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Using Cooperative Game Theory to determine profit distribution in IPD projects

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Abstract

Purpose- IPD (Integrated Project Delivery) mode is regarded as an effective project delivery method that could achieve the consensus project goals by a collaborative team. It requires all stakeholders to involve at the early stage of the project and share the information promptly to improve productivity. However, the number of projects using IPD remains small. The lack of fair incentive scheme is one of the main reasons. The purpose of this paper is to analyze and establish a fair profit distribution scheme among stakeholders for IPD projects.

Design/methodology/approach- This study uses cooperative game theory as the method for analyzing profit distribution among the designer, construction contractor, owner and BIM consultant, who are all key stakeholders in IPD projects. The Shapley value is used as the solution to the cooperative game theory because it can assess the marginal contribution of each stakeholder to the coalition. In addition, fuzzy comprehensive evaluation (FCE) and analytic hierarchy process (AHP) are used to assess the risk levels of each stakeholder in the coalition in order to modify the profit distribution based on the marginal contribution.

Findings- A modified Shapley value model, which includes four categories of risk factors, i.e. operation, economic, profit and market risks, was established in this study. The results show that the modified Shapley value can help establish a fair profit distribution scheme for the IPD projects. Practitioners are also encouraged to focus on information sharing to reach the full potential of IPD.

Originality/value- This study aims to investigate the knowledge gaps on solving the profit distribution of IPD projects. It can help address the slow adoption of IPD in the construction industry. In addition, the modified Shapley value model provides a valuable reference for determining a fair profit distribution scheme in IPD projects.

Keywords: IPD, Cooperative Game Theory, BIM, Shapley Value, Profit Distribution.

1. Introduction

The construction industry is highly fragmented, and construction owners are risk evasive in a project (Rahman & Kumaraswamy, 2004). Other construction stakeholders interpret contract terms differently to maximize their own benefit. In order to address the issue, various contract terms have been developed over the past few decades. In the 1940s, government and enterprises started Design-Bid-Build (DBB) in the United Stated, which can increase efficiency and make the responsibility of all stakeholders clear. However, as a bilateral contract relationship among owner, contractor, and designer (Ghassemi & Becerik-Gerber, 2011), it has many problems such as high levels of fragmentation, long construction period and high costs of collaboration. Construction Management (CM) was then introduced in the 1960s as a solution to these problems by involving CM managers and general contractors in the early stage of a project. However, it did not address the underlying problem of fragmented information resulting from the limited ability of CM managers (Tatum, 1983). In the 1990s, Design-Build (DB), whereby the owner contracts with a single entity to perform both design and construction under a single DB contract, had been increased to be used to improve the productivity, clarify responsibility and enhance information sharing (Ling, Chan, Chong, & Ee, 2004). However, as the objectives of owners and general contractors are sometimes not consensus, DB may not always deliver the premium result (Konchar & Sanvido, 1998). Later, Project Partnering (PP) was used to achieve the stakeholders' consensus objectives by building a project team at the early stage of the project. It has improved the control of schedule, cost, and quality. In order to improve project outcomes through a collaborative approach of aligning incentives with goals of a project team, a new project delivery method named Integrated Project Delivery (IPD) was put forward in the United States (Matthews & Howell, 2005). Compared to traditional delivery model, the IPD model emphasizes relationships, collaboration and mutual goals rather than individual responsibilities and achievements. IPD optimizes the construction period, the cost and the sustainability of a project (Cohen, 2010), many professional organizations support the advancement of IPD (Ghassemi & Becerik-Gerber, 2011).

Although some projects have demonstrated its benefits (Matthews & Howell, 2005), the number of projects using IPD is still small (Sive, 2009). There are many reasons for the slow development, such as the defective mechanism of shared risk and profit distribution (Kent & Becerik-Gerber, 2010), information sharing (Zhiliang & Jiankun, 2011), collaborative decision making and control, liability waivers among the major stakeholders (Smith, Mossman, & Emmitt, 2011) and so forth. Among these problems, several researchers have pointed out that the lack of enough positive incentives is the main reason that slows down the development of IPD (Anderson & Tucker, 1990; Lowe & Muncey, 2009; Matthews &

Howell, 2005). This is because the collaborative behavior in IPD model calls for the incentives that promote all the parties to reinforce the concentration of project performance and to diminish the natural tendency to protect oneself at the expense of the community. In the study of incentives work, Levitt (1995) argued that economics is the root of the incentives, particularly by commercial entities. To promote the development of IPD model, one important strategy is to determine a fair and rewarding profit or cost savings distribution scheme. Cooperative Game Theory can be used to establish such scheme (Wilson, 1977). It allows choosing the most favorable one out of a set of different behaviors.

Many studies have adopted the Cooperative Game Theory in the construction industry on topics such as selecting a proper construction site and the profit distribution among stakeholders (Jia & Yokoyama, 2003). There are many solution concepts in cooperative game theory like stable sets, core, the nucleolus, the bargaining sets, the Shapley value and so on (Osborne & Rubinstein, 1994). However, the stable sets are in general not easy to handle, as there are typically many of them and they are not easy to find (Tijs, Branzei, Ishihara, & Muto, 2004). This has greatly limited the use of stable sets, despite their conceptual appeal (Aumann, 1987). The cores achieve the classification of all the distribution strategies, while some cores may be empty. In addition, the distribution of the cores is not unique, which raises the difficulty for decision making (Driessen, 2013). To address it, the nucleolus is adopted by some researchers because of its uniqueness (Deng & Papadimitriou, 1994). However, the complexity of the calculation process hinders its application on the profit distribution. The bargaining sets, introduced by Aumann and Maschler (1961), are more closely tied to the bargaining process. However, it determines a range of data set while the specific result cannot be achieved. According to Winter (2002) and Jene and Zelewski (2014), the Shapley value is arguably the most "cooperative" and "classic" of all the solution concepts in cooperative game theory; because it represents the marginal contribution of each stakeholder to the coalition. There are also other profit distribution methods, such as cost-oriented, risk-oriented or equity based method. However, the extra profit or cost savings is owing to the formation of the alliance, which is relevance to the possibility of a participant to work together with others to form an alliance. For example, if the cooperation can only be achieved with a player, he should be allocated more although he costs less. Otherwise, no one can enjoy the benefits of the alliance. Therefore, the Shapley value delivers a unique, fair and unique solution to the problem compared with other methods (Fatima, Wooldridge, & Jennings, 2008). It has also been advocated by several scholars at present (Jian-hua & Hen-xin, 2004; H.-d. ZHANG, Yan, & FANG, 2009). However, it assumes that all the parties concerned have same risks, which is not always the case in reality. Therefore, this papers aims to investigate a fair and efficient profit distribution strategy of IPD projects based on the Cooperative Game Theory, using a modified Shapley value by introducing risk factors.

2. Literature review

In order to eliminate high transaction cost among project stakeholders and avoid high administration cost in enterprise integration, the IPD was developed in engineering projects. The American Institute of Architects (AIA) (2012) defines IPD as, "a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all stakeholders to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction. AIA (2012) investigated the IPD projects in America and it indicated that construction period, cost and sustainability performance exceeded the owners' expectation. At the same time, some obstacles were found when implementing IPD, including immature Building Information Modeling (BIM) platform (Zhiliang & Jiankun, 2011), ineffective mechanism of shared risk and profit distribution (Kent & Becerik-Gerber, 2010), multi-part contract (Kermanshachi, 2010), collaborative decision making and control (Kent & Becerik-Gerber, 2010), liability waivers among key stakeholders (Smith et al., 2011). Of all the problems, profit distribution is most concerned one from stakeholders (L. Zhang & Chen, 2010).

IPD profit distribution structures recognize and reward early involvement. Profit distribution rewards “what’s best for project” behaviour by providing incentives tied to project goals (Sive, 2009). These goals may vary but are usually associated with cost, schedule, and quality which are commonly used to measure project success. Making fair profit distribution methods is the key to IPD success. Many studies have been conducted how to establish a fair profit distribution scheme, such as schemes based on value (Ibbs, Kwak, Ng, & Odabasi, 2003), incentive pool (Lichtig, 2006), innovation and outstanding performance and profit sharing (Brady, Davies, & Gann, 2005). However, the value, incentive pool and outstanding performance are difficult to be quantified, which leads to a degree of uncertainty of the distribution strategy. As such, using profit sharing method seems to be more suitable.

Cooperative Game Theory has been applied in engineering projects, such as in the profit distribution of Project Partnering (Lazar, 2000) and Public-Private-Partnership (PPP) (Scharle, 2002), project management and Franchise determination method of BOT projects (Shen, Bao, Wu, & Lu, 2007). Cooperative game theory emphasizes the collective rationality, efficiency, fairness and equality rather than individuals’ rationality and individual optimal decisions. The essential difference between cooperative game and non-cooperative game is whether information can be effectively shared among stakeholders and whether a binding contract can be implemented. They are considered as the basic condition of cooperative game that makes single players with common interest ally under the premise of pursuing the same goal (Kreps, 1990). In cooperative game, cooperation benefits are greater than the sum of individual returns. Compared to the non-cooperative game theory, the three most basic questions of cooperative game theory are still not fully resolved: cooperative game solution, the structural stability of the cooperative game solution, the formation mechanism of the cooperative game solution (Güth, 1991). Shapley and Shubik (1954) used the axiomatic method to give a Shapley Value for profit distribution solution. The Shapley value is proven to lie close to the heart of cooperative game theory and has been applied in various conditions to allocate savings and costs (Winter, 2002). For example, Bartholdi III and Kemahlioğlu-Ziya (2005) modeled the relationship between retailers and suppliers and used the Shapley value to allocate the profit. It is found that the Shapley value allocations are individually rational and are guaranteed to coordinate the supply chain. Nigro and Abbate (2011) used the Shapley value to address the profit sharing process of business networks. However, Nigro and Abbate (2011) also argued that a firm that decides to link its business to other firms accepts a sort of dependence from them will lead to opportunistic behavior and then the risk of not achieving the desired objectives can arise. As such, it is also important to quantify such risk while achieving fair profit distribution.

3. Research method

Cooperative game theory can be used to analyse how to allocate the profit effectively. The major issue in cooperative game theory is to analyse the distribution of profit gained through cooperation.

3.1 Basic assumptions

In IPD projects, a closer relationship among stakeholders based on multiple agreements is established compared to traditional project delivery. Each stakeholder takes part in the collaboration because they cannot complete the whole project individually. As such, reasonable profit distribution mechanism is the pre-condition for the collaboration to run smoothly. The profit discussed in this paper will be divided into two parts: fixed profit and additional profit. While fixed profit equals to the average profit of industry, additional profit corresponds to the marginal contribution made by the stakeholders. If the stakeholders do not cooperate, they will only harvest the industry average profit. Therefore, the key point to solve the problem of distribution is to allocate additional profit, rather than the average profit. It is necessary to satisfy the following assumptions when using cooperative game theory (Branzei, Dimitrov, & Tijs, 2008):

1. All stakeholders will take the profit distribution strategy which can maximize their profit;
2. All stakeholders will not quit in order to achieve the profit distribution scheme;
3. All stakeholders can be fully trusted and there is the necessary information sharing among stakeholders; and
4. In order to guarantee the success of the profit distribution scheme, multiple agreements to restrain the stakeholders should be established.

3.2 The Shapley value

Assuming N is the set of stakeholders. S refers to one of alliances in N. $V(s)$ represents the profit of alliance S and $m = 1,2,3,4$ represents designer, owner, construction contractor and BIM consultant respectively and $x_m (m = 1,2,3,4)$ refers to the profit getting from the alliance or coalition. $V(m)$ represents maximum utility of stakeholder m without cooperation. The profit of coalition should be greater than the sum of profits from individual stakeholders. The concept can be expressed by Eq. 1:

$$V(s) > \sum_{m \in S} V(m) \qquad \text{(Eq.1)}$$

Set x_m is the profit of m getting from the cooperation alliance. So the profit distribution should meet the following conditions: 1) Collective rationality: the profit of alliance is equal to the profit of the sum of personal distribution, which can be expressed as $\sum_{m=1}^{n} x_m = V(s)$.

2) Individual rationality: the stakeholders can get more in the cooperation, which means $x_m > v(m)$. Otherwise, stakeholder m will refuse to take in the alliance. There are many types of distribution in the alliance, while only the dominant one will be received by all the stakeholders. So in that case, it is important to explore the optimizing types of distribution.

According to the concept of Shapley value, the profit of stakeholder m, i.e. x_m, equals to its marginal contribution (refer to Eq. 2). When the players try to participate in the game, they will forecast that how much gain they can obtain in advance Jia and Yokoyama (2003)

$$x_m = \sum_{m \in N} \frac{(|s|-1)!(n-|s|)}{n!}[v(s) - v(s-m)] \qquad \text{(Eq. 2)}$$

Where $|s|$ is the number of alliance S and n is the total number of the stakeholders. $v(s)$ is the profit of the alliance. $v(s-m)$ refers to the profit without stakeholder m.

Due to random combination orders of cooperation, if a stakeholder m cooperates with the alliance which consists of members $S-m$, it receives a profit of $v(s) - v(s-m)$, which is the marginal amount it contributes to the alliance. The Shapley value x_m is the expected payoff to stakeholder$m$. $\frac{(|s|-1)!(n-|s|)}{n!}$ is the probability of that stakeholder m joins the alliance S$-m$.

3.3 A modified Shapley value approach

The Shapley model distributes the extra profit according to the marginal contribution. However, this method assumes that the risk of each stakeholder is equal, i.e. $1/m$. The risk borne by stakeholders will affect profit distribution. As such, it is necessary to introduce the concept of risk coefficient to modify the Shapley model.

In IPD projects, the risk borne by stakeholders is very complicated. At present, several studies have been conducted to identify the various risk categories in construction projects. Kangari (1995) has conducted a survey of the top 100 U.S. construction contractors and identified 23 risk descriptions. Strassman and Wells (1988) have identified several risk factors associated with a construction project. These works, as well as the studies by Akinci and Fischer (1998); Bullock (1989), Kumaraswamy (1997); Lifson and Shaifer (1982) and McKim (1992) are all useful in identifying the potential risk indicators. Usually, the risk of a project can be divided into two aspects: internal risks and external risks (Hastak & Shaked, 2000; Tah & Carr, 2000; Tang, Qiang, Duffield, Young, & Lu, 2007). Internal risks include operation risk, economic risk, profit risk and external risk includes market risk. This paper will consider these four categories of risks:

- Operation Risk R_1: unproductive labor risk r_{11}, information resource risk r_{12}, technical change risk r_{13} and material or equipment quality risk r_{14}.
- Economic Risk R_2: financial risk r_{21}.
- Profit Risk R_3: unpredictable cost risk r_{31}, contractual risk r_{32} and inadequate design risk r_{33}.
- Market Risk R_4: interest rate fluctuation risk r_{41} and political risk r_{42}.

Various risk evaluation methods, including genetic algorithm, neural network, the fuzzy comprehensive evaluation (FCE) method (Yanchao, Kai, Yahui, & Chunguo, 2011) and analytic hierarchy process (AHP) method (Saaty, 2008) can be used to evaluate the risks borne by stakeholders. Considering the fuzziness and uncertainty of risks, it is suitable to use FCE method in IPD projects. AHP is then adopted to evaluate the weight of each risk factor. The main steps are presented as follows：

1) There are two levels of risk in the risk evaluation equation. The overall risk level (RL) of the stakeholder can be determined by:

$$\mathrm{RL} = \sum_{i=1}^{4} W_i \times R_i \qquad \text{(Eq. 3)}$$

Where W_i is the weight of Level 1 risks (i.e. operation risks, economic risk, profit risk and market risk) and R_i refers to the comprehensive evaluation matrix of Level 1 risks.

2) Level 1 risk factors can be determined by:

$$R_i = \sum_{j=1}^{n} W_{ij} \times R_{ij} \qquad \text{(Eq. 4)}$$

Where W_{ij} is the weight of Level 2 risks under the Level 1 risks R_i and R_{ij} refers to the comprehensive evaluation matrix of Level 2 risks.

3) Risk levels are assessed under a 5-point Likert scale where 1=lowest; 3=low; 5=moderate; 7=high; and 9=highest. The evaluation matrix r_{ij} will be determined by a scoring method. For example, supposing there are 10% of experts who believe unproductive labor risks the lowest important risk factor and 90% believe it is low in operation risk R_1 for designer, then $r_{11} = \{0.1 \quad 0.9 \quad 0 \quad 0 \quad 0\}$.

4) The stakeholders were also asked to compare each factor against other factors based on Saaty's 1-9 point scale using pair-wise comparison method to establish relative importance (1 = equally important; 9 = significantly more important). By conducting a pair-wise comparison of Level 2 risk factors, the data from each stakeholder are transformed into an original AHP input matrix (V_e):

$$V_e = \begin{bmatrix} 1 & \cdots & \frac{1}{v_{ije}} \\ \vdots & \ddots & \vdots \\ v_{ije} & \cdots & 1 \end{bmatrix}, \text{(e=1, 2 … 10)} \qquad \text{(Eq. 5)}$$

Where v_{ije} is the relative importance of Level 2 factor i within Level 1 risk group i.

5) The 10 original AHP input matrixes are then consolidated into one AHP input matrix by calculating the mean of each vector. The consolidated AHP input matrix $|V|$ was normalized using Equation 6 (using Level 1 risk R3: Profit risk as an example):

$$|V| = \begin{bmatrix} 1/S_1 & v_{12}/S_2 & v_{13}/S_3 \\ v_{21}/S_1 & 1/S_2 & v_{23}/S_3 \\ v_{31}/S_1 & v_{32}/S_2 & 1/S_3 \end{bmatrix} \quad \text{(Eq. 6)}$$

Where S_j is the sum of column j of $|V|$ (refer to Equations 7 to 9).

$$S_1 = 1 + v_{21} + v_{31} \quad \text{(Eq. 7)}$$

$$S_2 = v_{12} + 1 + v_{32} \quad \text{(Eq. 8)}$$

$$S_3 = v_{13} + v_{23} + 1 \quad \text{(Eq. 9)}$$

Eigen vectors can be derived by dividing the sum of each row of $|V|$ by 3.

$$\omega_i = \begin{bmatrix} \sum \text{row1}/3 \\ \sum \text{row2}/3 \\ \sum \text{row3}/3 \end{bmatrix} = \begin{bmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \end{bmatrix} \quad \text{(Eq. 10)}$$

6) One of the common issues in generating pair-wise comparison matrix is non-consistency. To ensure consistency, Saaty (1980) recommended a maximum eigenvalue $\lambda_{max} > n$ for inconsistent. If consistency index (CI) is sufficiently small, the estimate of the weight is acceptable.

$$CI_i = \frac{\lambda_{maxi} - n}{n-1} \quad \text{(Eq. 11)}$$

Then the consistency ratio (CR) is used to examine the final inconsistency in pair-wise comparison (Saaty, 1980). RI is the random index, determined by averaging CI of a randomly generated reciprocal matrix, which has been presented in Saaty (1980)'s research.

$$CR_i = \frac{CI_i}{RI_i} \quad \text{(Eq. 12)}$$

7) Following a similar AHP process for other risk factors, RL of can be calculated and normalized:

$$RL = [RL_1, RL_2, RL_3, RL_4, RL_5] \quad \text{(Eq. 13)}$$

The final risk level of each stakeholder can be expressed as (Wp, 2012):

$$RL^* = 1 \times \mathrm{RL}_1 + 3 \times \mathrm{RL}_2 + 5 \times \mathrm{RL}_3 + 7 \times \mathrm{RL}_4 + 9 \times \mathrm{RL}_5 \quad \text{(Eq. 14)}$$

8) The risk borne by stakeholders is assumed to be equal in Shapley value model. For stakeholder m, the difference is:

$$\Delta\, RL_m = RL^* - \frac{1}{4}, \text{(m=1, 2, 3, 4)} \quad \text{(Eq. 15)}$$

The final profit distribution

$$x_m^* = x_m + \Delta\, RL_m \times v(s) \quad \text{(Eq. 16)}$$

4. Results

4.1 An example case

A case study is extracted from AIA (2012) to investigate the use of the modified cooperative game theory to address the problem of profit distribution in IPD. Autodesk Inc., a company (owner) that creates design software for the AEC industry. The company decided to put those goals forward with two of its own projects. The Waltham project is a 55,000 square foot, three-story interior tenant improvement that uses all of the space in a new speculative office building near Route 128 in Boston's technology corridor. KlingStubbins (designer), Autodesk software (BIM consultant) and Tocci (construction contractor) were chosen because of their qualifications, familiarity with the local market, BIM and willingness to abide by a "true" IPD agreement.

Assuming the designer, owner, construction contractor and BIM adopt traditional model, they would get the average profit of construction industry. So the profit without cooperation is shown in Table 1, namely $v(1) = 32, v(2) = 1814, v(3) = 1048, v(4) = 67$

Table.1 Stakeholders' Basic Information (Unit: million USD)

Stakeholders	Average Profit Rate of Industry[1]	Expected Cost	Expected Profit
Designer	2.50%	1231	32
Owner	11.10%	14530	1814
Construction contractor	7.09%	12223	1048
BIM consultant	5.80%	1089	67
Total profit			2961

1. McGraw-Hill (2015).

164.0844	2515.2422	1336.0095	129.6839	4145.02

If stakeholders collaborate with each other and share the information in real-time, more profit can be expected. Given that profits of the multi-stakeholders alliances have to be adjusted in practice and there is no standard to define the cooperation profits, some assumptions have to be made when multi-stakeholders alliances are formed (Jene & Zelewski, 2014; Lv & Zhao, 2013). The purpose of this example is to show how the above mentioned cooperative solution concepts can be applied in practice to solve the generic distribution problem. To make it more clearly to analysis, it is assumed that two-stakeholder alliance can increase the profit by 10%. A three-stakeholder alliance can increase the profit by 20% and a four-stakeholder alliance can increase the profit by 40%. Table 2 shows the profit distributions of two-stakeholder and three-stakeholder alliances.

Table 2. Expected profit and distributable profit of two-stakeholder and three-stakeholder alliance

Bi-stakeholders alliance	$i = 1$ $j = 2$	$i = 2$ $j = 3$	$i = 1$ $j = 3$	$i = 1$ $j = 4$	$i = 2$ $j = 4$	$i = 4$ $j = 4$
Expected Profit	2030.6	3148.2	1188	108.9	2069.1	1226.5

$v(i,j)$						
Distributable Profit $v(i,j)-v(i)-v(j)$	184.6	286.2	108	9.9	188.1	111.5
Tri-stakeholders alliance	$i=1$ $j=2$ $k=3$	$i=1$ $j=2$ $k=4$	$i=1$ $j=3$ $k=4$	$i=2$ $j=3$ $k=4$		
Expected Profit $v(i,j,k)$	3472.8	2295.6	1376.4	3514.8		
Distributable Profit $v(i,j,k)-v(i)-v(j)-v(k)$	578.8	382.6	229.4	585.8		

4.2 Profit distribution in IPD using unmodified Shapley value

The four stakeholders in this case collaborate based on a four-stakeholder coalition. According to the assumption, the profit of the IPD project would increase by 40%. As such, the total profit $v(S) = (32 + 1814 + 1048 + 67) \times (1 + 40\%) = 4145$ million dollars and the distributable profit equals to $4145 - 2961 = 1184$ million dollars.

Assume T_1 refers to all possible coalitions that involves designer. Similarly, T2, T3 and T4 refer to all possible coalitions that involve owner, contractor and BIM consultant respectively. The coalitions can be represented by:

$$T_1 = \{1, 1 \cup 2, 1 \cup 3, 1 \cup 4, 1 \cup 2 \cup 3, 1 \cup 2 \cup 4, 1 \cup 3 \cup 4, 1 \cup 2 \cup 3 \cup 4\}$$

$$T_2 = \{2, 1 \cup 2, 2 \cup 3, 2 \cup 4, 1 \cup 2 \cup 3, 1 \cup 2 \cup 4, 2 \cup 3 \cup 4, 1 \cup 2 \cup 3 \cup 4\}$$

$$T_3 = \{3, 1 \cup 3, 2 \cup 3, 3 \cup 4, 1 \cup 2 \cup 3, 1 \cup 3 \cup 4, 2 \cup 3 \cup 4, 1 \cup 2 \cup 3 \cup 4\}$$

$$T_4 = \{4,1 \cup 4,2 \cup 4,3 \cup 4,1 \cup 2 \cup 4,1 \cup 3 \cup 4,2 \cup 3 \cup 4,1 \cup 2 \cup 3 \cup 4\}$$

Based on Table 2, the profit distribution of each stakeholder under the unmodified cooperative game theory is shown in Table 3, Table 4, Table 5 and Table 6 respectively.

Table 3. Profit Distribution of Designer

T_1	1	1∪2	1∪3	1∪4	1∪2∪3	1∪2∪4	1∪3∪4	1∪2∪3∪4	Total
$v(s)$	32	2030.6	1188	108.9	3472.8	2295.6	1376.4	4145	
$v(s\text{-m})$	0	1814	1048	67	3148.2	2069.1	1226.5	3514.8	
$v(s)$- $v(s\text{-m})$	32	216.6	140	41.9	324.6	226.5	149.9	630.2	
s	1	2	2	2	3	3	3	4	
$\frac{(\lvert s\rvert-1)!\,(n-\lvert s\rvert)}{n!}$	1/4	1/12	1/12	1/12	1/12	1/12	1/12	1/4	
X_m	8.00	18.05	11.67	3.49	27.05	18.88	12.49	157.55	257.18

Table 4. Profit Distribution Value of the Owner

T_2	2	1∪2	2∪3	2∪4	1∪2∪3	1∪2∪4	2∪3∪4	1∪2∪3∪4	Total
$v(s)$	1814	2030.6	3148.2	2069.1	3472.8	2295.6	3514.8	4145	
$v(s\text{-m})$	0	32	1048	67	1188	108.9	1226.5	1376.4	
$v(s)$- $v(s\text{-m})$	1814	1998.6	2100.2	2002.1	2284.8	2186.7	2288.3	2768.6	
s	1	2	2	2	3	3	3	4	
$\frac{(\lvert s\rvert-1)!\,(n-\lvert s\rvert)}{n!}$	1/4	1/12	1/12	1/12	1/12	1/12	1/12	1/4	
X_m	453.50	166.55	175.02	166.84	190.40	182.23	190.69	692.15	2217.38

Table5. Profit Distribution Value of the Construction Contractor

T_3	3	1∪3	2∪3	3∪4	1∪2∪3	1∪3∪4	2∪3∪4	1∪2∪3∪4	Total
$v(s)$	1048	1188	3148.2	1226.5	3472.8	1376.4	3514.8	4145	
$v(s\text{-m})$	0	32	1814	67	2030.6	108.9	2069.1	2295.6	
$v(s)$- $v(s\text{-m})$	1048	1156	1334.2	1159.5	1442.2	1267.5	1445.7	1849.4	
s	1	2	2	2	3	3	3	4	

$\frac{(\lvert s\rvert-1)!\,(n-\lvert s\rvert)}{n!}$	1/4	1/12	1/12	1/12	1/12	1/12	1/12	1/4	
X_m	262.00	96.33	111.18	96.63	120.18	105.63	120.48	462.35	1374.78

Table 6. Profit Distribution Value of the BIM Consultant

T_4	4	1∪4	2∪4	3∪4	1∪2∪4	1∪3∪4	2∪3∪4	1∪2∪3∪4	Total
$v(s)$	67	108.9	2069.1	1226.5	2295.6	1376.4	3514.8	4145	
$v(s\text{-m})$	0	32	1814	1048	2030.6	1188	3148.2	3514.8	
$v(s)$- $v(s\text{-m})$	67	76.9	255.1	178.5	265	188.4	366.6	630.2	
s	1	2	2	2	3	3	3	4	
$\frac{(\lvert s\rvert-1)!\,(n-\lvert s\rvert)}{n!}$	1/4	1/12	1/12	1/12	1/12	1/12	1/12	1/4	
X_m	16.75	6.41	21.26	14.88	22.08	15.70	30.55	157.55	285.18

4.3 Profit distribution in IPD using modified Shapley value

4.3.1 Weights for Level-1 and Level-2 risk factors

10 experts were selected to rate the risk levels of the IPD project. These experts included two owners, two contractors, two designers, two BIM consultants and two academics. They were selected due to their previous experience on IPD projects. The background of these experts is shown in Table 7.

Table 7. Background of experts

Expert Number	Companies or Universities	Working Experience (years)	Position	Number of IPD Projects Participated/Studied in
1	Owner	10	Project Manager	2
2	Owner	8	Project Manager	2

3	Contractor	8	Project Manager	2
4	Contractor	9	BIM Director	3
5	Designer	6	BIM Design Director	4
6	Designer	10	BIM Project Manager	3
7	BIM Consultant	5	Technical Director	3
8	BIM Consultant	7	BIM Project Manager	3
9	Academics	15	Professor	3
10	Academics	12	Professor	4

Using AHP, the normalized matrix and the weights of Level-1 risk factors can be calculated. The weights of operation risk R_1, economic risk R_2, profit risk R_3 and market risk R_4 for designer, owner, contractor and BIM consultant are shown in Table 8.

Table 8. Normalized matrix and weights of Level-1 risk factors

	Normalization |V |	R_1	R_2	R_3	R_4	Sum	Eigen vector, weights $\omega_1, \omega_2, \omega_3, \omega_4$
Designer	R_1	0.26	0.32	0.23	0.24	0.26	0.26
	R_2	0.20	0.24	0.23	0.35	0.25	0.20
	R_3	0.35	0.32	0.31	0.24	0.30	0.35
	R_4	0.20	0.12	0.23	0.18	0.18	0.20
	Normalization |V |	R_1	R_2	R_3	R_4	Sum	Eigen vector, weights $\omega_1, \omega_2, \omega_3, \omega_4$
Owner	R_1	0.21	0.26	0.17	0.21	0.84	0.21
	R_2	0.28	0.34	0.39	0.28	1.29	0.32

	R_3	0.31	0.23	0.26	0.31	1.11	0.28
	R_4	0.21	0.17	0.17	0.21	0.76	0.19
	Normalization |V |	R_1	R_2	R_3	R_4	Sum	Eigen vector, weights $\omega_1, \omega_2, \omega_3, \omega_4$
Contractor	R_1	0.30	0.35	0.29	0.26	0.30	0.30
	R_2	0.20	0.23	0.21	0.34	0.20	0.25
	R_3	0.30	0.31	0.29	0.23	0.30	0.28
	R_4	0.20	0.12	0.21	0.17	0.20	0.18
	Normalization |V |	R_1	R_2	R_3	R_4	Sum	Eigen vector, weights $\omega_1, \omega_2, \omega_3, \omega_4$
BIM Consultant	R_1	0.31	0.25	0.35	0.34	0.31	0.31
	R_2	0.31	0.25	0.20	0.26	0.31	0.25
	R_3	0.23	0.33	0.26	0.23	0.23	0.26
	R_4	0.15	0.17	0.20	0.17	0.15	0.17

Similarly, using AHP, the weights of Level 2 risk factors are shown in Table 9.

Table 9. The weights of Level-2

	No.	Factors, criteria and attributes	Level-2 weight *(Eq.10)*	Level 1 weight *(Eq.10)*
Designer		**Level-1:Operation risk (R_1)**		0.26
	r_{11}	human resource risk	0.31	
	r_{12}	information resource risk	0.25	
	r_{13}	technical change risk	0.27	
	r_{14}	material or equipment quality risk	0.17	
		Level-1 : Economic Risk (R_2)		0.25

	No.	Factors, criteria and attributes	Level-2 weight	Level 1 weight
	r_{21}	financial risk	1.00	
		Level-1 : Profit Risk (R_3)		0.30
	r_{31}	unpredictable cost risk	0.28	
	r_{32}	contractual risk	0.39	
	r_{33}	inadequate design risk	0.33	
		Level-1 :Market Risk (R_4)		0.18
	r_{41}	interest rate fluctuation risk	0.50	
	r_{42}	political risk	0.50	
	No.	Factors, criteria and attributes	Level-2 weight *(Eq.10)*	Level 1 weight *(Eq.10)*
Owner		**Level-1:Operation risk (R_1)**		0.21
	r_{11}	human resource risk	0.38	
	r_{12}	information resource risk	0.32	
	r_{13}	technical change risk	0.16	
	r_{14}	material or equipment quality risk	0.14	
		Level-1 : Economic Risk (R_2)		0.32
	r_{21}	financial risk	1.00	
		Level-1 : Profit Risk (R_3)		0.28
	r_{31}	unpredictable cost risk	0.41	
	r_{32}	contractual risk	0.26	
	r_{33}	inadequate design risk	0.33	
		Level-1 :Market Risk (R_4)		0.19
	r_{41}	interest rate fluctuation risk	0.54	
	r_{42}	political risk	0.46	
Contractor	No.	Factors, criteria and attributes	Level-2 weight *(Eq.10)*	Level 1 weight *(Eq.10)*

	No.	Factors, criteria and attributes	Level-2 weight	Level 1 weight
		Level-1:Operation risk (R_1)		0.30
	r_{11}	human resource risk	0.19	
	r_{12}	information resource risk	0.23	
	r_{13}	technical change risk	0.30	
	r_{14}	material or equipment quality risk	0.28	
		Level-1 : Economic Risk (R_2)		0.25
	r_{21}	financial risk	1.00	
		Level-1 : Profit Risk (R_3)		0.28
	r_{31}	unpredictable cost risk	0.32	
	r_{32}	contractual risk	0.36	
	r_{33}	inadequate design risk	0.32	
		Level-1 :Market Risk (R_4)		0.18
	r_{41}	interest rate fluctuation risk	0.40	
	r_{42}	political risk	0.60	

	No.	Factors, criteria and attributes	Level-2 weight *(Eq.10)*	Level 1 weight *(Eq.10)*
BIM consultant		**Level-1:Operation risk (R_1)**		0.31
	r_{11}	human resource risk	0.32	
	r_{12}	information resource risk	0.36	
	r_{13}	technical change risk	0.32	
	r_{14}	material or equipment quality risk	0.32	
		Level-1 : Economic Risk (R_2)		0.25
	r_{21}	financial risk	1.00	
		Level-1 : Profit Risk (R_3)		0.26
	r_{31}	unpredictable cost risk	0.37	
	r_{32}	contractual risk	0.30	

r_{33}	inadequate design risk	0.33	
	Level-1 :Market Risk (R_4)		0.17
r_{41}	interest rate fluctuation risk	0.40	
r_{42}	political risk	0.60	

Then the consistency of the two level pair-wise comparisons is checked by the consistency ratio (CR). If CR < 0.10, the results can be accepted; otherwise the data has to be adjusted and calculated again until the consistency can be achieved (Saaty, 1980). Based on *Eq*.11 and *Eq*.12, the CR of the two Level Pair-Wise Comparisons can be calculated in table 10.

Table 10 Consistency Check of the two Level Pair-Wise Comparisons

Level-2		Level-1	
CR_{ij}		CR_i	
CR_{11}	0.0926	CR_1	0.0849
CR_{12}	0		
CR_{13}	0.0479		
CR_{14}	0		
CR_{21}	0.0833	CR_2	0.0386
CR_{22}	0		
CR_{23}	0.0958		
CR_{24}	0.0119		
CR_{31}	0.0522	CR_3	0.0926
CR_{32}	0		
CR_{33}	0.0814		
CR_{34}	0.0833		
CR_{41}	0.0710	CR_4	0.0849
CR_{42}	0		
CR_{43}	0.0239		
CR_{44}	0.0833		

4.3.2 Risk levels of Level-1 and Level-2 factors

The risk levels of each stakeholder are also rated by the 10 experts. The risks levels are shown in Table 11. For example, as rated by the 10 experts, inadequate design (r_{33}) is a very high level risk factors for designer when compared to other stakeholders.

Table 11. Risk Evaluation of each stakeholder

Stakeholder	level 1	level 2	Evaluation				
			1	3	5	7	9
Designer	Operation Risk R_1	Unproductive labour riskr_{11}	0	0	0.4	0.3	0.3
		Information resource risk r_{12}	0	0	0.6	0.3	0.1
		Technical change risk r_{13}	0	0	0.3	0.6	0.1
		Material or equipment quality risk r_{14}	0.8	0.2	0	0	0
	Economic Risk R_2	Financial risk r_{21}	0.1	0.5	0.4	0	0
	Profit Risk R_3	Unpredictable cost risk r_{31}	0.3	0.3	0.4	0	0
		Contractual risk r_{32}	0.3	0.4	0.3	0	0
		Inadequate design risk r_{33}	0	0	0	0	1
	Market Risk R_4	Interest rate fluctuation risk r_{41}	0.3	0.2	0.5	0	0
		Political risk r_{42}	0.2	0.5	0.3	0	0
Owner	Operation Risk R_1	Unproductive labour riskr_{11}	0.1	0.1	0.4	0.4	0
		Information resource risk r_{12}	0.1	0.4	0.5	0	0
		Technical change risk r_{13}	0.4	0.3	0.3	0	0
		Material or equipment quality risk r_{14}	0.9	0.1	0	0	0
	Economic Risk R_2	Financial risk r_{21}	0	0	0	0.2	0.8
	Profit Risk R_3	Unpredictable cost risk r_{31}	0	0	0.3	0.2	0.5
		Contractual risk r_{32}	0	0	0.3	0.3	0.4
		Inadequate design risk r_{33}	0	0	0.1	0.5	0.4

	Market Risk R_4	Interest rate fluctuation risk r_{41}	0	0	0.1	0.3	0.6
		Political risk r_{42}	0	0	0.2	0.4	0.4
Contractor	Operation Risk R_1	Unproductive labour riskr_{11}	0.2	0.3	0.3	0.2	0
		Information resource risk r_{12}	0	0.4	0.2	0.2	0.2
		Technical change risk r_{13}	0	0	0.2	0.4	0.4
		Material or equipment quality risk r_{14}	0	0	0	0.2	0.8
	Economic Risk R_2	Financial risk r_{21}	0	0	0	0.2	0.8
	Profit Risk R_3	Unpredictable cost risk r_{31}	0	0	0.1	0.5	0.4
		Contractual risk r_{32}	0	0.4	0.5	0.1	0
		Inadequate design risk r_{33}	0	0.1	0.4	0.5	0
	Market Risk R_4	Interest rate fluctuation risk r_{41}	0	0.2	0.2	0.5	0.1
		Political risk r_{42}	0	0.4	0.3	0.3	0
BIM Consultant	Operation Risk R_1	Unproductive labour riskr_{11}	0	0	0.2	0.5	0.3
		Information resource risk r_{12}	0	0	0	0	1
		Technical change risk r_{13}	0	0	0	0.2	0.8
		Material or equipment quality risk r_{14}	0.3	0.3	0.2	0.2	0
	Economic Risk R_2	Financial risk r_{21}	0.3	0.4	0.3	0	0
	Profit Risk R_3	Unpredictable cost risk r_{31}	0.6	0.2	0.2	0	0
		Contractual risk r_{32}	0.7	0.2	0.1	0	0
		Inadequate design risk r_{33}	0.8	0.2	0	0	0
	Market Risk R_4	Interest rate fluctuation risk r_{41}	0.5	0.2	0.3	0	0
		Political risk r_{42}	0	0.2	0.3	0.2	0.3

4.3.3 Modified Shapley value

The final steps involve the aggregation of the weights and risk levels into the Shapley value. This is shown in Table 12. As can be seen from Table 12, using FCE and AHP, the final risk levels for designer, owner, contractor and BIM consultant are 4.5029, 7.0947, 6.6656 and 4.3644 respectively, where 1 = lowest and 9 = highest.

Table 12. Risk levels of all stakeholders in the IPD project

	Level-1 risk	*Level-2 risk*	w_{ij}	r_{ij}	$R_i = \sum_{j=1}^{n} w_{ij} \times r_{ij}$	W_i	$RL = \sum_{i=1}^{4} W_i \times R_i$ After being normalized	RL^*
Designer	Operation Risk R_1	r_{11}	0.31	$\{0, 0, 0.4, 0.3, 0.3\}$	$\{0.14, 0.03, 0.35, 0.33, 0.15\}$	0.26	$\{0.17, 0.27, 0.34, 0.09, 0.14\}$	4.5029
		r_{12}	0.42	$\{0, 0, 0.6, 0.3, 0.1\}$				
		r_{13}	0.19	$\{0, 0, 0.3, 0.6, 0.1\}$				
		r_{14}	0.08	$\{0.8, 0.2, 0, 0, 0\}$				
	Economic Risk R_2	r_{21}	1.00	$\{0.1, 0.5, 0.4, 0, 0\}$	$\{0.1, 0.5, 0.4, 0, 0\}$	0.25		
	Profit Risk R_3	r_{31}	0.22	$\{0.3, 0.3, 0.4, 0, 0\}$	$\{0.2, 0.24, 0.23, 0, 0.33\}$	0.30		
		r_{32}	0.29	$\{0.3, 0.4, 0.3, 0, 0\}$				
		r_{33}	0.50	$\{0, 0, 0, 0, 1\}$				
	Market Risk R_4	r_{41}	0.50	$\{0.3, 0.2, 0.5, 0, 0\}$	$\{0.25, 0.35, 0.40, 0, 0\}$	0.18		
		r_{42}	0.50	$\{0.2, 0.5, 0.3, 0, 0\}$				
Owner	Operation Risk R_1	r_{11}	0.47	$\{0.1, 0.1, 0.4, 0.4, 0\}$	$\{0.26, 0.23, 0.36, 0.15, 0\}$	0.21	$\{0.05, 0.05, 0.1, 0.25, 0.48\}$	7.0947
		r_{12}	0.30	$\{0.1, 0.4, 0.5, 0, 0\}$				
		r_{13}	0.14	$\{0.4, 0.3, 0.3, 0, 0\}$				
		r_{14}	0.09	$\{0.9, 0.1, 0, 0, 0\}$				
	Economic Risk R_2	r_{21}	1.00	$\{0, 0, 0, 0.2, 0.8\}$	$\{0, 0, 0, 0.2, 0.8\}$	0.32		
	Profit Risk R_3	r_{31}	0.55	$\{0, 0, 0.3, 0.2, 0.5\}$	$\{0, 0, 0.24, 0.32, 0.44\}$	0.28		
		r_{32}	0.18	$\{0, 0, 0.3, 0.3, 0.4\}$				
		r_{33}	0.27	$\{0, 0, 0.1, 0.5, 0.4\}$				
	Market	r_{41}	0.54	$\{0, 0, 0.1, 0.3, 0.6\}$	$\{0, 0, 0.15, 0.34, 0.51\}$	0.19		

	Risk R_4	r_{42}	0.46	{0, 0, 0.2, 0.4, 0.4}				
Contractor	Operation Risk R_1	r_{11}	0.15	{0.2,0.3,0.3,0.2,0}	{0.04, 0.15, 0.16, 0.26,0.39}	0.30	{0.01, 0.15, 0.19,0.29,0.36}	6.6656
		r_{12}	0.22	{0, 0.4,0.2,0.2,0.2}				
		r_{13}	0.32	{0, 0, 0.2,0.4,0.4}				
		r_{14}	0.32	{0, 0, 0, 0.2, 0.8}				
	Economic Risk R_2	r_{21}	1.00	{0, 0, 0.1, 0.5, 0.4}	{0, 0, 0, 0.2, 0.8}	0.25		
	Profit Risk R_3	r_{31}	0.55	{0, 0, 0.1, 0.5, 0.4}	{0, 0.18, 0.34, 0.36, 0.13}	0.28		
		r_{32}	0.23	{0, 0.4, 0.5, 0.1, 0}				
		r_{33}	0.22	{0, 0.1, 0.4, 0.5,0}				
	Market Risk R_4	r_{41}	0.40	{0, 0.2,0.2,0.5,0.1}	{0,0.32,0.26,0.38, 0.04}	0.18		
		r_{42}	0.60	{0, 0.4, 0.3, 0.3, 0}				
BIM consultant	Operation Risk R_1	r_{11}	0.25	{0, 0, 0.2,0.5,0.3}	{0.05, 0.05, 0.09,0.24,0.56}	0.31	{0.31, 0.20, 0.18,0.09,0.21}	4.3644
		r_{12}	0.27	{0, 0, 0, 0 ,1}				
		r_{13}	0.38	{0, 0, 0,0.2,0.8}				
		r_{14}	0.10	{0.3,0.3,0.2,0.2,0}				
	Economic Risk R_2	r_{21}	1.00	{0.3, 0.4, 0.3, 0, 0}	{0.3, 0.4, 0.3, 0, 0}	0.25		
	Profit Risk R_3	r_{31}	0.41	{0.6, 0.2, 0.2, 0, 0}	{0.7, 0.2, 0.1, 0, 0}	0.26		
		r_{32}	0.26	{0.7, 0.2, 0.1, 0, 0}				
		r_{33}	0.33	{0.8, 0.2, 0, 0, 0}				
	Market Risk R_4	r_{41}	0.38	{0.5, 0.2, 0.3, 0, 0}	{0.2, 0.2, 0.3, 0.12, 0.18}	0.17		
		r_{42}	0.63	{0,0.2,0.3,0.2,0.3}				

According to Equations 14 and 15, the final distributed profit for each stakeholder can be calculated, which is shown in Table 13. As shown in Table 13, the designer's and BIM consultant's profit are reduced by $138.69 million dollars and $177.49 million dollars respectively due to their relatively lower risk levels. However, the final profit is still higher than the expected profit without cooperation.

Table 13. Final distributed profit for each stakeholder

	Designer	Owner	Contractor	BIM Consultant	Total
RL	4.5029	7.0947	6.6656	4.3644	22.6276
Normalized RL	0.2275	0.3219	0.2406	0.2100	1
Average Risk	0.25	0.25	0.25	0.25	
$\Delta\, RL_m$	-93.0956	297.8622	-38.7705	-165.9961	
$\Delta\, RL_m \times v(s)$	-138.6893	178.9198	137.2641	-177.4946	
x_m	257.18	2217.38	1374.78	295.68	4145.02
x_m^*	164.0844	2515.2422	1336.0095	129.6839	4145.02

The framework of the profit distribution in IPD projects based on cooperative game theory can be seen in Fig.1. All parties will reach a multiparty agreement and are involved in the early stage of the project. They share the risk and reward through collaborative behavior (Kent & Becerik-Gerber, 2010). In the early beginning of the projects, jointly developed targets need to be established as the parties' first collaborative act. They are the mission statement of the IPD project, which serves as goals for target value design (Pishdad-Bozorgi, Moghaddam, & Karasulu, 2013). They joint site investigation is also vital for a better understanding of the whole project. The joint project control balances the interests of the stakeholders and can achieve the jointly agreed objectives, which is a significant paradigm shift for many owners. These characteristics of IPD achieve the information sharing and collaboration, guarantee the commitment of stakeholders to the projects, and promote the efficiency of the outcomes. If extra 40% are assumed to be achieved in this project, the profit distribution implemented as shown in Fig.1.

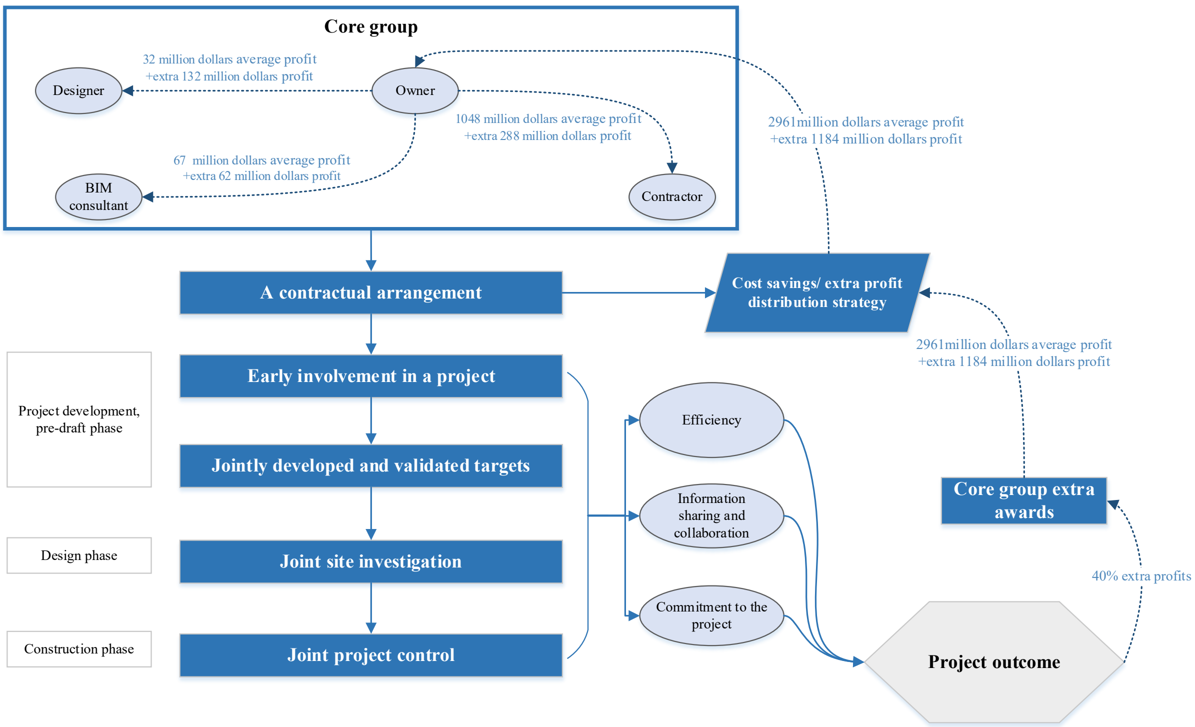

Fig. 1 Framework of profit distribution in IPD projects based on cooperative game theory

5. Discussions

Shared risk and reward is considered as one of the most important criteria of IPD. Unlike traditional projects where each party typically takes strategies to minimize their own risk, IPD contracts combine the risks and rewards of all team members in order to reach common project goals. This requires an effective distribution system which considers the marginal contribution of the stakeholder to the potential coalition that will be formed.

The findings reveal that Cooperative Game Theory can help solve the profit distribution scheme in IPD projects. The Shapely value used in this paper gives a unique solution which represents the marginal contribution of each stakeholder. By using the Shapley value as the basis for profit distribution, each stakeholder will try to contribute to the success of the coalition, rather than contribute based on their own interest. In addition, the Shapely value gives unique solution to the profit distribution. As such, each stakeholder can be certain on how much profit they will get from the IPD projects. In the example case provided, the four stakeholders accrued more profits than the expected industry average profits. The Shapley value method assumes each stakeholder has the same level of risks. However, it is not practical to assume so. As such, it is important to consider the risk levels of each stakeholder in the Shapley value. After considering the modified risk levels, the profit distribution model is more efficient as it consider both the marginal contribution and the risk level of each stakeholder.

It should also be noted that the success of the profit distribution scheme will also be dependent on information sharing between each stakeholder to increase the profit level of the coalition. It is not guaranteed that once a coalition is formed in IPD projects, the profit level will be increased. Building Information Modelling has been considered as a very good platform to increase information sharing activities. For example, Hartmann and Fischer (2007) firstly described how project teams can use 3D/4D models efficiently to support the communication of knowledge during the constructability review on construction project. With the rapid advancement of information and communication technologies (ICT), the integration of ICT into BIM increases the communication efficiency significantly. Integration of wired and wireless sensor networks for real-time data collection to support decision-making processes in construction job sites for real-time project management has now been implemented in many construction projects. Through the BIM platform, the stakeholders can be electronically linked for faster and smoother communication and the information will be transparent for all stakeholders.

6. Conclusions

The profit distribution among stakeholders in IPD projects is investigated. All stakeholders have incentives to cooperate as a coalition because this will result in reduced costs and consequently lead to increased profits. The profit distribution is analysed using a modified

Shapley value by introducing the risk level of each stakeholder. Using an example case, the results shown that by forming a four-stakeholder coalition in IPD project, the profits of owner, designer, contractor and BIM consultant can be increased. All stakeholders have accrued more profits when compared to the industry average profits. The profit distribution scheme assures a fair distribution of the coalition profit based on the marginal contribution that the stakeholder brings to the coalition. It also adjusts the marginal contribution based on the risk level that the stakeholder bears. By using such distribution scheme, stakeholders are willing to cooperate because there are known share of the coalition profit.

There are some limitations of this study. Only four stakeholders are considered as main stakeholders in IPD. However, there are more stakeholders in practice and the distribution of the profit from a coalition with more stakeholders is much more complicated. In addition, some assumptions have been made in the profit forecast process, which needs to be further updated in practice. Furthermore, the risk levels are assessed by a group of experts. Future research should also be conducted on the use of BIM platform to promote information sharing in order to reach the full potential of IPD.

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