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Evaluation of Cooperation during Project Delivery: An Empirical Study on the Hydropower Industry in Southwest China

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Abstract: Previous studies agree that cooperation among participants is critical to successfully deliver projects; however, little research has quantitatively illustrated how participants benefit from cooperation. Based on partnering and cooperative game theories, the Degree of Willingness to Cooperate (DWC) model has been used in this study to reflect the interactions among participants through dynamic simulation. With the support of data collected from a field survey, the outcomes of DWC model simulation have been tested, confirming that degrees of willingness to cooperate (DWCs) have significantly positive influences on cooperation gains, and incentives are effective in improving participants' rewards. Application of the DWC model then reveals the cooperation status of hydropower developments in Southwest China, suggesting five practical strategies for inter-organizational cooperation in project delivery. This study advances the knowledge area of multi-organizational dynamics during project delivery by building interdisciplinary linkage between partnering theory and cooperative game theory, which provides a structure to quantitatively unfold the cause-effect relationships between DWCs, incentives, and participants' rewards. This research also reveals the mutual goals and different priorities of project participants, and answers questions on how coalitions can be formed and how cooperation gains should be equitably allocated. The above

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findings can help practitioners to understand their positions in cooperation, make decisions taking account of optimally integrating participants' resources, and find ways to reach stable long-term partnering relationships.

CE Database Subject Headings: Partnering; Cooperative game; Cooperation model; Incentives; Hydropower development; China.

Introduction

Multi-organizational dynamics during project delivery have increasingly become research emphases as project participants' objectives, resources, and management structures are partly shared and closely interacted with each other (Lehtiranta 2014). Project delivery involves a range of participants such as clients, designers, superintendents and contractors, and their specific interests in project outcomes may lead to conflict resulting in poor quality, delays and cost overruns (Tang et al. 2013; Tang et al. 2007). Lack of synergy between project organizations is identified as a key obstacle to the implementation and efficient delivery of projects (Ates and Durakbasa 2012). As traditional competitive ways may make multi-organizational relationships adversarial, which ultimately has a negative impact on project delivery, cooperative strategies need to be adopted by project participants (Palacios et al. 2013). Many researchers advocate using the strategy of partnering that applies a win-win philosophy to enhance the cooperation between participants (Hong et al. 2012; Lubell et al. 2002). Partnering is a long-term commitment between two or more organizations for the purpose of achieving specific objectives by maximizing the effectiveness of each participant's resources based upon trust relationships (CII 1991). Partnering has been increasingly applied to improving the performance of project delivery during the past two decades. The success of partnering can be attributed to: firstly, partnering promotes participants' willingness to form an integrated project team working across organizational boundaries by specifying the mutual project objectives (Bennett and Jayes 1998); secondly, partnering arrangements are underpinned by incentive schemes, which use clearly defined rewards allocation to manage the processes, providing powerful motivations and necessary resources for participants to achieve high performance (Tang et al. 2008; Chan et al. 2008; Bower et al. 2002; Scott 2001). Existing studies tend to focus on the need to cooperate among project participants (Tang et al. 2009; CII 1991), critical success factors in implementation of partnering (Cheng and Li 2002; Black et al. 2000), and theoretical frameworks for explaining partnering mechanism (Cho et al. 2010; Tang et al. 2006; Growley and Karim 1995). Nevertheless, detailed quantifiable models that systematically evaluate how participants benefit from cooperation are lacking, and this may restrict a deeper understanding of partnering quintessence and weaken management resolve to pursue partnering (Wang et al. 2013; Tang et al. 2006). Thus, the objective of this study is to quantitatively investigate how degree of willingness to cooperate, associated with use of incentives, impact on the rewards of participants, by validating the outcomes of the Degree of Willingness to Cooperate (DWC) model simulation with the support of data collected from a fieldwork survey of hydropower industry in Southwest China.

The DWC Model

Background

Game theories have been used to study the conflict and cooperation between rational decision-makers (Owen 1995; Myerson 1991), which provide useful insights into the way participants plan and utilize the scarce resources they share together under different situations (Parrachino et al. 2006). Different from non-cooperative game theories, cooperative game theories facilitate fair allocation of coalitional gains by modeling the decision-making processes of multiple players (Rosen and Sexton 1993). The cooperative models with components of project development, environment, economic gains and special interest groups have been used to reach a more equitable distribution of payoffs among participants and improve the effectiveness of sharing information (Schreider et al. 2013; Madani 2011; Deidda et al. 2009; Suzuki and Nakayama 1976). These studies indicate the advantages of taking cooperative strategies over non-cooperative strategies based on Pareto optimum solutions (Schreider et al. 2013; Madani 2011; Qin et al. 2010; Deidda et al. 2009; Suzuki and Nakayama 1976). Studying participants' cooperative behaviors (e.g. degree of willingness to cooperate) is critical for understanding the way to reach a stable long-term partnering relationship (Cheung et al. 2003).

Cooperative strategy in long-term partnering relationship may be different from that in a one-shot game (Kreps et al. 1982; Fudenberg and Maskin 1986). The DWC model has been developed to analyze the long-term gaming process between participants with non-complete common interests (Zhang and Xue 2005). Compared to traditional cooperative game theories that focus on the result of payoff allocation (Shapley and Shubik 1969; Driessen 1991), the DWC model also considers the process of games between participants (Ye et al. 2004). The DWC model takes account of different factors such as participants' cognitions and historical results of games, which may have impacts on participants' willingness to cooperate and further bring changes to their decision processes (Ye et al. 2004). Due to the strength in simulating the dynamic game process of participants, the DWC model is appropriate in analyzing interplays of organizations that are in the same industry chain (Cai et al. 2014). Thus, this study uses the DWC model that simulates the process of cooperation among project participants, to quantitatively analyze the linkages between degrees of willingness to cooperate (DWCs), the use of incentives and the payoffs of cooperation during project delivery. The details of the DWC model follow.

Model Details

To calculate the influence of historical factors on participants' DWCs in simulating the process of cooperation among project participants, participants' expected payoff and actual payoff need to be considered. In the long-term reciprocally cooperative moves between participants, the comparisons between previous cooperation's expected payoffs and actual payoffs are historical factors, which have impacts on the participants' DWCs in the next period (Kadefors 2004). Expected payoff is the prospective payoff, and can be used as a benchmark to measure the effectiveness of cooperation. Actual payoff is influenced by participants' DWCs, which involve not only historical factors but also cognition factors. Cognition factors represent participants' understanding of project development environment and contingencies, which affect the moves of the participants that can be either competitive or cooperative (Cheung et al. 2003). The quantitative relationships among the above variables in the DWC model are reflected as equations from (1) to (5) derived from Zhang et al. (2006).

- Actual payoff is calculated as Eq. (1):

$$P_i^1(t)=P_i^{1'}(t)\{1+j_I[para_{(i+4)}\sin(t)+m_i(1-para_{(i+4)})y(t)]\} \tag{1}$$

Theoretical payoff $P_i^{1'}(t)$ is the payoff of participant *i* that does not consider the effects of environmental and contingency factors in period *t*, as calculated below:

$$\begin{aligned} P_i^{1'}(t)= & P_i(CC,CC)[1+\alpha_1(t)][1+\alpha_2(t)]/4+P_i(CC,NN)[1+\alpha_1(t)][1-\alpha_2(t)]/4 \\ & +P_i(NN,CC)[1-\alpha_1(t)][1+\alpha_2(t)]/4+P_i(NN,NN)[1-\alpha_1(t)][1-\alpha_2(t)]/4 \end{aligned} \tag{2}$$

where t=period; i=participant; $\sin(t)$*=project development environment factor; y(t)=project development contingency factor;* $para_{(i+4)}$*=project development environment factor's weight in* *actual payoff;* $1-para_{(i+4)}$*=project development contingency factor's weight in actual payoff;* $j_i=\begin{cases} 1, \text{ if } P_i^{1'}(t)\geq 0 \\ -1, \text{ if } P_i^{1'}(t)<0 \end{cases}$; *and* $m_i=\begin{cases} 1, \text{ if project development contingency factors' effect on participant } i \text{ is positive} \\ -1, \text{ if project development contingency factors' effect on participant } i \text{ is negative} \end{cases}$.

$P_i(CC,CC)$, $P_i(CC,NN)$, $P_i(NN,CC)$, *and* $P_i(NN,NN)$ *respectively represent the initial payoff of participant i under different strategic conditions of (cooperative, cooperative), (cooperative, competitive), (competitive, cooperative), and (competitive, competitive);* $\alpha_i(t)$*=DWC of participant i.*

- Expected payoff is calculated as Eq. (3):

$$P_i^0(t)=P_i^1(t-1)\{1+r_i[para_i\sin(t)+(1-para_i)\sum_{k=1}^{t}\frac{e^{-(t-k)}}{\sum_{k=1}^{t}e^{-(t-k)}}\omega_i(k)]\} \tag{3}$$

$$r_i=\begin{cases} 1, \text{ if } P_i^1(t-1)\geq 0 \\ -1, \text{ if } P_i^1(t-1)<0 \end{cases}$$

where $para_i$ =project development environment factor's weight in expected payoff; $1-para_i$=historical factor's weight in expected payoff; $e^{-(t-k)}$=attenuation index of historical factor's influence on expected payoff; $\omega_i(k)$=weight of the difference between actual payoff and expected payoff in period k, which is calculated as Eq. (4):

$$\omega_i(k)=\left[p_i^1(k)-p_i^0(k)\right]\Big/\sum_{k=0}^{t}\left|p_i^1(k)-p_i^0(k)\right| \tag{4}$$

- The DWC value in next period is calculated as Eq. (5):

$$\alpha_i(t+1)=para_{(i+6)}\sum_{k=1}^{t}\frac{e^{-(t-k)}}{\sum_{k=1}^{t}e^{-(t-k)}}\alpha_i(k)\omega_i(k)+(1-para_{(i+6)})\{-para_{(i+8)}\,sin(t)+q_{1i}(1-para_{(i+8)})y(t)\} \tag{5}$$

where $para_{(i+6)}$ =historical factor's weight in DWC value of next period; $1-para_{(i+6)}$=cognition factor's weight in DWC value of next period; $para_{(i+8)}$=project development environment factor’s weight in DWC value of next period; $1-para_{(i+8)}$=project development contingency factor’s weight in DWC value of next period; and $q_{1i}=\begin{cases}1, \text{ if } m_i=-1 \\ -1, \text{ if } m_i=1\end{cases}$.

Inferences from the DWC Model Simulation

To start the simulation, an initial payoff matrix of two participants was set in Table 1. As taking cooperative strategies has advantages over non-cooperative strategies on Pareto optimum solution due to optimally sharing the resources of participants in cooperation (Schreider et al. 2013; Madani 2011; Qin et al. 2010; Deidda et al. 2009; Suzuki and Nakayama 1976), it was set that the overall payoff of the two participants who both take cooperative strategies is highest compared to the other three non-cooperative circumstances. Specifically, it was set that the payoffs of the two participants are 30 respectively (with an overall payoff of 60) when they both take cooperative strategies, for the reason that project benefits should be equitably shared among parties (Tang et al. 2008; Zhang et al. 2006). When they both take competitive strategies, their payoffs are -10 respectively (with an overall payoff of -20), which reflects the lose-lose situation resulting from their adversarial relationship. When the two participants use different strategies, the one who adopts cooperative strategy has payoff of 10, whereas the other one who adopts competitive strategy has payoff of 40 owing to exploitation of additional rewards, with overall payoffs being 50 respectively.

To start the calculation, initial DWC values of two participants were set as: [1, 1], [1, -1], [-1, 1] and [-1, -1], where 1=fully cooperative, and -1=fully competitive. Based on the above model and parameters setting, Matlab was used to program and calculate, with payoffs of two participants in corresponding to the four circumstances shown in Table 2.

The results in Table 2 show that when initial DWCs of the two participants are both 1, the actual payoffs of them are both 15.15 after games, which have the highest overall payoff of 30.30. When initial DWCs of the two participants are 1 and -1, the actual payoffs of participants are 14.35 and 14.85 respectively, with their overall payoff being 29.20. When initial DWCs of the two participants are both -1, the actual payoffs of them are both 13.77 after games, which have the lowest overall payoff of 27.54. The results show that the higher the initial DWCs are, the higher the payoffs turn out to be, demonstrating that the DWCs have positive impacts on the cooperation gains of the participants.

Further, incentives were studied in the DWC model to quantitatively explore how they affect cooperation rewards of participants. The initial payoff matrix of two participants with incentives was set as shown in Table 3.

The main reason for introducing incentives into the cooperation processes is that project rewards should be more equitably shared among participants so that a more proactively partnering relationship could be created for achieving superior performance (Tang et al. 2008; Chan et al. 2008; Bower et al. 2002; Scott 2001). Accordingly, the initial payoff matrix (see Table 3) was changed to alleviate the imbalance of the payoff allocation, and when the two participants take different strategies, the one adopting cooperative strategy has payoff increased from 10 to 15, whereas the other one adopting competitive strategy has payoff decreased from 40 to 35. Based on the changed initial values in Table 3, payoffs of two participants with incentives were calculated in the DWC model, with the results shown in Table 4.

The payoffs in Table 4 are increased in comparison with the ones in Table 2, indicating that use of incentives contributes to improving the rewards of cooperation between participants.

Empirical Research Questions Arising from the DWC Model Simulation

The simulation results of the DWC model indicate two important hypotheses on the relationships between DWCs, use of incentives and rewards of participants:

H1: DWCs have positive impacts on the rewards of participants.

H2: Use of incentives contributes to improving the rewards of cooperation between participants.

To validate the two hypotheses arising from the DWC model simulation, an empirical research approach needs to be conducted. Relevant themes worthy of further investigation have been transferred into specific questions:

- To what extent do participants' objectives align with each other?
- What is the role of participants' actual DWCs in influencing the cooperation gains?
- How effective is use of incentives in improving participants' rewards?

Empirical Research Methods

Choice of the Hydropower Industry in Southwest China

China's demand for electricity increases by about 10% per year, and the country's power generation capacity ranks second only to the United States of America (McElroy et al. 2009). Renewable energy is a suitable way to decrease CO_2 emissions, and aligns with the long-term implementation strategy of sustainable energy systems (Batista et al. 2013; Lund and Mathiesen 2012; Olabi 2012; Li et al. 2011; AlbergØstergaard et al. 2010; Chang et al. 2010). In the past few decades, the share of hydropower has increased from 2% to 21% of the total power generation in China (China Electricity Council 2007), and hydropower has become an essential part of China's transformation from fossil fuels to sustainable energy (Zhang et al. 2011).

Southwest China was chosen as the study area because 70.8% of hydropower resources are located in this region (Fang et al. 2010; Zhu and Zhao 2002), with many major hydropower projects already in the processes of delivery and operation, providing a rich source of data for this study. The total economically exploitable amount of hydropower resource in China is 402,000 MW. This study surveyed 12 hydropower projects, with the installed capacity of these projects (81,400 MW) accounting for 20% of the above total amount.

The Chinese industrial culture shares many factors with partnering, which enables partnering concepts from North America (CII 1991; Cowan 1992), Europe (Egan 1998; Scott 2001) and Australia (ACA 1999) have been well accepted in China to improve efficiency of project delivery (Chan et al. 2008; Rahman and Kumaraswamy 2002). Tang et al. (2006) have conducted an empirical study to understand partnering mechanism, confirming that attitudinal factors such as willingness to cooperate are effective in facilitating open communication factors of partnering in the Chinese construction industry. Specifically, from the perspective of the clients of hydropower projects in Southwest China, Wang et al. (2013) indicate that it is critical to reach appropriate trade-offs between involved stakeholders by adopting partnering win-win philosophy in development of hydropower projects. Thus, the hydropower industry in Southwest China is a suitable study area for validating the outcomes of the DWC model simulation.

Methodological Triangulation Approach

Methodological triangulation approach is the use of multiple research methods to investigate the same theme (Fellows and Liu 1997), which enables both qualitative and quantitative data collection to be used to test or understand a research proposition (Love et al. 2002). The advantages of methodological triangulation approach include increasing the validity of insights, facilitating a deeper understanding of the phenomenon, and helping to reveal unique findings (Guion et al., 2011). Accordingly, this research applied methodological triangulation approach to test the two hypotheses derived from the DWC model simulation. It was decided that questionnaire, interview, direct observation, project document review and case study were used to meet the need of data collection and analysis in this study.

Questionnaire was chosen as the main survey method, and the questions in the questionnaire were formatted by applying a five-point Likert scale, which permitted the use of statistical techniques to analyze the data. Postal surveys avoid excessive leg-work, but then another problem is to obtain an adequate level of response (Thomas 1996). If the response rate in a postal survey is lower than 30-40%, the obtained data may be biased (Akintoye and Macleod 1997). To avoid this limitation, this questionnaire survey was conducted through six field trips to hydropower project sites in the Sichuan, Yunnan, Chongqing and Hubei provinces in Southwest China. To understand the overall issues of cooperation involving a variety of stakeholders in hydropower project developments, the key participants of the projects including clients, contractors (Contr.), designers (Desi.), and superintendents (Super.) were chosen as respondents. Superintendents act not only as agents for clients in conveying the instructions of clients to the contractors, but also as certifiers in measures of work value, quantity or time (Tang et al. 2013). The respondents had experience in development of significant projects, such as the Three Gorges Project in the upper reaches of Yangtze River, Xiluodu project in Jinsha River and Jinping project in Yalong River, with capacities of hydropower generators being 18200MW, 12600MW and 8400MW respectively. In total, 268 questionnaires were collected, and the distribution is: 44% from clients, 29% from constructors, 20% from superintendents and 7% from designers. Among the respondents, 30% held senior positions, such as project manager, chief engineer, department head, general manager and director, and the rest also had been working in the hydropower industry for many years. The fieldwork approach assisted that all the sent questionnaires had been collected.

The fieldwork in this study allowed that interviews with 67 respondents holding senior positions were conducted after the questionnaires had been completed, and the themes in the questionnaire were used as interview topics. Direct observation during site visits also improved the researchers' understanding of the environment and construction process of the hydropower projects, which objectively demonstrates the need for participants to cooperatively deal with them. Some project documents were reviewed to know how cooperative strategies were applied by participants in details. In addition, a case study of the Three Gorges Project (TGP) was undertaken for in-depth analysis of using incentives.

Questionnaire was used to collect quantitative data for validating the hypotheses from the DWC model simulation. Interview, direct observation, project document review, and case study were applied to further interpret the established relationships, and unfold the cooperation status of hydropower development in Southwest China. Given the variety of respondents, the methodological triangulation approach, and the significance of hydropower projects together with their geographic distribution, the bias of sample selecting could be reasonably reduced in this study.

Data Analysis Techniques

The data collected from questionnaires were analyzed using the Statistical Package for Social Science (SPSS) (SPSS 1997). The selected techniques for this study include estimation of the sample population mean, rank cases, one-way analysis of variance (ANOVA), and Pearson correlation. ANOVA was used to analyze the alignments of project participants' objectives. The Pearson correlation was applied to test the relationships between DWCs, use of incentives, and rewards of cooperation. The results of these inferential analyses were tested by significance level, which follows the usual level of 0.05, with a level of 0.01 being highly significant.

Validation of the DWC Model

As mutual goals will promote participants' cooperative attitude and enable them to consider their common interests by utilizing win/win thinking (Tang et al. 2006; Scott 2001), the hydropower project participants' objectives were investigated for ascertaining alignments/misalignments of them. Quality, schedule, and cost are the traditional key criteria for project objectives in the construction industry (Wang and Huang 2006; Westerveld 2003). Due to hydropower projects normally accompanying hazardous natural environment, safety is also an essential project objective for project delivery (Mitropoulos and Namboodiri 2011). Besides, impacts on ecology and environment, and resettlement of migrants caused by inundation of lands have become important concerns of participants in hydropower projects (Wang et al. 2013; Chang et al. 2010; Vörösmarty et al. 2010). Respondents were asked to rate the importance of the project objectives, where 1=not important, and 5=most important. The results are shown in Table 5.

Overall, “safety” and “quality” objectives were found to be the most important, which obtained apparently high ratings of 4.64 and 4.59 respectively, as shown in Table 5. “Schedule”, “cost”, “ecology and environment” and “resettlement of migrants” objectives had considerably high ratings (≥ 3.92), demonstrating these aspects are also worthy of participants' concerns. ANOVA was performed to test whether the participants' perceptions are equal (SPSS 1997). The ANOVA analysis results show that all groups have a common view on the criticality of “safety” and “quality”, providing sound basis for participants to collaboratively deal with problems related to natural hazards, unforeseen geological conditions, application of complex technologies and construction processes. However, there are disparities among the participants' perceptions on the other four objectives, suggesting the need for participants to establish alignment mechanisms, e.g. use of incentives, to promote the synergy among the participants in tackling issues on “schedule”, “cost”, “ecology and environment” and “resettlement of migrants”.

To explore the relationship between the participants’ cooperative willingness and the outcomes of cooperation, respondents were asked to score their degrees of willingness to cooperate with the other partners ranging from 1 to 5, where 1=extremely unwilling, and 5=extremely willing; and to rate the cooperation gains ranging from 1 to 5, where 1=minimally beneficial, and 5=maximally beneficial. The results are shown in Table 6.

As presented in Table 6, clients, as the partners of contractors, superintendents and designers, have the highest degree of willingness to cooperate with (DWC=4.49), correspondingly the gain of cooperation between clients and the other three participants is the most (score=4.29). The correlations between the DWCs and the cooperation gains are calculated, as shown in Column 4 of Table 6. All the DWCs are significantly correlated with the corresponding cooperation gains at the 0.01 level, demonstrating the close interrelations between DWCs and cooperation gains. This has validated the reciprocal interactions established in the DWC model, which can explain the calculated results (see Table 2): DWCs have positive impacts on the participants’ cooperation gains.

Further, respondents were asked to score the frequency of using incentives in the cooperation with other partners ranging from 1 to 5, where 1=not applied, and 5=always applied. They were also required to rate the reward improvement from using incentives, ranging from 1 to 5, where 1=insignificant improvement and 5=significant improvement. The results are shown in Table 7.

As seen in Table 7, contractors are the partners that clients, superintendents and designers most frequently apply incentives to (score=3.57), correspondingly the reward improvement from contractors is the most significant (score=3.44). The correlations between the frequencies of using incentives and the reward improvements are calculated, as shown in Column 4 of Table 7. The frequencies of using incentives are closely correlated with the reward improvements at the 0.01 level, validating the influence of using incentives on cooperation rewards considered in the DWC model, which can interpret the simulated results (see Table 4): use of incentives contributes to improving the rewards of cooperation between participants.

In general, the relationships in the DWC model have been tested and confirmed on the basis of the survey results. To more specifically understand the cause-effect relationships between cooperative behaviors, use of incentives and cooperation gains, the survey results were incorporated into the DWC model to evaluate the status of cooperation among the participants of hydropower project delivery in Southwest China.

The Cooperation Status of Hydropower Development in Southwest China

The respondents' survey results were converted to values ranging from -1 to 1 for use in the DWC model, with the cooperation payoffs of participants in pairwise classification shown in Table 8.

As shown in Table 8, clients and designers have the highest average DWC (score=0.82), correspondingly their overall payoff (score=30.21) is the highest, which are largely attributed to designers' key role in technical issues of hydropower developments. Interviews show that, on the one hand, many hydropower projects in Southwest China have high dams (e.g. exceeding 300m) and complex geologic conditions that pose significant technical challenges to the designers, on the other hand, clients tend to urge designers to complete the detailed design as soon as possible for early electricity generation. These frequently result in inadequate and incorrect design of the work. A high degree of cooperation between clients and designers is essential for discussing problems that designers may encounter, aligning the objectives of the two participants and optimally sharing the necessary resources, which can bring high overall payoff by reducing design-related problems such as variations, poor quality, reworks, delays, disputes and claims.

Compared to other pairs as shown in Table 8, contractors and designers have the lowest average DWC (score=0.54), with the overall payoff (score=27.91) being the lowest. This is due to both the objective misalignments of the two participants and the management structure of the industry. There are significant disparities on the importance of cost and schedule objectives between contractors and designers (see Table 5). Interviews during fieldtrips confirm that contractors emphasize the achievement of cost and schedule objectives much more than designers for financial considerations. Interviews also reveal that, contractors and designers having no hierarchical relationship in project management structure resulted in lacking formal communication channels between them, which can further influence their overall payoff of cooperation. Nevertheless, contractors and designers have similar priorities on the importance of quality and safety objectives (see Table 5), which provides a sound base for them to jointly improve constructability, value engineering and timely feedback of site conditions by establishing informal communication channels, thereby they still can obtain considerable overall payoff of cooperation.

As indicated in Table 8, clients are the ones with whom contractors, superintendents and designers have the generally highest degrees of willingness to cooperate, with the scores being 0.78, 0.90 and 0.87 respectively. Generally, DWC scores to designers, superintendents and contractors rank the second, third and fourth. These reflect the positions of the participants in Southwest China hydropower project developments. Clients dominate the whole business chain of hydropower projects during their life cycle and they largely direct the resource allocation involving the work of designers, superintendents and contractors, whereas contractors need to meet the requirements of clients, designers and superintendents during project delivery processes.

To further understand the impacts of incentives, the respondents' frequencies of using incentives collected from the survey are reflected in the change of Payoff Matrix in the DWC model. As a key rationale of introducing incentives to cooperation processes is that project rewards should be equitably shared among participants (Tang et al. 2008; Chan et al. 2008; Bower et al. 2002; Scott 2001), it was set that equally allocating payoff between two participants corresponds to the highest rating of using incentives (score=5). On this basis, the payoffs were adjusted according to the incentive ratings by respondents (see Column 2 and Column 3 of Table 9). The cooperation outcomes of participants with incentives in pairwise classification are shown in Table 9.

The results in Table 9 demonstrate that the overall payoffs of the project participants change with the level of using incentives. The more frequently incentives are used (see Column 2 of Table 9), the higher the overall payoffs are improved (see Column 6 of Table 9 = Column 5 of Table 9 － Column 5 of Table 8). This demonstrates incentives' influence in promoting the cooperation rewards of project participants.

As shown in Table 9, levels of using incentives among clients, superintendents and contractors are higher than those involving designers. This indicates that incentives are mainly applied in the construction phase of hydropower project developments, aiming at improving the performance of executing processes that are largely implemented by contractors. The case study of Three Gorges Project on using incentives at the construction stage can explain this.

Multiple incentive schemes with different weights were adopted in the TGP to align the objectives between clients and contractors, including incentives of quality (weight=45%), schedule

(24%), occupational health and safety (OH & S) and environment (15%), information management (10%), and coordination (6%), which had various measures to decide appropriate rewards. Besides, a value engineering incentive was also put in place to promote innovation for project cost saving, and the cost saving from a value engineering proposal presented by a contractor was to be shared by the client and the contractor in the proportion of 50:50. These incentives had incorporated measures extending from project results to construction processes, which facilitated continuous improvement by providing early warnings and encouraged participants to share needed information for optimal decision-making and innovation. Specifically, the incentives ensured that the contractors had motivation and necessary resources to accomplish the tasks assigned by the client and superintendents in a cooperative manner. The outcomes of the TGP implementation confirm the effectiveness of using the incentives. The cooperation relationships among involved project participants have been well established; The safety incidents decreased continuously; The specified project quality had met the required standards that ensure the TGP's main functions of power generation, navigation and flood control; The project development progress had strictly met the project delivery schedule of 17 years; The total cost of the project was RMB 173.1 billion (US$ 27.8 billion), 15% less than budget of RMB 203.9 billion (US$ 32.8 billion). These bring a large amount of payoffs to the client such as project cost saving, yearly income of RMB 21 billion (US$ 3.4 billion) from generating power of 84.68 billion kwh, and obtaining the permission from government to develop other major hydropower projects. The rewards of contractors from incentives can reach 3% of the value of completed work, which is a significant payoff improvement to the contractors. In addition, successful implementation of the TGP harvests good reputation that is an important intangible payoff for the contractors to expand their market share, e.g. the contractors with high performance in the TGP also won the bids of hydropower projects in Jinsha River developed by the client of the TGP.

Comparatively, the frequencies of using incentives involving designers are relatively low (see Table 9), demonstrating incentives are less applied in the design phase than in the construction phase. Although clients and designers have the highest average DWC and also have the highest overall payoff (see Table 8), the level of using incentives between them to improve the cooperation rewards is the lowest (score = 2.98, see Table 9), which is attributed to the factors related to market, technical complexity and clients' inadequate recognition of key issues of project developments. Firstly, with the increasing demand for energy, much more hydropower projects are being developed than before in Southwest China, resulting in that the designers normally are overloaded. In these circumstances, clients' incentives cannot create the effects as expected, due to designers being unable to allocate additional resources to fulfil the objectives of incentives such as earlier completion of design. Secondly, because of the technical complexity of the hydropower projects in Southwest China, it is difficult for clients to measure designers' performance on adequacy of design and value for money of selected option, to decide appropriate rewards in incentives. Thirdly, clients tend to focus on engineering issues related to construction, and lack the intention of using incentives for designers to conduct in-depth studies on other issues such as resettlement of migrants, ecology and environment at an early stage. This is in line with the survey results (see Table 5), in which resettlement of migrants, ecology and environment objectives are less important than safety, quality, schedule and cost objectives perceived by project participants.

However, resettlement of migrants and the issues related to ecology and environment have become main restrictions on hydropower project developments. For example, in the TGP it was forecasted that the number of migrants to be resettled was 1.13 million and the relevant costs accounted for 44.4% of the total budget, whereas 1.25 million affected residents have been relocated during the 17 years of project development, and the migrants resettlement costs have increased to be about 50% of the project costs. The costs of resettling migrants were mainly spent on compensations, hiring relocation lands, developing new communities, building infrastructure, and improving migrants' skills for sustainable living. Environment impacts are also important to the TGP, e.g. RMB 11.3 billion (US$1.8 billion) was spent on the geological hazard prevention and treatment in the reservoir area. In total, 2,874 high-cut slopes and 441 locations prone to landslide were technically treated; 175km of reservoir bank protection was delivered; 3,113 public monitoring points concerning 600 thousands of residents were established for early warning; 69,900 residents were relocated from the 646 communities affected by geological hazards. In addition, water storages of the TGP and other hydropower projects in Southwest China have importantly ecological impacts on the downstream areas of Yangtze River such as Dongting Lake and Poyang Lake. To reduce the high social, environmental and economic costs, the above themes also need to be incorporated into incentive schemes at an early stage for promoting designers to adequately conduct study in advance of construction phase, by which improving the level of using incentives in design phase to increase the overall payoff of hydropower project developments.

Practical Strategies for Cooperative Management

Promoting Cooperation among Project Participants by Partnering Approach

The outcomes of the DWC model simulation and validation demonstrate the positive effects of cooperation among project participants. The Partnering approach should be adopted to increase the participants' DWCs on the basis of mutual objectives, in which incentives should be incorporated to align the participants' different project priorities, enabling them to have motivations and resources to cooperatively fulfill the assigned tasks. The measures to promote cooperation should facilitate the participants' efficiently inputting necessary resources to each other's management processes of hydropower project design, construction and operation, for maximizing the contributions of all participants in successful delivery of hydropower projects.

Inputting More at Early Stages for Designers to Conduct In-depth Project Study

Clients and designers have the highest degree of willingness to cooperate with each other that brings them the highest overall payoff, suggesting that to establish appropriate cooperation mechanism between them should be a management emphasis, which assists clarifying clients' intentions, discussing problems that designers encounter, and jointly dealing with key engineering issues of hydropower project developments. However, the low level of using incentives between clients and designers suggests that the factors on market, technical complexity and clients' inadequate recognition of hydropower developments have restricted deeper cooperation between them. Clients should input more at early stages by developing and using suitable incentives, to motivate designers to conduct in-depth study in detailed design phase by optimally sharing the relevant resources of the two participants. The incentive schemes involving design need to not only consider engineering technical challenges but also emphasize social and environmental issues. In addition, applicable design measurements should be incorporated into the incentive schemes for clients to evaluate the extent to which designers perform in achieving the set objectives, to promote selection of cost effective options, and more importantly, to ensure the adequacy of hydropower project design.

Applying Incentives to Construction Processes in Achieving Superior Performance

Although cooperation can bring payoffs to project participants, their DWCs are different, which is originated from the objective misalignments of them as shown in Table 5. The practice of TGP demonstrates the effectiveness of using incentives in construction phase to align the objectives of clients and contractors. This suggests that appropriate incentives need to be developed and applied in project implementation, which should follow the partnering principle of equitably sharing project rewards in dealing with the different priorities between clients and contractors. The incentives involving construction should have measures that are not only tied to implementation results but also extended to the whole construction process, which facilitate providing early warnings, obtaining continuous improvement, and ultimately achieving project goals.

Fostering a Trust Relationship between Contractors and Designers by Creating Open Communication Mechanism

Contractors and designers have the lowest DWC, with the overall payoff being the lowest, owing to their significant disparities on the cost and schedule objectives (see Table 5), and their ineffective links in the hierarchical project management structure. To improve this situation, partnering between contractors and designers should be enhanced by fostering a trust relationship that follows win-win value. On the basis of trust, an open communication mechanism involving the two participants should be created, which has links across their organizational boundaries to ensure that needed information flow effectively and efficiently between them. The shared information needs to be well applied to the reciprocally interdependent design and construction processes in jointly improving constructability, presenting value engineering proposals, timely giving feedback of site conditions, and tackling technically complicated problems in implementation of hydropower projects.

Equitable Sharing of the Rewards between Stakeholders

Hydropower projects, e.g. the TGP, can bring benefits of power generation, navigation and flood control, and also cause social and environmental impacts such as resettlement of migrants, geological hazards and ecological issues in downstream areas. The rewards/risks from hydropower developments may lead to cooperative or competitive strategies taken by stakeholders, who have specific interests in the project outcomes. Approaches at both project and institutional levels should be adopted to equitably share the rewards from a hydropower project, to ensure that each stakeholder obtains more benefits with the project than without it. At the project level, project participants of clients, contractors, superintendents and designers need to apply cooperative strategies, as mentioned above, to successfully implement hydropower projects, thereby increasing the overall payoffs of them. At the institutional level, systematic institutional improvements are required to deal with the interest conflicts among the competing stakeholders, by revising laws to increase the compensation to affected communities, improving price of hydropower with adequately considering social and environmental costs, establishing inter-regional transfer payment system, supporting migrants' sustainable development, and taking measures to mitigate negatively environmental effects. Further study should be undertaken for deeper understanding the interactions between project delivery, environmental and social processes, to facilitate reaching appropriate trade-offs among all involved stakeholders of hydropower developments.

Conclusions

Summary and Conclusions

Existing studies tend to emphasize the need to cooperate among project participants during project delivery, but lack systematical and quantitative evaluation of how participants benefit from cooperation. On the basis of cooperative game and partnering theories, the DWC model has been used in this study to reflect the interactions between clients, contractors, superintendents and designers through dynamic simulation. A detailed survey of participants was conducted, and analysis of the results validated the outcomes of the DWC model simulation. This validation confirmed that the DWCs have significantly positive influences on the gains of cooperation between the participants, and use of incentives is effective in improving the rewards of the participants.

Evaluation of the cooperation status of hydropower developments in Southwest China by using the DWC model reveals that: 1) Clients are the ones with whom contractors, superintendents and designers have the highest degree of willingness to cooperate, showing that clients dominate the business chain of hydropower industry and largely direct the resource allocation involving the work of the other project participants; 2) Clients and designers have the highest DWC, correspondingly their overall payoff is the highest, demonstrating that high extent of cooperation between them can bring high benefits by reducing design-related problems such as variations, poor quality, reworks, delays, disputes and claims; 3) Contractors and designers have the lowest DWC, with the overall payoff being the lowest, which is due to the two participants' significant disparities on the cost and schedule objectives, and their ineffective links in the hierarchical project management structure; 4) Levels of using incentives among clients, superintendents and contractors are higher than those between designers and the above three participants, indicating that incentives are mainly applied in the construction phase of hydropower project developments. The outcomes of the TGP implementation demonstrate the effectiveness of using incentives in improving the contractors' performance of the project implementation; 5) Incentives are less applied in the design phase than in the construction phase, which is attributed to designers' resource restriction due to overloaded work, technical complexity and clients' inadequate recognition of key issues of hydropower developments.

The insights obtained in this research suggest broad practical strategies for inter-organizational cooperation in project delivery, which include: 1) promoting cooperation among project participants by partnering approach; 2) inputting more at early stages for designers to conduct in-depth project study; 3) applying incentives to construction processes in achieving superior performance; 4) fostering a trust relationship between contractors and designers by creating open communication mechanism; 5) equitable sharing of the rewards between project stakeholders.

Contributions to the Body of Knowledge

This study advances the area of multi-organizational dynamics during project delivery adopting win-win philosophy, which has important contributions to the body of knowledge from both theoretical and practical perspectives. First, it builds interdisciplinary linkage between partnering theory and cooperative game theory, providing a structure to quantify the impact of DWCs, associated with use of incentives, on the rewards of participants. Second, the empirical study reveals the mutual goals and different priorities of project participants, unfolds the cause-effect relationships between cooperative behaviors and incentives, and answers questions on how coalitions can be formed and how cooperation gains should be equitably allocated, to ensure participants' proper distribution of resources in jointly delivering projects. Third, the findings can help practitioners to understand their positions in cooperation, make decisions taking account of optimally integrating participants' resources, and find ways to reach stable long-term partnering relationships from the perspective of Pareto optimum solutions during project delivery.

Limitations and Future Research Directions

The principal limitation of this research lies in that all the samples are from the hydropower industry of Southwest China. Nevertheless, the theory building derived from this study has incorporated experience from different regions via literature, and the findings appear transferable to industries elsewhere in the world. Further study needs to test this. Moreover, the study on cooperative behaviours has focused on only DWC together with its effects, and further study can add other variables such as trust into the cooperation model, to draw a broader picture on how improvements may be obtained from cooperation among project participants. Future research should also be conducted on how to motivate value-engineering and innovation in advance of project implementation, establish joint early warning system during project delivery, and facilitate participants' proper inputting necessary resources to each other's management processes, which are on the basis of equitable reward allocations.

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Table 1. Initial Payoff Matrix of Two Participants

Strategy alternatives	Cooperative	Competitive
Cooperative	30, 30	10, 40
Competitive	40, 10	-10, -10

Table 2. Two Participants' Payoffs with Different Initial DWCs

Initial DWCs	Payoffs	Overall payoff
1, 1	15.15, 15.15	30.30
1, -1	14.35, 14.85	29.20
-1, 1	14.85, 14.35	29.20
-1, -1	13.77, 13.77	27.54

Table 3. Initial Payoff Matrix of Two Participants with Incentives

Strategy alternatives	Cooperative	Competitive
Cooperative	30, 30	15, 35
Competitive	35, 15	-10, -10

Table 4. Two Participants' Payoffs with Incentives

Initial DWCs	Payoffs	Overall payoff
1, 1	15.62, 15.62	31.24
1, -1	14.35, 14.87	29.22
-1, 1	14.87, 14.35	29.22
-1, -1	14.01, 14.01	28.02

Table 5. Importance of Objectives

Objectives	Overall		Client		Contr.		Super.		Desi.	
	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.
Safety	4.64	1	4.71	1	4.59	1	4.63	1	4.51	2
Quality	4.59	2	4.67	2	4.46	2	4.61	2	4.60	1
Schedule	4.38[b]	3	4.50	3	4.42	3	4.23	3	3.83	5
Cost	4.17[a]	4	4.18	6	4.37	4	4.04	4	3.55	6
Ecology and environment	4.11[a]	5	4.30	5	3.89	5	4.03	5	3.95	3
Resettlement of migrants	3.92[b]	6	4.39	4	3.47	6	3.52	6	3.86	4

Note：M.=mean; R.=rank; a ANOVA is significant at the 0.05 level; b ANOVA is significant at the 0.01 level; Contr.=contractors, Desi.=designers, and Super.=superintendents.

Table 6. The Project Participants' DWCs and the Cooperation Gains

Cooperation partner	DWC	Cooperation gain	Pearson correlation coefficient
Client	4.49	4.29	0.507 [b]
Contr.	4.12	3.91	0.610 [b]
Super.	4.33	4.17	0.594 [b]
Desi.	4.35	4.19	0.580 [b]

Note: [b] Correlation is significant at the 0.01 level (2-tailed).

Table 7. Frequency of Using Incentives and Reward Improvement

Cooperation partner	Frequency of using incentives	Reward improvement	Pearson correlation coefficient
Client	3.37	3.34	0.669 [b]
Contr.	3.57	3.44	0.582 [b]
Super.	3.42	3.34	0.629 [b]
Desi.	3.14	3.17	0.623 [b]

Note: [b] Correlation is significant at the 0.01 level (2-tailed).

Table 8. The Cooperation Outcomes of Participants in Pairwise Classification

Cooperation pair	DWCs	Average DWC	Payoffs	Overall payoff
Client, Contr.	0.68, 0.78	0.73	14.84, 14.82	29.66
Client, Super.	0.69, 0.90	0.80	14.87, 14.81	29.68
Client, Desi.	0.77, 0.87	0.82	15.12, 15.09	30.21
Contr., Super.	0.76, 0.54	0.65	14.63, 14.69	29.32
Contr., Desi.	0.60, 0.48	0.54	13.94, 13.97	27.91
Super., Desi.	0.66, 0.47	0.57	14.37, 14.42	28.79

Table 9. The Cooperation Outcomes of Participants with Incentives in Pairwise Classification

Cooperation pair	Frequencies of using incentives	Average frequency of using incentives	Adjusted payoff matrix	Payoffs	Overall payoff	Increased payoff from using incentives
Client, Contr.	3.34, 3.11	3.23	Client: [30 19.69 ; 30.31 -10], Contr.: [30 30.31 ; 19.69 -10]	15.24, 15.21	30.45	0.79
Client, Super.	3.27, 3.21	3.24	Client: [30 19.72 ; 30.28 -10], Super.: [30 30.28 ; 19.72 -10]	15.29, 15.24	30.53	0.85
Client, Desi.	2.83, 3.12	2.98	Client: [30 18.94 ; 31.06 -10], Desi. : [30 31.06 ; 18.94 -10]	15.37, 15.23	30.60	0.39
Contr., Super.	3.42, 3.10	3.26	Contr.: [30 19.78 ; 30.22 -10], Super.: [30 30.22 ; 19.78 -10]	15.16, 15.18	30.34	1.02
Contr., Desi.	2.90, 3.16	3.03	Contr.: [30 19.09 ; 30.91 -10], Desi. : [30 30.91 ; 19.09 -10]	14.14, 14.19	28.33	0.42
Super., Desi.	3.14, 3.17	3.16	Super.:[30 19.48 ; 30.52 -10], Desi. : [30 30.52 ; 19.48 -10]	14.63, 14.69	29.32	0.53