9	331069.6	2		46507.4	45582.7	23906	2	
330308.4	330307	330308	3		40813.2	33030.3	23253	3	
85000.6	850866	850868.6	4		28362.3	28362.3	19994.5	4	
170173.7	430173.6	160173.6	5		64872.4	53465.6	59983.8	5	
17904.4	21904.4	27904.4	6		51616.2	44877.8	23955.7	6	
99943.95	18994.02	19994.4	7		24178.5	19994.6	15810.7	7	
16955.9	226081.5	169558.9	8		38579.1	22327.8	32546.3	8	

$$\begin{aligned}
&\psi_1^* = 71694.1, \quad \psi_2^* = 557926.1, \quad T^* = 0.03, \\
&Q_1^* = 538350, \quad Q_2^* = 110355, \quad Q_3^* = 653613, \quad Q_4^* = 538350, \\
&Q_5^* = 107670, \quad Q_6^* = 121881, \quad Q_7^* = 688328, \quad Q_8^* = 565199, \\
&D_1^* = 149978, \quad D_2^* = 888350.
\end{aligned}$$

The profit level of each member of the chain can be obtained as follows.

$$\begin{aligned}
&\pi_{s1}^* = 2.65324 * 10^{22}, \quad \pi_{s2}^* = 2.54436 * 10^{22}, \\
&\pi_{s3}^* = 2.65347 * 10^{22}, \quad \pi_M^* = 7.96040 * 10^{22}, \\
&\pi_T^* = \pi_M^* + \pi_{s1}^* + \pi_{s2}^* + \pi_{s3}^* = 1.09105 * 10^{21}.
\end{aligned}$$

In line with the outputs obtained in this game, our cycle time was 0.03 seconds, and the cost of services and goods provided were 71694.1 and 557926.1 tthousand Rials, respectively. Next, the amounts of raw materials required for each type of material were 538350, 110355, 653613, 538350, 107670, 121881, 688328 and 565199, respectively. The demands for the item were also determined to be 149978 and 888350, respectively. In this game, after calculations and obtaining the decision variables of each chain member, we tried to separately obtain the profit and production level of each member (as well as the total level of service in the game), which were equal to $265340000, 254436000$, $265347000, 796040000$ and 10910500 thousand Rials, respectively.

4.4 A case study of the outputs in the collaboration game model

Table 15 reports the decision variables of the suppliers, namely, production costs and level of raw materials produced by the suppliers, respectively.

Table 15: The decision variables of the collaboration model

3	2	1	Raw Material	Supplier Parameter	3	2	1	Raw Material	Supplier Parameter
187863	224022	202509	1	V_{js}	27752.2	30465.6	25311	**1**	F_{JS}
271809	371514	319061	2		34760.7	34298.3	28460.4	**2**	
94368	1584410	129488	3		34760.7	34493.9	29605.6	**3**	
107281	160920	138661	4		15781.2	15780.6	11597.1	**4**	
205554	347043	220223	5		36033.6	30329.9	23588.8	**5**	
50506,7	155120	116741	6		30333.5	26864.9	21403.6	**6**	
85851.4	134063	108832	7		14967.7	12875.6	10784.1	**7**	
111100	190270	124675	8		33723	25547.6	30656.6	**8**	

$$\psi_1^* = 60334.8, \quad \psi_2^* = 70324, \quad T^* = 0.001,$$
$$Q_1^* = 624394, \quad Q_2^* = 962385, \quad Q_3^* = 484751, \quad Q_4^* = 536338,$$
$$Q_5^* = 107268, \quad Q_6^* = 793390, \quad Q_7^* = 367343, \quad Q_8^* = 426047,$$
$$D_1^* = 168996, \quad D_2^* = 29351.9.$$

The profit and production levels of each chain member can be obtained as follows.

$$\pi_{s1}^* = 5.53741 * 10^6, \pi_{s2}^* = 7.1111 * 10^6, \pi_{s3}^* = 5.00183 * 10^6,$$
$$\pi_M^* = 1.22475 * 10^{10},$$
$$\pi_T^* = \pi_M^* + \pi_{s1}^* + \pi_{s2}^* + \pi_{s3}^* = 1.22298 * 10^{10}.$$

Based on the outputs obtained in this game, our cycle time was 0.001 seconds, and moreover, the production costs were 60334.8 and 70324 thousand Rials, respectively. Additionally, the levels of basic equipment required for the various types of materials were $624394, 962385, 484751, 536338, 107268$, $793390, 367343$ and 426047, respectively. Finally, we obtained the demand for each of the final products (168996 and 29351.9, respectively). In this game, pursuant to calculations and acquiring the decision variables of each member of the chain, an effort was made to obtain the levels of production and earning profit for each member separately, as well as the earning profit level of the entire game, which were equal to $5537.41, 71111.1, 50018.3, 12247.5$ and 12229.8 thousand Rials, respectively.

5 Summary and Conclusion

The aim of this paper was to optimize the interaction of stakeholders in the lean management process via a dynamic game theory approach in the National Company of Southern Oilfields. According to the investigation conducted in this research, if the desired chain vertically increases its type of coordination, that is, so that the manufacturer plays the role of the leader and imposes all its policies on the following members (suppliers), then the horizontal coordination and other types of coordination will be more profitable, which is the same as what happens in the Stackelberg game. After studying the sensitivity of important and key parameters of the problem and analyzing the final results of each of the games, we found the important role played by the manufacturer among the supply chain members in this industry and case study. According to the outputs obtained by the Stackelberg game for this case, studies with production optimization will be most beneficial. So, the organizations in question must first examine their existing policies if these are based on the Stackelberg game policies. In order to further increase the profit with more efficient production, it is necessary to change the important parameters of the model. But, if the policy governing the policy organization is different from the policies proposed in the Stackelberg game, the relevant organization must first create the necessary infrastructure to implement the new policy and then try to change the important parameters.

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