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

Weiwei He¹; Wenzhe Tang²; Yongping Wei³; Colin F. Duffield⁴; Zhen Lei⁵

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

¹ Postgraduate Researcher, Institute of Project Management and Construction Technology, State Key Laboratory of Hydrosience and Engineering, Tsinghua University, Beijing 100084, China.

² Associate Professor, Institute of Project Management and Construction Technology, State Key Laboratory of Hydrosience and Engineering, Tsinghua University, Beijing 100084, China (corresponding author). E-mail: twz@mail.tsinghua.edu.cn

³ Senior Research Fellow, The University of Melbourne, Australia China Centre on Water Resources Research, Victoria 3010, Australia.

⁴ Associate Professor, The University of Melbourne, Dept. of Infrastructure Engineering, Victoria 3010, Australia.

⁵ Ph.D. candidate, Institute of Project Management and Construction Technology, State Key Laboratory of Hydrosience and Engineering, Tsinghua University, Beijing 100084, China.

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

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

24 **Introduction**

25 Multi-organizational dynamics during project delivery have increasingly become research emphases
26 as project participants' objectives, resources, and management structures are partly shared and
27 closely interacted with each other (Lehtiranta 2014). Project delivery involves a range of participants
28 such as clients, designers, superintendents and contractors, and their specific interests in project
29 outcomes may lead to conflict resulting in poor quality, delays and cost overruns (Tang et al. 2013;
30 Tang et al. 2007). Lack of synergy between project organizations is identified as a key obstacle to the
31 implementation and efficient delivery of projects (Ates and Durakbasa 2012). As traditional
32 competitive ways may make multi-organizational relationships adversarial, which ultimately has a
33 negative impact on project delivery, cooperative strategies need to be adopted by project participants
34 (Palacios et al. 2013). Many researchers advocate using the strategy of partnering that applies a
35 win-win philosophy to enhance the cooperation between participants (Hong et al. 2012; Lubell et al.
36 2002). Partnering is a long-term commitment between two or more organizations for the purpose of
37 achieving specific objectives by maximizing the effectiveness of each participant's resources based
38 upon trust relationships (CII 1991). Partnering has been increasingly applied to improving the
39 performance of project delivery during the past two decades. The success of partnering can be
40 attributed to: firstly, partnering promotes participants' willingness to form an integrated project team

41 working across organizational boundaries by specifying the mutual project objectives (Bennett and
42 Jayes 1998); secondly, partnering arrangements are underpinned by incentive schemes, which use
43 clearly defined rewards allocation to manage the processes, providing powerful motivations and
44 necessary resources for participants to achieve high performance (Tang et al. 2008; Chan et al. 2008;
45 Bower et al. 2002; Scott 2001). Existing studies tend to focus on the need to cooperate among project
46 participants (Tang et al. 2009; CII 1991), critical success factors in implementation of partnering
47 (Cheng and Li 2002; Black et al. 2000), and theoretical frameworks for explaining partnering
48 mechanism (Cho et al. 2010; Tang et al. 2006; Growley and Karim 1995). Nevertheless, detailed
49 quantifiable models that systematically evaluate how participants benefit from cooperation are
50 lacking, and this may restrict a deeper understanding of partnering quintessence and weaken
51 management resolve to pursue partnering (Wang et al. 2013; Tang et al. 2006). Thus, the objective of
52 this study is to quantitatively investigate how degree of willingness to cooperate, associated with use
53 of incentives, impact on the rewards of participants, by validating the outcomes of the Degree of
54 Willingness to Cooperate (DWC) model simulation with the support of data collected from a
55 fieldwork survey of hydropower industry in Southwest China.

56 **The DWC Model**

57 ***Background***

58 Game theories have been used to study the conflict and cooperation between rational
59 decision-makers (Owen 1995; Myerson 1991), which provide useful insights into the way
60 participants plan and utilize the scarce resources they share together under different situations
61 (Parrachino et al. 2006). Different from non-cooperative game theories, cooperative game theories
62 facilitate fair allocation of coalitional gains by modeling the decision-making processes of multiple

63 players (Rosen and Sexton 1993). The cooperative models with components of project development,
64 environment, economic gains and special interest groups have been used to reach a more equitable
65 distribution of payoffs among participants and improve the effectiveness of sharing information
66 (Schreider et al. 2013; Madani 2011; Deidda et al. 2009; Suzuki and Nakayama 1976). These studies
67 indicate the advantages of taking cooperative strategies over non-cooperative strategies based on
68 Pareto optimum solutions (Schreider et al. 2013; Madani 2011; Qin et al. 2010; Deidda et al. 2009;
69 Suzuki and Nakayama 1976). Studying participants' cooperative behaviors (e.g. degree of
70 willingness to cooperate) is critical for understanding the way to reach a stable long-term partnering
71 relationship (Cheung et al. 2003).

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

85 during project delivery. The details of the DWC model follow.

86 **Model Details**

87 To calculate the influence of historical factors on participants' DWCs in simulating the process of
88 cooperation among project participants, participants' expected payoff and actual payoff need to be
89 considered. In the long-term reciprocally cooperative moves between participants, the comparisons
90 between previous cooperation's expected payoffs and actual payoffs are historical factors, which
91 have impacts on the participants' DWCs in the next period (Kadefors 2004). Expected payoff is the
92 prospective payoff, and can be used as a benchmark to measure the effectiveness of cooperation.
93 Actual payoff is influenced by participants' DWCs, which involve not only historical factors but also
94 cognition factors. Cognition factors represent participants' understanding of project development
95 environment and contingencies, which affect the moves of the participants that can be either
96 competitive or cooperative (Cheung et al. 2003). The quantitative relationships among the above
97 variables in the DWC model are reflected as equations from (1) to (5) derived from Zhang et al.
98 (2006).

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

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

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

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

102 where t =period; i =participant; $\sin(t)$ =project development environment factor; $y(t)$ =project
103 development contingency factor; $para_{(i+4)}$ =project development environment factor's weight in

104 *actual payoff; $1 - para_{(i+4)}$ = project development contingency factor's weight in actual payoff;*

$$105 \quad j_i = \begin{cases} 1, & \text{if } P_i^l(t) \geq 0 \\ -1, & \text{if } P_i^l(t) < 0 \end{cases} \quad ; \quad \text{and}$$

$$106 \quad m_i = \begin{cases} 1, & \text{if project development contingency factors' effect on participant } i \text{ is positive} \\ -1, & \text{if project development contingency factors' effect on participant } i \text{ is negative} \end{cases}$$

107 $P_i(CC,CC)$, $P_i(CC,NN)$, $P_i(NN,CC)$, and $P_i(NN,NN)$ respectively represent the initial payoff
108 of participant i under different strategic conditions of (cooperative, cooperative), (cooperative,
109 competitive), (competitive, cooperative), and (competitive, competitive); $\alpha_i(t)$ = DWC of participant i .

110 • Expected payoff is calculated as Eq. (3):

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

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

111 where $para_i$ = project development environment factor's weight in expected payoff;
112 $1 - para_i$ = historical factor's weight in expected payoff; $e^{-(t-k)}$ = attenuation index of historical factor's
113 influence on expected payoff; $\omega_i(k)$ = weight of the difference between actual payoff and expected
114 payoff in period k , which is calculated as Eq. (4):

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

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

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

116 where $para_{(i+6)}$ = historical factor's weight in DWC value of next period; $1 -$
117 $para_{(i+6)}$ = 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 $q_{1i} = \begin{cases} 1, & \text{if } m_i = -1 \\ -1, & \text{if } m_i = 1 \end{cases}$.

120 ***Inferences from the DWC Model Simulation***

121 To start the simulation, an initial payoff matrix of two participants was set in Table 1. As taking
122 cooperative strategies has advantages over non-cooperative strategies on Pareto optimum solution
123 due to optimally sharing the resources of participants in cooperation (Schreider et al. 2013; Madani
124 2011; Qin et al. 2010; Deidda et al. 2009; Suzuki and Nakayama 1976), it was set that the overall
125 payoff of the two participants who both take cooperative strategies is highest compared to the other
126 three non-cooperative circumstances. Specifically, it was set that the payoffs of the two participants
127 are 30 respectively (with an overall payoff of 60) when they both take cooperative strategies, for the
128 reason that project benefits should be equitably shared among parties (Tang et al. 2008; Zhang et al.
129 2006). When they both take competitive strategies, their payoffs are -10 respectively (with an overall
130 payoff of -20), which reflects the lose-lose situation resulting from their adversarial relationship.
131 When the two participants use different strategies, the one who adopts cooperative strategy has
132 payoff of 10, whereas the other one who adopts competitive strategy has payoff of 40 owing to
133 exploitation of additional rewards, with overall payoffs being 50 respectively.

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

138 The results in Table 2 show that when initial DWCs of the two participants are both 1, the actual
139 payoffs of them are both 15.15 after games, which have the highest overall payoff of 30.30. When

140 initial DWCs of the two participants are 1 and -1, the actual payoffs of participants are 14.35 and
141 14.85 respectively, with their overall payoff being 29.20. When initial DWCs of the two participants
142 are both -1, the actual payoffs of them are both 13.77 after games, which have the lowest overall
143 payoff of 27.54. The results show that the higher the initial DWCs are, the higher the payoffs turn out
144 to be, demonstrating that the DWCs have positive impacts on the cooperation gains of the
145 participants.

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

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

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

160 ***Empirical Research Questions Arising from the DWC Model Simulation***

161 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 CO₂ 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

184 already in the processes of delivery and operation, providing a rich source of data for this study. The
185 total economically exploitable amount of hydropower resource in China is 402,000 MW. This study
186 surveyed 12 hydropower projects, with the installed capacity of these projects (81,400 MW)
187 accounting for 20% of the above total amount.

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

199 ***Methodological Triangulation Approach***

200 Methodological triangulation approach is the use of multiple research methods to investigate the
201 same theme (Fellows and Liu 1997), which enables both qualitative and quantitative data collection
202 to be used to test or understand a research proposition (Love et al. 2002). The advantages of
203 methodological triangulation approach include increasing the validity of insights, facilitating a
204 deeper understanding of the phenomenon, and helping to reveal unique findings (Guion et al., 2011).
205 Accordingly, this research applied methodological triangulation approach to test the two hypotheses

206 derived from the DWC model simulation. It was decided that questionnaire, interview, direct
207 observation, project document review and case study were used to meet the need of data collection
208 and analysis in this study.

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

228 had been collected.

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

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

243 ***Data Analysis Techniques***

244 The data collected from questionnaires were analyzed using the Statistical Package for Social
245 Science (SPSS) (SPSS 1997). The selected techniques for this study include estimation of the sample
246 population mean, rank cases, one-way analysis of variance (ANOVA), and Pearson correlation.
247 ANOVA was used to analyze the alignments of project participants' objectives. The Pearson
248 correlation was applied to test the relationships between DWCs, use of incentives, and rewards of
249 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

316 designers may encounter, aligning the objectives of the two participants and optimally sharing the
317 necessary resources, which can bring high overall payoff by reducing design-related problems such
318 as variations, poor quality, reworks, delays, disputes and claims.

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

332 As indicated in Table 8, clients are the ones with whom contractors, superintendents and
333 designers have the generally highest degrees of willingness to cooperate, with the scores being 0.78,
334 0.90 and 0.87 respectively. Generally, DWC scores to designers, superintendents and contractors
335 rank the second, third and fourth. These reflect the positions of the participants in Southwest China
336 hydropower project developments. Clients dominate the whole business chain of hydropower
337 projects during their life cycle and they largely direct the resource allocation involving the work of

338 designers, superintendents and contractors, whereas contractors need to meet the requirements of
339 clients, designers and superintendents during project delivery processes.

340 To further understand the impacts of incentives, the respondents' frequencies of using incentives
341 collected from the survey are reflected in the change of Payoff Matrix in the DWC model. As a key
342 rationale of introducing incentives to cooperation processes is that project rewards should be
343 equitably shared among participants (Tang et al. 2008; Chan et al. 2008; Bower et al. 2002; Scott
344 2001), it was set that equally allocating payoff between two participants corresponds to the highest
345 rating of using incentives (score=5). On this basis, the payoffs were adjusted according to the
346 incentive ratings by respondents (see Column 2 and Column 3 of Table 9). The cooperation outcomes
347 of participants with incentives in pairwise classification are shown in Table 9.

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

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

358 Multiple incentive schemes with different weights were adopted in the TGP to align the
359 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

382 performance in the TGP also won the bids of hydropower projects in Jinsha River developed by the
383 client of the TGP.

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

402 However, resettlement of migrants and the issues related to ecology and environment have
403 become main restrictions on hydropower project developments. For example, in the TGP it was

404 forecasted that the number of migrants to be resettled was 1.13 million and the relevant costs
405 accounted for 44.4% of the total budget, whereas 1.25 million affected residents have been relocated
406 during the 17 years of project development, and the migrants resettlement costs have increased to be
407 about 50% of the project costs. The costs of resettling migrants were mainly spent on compensations,
408 hiring relocation lands, developing new communities, building infrastructure, and improving
409 migrants' skills for sustainable living. Environment impacts are also important to the TGP, e.g. RMB
410 11.3 billion (US\$1.8 billion) was spent on the geological hazard prevention and treatment in the
411 reservoir area. In total, 2,874 high-cut slopes and 441 locations prone to landslide were technically
412 treated; 175km of reservoir bank protection was delivered; 3,113 public monitoring points
413 concerning 600 thousands of residents were established for early warning; 69,900 residents were
414 relocated from the 646 communities affected by geological hazards. In addition, water storages of the
415 TGP and other hydropower projects in Southwest China have importantly ecological impacts on the
416 downstream areas of Yangtze River such as Dongting Lake and Poyang Lake. To reduce the high
417 social, environmental and economic costs, the above themes also need to be incorporated into
418 incentive schemes at an early stage for promoting designers to adequately conduct study in advance
419 of construction phase, by which improving the level of using incentives in design phase to increase
420 the overall payoff of hydropower project developments.

421 **Practical Strategies for Cooperative Management**

422 ***Promoting Cooperation among Project Participants by Partnering Approach***

423 The outcomes of the DWC model simulation and validation demonstrate the positive effects of
424 cooperation among project participants. The Partnering approach should be adopted to increase the
425 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

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

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

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

468 ***Equitable Sharing of the Rewards between Stakeholders***

469 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

492 designers through dynamic simulation. A detailed survey of participants was conducted, and analysis
493 of the results validated the outcomes of the DWC model simulation. This validation confirmed that
494 the DWCs have significantly positive influences on the gains of cooperation between the participants,
495 and use of incentives is effective in improving the rewards of the participants.

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

513 The insights obtained in this research suggest broad practical strategies for inter-organizational

514 cooperation in project delivery, which include: 1) promoting cooperation among project participants
515 by partnering approach; 2) inputting more at early stages for designers to conduct in-depth project
516 study; 3) applying incentives to construction processes in achieving superior performance; 4)
517 fostering a trust relationship between contractors and designers by creating open communication
518 mechanism; 5) equitable sharing of the rewards between project stakeholders.

519 ***Contributions to the Body of Knowledge***

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

532 ***Limitations and Future Research Directions***

533 The principal limitation of this research lies in that all the samples are from the hydropower industry
534 of Southwest China. Nevertheless, the theory building derived from this study has incorporated
535 experience from different regions via literature, and the findings appear transferable to industries

536 elsewhere in the world. Further study needs to test this. Moreover, the study on cooperative
537 behaviours has focused on only DWC together with its effects, and further study can add other
538 variables such as trust into the cooperation model, to draw a broader picture on how improvements
539 may be obtained from cooperation among project participants. Future research should also be
540 conducted on how to motivate value-engineering and innovation in advance of project
541 implementation, establish joint early warning system during project delivery, and facilitate
542 participants' proper inputting necessary resources to each other's management processes, which are
543 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

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Author/s:

He, W;Tang, W;Wei, Y;DUFFIELD, C;Lei, Z

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