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A Game Theory Approach for Solving the Knowledge Sharing Problem in Supply Chain

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Abstract Knowledge management is the process of capturing, developing, sharing, and effectively using organizational knowledge as we known Knowledge management literature emphasizes the importance of knowledge as a valuable asset for SMEs. This paper highlights the efficient sharing of knowledge as a way of creating core competencies in the SMEs that are in civil construction activities. This perspective mainly focuses on the analysis of attributes that should provide the resources for generating a competitive advantage. We want to gain to two objectives, first examination of supplier's perceived payoff of sharing knowledge is contingent on the knowledge sharing behavior of other suppliers and second objective is analyzing the perceived payoff of knowledge sharing and determine if it can be characterized by an archetypical game in the game theoretic model. An empirical study was conducted among nearly 72 suppliers in a local civil construction supply chain in north of Iran. The results indicated that the supplier's perceived payoff sharing knowledge was contingent on the knowledge sharing behavior of other suppliers. In addition, the perceived payoff of knowledge sharing among them could be characterized by a multi-person assurance game. In conclusion, discusses some implication for managers who aim to effective knowledge sharing in their supply chain to acquire sustained competitive advantage.

Keywords Knowledge Sharing, Game Theory, Supply Chain, Civil Construction.

1 Introduction

No single organization can rely only on internal knowledge resources. In recent years, inter-organizational knowledge sharing has received increasing attentions by researchers and practitioners (Easterby-Smith et al. [1], Hau and Evangelista [2], Van Wijk et al. [3], Seyyedeh and Daneshgar [4]). In a knowledge economy, effective sharing of knowledge makes businesses function more effectively. According to a recent study, transfer and sharing knowledge between supply chain partners across borders helps make the participating parties benefit and prosper through mutual cooperation. Thus knowledge sharing between supply chain partners can be both fruitful as well as threatening. Many of organizational relationships

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have been created to transfer knowledge however with different intensities, directions and purpose. In supply chain relationship, knowledge sharing is not explicitly defined as the main target by the supply chain partners and it usually takes place informally and spontaneously (Seyyedeh and Daneshgar [4]). The major stuff of information shared by companies include of data on production planning, cost, demand forecasting, inventory levels, sales and prices. Other more valuable chunks of information are know-how, managerial and communication skills. Inter-organizational knowledge sharing can prove to be a worthwhile exercise only when it is a joint activity between supply chain partners in which every party attempts to create more value together than what they would be able to create individually. For example, suppliers must ensure that only the right type of knowledge moves between them. This exchange of knowledge between the suppliers does not occur simply. Successful supplier integration requires processes that facilitate the use and transfer of knowledge across functional and organizational boundaries (Lawson et al. [5]). Sharing knowledge between suppliers can help in problem solving by better decision making, increased manpower efficiency, Faster response to market changes, increased organizational productivity and improving manufacturability (Takeishi [6], Steensma et al. [7], Tsai [8] Yli-Renko et al. [9] Zahra et al. [10] Lane et al. [11]). Supplier's partnership in supply chain is a special type of inter-organizational relationship that is highly knowledge intensive and for this reason the current paper only focuses on this kind of inter-organizational relationship. Knowledge plays an essential role in competition. They would obtain great benefit, if suppliers could own the knowledge that in rare and important. That is, once if they share their scarce knowledge, their knowledge would be lost and benefit would also be damaged (Yang and Wu [12]). In this case, why would suppliers share their specific knowledge with others?

However, there are still gaps in our understanding of why and when knowledge sharing occurs between them. For this reason, this paper seeks to advance understanding on knowledge sharing by carrying out an empirical study that uses the game-theoretic framework. It has two objectives. One is to investigate if a firm’s perceived payoff of sharing knowledge is contingent on the knowledge sharing and determine if it can be characterized by an archetypical game in the game-theoretic model. These objectives have implications on how managers can promote knowledge sharing in their organizations.

This paper is organized as follows. First, it discusses the existing study done on knowledge sharing and conceives knowledge sharing as a decision made on the basis of a contextually determined perceived payoff by the supplier which shares. It further argues the fundamental of game theory and the three archetypical games. Finally, this paper analyses the finding that emerged from the study and discusses some implications for managers who aim to effective knowledge sharing in their supply chain to acquire sustained competitive advantage.

2 Knowledge sharing in supply chain

Lee [13] defined knowledge sharing as activities of transferring or disseminating knowledge from one person, group or organization to another. Bartol and Srivastava [14] defined knowledge sharing as individuals sharing organizationally relevant information, skills, opinions, ideas and suggestions with one another. Song [15] noted that through efficient and effective knowledge sharing, organizations can increase innovation and creativity, Increase profit and reduce cost, and reduce risks due to uncertainty (Yeh et al. [16]). Connelly and Kelloway [17] indicated that knowledge sharing is a set of behaviors that involve the

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exchange of information or assistance to others. Ardichivili et al. [18] discuss that knowledge sharing consists of both the supply of new knowledge and the demand for new knowledge.

Authors also point to knowledge nature and knowledge source as important antecedents of knowledge sharing (Narteh, [19], Alashwal et al. [20] Bou-Llusar and Segarra-Cipres [21]). Menon and Pfeffer [22] discusses that firms like to achieve knowledge from external sources rather than internally because external knowledge seems to be rare and unique. Goh [23] explored a conceptual framework to explain how effective knowledge transfer can be managed. Pérez-Nordtvedt et al. [24] suggested that the attractiveness of external knowledge is a key factor that contributes to the effectiveness of transfer of knowledge between organizations.

Firms are willing to share and absorb knowledge from their partners. Steensma et al. [7] maintain that inter-firm knowledge sharing/transfer depends on the willingness of the "teacher" (the knowledge owner) to give resources and motivation of the "student" (the recipient) to learn from these resources. The more willing the knowledge owner firm helps the recipient firm to internalize knowledge superiorly.

When new knowledge is developed in suppliers, it has the potential to connect to knowledge held by other firms, i.e. be relevant to them (Schulz [25]). The value of combining knowledge elements in the organization has been argued to be of two different types. First, knowledge can sometimes be exploited in other contexts than where it was developed. The organization can better reduce costs economize on its knowledge by narrow the difference between "what is known within an organization and what is actually put to use". Second, by combining previously separated knowledge assets, organizations may elicit new opinions and concepts that can submit solutions previously not considered, i.e. reach a synthesis of knowledge and spurring innovation (Persson [26]). Research findings witness that whereas the amount and value of different kinds of knowledge are linked to knowledge acquisition outcomes, innovativeness and cost efficiency are defend as knowledge utilization outcomes (Wu et al. [27], Yli-Renko et al. [9]).

Knowledge sharing is here defined as occurring when a supplier shares knowledge with another supplier, with the aim of replicating specific behavior that has been shown superior to the current practices of the recipient unit. Today, the aim of supplier management is to achieve an optimal flow of high-quality, value-for-money materials and/or components from innovative suppliers (Zhou and Benton [28]). Zhenxin et al. [29] study illustrates the benefits of supply chain partnerships based on knowledge sharing. A close relationship means that channel participants share the risks and rewards and have willingness to maintain the relationship over the long term (Rashed et al. [30]). Knowledge sharing can greatly improve work-quality and decision- making skills, problem-solving efficiency as well as competency that will benefit the organization at large (Syed-Ikhsan and Rowland [31], Yang [32]). Wadhwa and Saxena [33] in their studies used only knowledge sharing as one of the variable in the determination of the relationship between supply chain members and organizational performance. Malhotra [34] in his study used knowledge creation in collaborating supply chain partnership that influence on long term advantage to the organization. Wagner and Buko [35] found that knowledge sharing activities in different supply chain members are influencing the firm performance. Knowledge sharing therefore always occurs in a dyadic relationship between a source supplier (knowledge owner) and knowledge receiver supplier (Mudambi and Navarra [36]). So, the first proposition is submitted,

P1. A supplier's perceived payoff of knowledge sharing in a group of suppliers is contingent on the knowledge sharing behavior of other suppliers in the supply chain.

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3 Knowledge sharing performance outcomes

Empirical results show that inter-organizational knowledge sharing leads to higher profitability and market efficiency (Choy et al. [37], Zahra et al. [10], Lane et al. [11], De Pablos [38]), increased manpower productivity (Choy et al. [37], Steensma et al. [7]), innovation and new product development (Wagner [39], Tsai. [8], Yli-Renko et al. [9], McEvily and Chakravarthy [40]), higher product quality and customer satisfaction (Cheng et al. [41], Tsang et al. [42]).

In order to identify an extensive list of performance outcomes, a vast review of the literature on knowledge sharing was conducted. A comprehensive search on the literature displays that there are related works on knowledge sharing performance outcomes. Some of them have derived a list of performance outcomes based on theoretical study, and some of them have provided their set of performance outcomes from quantitative or qualitative description, they are comprised in this study. By combining all these previous work (Chong [43], Chourides et al. [44], Kamasak and Bulutlar [45], Wagner [39], KPMG [46], Choy et al. [37], Egbu et al. [47], Plessis [48])., 21 performance outcomes resulting from knowledge sharing initiatives were identified as shown in Table 1. Although different words were used to describe them, some of the items have been found to overlap with each other. Therefore, the related items were merged and described as one.

4 Game theory

Game theory is a model of optimality taking into consideration not only benefits less costs, but also the interaction between participants. Also Game theory defined as the mathematical theory of interactive decision situations game used to simulated real-life situations. In a strategic game, it is assumed that each player choose the strategy that yields the maximum payoff for himself. A dominate strategy is one that out-performs all other strategies regardless of the choices made by the other players. In a two-person game, each player has two choices, being to participate or avoid. Thus, as shown in Table 2, the two players have possibly four joint decisions. The payoff matrix of a two-person game is shown in Table 2, where A_i, B_i, C_i and D_i refer to the payoffs of the player i and i=1 and 2. A refers to the situation where both players participate in the game. B is when player 1 participates while player 2 shirks. C is when player 1 shirks and player 2 participates. D is when both players shirk. In order to simplify the game model, we assume that $A_1 = A_2 = A$ and $D_1 = D_2 = D$, which implies both players have similar payoff when choosing the same strategy. To better explain the models, the authors assume the perspective of player 1, as shown in Table 3. Depending on the relative payoff value of A, B, C and D, a game can be classified as one of the three archetypes, namely, Prisoner's dilemma, Chicken or Assurance (Dixit and Skeath [49], Kay [50]).

Prisoner's dilemma. This game happens when C>A, A>D and D>B. In this archetype each player can choose avoid to gain better payoff. For both players, in a prisoner's dilemma game, avoiding is the dominate strategy. However, if both choose to avoid, each gets a payoff worse than if they both choose to participate. Both players must co-operate to achieve maximum benefit.

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Table 1 Knowledge sharing performance outcomes

Performance outcomes	Author(s)
Increased innovation	Kamasak and Bulutlar [45]; Wagner [39]; Gloet and Terziovski; Plessis[48];
Entry into different market type	Wagner[39], Plessis[48]
Find new or better ways of working	Choy et al. [37]; Plessis[48]; Chourides et al. [44]
Increased value for customers	Chourides et al. [44]; Gloet and Terziovski; Chourides et al. [44]
Improved new product development	Gloet and Terziovski; Chourides et al. [44]
Increased profits	KPMG [46]; De Pablos [38]; Hult et al. [56]
Reduced costs	KPMG [46]; Hult et al. [56]; Chourides et al. [44]
Increased market share	KPMG [46]; Argote and Ingram [57]; De Pablos[38];
Improved productivity	Argote and Ingram [57]; Hult et al. [56]; Egbu et al. [47]
Increased market size	Argote and Ingram [57]; Choy et al. [37]
Continuous improvement of competitive long-range service	Argote and Ingram [57]; De Pablos [38]; Madhok and Tallman [58]; Loebecke et al. [59]; Egbu et al. [47]
Enhanced product or service quality	De Pablos[38]; Chong [43]; Gloet and Terziovski; Hult et al. [56]; Chourides et al. [44]
Faster response to market change	KPMG [46]; Ghosh and Fedorowicz [60]; Yu et al. [62]; Chong [43]
Increased delivering	KPMG [46]; Egbu et al. [47]; Chong [43]; Ghosh and Fedorowicz [60]; Egbu et al. [47]
Intellectual capital development	Choy et al. [37]; Egbu et al. [47]
Increased manpower productivity	Choy et al. [37]; Egbu et al. [47]
Better decision making	KPMG [46]; Chong [43]; Ruggles [61]; Choy et al. [37]
Establishment of supporting culture for Organizational growth	Egbu et al. [47]; Choy et al. [37]; Chong [43]
Capability of knowledge gaps identification	Egbu et al. [47]; Choy et al. [37]
Improved motivation of employees	Choy et al. [37]; Egbu et al. [47]; Chong [43]
Development of staff attraction/retention	KPMG [46]; Choy et al. [37]; Egbu et al. [47]; Chong [43]

Table 2 Two-player payoff matrix

		Player 2	
		Participate	Avoid
Player 1	Participate	(A_1, A_2)	(B_1, B_2)
	Avoid	(C_1, C_2)	(D_1, D_2)

Table 3 Payoff setting for player 1 perspective

		Player 2	
		Participate	Avoid
Player 1	Participate	A	B
	Avoid	C	D

Game of chicken. If C>A, B>D, this game is named the Chicken. In this case, player 1 obtains a better payoff by participating. The game of chicken is known as a game of differentiation. The better strategy for each player is different with the other player strategy. The player chooses to participate, when the other player avoids and avoids if the other player participates. Hence, in this game, the dominated strategy does not exist.

Assurance game. The game is referred to as the assurance, when A>C, A>D, and D>B. In this situation, player 1 obtains a better payoff by participating. In an assurance game, both players maximize their payoff by choosing the same strategy as the other. Hence, the dominant strategy does not exist.

Also, with need extending the game to multi-person game. In a multi-person game, the payoff for each player is dependent on the number of players who participate and avoid. Supposing in a population of N players, there are n number of player who participate. In this situation, each participant gets a payoff of p(n), while each player by choosing to avoid gets a payoff s(n). If an avoider player decides to participate, the number of players who participate will be n+1. Player gets a payoff p(n+1). When player decides to avoid in the same way, his payoff would be s(n). Hence, a player choose to participate if $p(n+1) > s(n)$ and avoid if $p(n+1) < s(n)$.

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For example, Figure 1 shows multi-person chicken game. The horizontal axis represents the number of participants while the vertical axis represents a player's payoff. In this game, $p(n+1) > s(n)$ for small values of n, but $p(n+1) < s(n)$ for large value of n. In the prisoners' dilemma game, shirking is the dominant strategy, $s(n) > p(n+1)$ for all values of n. Finally, In the assurance game, $s(n) > p(n+1)$ for small values of n whereas $p(n+1) > s(n)$ for large values of n (Dixit and Skeath [49]).

In summary, a multi-person game can be illustrated graphically using two lines, namely AB and CD that show the payoff of the individual who participates and avoids respectively. At the point A and point C, the rest of population participates; at point B and point C, none in the population participate. When knowledge sharing is conceived as a decision made on the basis of the perceived payoff, it is compatible with the structure of a strategic game. Hence, the second proposition is submitted,

P2. A supplier's perceived payoff in sharing knowledge among a group of suppliers can be characterized by an archetypical multi-person game in game theory.

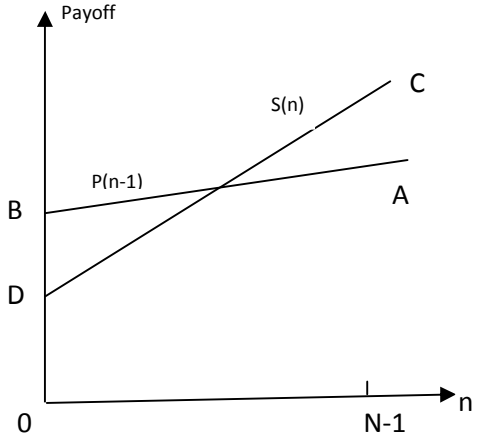

Fig.1 Example of multi-person chicken game [49]

5 Game theory and knowledge sharing

Game theory evaluates rational choices and is useful for explaining personal behavior as well in predicting personal decision-making. Ho et al. [51] build a single-instance two-person game model to characterize individuals' tacit knowledge sharing behavior. Bolton [52] and Shefrin [53] demonstrate the predictive quality of game theory. Ledebur suggests game theory to analysis of knowledge transfer by new employees in companies (IWH-Diskussinspapiere 3/2006). He claims that a company can optimize its profits by innovations due to sufficient transfer. Chua [54] investigated a multi-person game to analysis individual's perceived payoff of knowledge sharing between all students in an institute of higher education. Kesten [55] suggests game theory can provide more accurate forecasts than unaided judgment, because it counters judgmental biases.

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6 Research Design

An empirical study conducted in suppliers of civil construction company (local civil construction company in north of Iran). Shoa-E-Shargh company was established in year 1361 (1982) with the aim of production and supply of concrete products and developed gradually with production of different types of concrete, metal and wooden products in relation to road, building (civil construction) and urban elements. The Shoa-E-Shargh company concrete, under supervision of experienced engineers experts and personnel with an experience of about 30 years, by receiving appreciation tabiets from related organization and gaining title of "Exemplary Unit" in several periods, is placed within reputable and advanced companies of the country regarding standard and desired volumes and quality of the products. Currently, this company's supply chains include about one hundred suppliers.

With a literature review of knowledge sharing outcomes, as shown in Table 1, certain variables and factors that were introduced by authors in their works are identified. They are classified in this paper by a bibliographical manner. The 21 items for measuring knowledge sharing outcomes can be grouped into five dimensions,

1. Firm performance
2. Market share
3. Profitability
4. Employee empowerment

The questionnaire includes four sections within which these five items are presented, Shown in the Appendix. Sections 1, 2, 3 and 4 measure the payoff of knowledge sharing under the four situations, namely, S1, S2, S3 and S4 respectively. Its purpose was to measure the supplier's perceived payoff of knowledge sharing under different situations. For parsimonious reasons, only four definitive situations have been included, (S1) when both the supplier and the rest of other suppliers share knowledge, (S2) when the supplier is the only one which shares knowledge but none of the other suppliers do, (S3) when the supplier is the only one which does not share knowledge but all other suppliers do and (S4) neither the supplier nor the rest of other suppliers shares knowledge. These situations are illustrated in Table 4. P1 can be tested by analyzing the variances of the supplier's payoff of knowledge sharing under the four situations. S1 and S2 represent point A and point B on the P(n+1) line, while S3 and S4 represent point C and D on the s(n) line in the multi-person game payoff graphs shown in Figure 1. P2 can be tasted by comparing S1 with S3 and S2 with S4 using one-tail T-tests.

Table 4 Four situation in knowledge sharing

		Player 2	
		Participate	Avoid
Player 1	Participate	S1	S3
	Avoid	S2	S4

7 Data collection and analysis

Samples were collected from civil construction suppliers. The questionnaires were mail & fax to all of the civil construction suppliers manager that participate with Shoa-E-Shargh company who listed in Rasht Yellow Book. Companies that sent filled questionnaires to Shoa-E-Shargh Center Office were 78 companies. 72 questionnaires were valid and import to

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software for analyzing. Features of sample are shown in Table 5. Afterwards, Table 6 shows Cronbach's alpha coefficients, mean scores and standard deviation obtained for four variables in the questionnaire. In the case of reliability analysis, Cronbach's alpha was employed. As shown in Table 6, Cronbach's alpha for the four situation was found within acceptable limits ($\alpha>0.7$).

Since a linear relationship between the payoff and the number of participants is assumed, figure 2 shows the values of S1, S2, S3 and S4 plotted on the payoff graph. The sample size was more than 30 (n=72) and the data were interval-scaled, so normal distribution could be assumed. Furthermore, the standard deviations were also known. Hence, to test P1, it would be appropriate to use ANOVA and a one-tail t-test to test P2.

By using ANOVA test, at the 5 percent level of significance, S1, S2, S3 and S4 were found not to have equal variances ($p<0.05$). Thus P1 is supported. This mean that a supplier's perceived payoff of knowledge sharing varied according to the different situation which depict whether supplier and the rest of other suppliers sharing knowledge or otherwise.

By using one-tail t-test, at the 5 percent level of significance, S1>S3 ($p<0.05$) and S2<S4 ($p<0.05$). Thus P2 is supported. The first inequality means that when the rest of the other suppliers share knowledge, a supplier is better off sharing knowledge than if it didn't. The second inequality means that when the rest of the other suppliers don't share knowledge, a supplier is better off not sharing knowledge than if it did. Such a payoff structure corresponds to that of a multi-person assurance game.

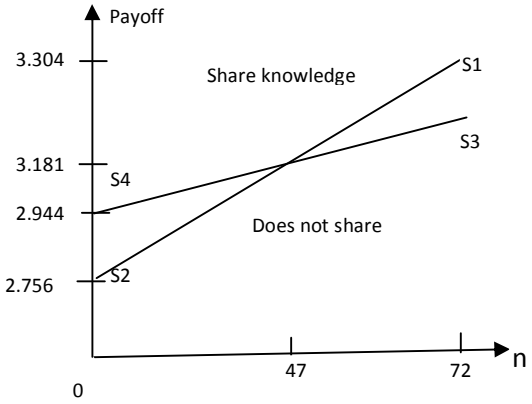

Fig. 2 Value of S1, S2, S3,and S4 plotted

Table 5 Features of sample

Description		Frequency	Percentage
SME employees			
	Less than 10	۲۸	۳۹
	10-50	۳۵	۴۸
	More than 50	۹	۱۲
SME history			
	0-5 years	۲۲	۳۱
	6-10 years	۴۳	۶۰
	11-15 years	۶	۸
	16 or above	۱	۱

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Table 6 Conbach's alpha coefficient and descriptive statistics of Four situation

Variables	Mean score	Standard deviation	cronbach's alpha coefficient(n=72)
S1	3.304	0.651	0.785
S2	2.754	0.582	0.812
S3	3.181	0.703	0.834
S4	2.944	0.664	0.756

8 Results and discussion

First, since S1, S2, S3 and S4 were found not to have equal variance, this implies that a supplier's perceived payoff varied according and the rest of other suppliers to share knowledge or otherwise. The notion of payoff represents an aggregation of all interests and concerns held by a suppliers and its purpose is to serve as proxy to a supplier's likelihood to share knowledge. Hence, the confirmation of P1 means that a supplier's decision to share knowledge is influenced in part by the decisions of others to share knowledge as well. Managers who wish to promote asynchronous knowledge sharing need to arrange guidelines of cooperation, shared value, mutual interest and trust in the supply chain members.

Second, a supplier's perceived payoff of knowledge sharing varied with the number of suppliers which participated in knowledge sharing. Given the number of suppliers which participated in knowledge sharing, a supplier's perceived payoff of knowledge sharing and that of restraining knowledge differed. A supplier is better sharing knowledge than restraining knowledge, when the rest of the other suppliers share knowledge (S1>S3).When the rest of the other suppliers restraining knowledge, a supplier gains more payoff by restraining knowledge than sharing knowledge (S2<S4). When a linear relationship between the payoff and the number of participants is assumed as in Figure 2, a supplier's perceived payoff to share knowledge intersects with that to restrain knowledge at the point where the number of participants which shared knowledge is 47 (65 per cent). In other words, when there were at least 47 suppliers which shared knowledge, a supplier was better off sharing than restraining knowledge. Moreover, in reality, S1-S2 and S3-S4 in Figure 2 do not have to be straight lines and may intersect at more than one point. Hence, the minimum participation rate of 65 per cent of the population needed to create the tendency for knowledge sharing may not be a generalizable figure. Nevertheless, the results still have practical implications for managers.

9 Conclusions

Enhancement of effectiveness and efficiency by spreading good ideas and practices are main benefits of knowledge sharing between companies. The present study claims that sharing knowledge and expertise between supply chain members will potentially develop a common knowledge base that in turn, will facilitate both the connectivity of the supply chain members with one another, as well as the various joint decision processes. This paper represents a game-theoretic framework for Effective knowledge sharing between suppliers in civil construction. From the data collected, it was confirm that supplier's likelihood to share knowledge was contingent on the likelihood of the others to do likewise. In addition, the perceived payoffs of knowledge sharing among a group of suppliers could be characterized by a multi-person assurance game. The findings which have emerged from this study have the following implications for suppliers to make better decisions and Shoa-E-Shargh managers who aim to sustain asynchronous knowledge sharing among group of suppliers in its supply

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chain. First, suppliers need to understand the interests and concerns of the other suppliers and introduce specific interventions to improve the perceived payoff of knowledge sharing and gain better performance results. Second, Shoa-E-Shargh Company managers need to target an initial minimum participation rate to create to propensity for more cooperation and collaboration. Shoa-E-Shargh company uses supplier outputs to make products. So, they should create varied ways to reach effective collaboration in supply chain by knowledge sharing between suppliers. These ways can be strategic alliances, co-operation in projects by HR sharing, sharing their production devices.

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