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Identification and prioritization of determinants of the interaction between lean production management stakeholders "Case study: The National Iranian Oil Company"

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Abstract

The present study aimed to identify and prioritize determinants of the interaction between lean production management stakeholders in the National Iranian Oil Company. The statistical population consisted of all key experts in the field of National Iranian Oil Company and the statistical sample included 25 experts of the National Iranian South Oil Company who were selected using the purposive sampling method. To analyze the data obtained from interviews and questionnaires, the most important criteria and key sub-criteria affecting the supply chain were first localized using Saaty's Delphi method, and then the relationships of the factors were determined using the Fuzzy DEMATEL method and with the help of experts, and the criteria and sub-criteria were ranked. MATLAB software was also utilized for data analysis. In this research, the initial framework of the stakeholder interaction management model was created using the dynamic game theory approach in the lean management process, and their solutions were compared in three game scenarios, namely Nash, Stackelberg, and cooperative scenarios. Based on the research results, the correct layout was the most effective criterion, and up-to-date and efficient equipment was the most affectable sub-criterion. Among the main criteria, logistics ability was the most effective criterion, and financial ability was the most affectable criterion. In terms of interaction, new production items had the highest interaction and correct layout had the lowest interaction. The highest interaction of the main criteria was related to experience and the least was related to production ability. Based on the results, the producer preferred to choose the Stackelberg game with the suppliers and act as a leader and make decisions independently from the suppliers in the present study, thereby, obtaining more profit and production, and then more popularity among people.

Keywords: stakeholder interaction, lean management, fuzzy DEMATEL method, The National Iranian Oil Company
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1 Introduction

Most organizations pay special attention to solving problems and removing weaknesses in their systems and processes to increase productivity and reduce existing costs, and finally achieve a competitive advantage for sustainable survival in the global arena [17]. The movement towards management, provision of services, and production of world-class products, which is called the managerial and industrial revolution of the 21st century, require the implementation of lean management as a prerequisite of world-class management. Lean management via continuous improvement, eradicating waste and creating value in the organization along with attracting the participation of employees, on the one hand, and stakeholders, on the other hand, cause many benefits to production and service systems to control costs and improve service quality. Lean is a set of capabilities and competencies that cause the survival and progress of organizations in the business [14]. In this regard, lean management strategies remove many obstacles from the path of organizations and maintain the survival and continuous improvement of the organization by changing the organizational culture, increasing flexibility, increasing productivity, and profitability, and establishing a correct relationship with customers. Furthermore, technological advances, which are competitive advantages in the global arena and have attracted the attention of companies and organizations, have caused a huge development in the communication of organizations, flexibility, processes, and the nature of competition so that organizations cannot enter the global market and compete in it without taking step towards the path of these developments [9]. Lean management improves the ability of organizations to supply high-quality services and products and it is thus an important factor for organizational productivity. The presence of different stakeholders with different interests and meeting different expectations, and their ways of interaction in the lean management process have caused a serious challenge for managers in the correct implementation of lean management [9]. This issue becomes more important in projects that are related to many organizations, groups, and people due to their breadth and complexity. The oil and gas projects are examples of these projects. Given that the National Iranian Oil Company operates as a project-centered organization, the existence of different expectations and interests of the stakeholders in the implementation of huge projects, and the establishment and implementation of the lean management system in these companies always lead to challenges and conflicts. Since it is impossible to fulfill all the expectations of the stakeholders, it is necessary to prioritize them in different ways [1]. Given the importance of this issue, the present study aimed to identify and prioritize determinants of the interaction between lean production management stakeholders in the National Iranian Oil Company.

Theoretical basis and research background

Lean philosophy is an approach to business that focuses on minimizing waste by increasing the use of benefits and reducing delay time [16] and creates more value for customers by eliminating non-value-added activities [3].

Organizations must provide suitable bases for the institutionalization of lean thinking at all levels to become a lean economic enterprise. The institutionalization of this thinking is closely related to the types of attitudes and values governing the organization and its employees. Lean thinking should become a culture in organizations. The greater the individuals are committed to basic and core values of organizations, such as lean thinking, and the more members believe in this value, the stronger that culture and values are and have a greater effect on the organization members' behavior [4].

Lean management is taken from lean production as a type of production management based on the prototype of the Toyota production system presented by experts and scientists after a review of more than 90 automobile factories and comparative analysis at the Massachusetts Institute of Technology in 1990. It has been performed with the participation of 17 countries in the International Motor Vehicle Program (IMVP) worldwide. Lean management puts "full" participation, continuous improvement, value "creation", and positive energy "stimulation" at its core. Its significant innovative performance has proven its validity and benefits and changed the developmental path of companies over the past few decades led by manufacturing companies [15]. Numerous successful cases of lean management performance indicate that lean management plays an important role in increasing innovation in corporate governance. Lean management can help companies improve their management innovation level [5]. The effects of implementing lean management are not ideal.
Cunningham and Gium report that lean production companies, which have a management costing system based on the value stream, have a systematic focus on continuous growth and elimination of waste through a simpler accounting process and a more strategic management accounting system [10].

In the field of the impact of lean methods on performance, researchers believe that lean systems help improve sustainability. Lean systems are determining factors for improving overall sustainability [5]. In the study of management and control accounting practices in a lean manufacturing environment, Fullerton et al. [8] found that there were direct positive relationships between the implementation of lean production and a simplified strategic reporting system, costing based on value stream, visual performance measurement information, and employee empowerment. Inventory tracking had a direct negative relationship with them, even though the relationship was conditional on the extent of senior manager's support for changes in production strategies so that companies decreased their reliance on inventory tracking in the presence of strong management support. Given direct connections between management and control accounting activities, they concluded that these activities worked as a package and together in a lean production environment.

Khodamipour et al. [10] examined management accounting and monitoring methods in the lean production environment and concluded that the lean strategy was rapidly changing to a dominant paradigm in manufacturing companies. To develop a model for evaluating lean production in small and medium enterprises, using the combination of confirmatory factor analysis and clustering methods, Pouya and Soltani [13] concluded that industries would have a higher performance in lean production if they paid more attention to timely production, suppliers, and customers. Pakmaram and Rostamnejad [12] examined the simultaneous use of lean production and ERP towards a lean implementation process based on ERP. Their research indicated that new advancements in IT and the onset of hybrid "Push-Pull" production control mechanisms allowed ERP and lean methods to converge towards a situation where the ERP system could be used to support the deployment of lean methods. This research analyzes the prominent processes of lean and ERP implementation available in scientific articles, investigates the simultaneous implementation process in real-time, and also develops and presents a process for lean implementation based on ERP. The findings of this study indicate that the implementation of a simultaneous ERP system can mediate the use of lean production methods.

Feghhi Farahmand [7] presented a model for evaluating lean production in small and medium industries, using the combination of confirmatory factor analysis, clustering, and LINMAP techniques, and raised four questions. The research results provided a model with eight constructs for lean production, including just-in-time (JIT) manufacturing, total quality management, repairs and maintenance, relationships with suppliers, relationships with customers, human resource management, process management, and plant improvement programs.

Ebrahimipour et al. [6] examined the effects of implementing lean management on improving hospital processes in Tehran. This case study examined the level of patient satisfaction and discharge with personal satisfaction before and after the intervention. A Spaghetti chart was used to implement lean management. All medical, administrative, and paraclinical departments of a private hospital in Tehran were examined from January 2015 to July 2016.

Research methodology

The present research was applied based on the purpose, operational in terms of design, and had a field type in terms of the data collection method. The present research had a mathematical model and estimated the stakeholders' expectations in the process of lean management implementation, using dynamic game theory and was a practical model for managers.
The statistical population consisted of key experts in the field of subject, including all senior managers, middle managers, and employees of the National Iranian Oil Company. The statistical sample was obtained equal to 25 experts of the National Iranian South Oil Company using the purposive sampling method.

Data collection tools and methods

In the present research, we use questionnaires and interviews to collect data from the samples and finally analyzed the data. The books, relevant articles, the internet, library resources, and the archive of the National Iranian Oil Company were used to collect data, and the interviews were used to know the options facing the Iranian Oil Company, its customers, and assumptions based on the preferences of each party, and the ranks of these preferences to examine the optimal interaction in the implementation of the lean management process.
In the present research, the content validity was performed to examine the validity of the interview forms using the review of theoretical bases and experts' confirmation. Therefore, structured interviews and questionnaires were used to collect data.
The criteria affecting production and profit were given to the experts and they were asked to give their opinions about the main factors to localize the questionnaire about localization of the main factors. Therefore, a number was assigned to each of the main factors based on a scale of one to ten (from unimportant to very important) and they should introduce another effective factor and criterion according to the research purpose if necessary. Only factors and criteria with a mean of greater than seven were taken into consideration. The questionnaire about sub-factors (sub-criteria) was then given to the experts and it was reviewed and completed like the previous questionnaire. Using

the Saaty Delphi method, the most effective criteria and key sub-criteria in the supply chain were localized, and then their relationships were identified using the Fuzzy DEMATEL method and with the help of experts. Furthermore, the dynamic game theory method and MATLAB software were used to investigate and analyze the stakeholders' interaction in lean management.

Analysis of research findings

First stage: Localization of research variables

Table 1 presents the results of localizing the main factors of criteria and sub-criteria extracted from the research literature that affect production and profit:

Table 1: Criteria and sub-criteria and their abbreviations

Criteria	**Financial capability (FC)**	**Logistics capability (LC)**	**Experience (HE)**	**Production capability (HC)**
Sub-criteria	Goods order (FC1) Up-to-date and efficient equipment (FC2)	Correct layout (LC1) Land transportation (LC2) Maritime transportation (LC3)	Knowledge about the production (HE1) Expert human resources (HE2) Construction (HE3)	Production speed (HC1) New production items (HC2) Production staff (HC3)

Second stage: fuzzy DEMATEL technique

Four main criteria and nine sub-criteria were used to investigate the determinants of the supply chain as listed in Table 1.

The following steps are taken to implement the fuzzy DEMATEL technique:

The first step: calculation of the matrix of mean comments (the fuzzy direct-relation matrix of sub-criteria)

In this step, each expert was asked to express the effect of factor i on factor j in a verbal expression: "no effect, low effect, medium effect, high effect, and very high effect". Their opinions were considered according to the triangular fuzzy numbers corresponding to the opinions, which were converted into fuzzy numbers, and then the fuzzy direct-relation matrix (As) at a dimension of $N * N$ in which each entry aij was a fuzzy number as $a_{ij} = (l_{ij}, m_{ij}, u_{ij})$ and from the mean of all opinions.

Table 2: The direct-relation matrix of sub-criteria (mean opinions of three experts)

	FC_1			...	HC_3			HC_2			$\sum ui$
	l	m	u	...	l	m	u	l	m	u	
FC_1	0	0	1	...	2	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		

We first obtained the mean of all experts 'opinions and then the mean of experts' opinions by removing the expert i:

The reliability of the third expert's questionnaire was equal to 96.72, the reliability of the second expert's questionnaire was equal to 95.23, and the reliability of the first expert's questionnaire was equal to 96.24.

Second step: normalization of the fuzzy direct-relation matrix of the sub-criteria

After obtaining the fuzzy direct-relation matrix, we must normalize it. In Table 2, the largest value was equal to $\sum u = 40.3333$. Therefore, all fuzzy numbers in the above table are divided by this number, and the normalized Table 3 is obtained.

Table 3: The normalized fuzzy direct-relation matrix of sub-criteria (Xs)

	FC_1			...	FC_2			HC_3		
	l	m	u	...	l	m	u	l	m	u
FC_1	0	0	0.0248	...	0.0744	0.0744	0.0992	0.046	0.0744	0.0992
FC_2	0.0744	0.0744	0.0992	...	0	0	0.0248	0.0496	0.0744	0.0992
LC_1	0	0.0248	0.0496	...	0	0.0248	0.0496	0.0496	0.0744	0.0992
LC_2	0.0496	0.0744	0.0992	...	0.0248	0.0496	0.0744	0.0496	0.0744	0.0992
LC_3	0.0248	0.0496	0.0744	...	0.0083	0.0331	0.0579	0.0496	0.0744	0.0992
HE_1	0.0496	0.0744	0.0992	...	0.0413	0.0661	0.0909	0.0496	0.0744	0.0992
HE_2	0.0661	0.0744	0.0992	...	0.0496	0.0744	0.0992	0.0496	0.0744	0.0992
HE_3	0.0744	0.0744	0.0992	...	0.0744	0.0744	0.0992	0.0496	0.0744	0.0992
HC_1	0.0248	0.0496	0.0744	...	0.0248	0.0496	0.0744	0.0248	0.0496	0.0744
HC_2	0.0496	0.0744	0.0992	...	0.0496	0.0744	0.0992	0.0744	0.0744	0.0992
HC_3	0.0661	0.0744	0.0992	...	0.0496	0.0744	0.0992	0	0	0.0248

The third step: calculating the total fuzzy relation matrix of sub-criteria and criteria

When matrix A was normalized and matrix X was obtained, we obtained the total fuzzy relation matrix of (Ts) and (Tc).

Table 4: Total fuzzy relation matrix of sub-criteria (Ts)

	FC1			FC2			...	HC3		
	I	M	U	I	M	U		I	M	U
FC1	0.0369	0.1062	0.8127	0.1010	0.1684	0.8434	...	0.0812	0.1830	0.9292
FC2	0.1028	0.1588	0.7906	0.0299	0.0845	0.6881	...	0.0765	0.1638	0.8311
LC1	0.0280	0.1221	0.7839	0.0233	0.1151	0.7528	...	0.0749	0.1743	0.8791
LC2	0.0816	0.1785	0.9009	0.0540	0.1491	0.8393	...	0.0806	0.1866	0.9496
LC3	0.0527	0.1409	0.7972	0.0331	0.1193	0.7464	...	0.0762	0.1866	0.8330
HE1	0.0907	0.1883	0.9313	0.0765	0.1684	0.8827	...	0.0906	0.1931	0.9827
HE2	0.1056	0.1894	0.9595	0.0843	0.1810	0.9168	...	0.0897	0.1990	1.0125
HE3	0.1138	0.181	0.9198	0.1077	0.1743	0.8794	...	0.0897	0.1912	0.9706
HC1	0.0535	0.1458	0.8207	0.0488	0.1388	0.7837	...	0.0524	0.1528	0.8657
HC2	0.0922	0.1894	0.9595	0.0848	0.1810	0.9168	...	0.01140	0.1990	1.125
HC3	0.1007	0.1794	0.9105	0.0809	0.1724	0.8709	...	0.0382	0.1199	0.8921

Table 5: Total fuzzy relation matrix of criteria (Tc)

	FC			LC			HE			HC		
	I	M	U	L	M	U	L	M	U	L	M	U
FC	0.0676	0.1295	0.7837	0.0309	0.1014	0.6995	0.0753	0.1610	0.8375	0.0662	0.1599	0.8516
LC	0.0455	0.1375	0.8043	0.0382	0.1152	0.7158	0.0626	0.1572	0.8468	0.0771	0.1722	0.8772
HE	0.0964	0.1798	0.9149	0.0687	0.1536	0.8166	0.0776	0.1608	0.9209	0.0869	0.1878	0.9650
HC	0.0768	0.1678	0.8770	0.0575	0.1430	0.7826	0.0813	0.1769	0.9104	0.0665	0.1567	0.9065

The fourth step: obtaining the intensity and direction of the influence of factors

We calculated rj and di indices. The index di represented the sum of row i and the index rj represents the sum of the column j of the matrix Ts. We also calculated Di and Rj indices. Di index represented the sum of row i and Rj index indicated the sum of the column j of the Ts matrix. For analysis, we needed two indices, influence, and affectability intensity, as well as the direction of influence, which were calculated using the above two indices for each $i = j$. The sum of $D + R$ for each factor indicated the importance (weight) of that factor, the R-value of each factor indicated its influence on other factors, and the corresponding D value indicated the intensity of affectability of the factor.

Based on the results in Table 11, the correct layout was the most effective criterion, followed by the expert manpower, land transportation, construction, and consulting forces. However, up-to-date and efficient equipment

Table 6: Calculation of the intensity index and direction of influence of the sub-criteria (in a fuzzy manner)

	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
HE1	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 7: Calculation of the intensity and direction of the influence of the criteria (in a fuzzy manner)

	D~i			*R~j*			*D~I + R~j*			*D~I - 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 8: Definite total relation matrix of sub-criteria (Ts)

	FC1	FC2	LC1	LC2	LC3	HE1	HE2	HE3	HC1	HC2	HC3
FC1	0.2655	0.3203	0.1985	0.2942	0.2990	0.3371	0.3196	0.3196	0.2970	0.3463	0.3441
FC2	0.3027	0.2217	0.2381	0.1605	0.2336	0.2779	0.2892	0.3090	0.2570	0.3032	0.3088
LC1	0.2653	0.2516	0.2847	01704	0.2789	0.3183	0.2872	0.3036	0.2975	0.3286	0.3257
LC2	0.3349	0.2979	0.3210	0.2031	0.2528	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	0.3367	0.2332	0.3336	0.2915	0.3155	0.3623	0.3385	0.3718	0.3649
HE2	0.3610	0.3408	0.3418	0.2397	0.3370	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 9: Definite total relation matrix of 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

was the most affected criterion, followed by the production speed, knowledge, and awareness of production methods, production staff, air transportation equipment, and new production items were known as the most affected criteria. In this regard, logistics capability and experience criteria were the most effective, and financial capability and production ability were the most affected criteria.

According to Table 12, research variables are also ranked based on the level of interaction. The results of this ranking also indicated that the new production items had the highest interaction, followed by the production staff, consulting forces, construction, expert human resources, air transportation, land transportation, knowledge about production methods, production speed, up-to-date and efficient equipment, and correct layout. Among the main criteria, the highest interaction was related to experience, followed by production capability, financial capability, and logistics capability.

Table 10: Calculation of definite indices, influence intensity, and direction

	$(D+R)$	$(D-R)$	Type of criteria	Sub-criteria	$(D+r)^{\text{def}}$	$(d-r)^{\text{def}}$	Type of criteria
FC	2.3568	-0.0909	Affectability	FC1	6.8417	-0.1598	Affectability (effect)
			(effect)	FC2	6.1890	-0.3857	Affectability (effect)
LC	2.2209	0.0949	Affectability	LC1	5.4118	0.8117	Affectability (cause)
			(cause)	LC2	6.6755	0.1826	Affectability (cause)
				LC3	6.3451	-0.2721	Affectability (effect)
HE	2.6088	0.0467	Effective	HE1	7.2290	0.009	Affectability (cause)
			(cause)	HE2	7.1098	0.3742	Affectability (cause)
				HE3	7.1865	0.0656	Affectability (effect)
HC	2.5744	-0.0507	Effective	HC1	6.5170	-0.2444	Affectability (effect)
			(effect)	HC2	7.5261	-0.0230	Affectability (effect)
				HC3	7.2308	-0.2276	Affectability (effect)

Table 11: Rating effective.affectable criteria and sub-criteria

Criteria. Sub-criteria	**Effective factors**	**Factor code**	$\boldsymbol{d-r}$	**Effect rank**
	Rating effective sub-criteria			
Sub-criteria	Correct layout	LC1	0.8117	1
	Expert human resources	HE2	0.3742	2
	Land transportation	LC2	0.1826	3
	Construction	HE3	0.0656	4
	Consulting forces	HE1	0.009	5
Criteria	Logistics capability	LC	0.0949	1
	Experience	HE	0.467	2
	Rating affectable sub-criteria			
	Affectable factors	**Factor code**	$\boldsymbol{d-r}$	**Affectability rank**
Sub-criteria	Up-to-date and efficient equipment	FC2	-0.3857	1
	Production speed	LC3	0.2721	2
	Knowledge about production	HC1	-0.2444	3
	Production staff	HC3	-0.2276	4
	Air transportation equipment	FC1	-0.1598	5
	New production items	HC2	-0.0230	6
Criteria	Financial capability	FC	-0.0909	1
	Production capability	HC	-0.0507	2

Table 12: Ranking degrees of the interaction of criteria and sub-criteria

Criteria. Sub-criteria	**Effective factors**	**Factor code**	$\boldsymbol{r+d}$	**Interaction rank**
Sub-criteria	New production items	HC2	7.5261	1
	Production staff	HC3	7.2308	2
	Consulting forces	HE1	7.2290	3
	Construction	HE3	7.1865	4
	Expert human resources	HE2	7.1098	5
	Air transportation equipment	FC1	6.8417	1
	Land transportation	LC2	6.6755	2
	Knowledge about production	HC1	6.5170	3
	Production speed	LC3	6.3451	4
	Up-to-date and efficient equipment	FC2	6.1890	5
	Correct layout	LC1	5.4118	6
Criteria	Experience	HE	2.6088	
	Production capability	HC	2.5744	
	Financial capability	FC	2.3568	
	Logistics capability	LC	2.2209	

Since profit optimization was the main topic of the present study, the objective function and restrictions indicated an optimization problem. The game theory was also added to the model as optimization problem restrictions. The problem-solving was based on the optimization approach, and the theory of independent games was used in solving problems, and thus the optimal value of each decision variable was obtained so that the problem was first modeled in a real state and then three Nash, Stackelberg, and cooperative game scenarios were compared.
In the Nash game, both models are implemented simultaneously because there is such a rule in the Nash game, but since the members are leaders and followers in the second game (Stackelberg), first, the follower function is performed, and the obtained optimal value is entered into the model or the leader function, and finally, the leader function is optimized. Due to the cooperation strategy between the members in the third game, the members first cooperate on some variables and then the model becomes single-level after the cooperation, and finally, the single-level model is optimized.

Input parameters of the problem

In Table 13, the input parameters consist of the producer. In this case study, it is assumed that the producer produces two different groups of services which mainly consist of eight raw materials. The units of the parameters cm_i, AS_i, ψ_i, and hm_i are thousand rials. The unit of P_i is the number per second, and the units of u_{ij} and Q_j are equal to the number, and finally, the unit of T is second.

Table 13: Public supplier input parameters

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

Table 14 presents the input parameters of suppliers of raw materials. In this case study, three suppliers are considered for each raw material, and eight raw materials are necessary for the production of two groups of services that are provided by the suppliers. In this part, the unit of F_{js} and Cs_{js} are equal to one thousand rials, and the unit of v_{js} is the number per second, and finally, they do not have any unit of measurement, and η_{js} and θ_{js} are also unitless.

Total input parameters: In this model, three types of parameters presented in Table 15 play fundamental roles in obtaining the outputs.

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

Table 16 presents the supplier decision variables, including the cost of providing products and production services and the number of raw materials produced by the suppliers in the Nash model.

The profit and production values of each chain member in this model are as follows:

$$\pi^*_{s1} = 1.0349 * 10^9, \pi^*_{s2} = 1.11284 * 10^9, \pi^*_{s3} = 1.514492 * 10^9$$
$$\pi^*_M = 4.03798 * 10^9$$
$$\pi^*_T = 7.75735 * 10^9$$

Table 14: Input parameters of suppliers

Supplier / Parameter	Raw materials	1	2	3	Supplier / Parameter	Raw materials	1	2	3
η_{js}	1	4	5	4	θ_{js}	1	2	2	1.5
	2	5	6	6		2	2.5	2	2.5
	3	3	2	5		3	1	1.5	2
	4	6	5	2		4	1.5	2	0.5
	5	5	6	5		5	1	2	1.5
	6	7	5	6		6	0.5	2.5	1
	7	4	2	4		7	1.5	2	1.5
	8	3	1	4		8	1.5	1.5	0.5
Cs_{js}	1	5	5	6					
	2	4	3	3					
	3	5	5	6					
	4	5	3	6					
	5	4	5	6					
	6	2	3	1					
	7	5	3	4					
	8	2	3	2					

Table 15: General input parameters

γ_i	Base share of supplier I in the market for the purchase of materials and equipment
α_i	Base share of goods i
β_i	Product i sensitivity factor

Table 16: Suppliers' decision variables in the Nash model

Supplier / Parameter	Raw materials	1	2	3	Supplier / Parameter	Raw materials	1	2	3
F_{JS}	1	27075.9	27075.9	23691.8	V_{js}	1	41292.3	28066.7	20717.9
	2	23014.4	23011	22014		2	11381.5	14171.6	11378.5
	3	35957.5	35857.5	35960		3	10739.9	2334.7	10741.6
	4	3199.68	3198.79	2300.12		4	28685.2	35040.3	28688.5
	5	7193.85	7194.3	7194.5		5	59751.2	72477.5	59756.6
	6	8851.44	8852	8850.96		6	55207.8	55911.1	55204.2
	7	5757.42	5756.58	5757		7	15568.4	18828.2	15562.1
	8	28767	28766	2580		8	77066.2	10273.2	77066.2

According to the outputs in this game, our cycle time was equal to 0.015 seconds, the costs of preparing products were 60311.5 and 70407.4 thousand rials, respectively, and also there were 23937.5, 37931.6, 85057.3, 63618.3, 127236.6, 6997.1, 32683.8, and 25686.7 raw materials required for each material respectively, and the amounts of demand for each final product were 0 and 29185.2 numbers respectively. After calculating and obtaining the decision variables of each chain member in this game, we sought to obtain the service level of each member separately and the service of the whole game, which were equal to 103490, 1112840, 1514492, 403798, and 775735 thousand rials respectively.

Table 17 reports the suppliers' decision variables in the Stackelberg model in the order of the costs of products and amounts of raw material produced by the suppliers:

Table 17: Suppliers' decision variables in the Stackelberg model

Supplier / Parameter	Raw materials	1	2	3	Supplier / Parameter	Raw materials	1	2	3
F_{JS}	1	23546	33855.2	31812.6	V_{js}	1	202117.4	255952.4	80279.7
	2	33906	45582.7	46507.4		2	331069.6	441416.9	331062.1
	3	23253	33030.3	40813.2		3	330308	330307	330308.4
	4	19994.5	28362.3	28362.3		4	850868.6	850866	85000.6
	5	59983.8	53465.6	64872.4		5	160173.7	130173.6	170173.7
	6	33955.7	44877.8	51616.2		6	27904.4	21904.4	17904.4
	7	15810.7	19994.6	24178.5		7	19994.4	18994.02	99943.95
	8	32546.3	22327.8	38579.1		8	169558.9	226081.5	16955.9

The amount of profit of each chain member is as follows:

$$\pi_{s1}^{*} = 2.65324 * 10^{22}, \pi_{s2}^{*} = 2.54436 * 10^{22}, \pi_{s3}^{*} = 2.65347 * 10^{22}$$
$$\pi_{M}^{*} = 7.96040 * 10^{22}$$
$$\pi_{T}^{*} = \pi_{M}^{*} + \pi_{s1}^{*} + \pi_{s2}^{*} + \pi_{s3}^{*} = 1.09105 * 10^{21}$$

According to the outputs in this game, our cycle time was equal to 0.03 seconds and the costs of services and goods were 71694.1 and 557926.1 thousand rials respectively, and there were 538350, 110355, 653613, 538350, 107670, 121881, 688328, and 565199 numbers of raw materials required for each type of material respectively, and the amounts of demand for each item were 149978 and 888350 numbers respectively. After calculations and obtaining the decision variables of each chain member in this game, we tried to obtain the levels of profit and production of each member separately, and the total service of the game which were 265340000, 254436000, 265347000, 796040000, and 10910500 thousand rials respectively.
Table 18 reports the suppliers' decision variables in the cooperative model, namely the costs of products and the amount of raw materials produced by the suppliers:

Table 18: The decision variable in the cooperative model

Supplier Parameter	Raw materials	1	2	3	Supplier Parameter	Raw materials	1	2	3
F_{JS}	1	25311	30465.6	27752.2	V_{js}	1	202509	234022	187863
	2	28460.4	34298.3	34760.7		2	319061	371515	271809
	3	29605.6	34493.9	34760.7		3	129488	1584410	94368
	4	11597.1	15780.6	15781.2		4	138661	160920	107281
	5	33588.8	30329.9	36033.6		5	220223	347043	205554
	6	21403.6	26864.9	30333.5		6	116741	155120	50516.7
	7	10784.1	12875.6	14967.7		7	108832	134063	85851.4
	8	30656.6	25547.6	33673		8	124675	190270	111100

The amounts of production and profit of each chain member are as follows:

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

According to the outputs in this game, our cycle time was equal to 0.001 seconds and the production costs were equal to 60334.8 and 70324 thousand rials respectively, and then there were 624394, 962385, 48 4751, 536338, 107268, 793390, 367343, and 426047 numbers of the basic equipment required for each type of material respectively, and finally, we obtained the amounts of demand for each final product equal to 168996 and 29351.9 numbers respectively. After calculations and obtaining the decision variables of each chain member in this game, we tried to obtain the levels of production and profit of each member separately, as well as the total profit level of the game and they were equal to 5537.41, 71111.1, 50018.3, 12247.5, and 12229.8 thousand rials respectively.

Summary and conclusion

Based on the research results, financial capability (FC), logistic capability (LC), experience (HE), and production capability (HC) were considered to be the most important and effective criteria on the interaction of lean production management stakeholders in the National Iranian Oil Company. The identified sub-criteria were as follows.

Air transportation equipment (FC1), up-to-date and efficient equipment (FC2), correct layout (LC1), land transportation (LC2), production speed (LC3), expert human resource (HE2), construction (HE3), new production items (HC2), and production staff (HC3).

The results of ranking criteria and sub-criteria indicated that the correct layout was the most effective criterion and the up-to-date and efficient equipment was the most affectable sub-criteria. Among the main criteria, logistics capability was the most effective criterion and financial ability was the most affectable criterion. In terms of interaction, new production items had the highest interaction and correct layout had the lowest interaction. The highest interaction of the main criteria was related to experience and the lowest interaction belonged to production capability.

The results of lean management implementation systems and supply chain models indicated that the manufacturer preferred to act as a leader compared to a situation where all chain members had the same power and made their decisions at the same time because the producer's profit level changed from $4.03798 * 10^9$ to $7.96040 * 10^{22}$, and the producer's profit and production of became more than 2 times in the Stackelberg model. According to the status of Iran, where the government operates, and according to the status of popularity among people, this supplier had the ability to become a leader in this target competitive chain because it had enough power and influence in every aspect. Furthermore, the cooperative game brought less profit and production for the producer and suppliers so that their total profit was $1.22298 * 10^{10}$ but the total profit of the producer and suppliers was $1.09105 * 10^{21}$ in the Stackelberg game, indicating a 100% reduction; hence, the producer preferred not to cooperate with the suppliers, instead preferred to act as a leader in the chain. It is worth mentioning that the total profit and production of the producer and the supplier had an increase of 2% in the cooperative game compared to the Nash game, indicating that the cooperative game makes more profit and production for the producer and suppliers than the Nash game.

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