Risk Management in the Chinese Construction Industry

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Abstract: There has been an increase in research on risk management practice in the construction industry. However, little research has been conducted to systematically investigate the overall aspects of risk management on the perspectives of various project participants. This paper reports the findings of an empirical Chinese industry survey on the importance of project risks, application of risk management techniques, status of the risk management system, and the barriers to risk management, which were perceived by the main project participants. The risk management strategies adopted in the Three Gorges Project were also studied. The study reveals that: Most project risks are commonly of concern to project participants; the industry has shifted from risk transfer to risk reduction; current risk management systems are inadequate to manage project risks; and lack of joint risk management mechanisms is the key barrier to adequate risk management. Future studies should be conducted to systematically improve the risk management in construction by different approaches that facilitate equitable sharing of rewards through effective risk management among participants. Such studies should also consider the establishment of an open communication risk management process to permit the corporate experience of all participants, as well as their personal knowledge and judgment, to be effectively utilized.

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Introduction

Risk management is an important part of the decision-making process in construction (Kangari 1995), and now widely accepted as a vital tool in the management of projects (Wood and Ellis 2003). A variety of risk management techniques has been studied and introduced in the literature (COSO 2004; Lyons 2003; Walker and Johannes 2003; Cano and Cruz 2002; Elkington and Smallman 2002; Velde and Donk 2002; Grimsey and Lewis 2002; Duffield 2001; Jaafari 2001; Raz and Michael 2001; Floricel and Miller 2001; Turner and Simister 2001; Berends 2000; Dey 1999; Barber et al. 1999; Standards Association of Australia 1999; Smith 1999; Baldry 1998; Akincl and Filscher 1998; Lu and Lu 1998; Kliem and Ludin 1997; Chapman 1997; Williams 1997; Kometa et al. 1996; Lei 1996; Stewart and Forturne 1995; Thompson and Perry 1992), which are included in the risk management processes of risk identification, risk analysis, risk response, and risk monitoring. The ultimate purpose of developing these risk management techniques is to add value to project delivery and improve efficiency of the construction industry during practice. Thus there has been an increase in research aimed at investigating risk management practice in the construction industry (Wood and Ellis 2003).

Previous empirical studies on risk management practice are mainly regarding: (1) perceptions of the typical large United States contractors towards construction risk allocation, and the importance of different risk categories (Kangari 1995); (2) usage of techniques at different risk management stages of major United Kingdom companies (Baker 1999; Baker et al. 1999); (3) usage of risk management techniques and barriers to risk management in the Queensland engineering construction industry (Lyons and Skitmore 2003); (4) general contractors' perception on risks and the use of risk management techniques in the United Kingdom (Akintoye and Macleod 1997); (5) contractors' application of various analytical techniques for risk assessment in Hong Kong (Shen 1997); (6) various risks perceived by the contractors in Chinese construction market (Fang et al. 2004); (7) critical risks associated with China's build-operate-transfer (BOT) projects and the effectiveness of mitigation measures (Wang et al. 1999); (8) perceptions of risk allocation in the construction industry of mainland China and Hong Kong (Rahman and Kumaraswamy 2002a); (9) allocation of risk in PPP/PFI construction projects in the United Kingdom (Bing et al. 2005); (10) contractual risk and liability sharing in hydropower construction (Charoenngam and Yeh 1999); (11) practices of using risk management approaches in selected Hong Kong industries (Tummala et al. 1997); (12) risk management services, tools, and techniques currently used by consultants (Wood and Ellis 2003); (13) risk management in the

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conceptual phase of a project (Uher and Toakley 1999); (14) risks perceived by the BOT road project participants in India (Thomas et al. 2003); and (15) Kuwaiti contractors' perspectives on construction risks and the mitigation strategies (Kartam and Kartam 2001).

Except for the studies of Rahman and Kumaraswamy (2002a), Thomas et al. (2003), and Lyons and Skitmore (2003), the surveys above were typically undertaken on the basis of the perceptions of one group of project participant, e.g., contractors or consultants. However, many project risks cannot be controlled by one party. Akincl and Filscher (1998) pointed out the uncontrollable risk sources for contractors, which include broad themes such as estimator-specific factors, design and project-specific factors, subcontractor-generated risk factors, client related factors, unknown geology conditions, economic and political risk factors, and contract-specific factors. Dealing with these risks involves a range of participants who have a specific and conspicuous interest in the outcomes of project process, and the aggregate sum of values, beliefs, and expectations of these diverse groups will determine the cultural profile of the project risk management process, in which the expectations and behavior patterns of participants are likely to differ markedly (Baldry 1998). For contractors, the main business objective is ultimately profit; for clients, the project objectives should be an optimum combination of time, cost, and quality, which contributes to their business objectives (Tang et al. 2006). The survey results of Rahman and Kumaraswamy (2002a) revealed quite wide divergences with many individual cases of diametrically opposing views on allocating particular risks within specific group. Thomas et al. (2003) also confirmed that the factors and their relative influence on the risk acceptance of project participants are considerably different. Scott (2001) and Carr et al. (1999) claimed that these misalignments between clients and contractors dealing with increased risk in the traditional delivery systems have resulted in the adversarial situations between project participants, which has significantly affected the productivity and efficiency of the construction industry. Baldry (1998) pointed out that the conflicts among project participants can equally contribute to project failure as technical deficiencies. Chapman (1997) also indicated that clients and contractors necessarily have different objectives, but a contract which leads to confrontation is perhaps the biggest single risk that most projects encounter.

To mitigate the risks due to the misalignments between project participants, many researchers raised the strategies of partnering, alliancing, and relationship contracting that adopt cooperative philosophy to seek congruence in objectives (Tang et al. 2006, 2004; Rahman and Kumaraswamy 2004, 2002b; Kadefors 2004; Walker and Hampson 2003; Bower et al. 2002; Gallagher 2002; Hoisie 2001; Scott 2001; NAO 2001; Bresnen and Marshall 2000; Association of Consultant Architects 2000; Barlow 2000; Carr et al. 1999; ACA 1999; Bennett and Jayes 1998; Baldry 1998; Egan 1998; Pietroforte 1997; Li and Green 1996; Crowley and Karim 1995; Hanly and Valence 1993; Cowan 1992; CII 1991). Rahman and Kumaraswamy (2004, 2002a,b) concluded that the construction industry is moving towards joint risk management by the application of partnering principles. Tang et al. (2006) further revealed the important role of partnering in enhancing risk management, and indicated that partnering helps participants to share added information by the improvement of open communication, which facilitates optimum decision making to reduce lost opportunities dealing with project risks. Essentially risk management is decision making (Kliem and Ludin 1997). Whether a decision is good or poor is largely decided by the efficiency of information obtained by the decision maker, and information is the main resource in the steps of risk identification and analysis. The efficiency of information can be calculated as follows (Buck 1989)

$$\xi\ (\text{information}) = (\text{value of information})/(\text{value of perfect information}) \tag{1}$$

If an information message eliminates all uncertainties, the value of information is said to be perfect and $\xi(\text{information})=1$. In other circumstances a decision needs to be made based on information still containing uncertainties, with $\xi(\text{information})$ lower than 1. Project participants always hope that the $\xi(\text{information})$ is high, but with the cost of obtaining information being acceptable. However, not all information required to handle future uncertainties is discernible, and not all risks are identifiable and quantifiable at the planning stage (Rahman and Kumaraswamy 2002b). Besides, the experiences and recognitions of individuals from various organizations are different, and they tend to be more concerned about the risks that are critical to their own organizations, thus they may not always see the overall picture of the project with the risks behind it. Open communication allows an organization to measure its risk management system against relevant organizations, which may provide comparative information and peer review feedback; external organizations also frequently provide valuable information on the functioning of an organization's risk management system, the implications of which can be important for an organization to take appropriate corrective actions (COSO 2004). Thus, organizations should spend more effort up front to put a foundation for improving communication, resolving conflicts, and making process improvements among participants (Jiang et al. 2002). Clients and contractors need to establish constructive dialogue involving input to each other's risk management process (Chapman 1997), in which participants are able to disseminate project experiences such that planning, design, and management procedures may benefit from a continual learning process (Baldry 1998).

However, the level and form of open communication risk management process needed significant changes within organizations, which can be quite fundamental and very complex (Chapman 1997). Establishing such an open communication risk management process is difficult because of the need to consider the concerns of different organizations and balance the interests of all project participants; parties need to become more collaborative and integrated, and data processing and data management often become a shared responsibility of multiple organizations, in which information comes from internal and external sources to facilitate response to changing conditions (COSO 2004). A successful implementation risk management strategy for the risk manager to adopt will use such an accommodation approach: Looking for all participants, finding compromise zones, and narrowing differences between antagonists (Williams 1997), which should be conducted within an integrated and collaborative framework that has the potential to overcome traditional dispersion of responsibilities on projects (Jaafari 2001). Elkington and Smallman (2002) indicated that it is imperative for all project participants to come to grips with risks on overall perspectives. Cano and Cruz (2002) also pointed out that risk management research areas should include: Project risk management processes, techniques and tools, organizational aspects, contracting

Table 1. Perceptions of Respondents on Importance of Risks

Risks	Overall		Client		Contractor		Superint.		Designer		Management		Planner	
	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.
Quality of work	3.62	1	3.72	1	3.53	4	3.89	1	3.7	2	3.22	3	3.43	2
Premature failure of facility	3.6[a]	2	3.5	3	3.8	2	3.79	2	3.5	4.5	3.22	3	2.57	20.5
Safety	3.54[a]	3	3.44	4	3.93	1	3.58	3	3.35	9	3.22	3	2.33	28
Inadequate or incorrect design	3.41	4	3.67	2	3.33	9.5	3.16	7	3.86	1	3	6	2.71	17
Financial	3.31	5	3	11	3.73	3	3	13.5	3.45	6.5	2.89	9.5	3.25	4.5
Failure to identify defects	3.3	6	3.28	5	3.23	11	3.37	5	3.57	3	2.78	14	3.5	1
Material or equipment quality	3.21	7	3	11	3.37	7.5	3.26	6	3.15	13	3.11	5	2.5	23.5
Force majeure	3.21	8	2.61	19.5	3.47	5	3.42	4	2.95	22	3.33	1	3	10.5
Inadequate manag't method	3.15	9	3.11	8.5	3.37	7.5	3	13.5	3.15	13	2.89	9.5	3	10.5
Inadequate planning	3.14	10	3.17	6.5	3.1	14	3	13.5	3.45	6.5	2.33	25	3.38	3
Claims and disputes	3.09[a]	11	2.47	25	3.43	6	3.05	11	3.1	17.5	2.89	9.5	3	10.5
Incompetence of subcontractor	3.05	12	3	11	3.07	15.5	3.11	9	2.9	24	2.44	22.5	3	10.5
Unforeseen site condition	3	13	2.5	24	3.33	9.5	3	13.5	3.15	13	2.89	9.5	2.38	26
Feasibility of const'n method	2.98	14	2.94	14	3.07	15.5	3.11	9	3.1	17.5	2.67	17.5	2.43	25
Shortage of skills/techniques	2.97	15	3.11	8.5	2.83	23	3.11	9	3.4	8	2.33	25	3	10.5
Delay of drawing supply	2.94	16	2.95	13	3.13	12.5	2.68	20.5	3.1	19	2.78	14	2.5	23.5
Insufficient technology	2.94[b]	17	2.67	18	3.13	12.5	2.79	17.5	3.5	4.5	2.22	28	2.57	20.5
Poor coordination	2.88[a]	18	3.17	6.5	2.87	20.5	2.63	23	3.15	13	2.22	28	2.88	14
Change in codes and regulations	2.88	19	2.83	15.5	2.97	18.5	2.53	25	3.19	10	2.56	20.5	3.25	4.5
Inappropriate risk allocation	2.86	20	2.56	21.5	3.03	17	2.74	19	2.95	22	2.33	25	3.14	6.5
Exchange rate fluctuation and inflation	2.81	21	2.11	31	2.97	18.5	2.68	20.5	3.15	13	2.89	9.5	2.57	20.5
Third party delay	2.8	22	2.83	15.5	2.87	20.5	2.32	28.5	2.95	22	2.56	20.5	3.14	6.5
Quantity variations	2.76	23	2.53	23	2.63	29.5	2.63	23	3.14	16	2.89	9.5	3	10.5
Adequacy of insurance	2.74	24	2.33	28.5	2.8	26	2.79	17.5	2.85	25	2.67	17.5	2.86	15
Poor definition of scope	2.66	25	2.44	26.5	2.83	23	2.47	26	2.7	27	2.78	14	2.33	28
Shortage of labor, materials and equipment	2.65	26	2.44	26.5	2.83	23	2.89	16	2.75	26	2.22	28	2.29	30.5
Conflicts in documents	2.65	27	2.56	21.5	2.8	26	2.21	30	3	20	2.67	17.5	2.67	18
Poor relationship between parties	2.65	28	2.61	19.5	2.67	28	2.63	23	2.6	29	2.67	17.5	2.83	16
Organizational interface	2.57[a]	29	2.78	17	2.8	26	2.32	28.5	2.55	30.5	1.89	31.5	2.33	28
Environmental	2.54	30	2.22	30	2.63	29.5	2.42	27	2.62	28	2.44	22.5	2.57	20.5
Site access	2.4	31	2.33	28.5	2.57	31	2.11	31	2.55	30.5	2	30	2.29	30.5
Logistics	1.93	32	1.83	32	2.07	32	1.68	32	2.15	32	1.89	31.5	1.86	32

Note: M.=mean; R.=rank.

[a]ANOVA is significant at the 0.05 level.

[b]ANOVA is significant at the 0.01 level.

aspects (strategies to avoid contractual rivalry), and attitude to risks, which should be from the viewpoints of all participants.

In summary, reviewing previous studies leads to the conclusion that previous surveys were typically undertaken from the perspective of one specific group of project participants and there is a clear need to systematically investigate the overall aspects of risk management on the perspectives of various project participants. This can help practitioners to build an open communication risk management process that should be done with appropriate disclosure to enable participants to understand organizations' appetites of bearing risks and the ways of dealing with them, and also to enable relevant parties to understand clearly the circumstances and risks they face, which help the participants in a position to readily make informed decisions related to the tradeoff between risk and reward (COSO 2004; Standards Australia International 2000).

The success of a survey depends largely on whether the research parameters included in the data collection instrument are the key issues worthy of investigation. Although the surveys as previously reviewed were normally focused on one specific theme, e.g., project risks, these studies collectively described the key research themes on risk management, including the importance of project risks, risk management techniques being applied, and the barriers to risk management. Accordingly, these themes have been systematically investigated in this study, and a questionnaire was used as the principal survey method, in which the questions (see Tables 1, 3, and 7) were designed based on the reviewed studies as well as the writers' experience and recognition of risk management. Further, as Smith (1999) and Standards Association of Australia (1999) theoretically demonstrated the importance of risk management system for an organization, the status of the risk management system for organizations has also been investigated by using two questions (see Tables 5 and 6). This paper reports the findings of this survey into the Chinese construction industry regarding the above themes on risk management, which were perceived by the main participants of the industry. A case study of the risk management strategies of the Three Gorges Project, which is one of the largest projects in China, has also been conducted to further illustrate the key points from the survey.

Empirical Research Method

Selection of China as Study Area

Resource limitations meant it was impractical to conduct a global industries survey. Thus, it was decided to focus this study on a specific study area of China. Choosing China as the study area is because the rapid economic expansion in China has resulted in many construction activities and has created the largest construction market in the world (Chen 1998), thus it provides a rich source of data for this study. The World Bank has estimated that China's expenditure in infrastructure will soon be the highest among all East Asian countries and is expected to account for $750 billion (United States) over the period 1995–2004 (Wang and Tiong 2000). It is expected that significant insights into risk management practice can be obtained through a deep understanding of the Chinese construction industry.

Six areas (Hubei, Beijing, Shanghai, Jiangsu, Heilongjiang, and Guangxi) were carefully chosen for sources of data. The areas are scattered over the Central, North, East, Southeast, Northeast, and Southwest regions of China. In 2001 the overall construction production value of the six areas was $55 billion (United States), accounting for 29.4% of the whole construction industry in China (National Statistic Bureau of China 2002).

It was decided to use the principal stakeholders of the Chinese construction industry as respondents, including clients, contractors, designers, superintendents, management organizations, and planning organizations. Superintendents have dual roles: To act as agents of clients in conveying the clients' instructions to contractors, and as certifiers for the purpose of issuing certificates and making decisions as to reasonable measures of value of work, quantities, or time. Management organizations are in charge of the management of projects in the name of government to ensure the projects are being complied with regulations and public interest. Planning organizations are in charge of general projects planning for an industry and a region, and deciding the long term project development strategies.

The chosen respondents were believed to have experience in the delivery of significant projects, which were drawn from the oil and gas, energy, transportation, industrial and commercial building, and public infrastructure industries. All kinds of project delivery strategies can be included in this study.

Data Collection Using Triangulated Approach

Regarding data collection, Love et al. (2002) reviewed why triangulated approaches should be used:

1. A single method may not reveal some unknown aspects of the results obtained because of the restrictions in the method;
2. Triangulation facilitates gain complete understanding of a given construction management research phenomenon; and
3. Triangulation enables both qualitative and quantitative data collection to be used to test or understand the research proposition(s).

As the objective of this research is to investigate the perceptions on different groups of the industry, which is a kind of interorganization triangulation, it was decided to apply three methods of questionnaire, interview, and case study to this study.

Questionnaire and Interview

A questionnaire was chosen as the principal survey method. Most questions were applied a five point Likert scale, and other questions were applied multichoice, which permits different statistical techniques to be used to analyze the collected data. Postal surveys avoid the legwork problem, but then another problem is to obtain an adequate level of response (Thomas 1996). Akintoye and Macleod (1997) argued that postal surveys can be biased if the return rate is lower than 30–40%. To avoid these limitations of the postal survey, the questionnaire survey was conducted through fieldwork, with the projects and respondents being chosen and conducted in advance. The questionnaire was completed face to face by each respondent.

Respondents to the questionnaire represent different roles in the construction industry, mainly including management organizations, client, contractor, designer, and superintendent. The total number of respondents is 115, and the distribution of samples is as follows: 18 (Hubei), 38 (Beijing), ten (Shanghai), 19 (Jiangsu), ten (Heilongjiang), and 20 (Guangxi). The distribution of samples according to groups is as follows: 19 (clients), 30 (contractors), 21 (designers), 20 (superintendents), ten (management organizations), eight (planning organizations), and seven (others). Ninety percent of the respondents held senior positions in their organizations, such as director, general manager, or project manager, and the others also had been involved in the industry for many years. The chosen respondents were initially identified and contacted via personal relationships and reputation. Direct contact confirmed their willingness to assist in this study. The fieldwork approach used in this survey enabled all questionnaires sent to be collected after interviews were held with participants. Thus, in this case, the response rate reached 100%. The fieldwork in this study allows that an interview with each respondent be followed after each questionnaire had been completed, and the interview results are used to test and interpret the results from the questionnaire survey.

Given the geographic position and economic status of these areas, and the variety of respondents, projects, and project delivery strategies, bias of selecting samples can be reasonably avoided, and the data collected can, to a large extent, be taken to be representative of the whole construction industry in China.

Case Study

Case study was applied to conduct in-depth analysis of the risk management practice of the Three Gorges Project, which is one of the largest projects ever to have been undertaken in China. To collect sufficient data for a deep understanding of the project, 3 weeks of fieldwork was conducted at the project site. Besides questionnaires and interviews with respondents at the site, data were also collected through direct observation and reviewing the published project documents.

Data Analysis Techniques

The data collected from the questionnaire were analyzed with the assistance of Statistical Package for Social Science (SPSS 1997). The selected techniques that are appropriate to this study include the following:

- Estimation of the sample population mean;
- Rank cases;
- One-way analysis of variance (ANOVA); and
- Spearman rank correlation.

Of these statistical techniques the ANOVA and Spearman rank correlation have been adopted for inferential analysis with the results being tested by a significant level. The hurdle of significance in this study follows the usual level for statistical significance of 0.05, with a level of 0.01 being highly significant.

Table 2. Correlation among Participants on Importance of Risks

	Client	Contr.	Superin.	Design.	Mgmt.	Planner
Client	1.000	—	—	—	—	—
	—	—	—	—	—	—
Contractor	0.642[b]	1.000	—	—	—	—
	0.000	—	—	—	—	—
Superintendent	0.655[b]	0.823[b]	1.000	—	—	—
	0.000	0.000	—	—	—	—
Designer	0.734[b]	0.699[b]	0.660[b]	1.000	—	—
	0.000	0.000	0.000	—	—	—
Management	0.348	0.709[b]	0.650[b]	0.483[b]	1.000	—
	0.051	0.000	0.000	0.005	—	—
Planner	0.435[a]	0.298	0.295	0.476[b]	0.197	1.000
	0.013	0.097	0.102	0.006	0.280	—

[a]Correlation is significant at the 0.05 level (2-tailed).

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

Survey Results and Analysis

Importance of Risks

Respondents were asked to list the importance of 32 possible risks identified in the literature, listed in the first section, on a scale of 1–5, where 1 represented negligible risk and 5 extreme risk. The results are presented in Table 1.

ANOVA was performed to test the perceptions of client, contractor, superintendent, designer, management organization, and planner. The one-way ANOVA is used to test whether several means are equal (SPSS 1997). The perceptions of the groups are different on the "premature facility failure" (mean=3.6, ANOVA $p=0.043$) and "safety" (mean=3.54, ANOVA $p=0.013$), which were given much lower ratings (2.57 and 2.33, respectively) by planners. This can be because planners are only involved in project initiation at the early stage. Different perceptions exist on "claims and disputes" (mean=3.09, ANOVA $p=0.020$), which is given an apparent low rating (2.47) by clients. There are different perceptions on "insufficient technology" (mean=2.94, ANOVA $p=0.006$), which was given a much high rating (3.5) by designers who need sufficient technology to fulfill their designs. There are also different perceptions on "poor coordination" (mean=2.88, ANOVA $p=0.013$) and "organizational interface" (mean=2.57, ANOVA $p=0.017$), showing the groups have different concerns on these factors. Despite the different perceptions on the above six risks, there are no significant differences among the groups on the ratings of the other 26 risks, suggesting all groups have a common view on the severities of most project risks.

Overall, the five most important risks are "poor quality of work," "premature failure of the facility," "safety," "inadequate or incorrect design," and "financial risk." To test whether there was consensus among the various groups on the rankings of the importance of project risks, the Spearman rank correlation coefficient r_s was computed, as shown in Table 2.

The Spearman rank correlation coefficients r_s between groups show that the risk ranking of clients has significant agreement ($p=0.00$) with the risk rankings of contractors, superintendents, and designers. Clients also have significant agreement with the ranking by planners ($r_s=0.435$ at the significance level of 0.013). Contractors have significant agreement with clients, superintendents, designers, and management organizations at the $p<0.001$ level, and disagree only with the rankings of the planners. This is understandable, as planners consider the project risks mainly at a very early stage, whereas contractors focus on the project delivery stage. Similarly, the rankings of superintendents have significant agreement with the rankings of clients, contractors, designers, and management organizations, but have a low correlation with the ranking of planners. Designers have significant agreement with all other groups at the level of $p<0.01$, showing that designers tend to consider the project risks from a project lifecycle perspective, which is consistent with all other groups. Planners have significant agreement with clients at the 0.05 level and with designers at the 0.01 level, showing the risks considered by planners at the early stages are also figured at later stages by designers and clients. The principal participants (clients, contractors, superintendents, and designers) have significantly similar perceptions on project risks.

As project risks are mainly allocated to clients and contractors, it is necessary to further discuss the priorities on the same risks for these two groups. For clients, the five most important risks were "poor quality of work," "inadequate or incorrect design," "premature failure of the facility," "safety," and "failure to identify defects," whereas the top five risks for contractors were "safety," "premature failure of the facility," "financial," "quality of work," and "force majeure." Clients are most concerned about "quality of work," which also obtained a high rank (fourth) from contractors. Both clients and contractors are very concerned about "safety" and "premature failure of the facility."

However, there are notable disparities among these risks. "Inadequate or incorrect design" was ranked second by clients. Interviews confirmed that many problems such as rework, delay, additional costs, and claims originate from this aspect. Contractors ranked this risk only ninth, which is reasonable because normally clients take most of the risks regarding design. There is also a disparity regarding "financial risk." This was ranked third by contractors, but clients only ranked it 11th. Interviews show that normally contractors have to bid for jobs with narrow margins and high risk under the pressure of the competitive market, whereas clients have much less financial pressure. "Failure to identify defects" was ranked fifth by clients, whereas it was ranked 11th by contractors. Interviews reveal that contractors tend to rely on superintendents to identify project defects. "Force majeure" was ranked fifth by contractors, whereas it was ranked 19th by clients. This is because clients have much more capability of bearing risks than contractors. Interviews show that most clients are able to use a contingency to cover unforeseen risks, but it is difficult for contractors to cover serious risk incidents because of their narrow margins.

There are also disparities between clients and contractors beyond the top five risks. "Claims and disputes" was ranked sixth by contractors, but clients ranked this risk only 25th. The different perceptions on "claims and disputes" between clients and contractors are largely attributed to the risk allocation in contracts. Most contractors indicated that to win the contracts they have to price their work with a small margin and bear high risks. This leaves them with significant financial pressure, which is confirmed by contractors ranking "financial" as the third risk. Thus, "claims and disputes" has been seen as an important way for contractors to mitigate their risks and recoup their profit margins for the improvement of financial capabilities. However, as clients drive the contracting process, they are able to avoid many risks in advance through contracts, and this gives clients more flexibility than contractors to deal with claims and disputes. Besides, clients normally have stronger financial capacity than contractors. This is consistent with the established disparity regarding "financial risk" between clients and contractors and thus the impact of "claims

Table 3. Application of Risk Management Techniques

Techniques of risk management	Overall		Client		Contractor		Superint.		Designer		Management		Planner	
	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.
(a) Risk identification														
Checklists	2.73	11.5	2.74	12	2.53	13	3.11	10	2.75	11	2.75	12.5	2.2	15
Brainstorming	3.40	3	3.63	3	3.37	2.5	3.68	4	3.45	1.5	3.13	8.5	2.8	9
Consulting experts	2.99	9	3.26	6.5	2.6	10.5	2.95	12	3.25	6	3.13	8.5	3.6	2
(b) Risk analysis														
Qualitative analysis	3.39	4	3.68	1.5	3.13	6	3.47	5	3.4	3.5	3.25	5	3.17	5
Semiquantitative analysis	2.73	11.5	2.95	10	2.53	13	2.95	12	2.6	13.5	2.75	12.5	2.6	10
Quantitative analysis	2.6	14	2.79	11	2.6	10.5	2.53	15	2.7	12	2.38	16	2	16.5
Consulting experts	3.06	8	3.32	5	2.63	9	2.95	12	3.3	5	3.25	5	3	1
Joint evaluation by key participants	3.64	1	3.68	1.5	3.57	1	3.79	1.5	3.45	1.5	3.88	1	3.67	3
Use of computers and other modeling	2.1	17	2	17	1.87	17	2.16	17	2.35	16	2.25	17	3.33	16.5
(c) Risk response														
Avoid the risk	2.98	10	2.68	13.5	2.77	8	3.16	8.5	3.1	9.5	3.5	2	3	7.5
Reduce the likelihood of occurrence	3.39	4	3.26	6.5	3.37	2.5	3.74	3	3.2	7.5	3.25	5	3.17	5
Reduce the consequences	3.41	2	3.37	4	3.23	4.5	3.79	1.5	3.4	3.5	3.25	5	3.17	5
Transfer the risk	3.18	6	3	9	3.1	7	3.42	6	3.2	7.5	3	10.5	3	7.5
Retain the risk	2.4	16	2.42	16	2.5	15	2.26	16	2.25	17	2.63	14	2.5	11
(d) Risk monitoring														
Periodic document reviews	3.15	7	3.05	8	3.23	4.5	3.26	7	3.1	9.5	3.25	5	2.33	13
Periodic risk status reporting	2.71	13	2.68	13.5	2.53	13	3.16	8.5	2.5	15	3	10.5	2.33	13
Periodic trend reporting	2.53	15	2.53	15	2.33	16	2.84	14	2.6	13.5	2.5	15	2.33	13

Note: M.=mean; R.=rank.

and disputes" on financial for clients is not as crucial as for contractors. Therefore, reducing risks through claims and disputes is emphasized by contractors, whereas clients considered costs from claims and disputes as normal expenditure that can be covered by contingencies. "Unforeseen site conditions" was ranked ninth by contractors, whereas this risk was ranked 24th by clients. Interviews show that "unforeseen site conditions" can bring greater difficulties to contractors that may not be recoverable through claims. "Exchange rate fluctuation and inflation" was ranked 18th by contractors, whereas clients ranked it 31st. Interviews show that this risk for contractors mainly comes from the increasing cost of construction materials. Many projects last a considerable period, and in most circumstances contractors have to cover the additional costs from the rising price of the construction materials.

Application of Risk Management Techniques

Respondents were next asked to identify the risk management techniques being used in their projects. These techniques are summarized based on the literature listed in the first section, in a way that facilitates understanding for respondents. Respondents were asked to respond on a scale of 1–5, where 1=never used; 2=seldom used; 3=sometimes used; 4=often used; and 5=always used. The results are given in Table 3.

ANOVA was performed to test the perceptions of all groups on the use of the risk management techniques listed. All computed results of ANOVA are with the significance level higher than 0.05, which shows that all groups have no significant differences in the ratings of the techniques. This suggests the extent to which all groups use risk management techniques is similar.

To test how well the different groups agree on the priorities regarding application of risk management techniques, the Spearman rank correlation coefficient r_s was calculated, as shown in Table 4.

The Spearman rank correlation coefficients among clients, contractors, superintendents, designers, management organizations, and planners are all at the significance level of 0.01, except for planners, who have a correlation with contractors and superintendents at a significance level of 0.05. This shows that all six groups have significant agreement on the priorities of using risk management techniques.

Table 4. Correlation among Participants on Application of Risk Management Techniques

	Client	Contr.	Superin.	Design.	Mgmt.	Planning
Client	1.000	—	—	—	—	—
	—	—	—	—	—	—
Contractor	0.842[b]	1.000	—	—	—	—
	0.000	—	—	—	—	—
Superintendent	0.758[b]	0.893[b]	1.000	—	—	—
	0.000	0.000	—	—	—	—
Designer	0.940[b]	0.853[b]	0.773[b]	1.000	—	—
	0.000	0.000	0.000	—	—	—
Management	0.704[b]	0.812[b]	0.774[b]	0.746[b]	1.000	—
	0.002	0.000	0.000	0.001	—	—
Planner	0.726[b]	0.583[a]	0.528[a]	0.745[b]	0.752[b]	1.000
	0.001	0.014	0.029	0.001	0.000	—

[a]Correlation is significant at the 0.05 level (2-tailed).

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

Table 5. Perceptions on Formalization of Risk Management System

Statements	Overall	Client	Contr.	Super.	Des.	Mgmt.	Plan.
1. What do you think about your organization's risk management system?	2.61	2.84	2.27	2.89	2.75	2.75	1.83

As seen in Table 3, the technique most frequently used to identify risks is "brainstorming" (score=3.40). This is followed by "consulting experts" (score=2.99), and "checklists" (score=2.73).

Among risk analysis techniques, "joint evaluation by key participants" is used most frequently (score=3.64). This is followed by the "usage of qualitative analysis" (score=3.39), and "consulting experts" (score=3.06). Usage of both "semiquantitative analysis" (score=2.73) and "quantitative analysis" (score=2.6) is quite low. "Use of computers and other modeling methods" to calculate risks quantitatively is given the lowest rating (score=2.1), i.e., it is seldom used.

As to risk response, the methods of "reducing the consequences" (score=3.41) and "reducing the likelihood" (score=3.39) of risks are used most often. These are followed by "transferring risks" (score=3.18), "avoiding risks" (score=2.98), and "retaining the risk" (score=2.4). The responses on risk response strategies show that reducing the risk is the first priority of the industry rather than transferring and the risk, which has shifted from the traditional risk management strategy adopted by participants, in which as much of the risk as possible is transferred to others (ACA 1999). Yet, risk transfer still has a moderate to high rating, and retaining risk is the least used technique, suggesting the causes of creating interest conflicts among participants still exist.

"Periodic document reviews" (score=3.15) is the method most frequently used for risk monitoring, which is ahead of "periodic risk status reporting" (score=2.71) and "periodic trend reporting" (score=2.53). It appears that there is no adequate risk monitoring in the industry.

The perceptions of clients and contractors show they have similar priorities on the use of most risk management techniques. However, there are some disparities between clients and contractors in the use of "consulting experts." Clients more frequently apply the technique of "consulting experts" during both risk identification and risk analysis than contractors, indicating clients rely on external expertise to assist with risk management more than contractors. Other disparities between clients and contractors lie in risk response techniques. Contractors ranked "reduce the likelihood of the occurrence" second, whereas clients ranked it sixth. Contractors ranked "avoid risk" eighth, comparatively clients ranked it 13th. Contractors apply these techniques more frequently than clients, showing that contractors are more reluctant to take risks. This can be due to their lower capability of withstanding the effects of risks.

"Joint evaluation by key participants" for risk analysis, "reduce the consequences" for risk response, and "brainstorming" for risk identification are the most often used techniques. The application of risk management techniques shows that qualitative methods are much more frequently used by all groups than quantitative techniques in risk management. This situation also suggests a need to introduce partnering principles to risk management process. Partnering adopts cooperative philosophy that encourages open communication among participants. This is suitable for improving the effects of the above most frequently applied risk management techniques, e.g., "joint evaluation by key participants," thereby reducing the risks of a project substantially. "Risk reduction" rather than "risk transfer" was the first choice of participants for risk response and also provides a sound basis to establish such an open communication risk management process, which facilitates all parties to manage project risks collaboratively.

Overall, the ratings on the application of risk management techniques is not high, and qualitative techniques obtained much higher ratings than quantitative techniques, suggesting there is much room for improvement for using different risk management approaches, especially quantitative techniques.

Status of Risk Management System

To investigate the formalization of risk management systems being used in the industry, respondents were asked to respond on a scale of 1–5, where: 1=informal approach, which views the risks in a subjective manner; due to the nature of this approach many organizations implement risk management methods but do not realize that they are operating any kind of risk management procedure; and 5=formal approach, which consists of a set of procedures laid down by an organization for use in the risk management process; these procedures are structured and give guidelines to be followed, so that they can be used by any member of the organization; this enables a uniformity of procedures and ensures that the process is more objective than the informal approach (Smith 1999). The results are shown on Table 5.

The computed F ratio by using ANOVA was 1.651 at the significance level of 0.154 higher than 0.05, suggesting there are no significant disparities among the groups on the formalization of the risk management system. The ratings of all groups are lower than 3, and the overall rating is 2.61. This situation suggests that risk management systems adopted by different organizations tend to be informal.

To investigate the adequacy of the risk management systems being used in the industry, respondents were asked to respond on a scale of 1–5, where 1=strongly disagree and 5=strongly agree. The results are shown Table 6.

The computed F ratio by using ANOVA was 2.253 at the significance level of 0.055 higher than 0.05, suggesting there are no significant disparities among the groups on the adequacy of the risk management system. The ratings of all groups are ranged from 1.5 to 2.63, and the overall rating is only 2.25. Interviews also confirmed that all groups who perceived their current risk management systems were inadequate to manage project risks.

Table 6. Perceptions on Adequacy of Risk Management System

Statements	Overall	Client	Contr.	Super.	Des.	Mgmt.	Plan
2. Your organization's risk management system is adequate	2.25	2.52	1.97	2.63	2.14	2.56	1.5

Table 7. Barriers to Risk Management

Factors affecting risk management	Overall M.	Overall R.	Client M.	Client R.	Contr. M.	Contr. R.	Super. M.	Super. R.	Desi. M.	Desi. R.	Manage. M.	Manage. R.	Plan. M.	Plan. R.
Lack of joint risk management mechanisms by parties	3.88	1	3.56	5	3.93	7	3.74	6.5	4.1	1.5	3.80	2.5	4.43	1
Shortage of knowledge/ techniques on risk management	3.87	2	3.5	6	4.03	1.5	3.79	5	4	4	3.70	5.5	4.14	5
Different recognition of risk control strategies	3.85	3	3.67	3	3.93	7	4	2	3.9	5.5	3.80	2.5	4.29	2.5
Ineffective implementation of risk control strategies	3.83	4	3.83	1	3.93	7	3.74	6.5	3.86	7	3.40	9.5	4.14	5
Ineffective monitoring	3.82	5	3.72	2	4	3	3.84	3	3.9	5.5	3.30	11	3.71	11
Lack of formal risk management system	3.81[a]	6	3.61	4	3.87	9.5	3.37	9.5	4.05	3	3.80	2.5	4.29	2.5
No incentive for better risk management	3.73[b]	7	3.22	9	3.97	4.5	3.42	8	4.1	1.5	3.70	5.5	4.14	5
Lack of risk consciousness	3.71	8	3.33	7	3.77	11	4.16	1	3.71	11	3.40	9.5	4	8
Lack of historical data for risk trend analysis	3.69[a]	9	3.22	9	3.87	9.5	3.80	4	3.81	8.5	3.80	2.5	3.86	10
Inappropriate risk allocation	3.63[b]	10	3.22	9	4.03	1.5	3.21	11	3.81	8.5	3.50	7.5	4	8
Insufficient ongoing project information for decision-making	3.61[a]	11	3.17	11	3.97	4.5	3.37	9.5	3.76	10	3.50	7.5	4	8

Note: M.=mean, R.=rank.

[a]ANOVA is significant at the 0.05 level.

[b]ANOVA is significant at the 0.01 level.

Given the low ratings by all the groups regarding the current risk management systems, there is a clear need for the groups in the industry to improve their risk management processes systematically, which should enable their risk management systems to become more formal to deal with project risks effectively.

Barriers to Risk Management

To better understand the barriers to risk management, some possible factors that may affect risk management were further investigated. Respondents were asked to identify from their experience the most important barriers to risk management. To do this they were asked whether they agreed with a number of suggested barriers, by responding on a scale of 1–5, where 1=strongly disagree and 5=strongly agree. The results are given in Table 7.

ANOVA was performed to test the perceptions of different groups. The perceptions of the groups are different on the “lack of formal risk management system” (mean=3.81, ANOVA $p=0.027$), “no incentive to better risk management” (mean =3.73, ANOVA $p=0.004$), “lack of historical data for risk trend analysis” (mean=3.69, ANOVA $p=0.043$), “inappropriate risk allocation” (mean=3.63, ANOVA $p=0.008$), and “insufficient ongoing project information for decision-making” (mean=3.61, ANOVA $p=0.022$). Except for the different perceptions on the above five barriers to risk management, there are no significant differences among the groups on the ratings of the other six factors.

To test how well the different groups agree on the ranks of the barriers to risk management, the Spearman rank correlation coefficient r_s was calculated, as shown in Table 8.

The Spearman rank correlation coefficients among clients, contractors, superintendents, designers, and management organizations are all at the significance level of higher than 0.05, suggesting that these five groups have no significant agreement on the ranks of the barriers to risk management. Only planners have

Table 8. Correlation among Participants on Barriers to Risk Management

	Client	Contr.	Superin.	Design.	Mgmt.	Planner
Client	1.000	—	—	—	—	—
Contractor	0.131	1.000	—	—	—	—
	0.702	—	—	—	—	—
Superintendent	0.382	0.371	1.000	—	—	—
	0.246	0.261	—	—	—	—
Designer	0.328	0.179	0.177	1.000	—	—
	0.325	0.598	0.867	—	—	—
Management	0.123	0.300	0.108	0.479	1.000	
	0.719	0.370	0.751	0.136	—	—
Planner	0.323	0.177	0.170	0.661[a]	0.608[a]	1.000
	0.332	0.603	0.617	0.027	0.047	—

[a]Correlation is significant at the 0.05 level (2-tailed).

an agreement with designers and management organizations at the significance level of 0.05. Clients ranked "ineffective implementation of risk control strategies" as the first, whereas contractors ranked "shortage of knowledge/techniques on risk management" and "inappropriate risk allocation" as the first (tie), showing clients are more concerned with effectiveness of risk management strategies and the contractors intend to improve risk management knowledge and to have fair risk allocation. This situation shows that the extents to which the barriers affect the risk management for the main project participants are different from each other. Improvement of an organization's risk management system should be according to its own features, and development of open communication risk management process for participants should consider these differences.

Overall, "lack of joint risk management mechanisms by parties" is given the highest rating (score=3.88), and "different recognition of risk control strategies" (score=3.85) is ranked third. These barriers are just what partnering can remove by stressing trust and open communication, which can help organizations to contribute their historical data, project teams to exchange their recognition of the project, and individuals to introduce their personal experience, which can help participants to build a joint risk management mechanism. "Shortage of knowledge/ techniques on risk management" is ranked second, which is consistent with the survey results on risk management application, suggesting there is a need to increase the knowledge of risk management in the industry. The other eight barriers (see Table 7) were rated with moderate to high scores, ranging from 3.61 to 3.83, suggesting that the influences of these factors also should not be ignored.

Case Study of Three Gorges Project

Project Descriptions

The Three Gorges Project (TGP) is the largest hydropower project in China. The project plays a key role in harnessing the Yangtze River and developing the adjacent regions, which is located in Sandouping town, Yichang, Hubei province. The project comprises dams, power plants, and navigation facilities. The total investment is estimated to be $24.3 billion (United States) with the project delivery duration being 17 years. The key functions of the project are flood control, electricity generation, and navigation. The main participants of the project are the client—China Yangtze Three Gorges Project Development Corporation (CTGPC), the designer—Changjiang Water Resources Commission (CWRC), superintendents, contractors, and the management organization—TGP Construction Committee of the State Council, which have been combined with the project delivery system of the TGP as detailed in Fig. 1.

The construction of the TGP commenced in 1993, which is 14 years ago, thus the adopted delivery system is quite traditional. However, after years of practice, the limitations of the traditional system are being recognized, and a variety of innovative delivery strategies have been introduced to the TGP. Rahman and Kumaraswamy (2002b) also pointed out that recent Chinese industry practice seems to incorporate significant elements of neoclassical contracting.

Generally, the risk management strategies in the TGP are consistent with the survey results on risk importance, use of management techniques, and barriers to risk management, and the many features the TGP risk management practice are in line with the principles of partnering and alliancing that stress joint effort by participants, which are illustrated below.

Risk Management Strategies in TGP

The general survey results show that most risks are common concerns of project participants (see Table 1 and 2 and "lack of a joint risk management mechanism" is the most important barrier to risk management (see Table 7), suggesting the need for jointly and collaboratively managing project risks by participants. The risk management strategies applied in the TGP show one way in approaching this by introducing incentives into the management process. The TGP adopts extensive incentive schemes to promote cooperation among participants, which reflects the risk management philosophy that is gain share/pain share, allowing project participants to share rewards from effective risk management. The incentives are gradually developed in the course of practice during many years through joint efforts by the participants. The general combined incentive schemes in the TGP typically include incentives on: Quality (weight=45%), schedule (weight=24%), occupational health and safety (OH&S) and environment (weight=15%), information management (weight=10%), and coordination (weight=6%), which had various measures to allow an appropriate gain/pain sharing to be decided. The value of rewards from incentives can reach 3% of the cost of the work.

The weights of the incentives indicate the importance of a risk or concern that a particular incentive deals with as perceived by the project participants. The quality risk has been identified as most important for the TGP, which is consistent with the survey results of "quality of work (ranked first)" as shown in Table 1, thus the quality incentive is given a heaviest weight. As shown in Table 2 that the rankings of project risks among participants are strongly correlated, it is also recognized in the TGP that quality of work is relevant to all project participants, and the TGP quality management committee has been formed to achieve the quality objective that aims at zero quality failures, which include the key members from the client, the designer, contractors, superintendents, and management organizations. As the TGP construction schedule is another important issue for such a power project, the schedule incentive is set to ensure that the progress of the project construction is under control. OH&S and environment is also identified as a key issue of the project, which is in line with the survey results on "premature failure of facility (ranked second)" and "safety (ranked third)" as shown in Table 1. Thus the relevant incentive is set to mitigate this risk.

Encouraging all participants to collaboratively manage key project risks by using incentives in the TGP is consistent with the survey results on risk management techniques (see Table 3), in which "joint evaluation by key participants" is the most frequently used technique. The technique of reducing risks is another important risk management strategy used in the TGP, including "reduce the likelihood of occurrence" and "reduce the consequences." This is also in line with the survey results (see Table 3), in which reducing risks is the first choice among risk response techniques rather than transferring risks to others as much as possible. The application of the risk reduction technique is reflected in the measures tied with the themes that the incentives are dealing with. For example, comprehensive measures to reduce the likelihood of quality deviations have been incorporated into the quality incentive scheme, and there are five preventive measures incorporated in the OH&S and environment incentive scheme. The incentive measures to reduce the consequences of risk are

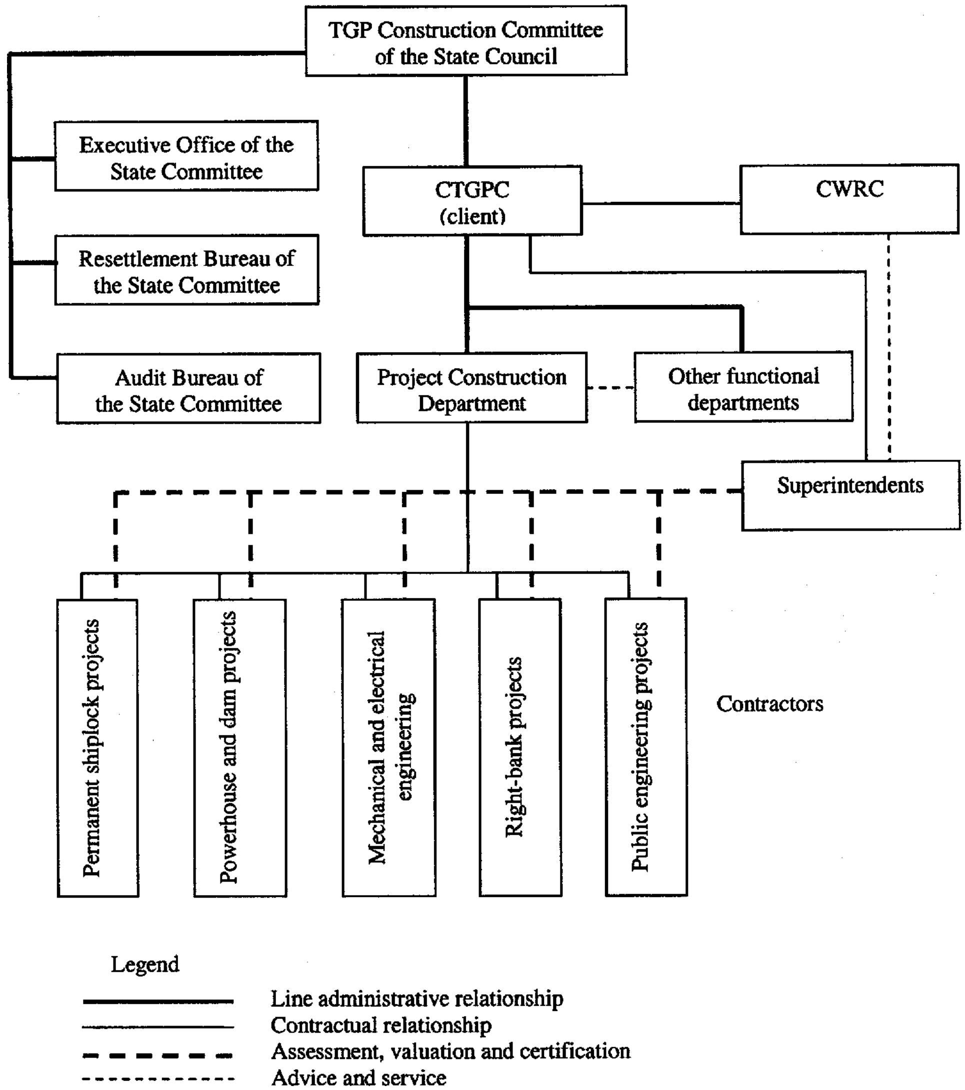

Fig. 1. Delivery system of TGP

also incorporated in the quality and OH&S incentive schemes. When quality and OH&S problems occur or there are early warnings of problems, these incentive measures require participants to take prompt action to reduce and control the consequences of the problems. The ultimate objective of incentive measures for reducing consequences is to find the causes of the problems and then upgrade the risk prevention strategies to avoid the occurrence of similar problems.

In addition, information management and coordination incentives have been set to enhance the application of the above risk management techniques by facilitating open communication among participants, which is illustrated below.

Open Communication Risk Management in TGP

The direct impact of risk reduction strategies from the TGP incentive schemes is that they enable all participants to understand what the key issues of the project are, and what possible measures could be taken. However, using these strategies and measures to deal with risks during construction requires the support of adequate information for participants to make appropriate decisions. Given the importance of the information on dealing with project risks, an information management scheme is incorporated in the TGP incentives, which promotes open communication among participants. As the TGP is such a large construction project with multidisciplinary components, the efficiency of information circulation would be greatly diminished if there was inadequate technical support. In the TGP the technical support for improving information management capabilities is the development and use of the Three Gorges Project Management System (TGPMS). The TGPMS incorporates computer technologies via communication, database, multimedia, office system, and management system, to deal with issues on scheduling, quality, contracts, procurement, financing, engineering, document control, material and equipment, safety, payment, and cost control (CTGPC 2002). TGPMS provides participants with a variety of communication methods. However, if the participants have no intention of using it actively or only input very limited data into the system (reluctance to openness), e.g., only providing data for payments, communication could still be ineffective. To avoid this situation and improve the effectiveness of TGPMS, the information management incentive clearly specifies the measures regarding the use of TGPMS. If a contractor uses TGPMS efficiently and inputs all necessary data into the system in a timely manner, the contractor is able to obtain rewards. Traditionally, parties keep information to protect themselves or for pursuit of claims (Carr et al. 1999; Crowley and Karim 1995). In TGP these considerations lose their basis, because effective communication and openness could result in direct rewards, enabling all participants to share their information in as much detail as possible. In this situation, project data/information can be exchanged correctly and in a timely way among departments, different management levels, and organizations, including the client, the contractors, the designer, the superintendents, and the management organizations, to enable them to effectively manage the project risks by monitoring, analyzing, and responding to the project activities.

Another approach to promote open communication in the TGP is by setting a coordination incentive that incorporates clear measures for efficient problem resolution, which stresses that all project issues be dealt with jointly and collaboratively. For example, due to the complexity of the project, with multidisciplinary components, many problems and issues have arisen from interfaces, and one party cannot solve the problems alone in the circumstances; specifically, the interface coordination measure is set to facilitate the resolution of conflicts among different jobs, departments, and organizations in the interfaces. Dealing with problems normally involves "claims and disputes." As the survey results (see Table 1) revealed, although this is quite important for contractors, the client in the TGP considers the "claims and disputes" as normal activities that should be within the coverage of the contingencies. Thus there are few significant interest conflicts between the client and the contractors on sharing the risks of the issues raised. With assistance of the motivation resulted from the coordination incentive, most project issues in the TGP have been resolved promptly and equitably.

In addition, quality incentive, OH&S incentive, and information management incentive also include measures on joint investigation and treatment of quality deviations, OH&S incidents, and project problems. These measures cannot only facilitate the collaborative management of different risks, but also provide the participants with additional rewards for managing them effectively.

The strategies adopted in the TGP can largely remove the barriers to risk management as the survey revealed (see Table 7), such as "lack of joint risk management mechanisms by parties," "different recognition of risk control strategies," "ineffective implementation of risk control strategies," "no incentive for better risk management," "inappropriate risk allocation," and "insufficient ongoing project information for decision making." The satisfactory performance of the TGP shows that the TGP risk management strategies are effective in managing the identified key project risks. The specified project quality was achieved in a systematic and orderly manner, and the completed works have met the required standards; the total cost of the project was forecasted under $21.8 billion (United States), which is 11% less than budget; the construction progress strictly met the schedule requirements of the project (Lu 2005); the safety incidents decreased continuously; and the industrial relationships among participants were good with communication among them being effective.

Conclusions

Based on the perceptions of the main project participants, the survey conducted in this study revealed the status of the risk management practice in the Chinese construction industry. The major findings of this study include:

1. The five most important project risks are "poor quality of work," "premature failure of the facility," "safety," "inadequate or incorrect design," and "financial risk." Despite the different perceptions on some risks, all groups have a common view on the severities on most projects;
2. The overall rating on the extent to which the project participants apply the risk management techniques is moderate. "Brainstorming" for identifying risks, "joint evaluation by key participants" in risk analysis, "reducing risks" within risk response strategies, and "periodic document reviews" in risk monitoring are the most frequently used techniques. The qualitative techniques are used much more often than quantitative techniques in the industry. All groups have significant agreement on the priorities on using the risk management techniques;
3. The risk management systems applied in the industry tend to be informal, which are inadequate to manage project risks;
4. "Lack of joint risk management mechanisms by parties" "shortage of knowledge/techniques on risk management," and "different recognition of risk control strategies" are the top three barriers to risk management, with other barriers being also rated with moderate to high scores; and
5. The technique of "reducing risks" is the principal risk management strategy used in the TGP, and the way the technique is applied depends on the importance of the risks perceived by the project participants, which mainly include quality, occupational health and safety (OH&S), environment, schedule, coordination, and information management. An open communication risk management process has been established in the TGP by setting measures included in incentives such as information management and coordination to promote joint and collaborative problem resolution. The outcomes of the TGP indicate that the risk management approach is effective.

Future Research Directions

The results of this survey suggest some potential strategies for future application in the construction industry. Future studies on risk management should be conducted to enhance the developments and applications on these strategies, which include the following:

1. The overall ratings on the application of risk management techniques is not high, which is consistent with the risk management systems being used by the participants, and are quite informal and inadequate to deal with project risks. This suggests that there is much room to systematically improve the risk management in the industry by using different approaches to increase both the organizations and individual's knowledge/skills on risk management, especially on quantitative techniques;
2. As most risks are common concerns of project participants, and "lack of a joint risk management mechanism" is the most important barrier to risk management with "different recognition of risk control strategies" being also ranked the third barrier, future studies should be conducted to build a collaborative risk management mechanism permitting the corporate experience of all participants as well as their personal knowledge and judgment to be effectively utilized;
3. The use of risk response strategies indicates that the industry has shifted from the traditional situation of transferring risks as much as possible to others to the current situation where

risk reduction is the first priority by participants. This provides a sound basis for implementing a joint risk management mechanism in the construction industry, in which collaborative risk reduction strategies should be an emphasis in future research;

4. Incentive schemes have been adopted in the TGP to allow project participants to equitably share rewards from effective risk management, suggesting future studies on this direction should be conducted as to how measures that are tied with the key project risks should be appropriately incorporated in the incentives;
5. The TGP risk management approach can largely remove the barriers to risk management in the industry. This indicates that the future open communication risk management process should not be only combined with partnering principles that provide joint problem resolution procedures, but also with the need to build effective communication infrastructures, which support the information contributed by all participants being able to promptly enter the risk management process to facilitate organizations as well as individuals' optimum decision making dealing with project risks; and
6. The above insights from this study were obtained from the survey on risk management practice in the Chinese construction industry. However, the research background has incorporated experience from different areas via literature, and these insights appear transferable to other industries beyond China. Further studies need to test these.

Acknowledgments

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