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Construction Project Risk Management in Singapore: Resources, Effectiveness, Impact, and Understanding

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Abstract

While previous studies have focused on the need for Project Risk Management (PRM), highlighting its potential benefits, resources invested in PRM have been rarely identified. This study aims to investigate the resource allocation, effectiveness, impact and understanding of construction PRM in Singapore. To achieve the objectives, a questionnaire survey was conducted with professionals and 43 complete questionnaires were returned. The results revealed that higher proportion of costs was invested in PRM than time and labor resources, and that more resources invested would not necessarily lead to a higher level of PRM effectiveness and greater assurance with the achievement of project objectives. Also, the results showed the low-level understanding of PRM in the survey firms and suggested that the overall impact of PRM on project outcomes differed according to levels of understanding. Despite the low-level understanding, all the nine PRM principles and guidelines were significantly agreed. Hence, this study provides a clear picture of PRM in the Singapore construction industry. The findings of this study can help practitioners to better implement PRM and assure the achievement of project outcomes.

Keywords: *resource, effectiveness, impact, project risk management, construction industry, singapore*

1. Introduction

Project Risk Management (PRM) is a critical component of project management as risks that are not well-managed may lead to project failures (Royer, 2000). This, in particular, is a concern to construction projects. A typical construction project may involve all forms of risks such as contractual, financial, operational, political and technical risks. The evanescent nature of the venture, the multitude of players with conflicting personalities and their different understanding of risks, make PRM a daunting task right at the onset. This is compounded by variations in the project such as harsh weather and productivity problems that make PRM a challenging process throughout its lifecycle. It is thus considered "truth" that no single project may be able to eliminate risks completely.

Mills (2001) pointed out that the construction industry had a poor reputation for managing risks, with many projects failing to meet deadlines and cost targets. The potential losses of poor PRM hence range from thousands of dollars (e.g., liquidated damages for small scale projects) to millions or billions of dollars (e.g., project failure). Typical reasons for poor PRM include but are not limited to contractors' lack of information and knowledge, insufficient resources such as money and time, and lack of expertise in risk techniques (Hlaing *et al.*, 2008). On the contrary, well-planned PRM from the initial stages of a project would allow a more credible estimate of the final project costs. Furthermore, Mills (2001) highlighted that PRM can be a form of opportunity management, arguing the earlier it is done, the more potential commercial benefits can be reaped later, which agreed with the double-edged nature of risks (Zou *et al.*, 2007), namely risks can encompass both threats and opportunities (Ward and Chapman, 2003).

While there have been extensive studies on the process of PRM and its consequences, little investigation has been conducted to assess the extent to which PRM is employed in projects, and its impact on project performance. Hence, the objectives of this study are:

(1) To explore the amount of resources invested in PRM and specific types of risk;
(2) To evaluate the effectiveness and impact of PRM on project outcomes and its association with the resource invested;
(3) To investigate the understanding of PRM and the relationship between such an understanding and the overall effectiveness and impact of PRM; and
(4) To examine the agreement to the principles and guidelines for PRM.

The results would highlight the effectiveness of PRM in

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relation to the resources allocated. Also, the recognition of the impact of PRM would assist the industry players to review their current strategy for PRM, principally in the context of Singapore.

2. Background

2.1 Benefits of Project Risk Management

Construction firms should implement PRM because construction businesses are usually plagued with complex and diverse risks (Deng and Low, 2013; Low *et al.*, 2009; Ock and Han, 2010; Zhao *et al.*, 2013) and they mainly depend on construction projects to earn revenue and profits. Previous studies indicated that PRM can bring about a number of benefits. Simister (1994) revealed that the benefits of project risk analysis and management included the formulation of more realistic plans, an increased understanding of the risks in a project, the assessment of contingencies that actually reflected the risks, the increased benefits from more rational risk taking, as well as the identification of the party best able to handle a risk. Also, Mok *et al.* (1997) pointed out that PRM allowed decision makers to confront risks in a more realistic manner and thus improved decision-making. Ali (2000) indicated that in addition to helping projects completed on time and within budget, PRM could develop different scenarios with different impacts, clarify the importance of project risks, and make management aware of possible project outcomes. Pennock and Haimes (2002) found that proper PRM can reap great benefits in terms of reducing technical and programmatic risks. In addition, Mills (2001) believed systematic risk management could produce a series of benefits, including a cost-benefit assessment of risk control actions, removal of unnecessary contingency, clear recognition and acceptance of risk at an early stage to avert risks at the minimum cost, and achievement of realistic cost estimating by itemizing and quantifying risks. Moreover, Hilson (1998) argued that PRM should become fully integrated into both the management of projects and into the organizational culture, and then projects teams can gain full benefits from PRM. Furthermore, Klemetti (2006) proposed a co-operative risk management model and indicated that construction projects can benefit from this model in the form of shorter decision-making, less transaction costs or better allocation of risks to the parties that can best handle them.

To implement PRM properly, reduce losses and obtain the potential benefits, various resources should be invested. In the long run, the benefits can far outweigh the resources invested in PRM. Thus, the resources invested can be justified by the benefits and PRM becomes convincing. However, few studies have investigated the amount of resources invested in construction PRM. Hence, this study attempts to investigate the resources distributed to PRM and the association between these resources and PRM effectiveness and impact on project outcomes.

2.2 Project Risk Management in the Singapore Construction Industry

A few studies have been conducted to investigate PRM in the Singapore construction industry. Chan and Mak (2000) found that the contractors in Singapore were reluctant to perform PRM due to the lack of a systematic method and the perception that PRM was a laborious process without substantial tangible benefits. Thus, Chan and Mak (2000) proposed a systematic PRM method for these contractors to better manage their risks and believed that the advancement in information technology would improve the efficiency in PRM and help demonstrate more benefits. Also, Ali (2000) investigated the application of PRM in preparing construction project cost estimation and capital budgeting and found that the "Estimating using Risk Analysis" method was superior over other traditional methods. Woo and Tee (2001) identified the risks relating to construction project delays in Singapore and found that delayed decisions and decisions based purely on costs made by owners were detrimental to project schedule performance. Moreover, Khan and Narasimhan (2006) focused on the risk analysis techniques and concluded that the application of the Monte-Carlo simulation in modeling project cost and schedule data can produce fairly accurate and realistic results in the Singapore construction industry. However, few studies have focused on PRM effectiveness and impact on project outcomes in the Singapore construction industry. Thus, this study attempts to evaluate the PRM effectiveness and impact, and to examine their relation to the understanding of PRM in Singapore contractors.

3. Methodology and Data Presentation

3.1 Research Design

In order to assess the resource, effectiveness and impact of PRM with regards to the construction projects in Singapore, an understanding of the current scenario and implementation status of the above is vital. A questionnaire survey was performed to study the extent to which PRM was implemented in the Singapore construction industry. In addition, professionals were interviewed to capture a comprehensive picture of the opinions and information from construction companies towards PRM. This would help ascertain solutions to effectively manage the risks identified, thereby encouraging an active risk management culture.

The professionals who participated in the survey and interviews had experience and knowledge relating to PRM. The sampling frame consisted of construction companies identified through the Contractors Registry System (CRS) at the Building and Construction Authority (BCA) website. The pilot study was conducted with four professionals to solicit comments on the readability, comprehensiveness, and accuracy of the questionnaire. Based on their comments, revisions were made to improve the readability and accuracy of the statement and footnotes were added to explain the terminologies used in the questionnaire.

3.2 Data Collection

The finalized questionnaire consisted of three sections. The first section included questions meant to profile the respondents.

Table 1. Profile of Respondents

Occupation	Years of Experience								Total	
	<5		5 to 10		11 to 15		>15			
Project Manager	-		5		5		3		13	30%
Quantity Surveyor	6		1		1		3		11	26%
Architect	-		1		5		1		7	16%
Contract Manager	1		4		1		-		6	14%
Risk Manager	1		2		3		-		6	14%
Total	8	19%	13	30%	15	35%	7	16%	43	100%

More specifically, the information about the occupation and years of working experience of the respondents was included.

The second section included several project-specific questions, which were aimed to solicit the data related to a selected project that they were involved. In this section, the data relating to the value, type and duration of projects that the respondents were engaged in were collected. Additionally, the respondents were asked to indicate the amount of cost, time and labor resources allocated for the formulation of the PRM plan and management of the risks identified. Specifically, in this study, the cost resource for PRM is the money allocated to the activities related to PRM in the project budget; the time resource for PRM is the time (hours) spent on PRM during project construction; and the labor resource for PRM is the individuals directly involved in PRM. The respondents can provide either the exact figures of project resources for PRM or the percentages represented by the resources for PRM among the total project resources. Common risks identified from the literature review and pilot study were listed and the respondents were asked to select no more than three risks that were of priority to their projects. Then, the respondents were requested to indicate the amount of resources that they allocated to manage their three prioritized risks, respectively. Also, the respondents were asked to assess the effectiveness of their PRM according to a five-point Likert scale (1 = very ineffective; 2 = ineffective; 3 = neutral; 4 = effective; and 5 = very effective). Moreover, the impacts of PRM on the project outcomes (i.e. project schedule, cost and quality) were rated according to another five-point scale (1 = very insignificant; 2 = insignificant; 3 = neutral; 4 = significant; and 5 = very significant).

The third section consisted of the questions to investigate the understanding level of PRM within the firms of the respondents in accordance with a five-point scale (1 = very low; 2 = low; 3 = middle; 4 = high; and 5 = very high). Also, nine principles and guidelines of PRM were presented in this section and the respondents were requested to rate their agreement to each one according to another five-point Likert scale (1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; and 5 = strongly agree).

A total of 43 completed questionnaires were returned after which the data in the responses were codified and analyzed using the Statistical Package for Social Sciences (SPSS) 17 software.

3.3 Data Presentation

The two largest groups of respondents who answered the survey were Project Managers and Quantity Surveyors, followed by Architects, Contract Managers and Risk Managers, as summarized in Table 1. 81% of the respondents had at least five years of experience in the construction industry. The wide experience range of the professional experience and expertise made the data reliable.

Table 2. Profile of Projects

Project Characteristics		N	%
Project Type	Residential Buildings	7	16%
	Institutional Buildings	11	26%
	Commercial Buildings	10	23%
	Specialized Industries	5	12%
	Infrastructure & Heavy Construction	10	23%
Project Value (Million)	<$1	3	7%
	$1 - $5	26	60%
	$5 - $10	5	12%
	$10 - $15	6	14%
	$15 - $30	0	0%
	>$30	3	7%
Project Duration (Year)	<1	3	7%
	1-3	10	23%
	3-5	30	70%

Table 2 summarizes the characteristics of projects undertaken by the respondents, with Institutional buildings at the top of the list (26%), followed by Commercial and Infrastructure/Heavy construction (23% for both). In addition, as most projects (86%) were in the range of US$1 to US$15 million, indicating that the size of the projects ranged from small to medium scale, with the exception of a few. It can also be seen that all the projects were completed within a period of five years, with the majority between three and five years (70%).

4. Data Analysis and Discussions

4.1 Project Resources Invested in Project Risk Management

Although the respondents could enter either exact figures or percentages of the project resources invested in PRM, the

Table 3. Project Resources Invested in PRM

Resource	% of Resources Invested in PRM	Response		Mean	SD
		N	%		
Cost	5%	8	19%	9.5%	3.0%
	6%	1	2%		
	7%	2	5%		
	10%	26	60%		
	15%	6	14%		
Time	3%	2	5%	7.0%	2.6%
	5%	23	53%		
	10%	18	42%		
Labor	5%	25	58%	6.6%	2.2%
	6%	4	9%		
	7%	2	5%		
	10%	12	28%		

Table 4. Types of Risks

Type	N	%
Contractual Risk	36	80%
Financial Risk	15	33%
Design Risk	20	44%
Procurement Risk	30	67%
Tender Risk	25	56%
Safety and Health Risk	30	67%
Security Risk	5	11%
Human Resource Risk	1	2%

majority of them provided percentages due to the confidential nature of the projects. Hence, the exact figures were converted to percentages to facilitate data analysis.

As shown in Table 3, the surveyed projects invested 5-15% of their costs in PRM, with the majority of projects (N = 26; 60%) having 10% of their project budget dedicated to PRM. On the average, these projects used 9.5% of their budget in PRM. In reality, as some interviewees indicated, there may be no hard-and-fast rule with regards to the amount of budget for PRM and the contextual setting would be more important in the budgeting for PRM.

In terms of time, the mean percentage dedicated to PRM was 7.0%, with 95% of the projects allocating 5% (N = 23; 53%) or 10% (N =18; 42%) of their time to PRM. Some interviewed risk managers highlighted the fact that PRM was an on-going process, and hence it was difficult to put an exact figure with regards to time. Several other professionals concurred, claiming that the time spent varied among the different construction phases. The opinions of the respondents seemed to be in tandem with the view of Flanagan and Norman (1993) that the perhaps assurance for the completion of projects was more important in construction than the amount of time spent in developing PRM strategies during various project phases.

Similar to the time invested, all the projects set aside 5-10% of their labor for PRM while the data distribution indicated that 72% of the projects utilized less than 8% of the project labor for PRM. On the average, the surveyed projects invested 6.6% of their labor in PRM.

Hence, it was found that the mean proportion of the costs invested in PRM was slightly higher than that of the time and labor invested, respectively. Although the amount of resources identified above is worth attention, a couple of interviewees stated that there might be no hard-and-fast rules for investing resources in PRM as the contextual settings of projects were more important to the resource allocation, similar to the conclusion drawn by Wang *et al.* (2004). Also, as Klemetti (2006) indicated, the "soft" method of risk management would benefit construction projects. Tang *et al.* (2006) argued that partnering could play an important role in improving PRM, and would facilitate optimum decision-making to reduce lost opportunities and dealing with project risks. Thus, it can be inferred that just investing resources in PRM would lead to only limited effectiveness of PRM.

4.2 Project Resources Invested in Specific Risks

The major risks expounded by scholars and the respondents in their projects were surveyed. As the list was not meant to be exhaustive the respondents were also encouraged to indicate otherwise. Table 4 summarizes the results.

Contractual risk exhibited the highest frequency (N = 36; 80%). Interviewees revealed that while the contractual framework posed considerable risks, it was still a good mechanism for risk allocation. This was in agreement with Hlaing *et al.* (2008) who pinpointed that flaws in contract documents weighed heavily in the perceptions of PRM of Singapore contractors. Contractual risk was closely followed by procurement risk (N = 30; 67%) and safety and health risk (N = 30; 67%). Procurement risk attracted attention because of the significant changes in construction project delivery methods, which enables clients to allocate more risks to contractors (Hlaing *et al.*, 2008). In addition, safety and health risk was another major concern for the contractors because of the statutory obligations imposed on the stakeholders to mitigate potential occupational hazards and risks. In Singapore, the Workplace Safety and Health Act 2006 has been issued to deal with the relevant safety and health issues.

Moreover, tender, terrorism, design, financial and human resource risk were also considered by the respondents. However, a project manager interviewed indicated that tender risk can overlap with contractual risk, and hence it would be sufficient that resources for the former were set aside for managing the latter. Also, financial and terrorism risks could be more or less mitigated by insuring projects while design risk may be largely left to professionals such as architects or professional engineers to deal with. Interestingly, human resource risk was given the least attention despite the argument that human resource plays a crucial role in determining the success of PRM (Edwards and Bowen, 1998). The Construction 21 (C21) study initiated by the

Table 5. Project Resources Invested in the Management of Specific Risks

Type	% of Cost Invested	Response		Mean	SD	% of Time Invested	Response		Mean	SD	% of Labor Invested	Response		Mean	SD
		N	%				N	%				N	%		
	1%	3	9%			2%	3	8%			2%	2	6%		
	2%	12	33%			3%	18	50%			3%	9	25%		
Contractual Risk (N=36)	3%	8	22%	3.8%	1.1%	4%	1	3%	3.1%	1.3%	4%	9	25%	4.2%	1.1%
	4%	4	11%			5%	13	36%			5%	13	36%		
	5%	9	25%			6%	1	3%			6%	3	8%		
	1%	9	30%			1%	2	7%			1%	4	13%		
	2%	9	30%	2.2%	1.0%	2%	6	20%			2%	7	23%		
Procurement Risk (N=30)	3%	9	30%			3%	9	30%	3.4%	1.3%	3%	8	27%	3.0%	1.3%
	4%	3	10%			4%	5	17%			4%	7	23%		
	-	-	-	-	-	5%	8	26%			5%	3	10%		
	-	-	-	-	-	-	-	-	-	-	6%	1	4%		
	1%	9	30%			1%	11	37%			1%	4	13%		
	2%	9	30%	2.1%	0.8%	2%	15	50%	1.8%	0.7%	2%	11	37%		
Safety and Health Risk (N=30)	3%	12	40%			3%	4	13%			3%	10	33%	2.7%	1.2%
	-	-	-	-	-	-	-	-	-	-	4%	2	7%		
	-	-	-	-	-	-	-	-	-	-	5%	2	7%		
	-	-	-	-	-	-	-	-	-	-	6%	1	3%		

Ministry of Manpower of Singapore had taken note of this aspect. As a result, professional development programs, improvement of curriculum, stricter codes of conduct and licensing to improve standards were introduced. In view of labor skills, similar efforts were initiated. This enrichment of human resource ensuring their self-sufficiency and quality could be a probable cause for the negligence of human resource as risk in Singapore.

Based on the top three risks indicated by the respondents, analysis on the amount of resources invested towards their management was carried out. As summarized in Table 5, on the average, projects devoted approximately 3.8%, 3.1% and 4.2% of resources in terms of cost, time, and labor, respectively, to the management of contractual risk. More specifically, 33% of the respondents spent 2% of costs on contractual risk management, 50% devoted 3% of time to managing this risk, and 36% assigned 5% of labor to dealing with this risk.

In case of procurement risk, on the average, projects set aside 2.2%, 3.4% and 3% of cost, time, and labor resources, respectively. The slightly lower figures than those for contractual risk can perhaps be explained by its close relationship with contractual risk. Contractual framework is a preferred method and an important tool for allocation of procurement risk (CIDB, 2004; Edwards and Bowen, 1998). This may cause more resource allocation to the contractual risk which in broad included some portion of procurement risk.

Safety and health risk should be emphasized because contractors had to comply with the act related to occupational hazards and risks. Hence, PRM cannot afford to overlook such an important area. However, as shown in Table 5, the proportion of the resource allocation for safety and health risk is, on average, 2.1% for cost, 1.8% for time and 2.7% for labor, which is much less an investment than the rest of the two areas. In addition, 40%, 50% and 37% of the respondents invested 3% of costs, 2% of time and 2% of labor in the management of this risk, respectively. Considering that legislations strictly require projects to mitigate potential safety and health risks, the analysis result was of interest and the possible reason may be that potential losses caused by poor management of the aforesaid risks might be greater than those of safety and health risk. However, this could seriously undermine the effectiveness of PRM in the event of accidents. Thus, the work would be forced to stop, leading to project delays, and more troubles might follow in the form of cost escalation and liquidated damages.

Another aspect of significance is the distribution of resources with the type of risk. It can be noted that higher proportion of cost and labor resources were invested in contractual risk management while higher percentage of time was spent on procurement risk management. It can therefore be inferred that resource allocation was highly dependent on the nature of risk. The greater importance attributed to contractual risk supported the higher proportion of cost and labor resources invested, thus partly confirming the result that higher percentage of costs was invested in PRM than time and labor (see Table 3).

4.3 Effectiveness and Impact of Project Risk Management

The respondents were asked to comment on the effectiveness of PRM using a five-point Likert scale (1 = very ineffective and 5 = very effective). The one-sample t-test was performed to test whether the PRM effectiveness and the impact were significant. As summarized in Table 6, the mean score of the overall effectiveness of PRM was 2.98 without significance (p-value = 0.844), suggesting that the overall effectiveness was perceived neutral. Also, the respondents rated the effectiveness in identifying and assessing risks. Although the mean score of 3.19

Table 6. Effectiveness and Impact of PRM

Code	Indicators	Response	1	2	3	4	5	Mean	SD	*p*-value*
OE	Overall Effectiveness	N	-	13	18	12	-	2.98	0.77	0.844
		%	-	30%	42%	28%	-			
EIAR	Effectiveness in Identifying & Assessing Risks	N	-	8	19	16	-	3.19	0.73	0.103
		%	-	19%	44%	37%	-			
OI	Overall Impact on Project Outcomes	N	1	11	20	8	3	3.02	0.91	0.868
		%	2%	26%	46%	19%	7%			
IPS	Impact on Project Schedule	N	-	11	24	8	-	2.93	0.67	0.498
		%	-	25%	56%	19%	-			
IPC	Impact on Project Cost	N	-	12	23	8	-	2.91	0.68	0.377
		%	-	28%	53%	19%	-			
IPQ	Impact on Project Quality	N	-	11	23	9	-	2.95	0.69	0.660
		%	-	26%	53%	21%	-			

*The results of the one-sample t-test (test value = 3.00, two-tailed).

Table 7. Correlation among the Indicators

Indicators	OE	EIAR	OI	IPS	IPC	IPQ	Cost	Time	Labor
OE	1.000								
EIAR	0.430*	1.000							
OI	0.441*	0.421*	1.000						
IPS	0.458*	0.562*	0.549*	1.000					
IPC	0.357*	0.131	0.194	0.402*	1.000				
IPQ	-0.002	0.112	0.191	0.096	0.294	1.000			
Cost	-0.025	-0.112	-0.057	0.174	0.060	0.105	1.000		
Time	-0.024	0.062	0.210	0.191	0.347*	0.093	0.000	1.000	
Labor	-0.384*	-0.172	-0.326*	-0.311*	-0.247	0.128	0.075	0.008	1.000

*Correlation was significant at the 0.05 level (two-tailed).

was larger than 3.00, this lacked statistical significance (*p*-value = 0.103). Thus, the result indicated that the respondents were neutral towards the effectiveness. However, the mean score over 3.00 could indicate that PRM was slightly effective in risk identification and assessment. This result echoed KPMG (2010), which claimed that PRM was effective at least in the areas of risk identification and assessment.

Furthermore, the impacts of PRM on project outcomes were gauged according to another five-point scale (1 = very insignificant and 5 = very significant). In terms of the overall impact, the mean score was 3.02 with the *p*-value of 0.868, indicating that the respondents were neutral towards the question and that PRM was not almighty to affect the construction project outcome significantly. This was also supported by the results from the subsequent survey questions, which investigated the impact of PRM on project schedule, cost and quality. Project schedule, cost and quality are recognized as the most common project objectives, which can be associated with project performance indicators (Ling *et al.*, 2009). The mean scores were 2.93, 2.91 and 2.95, respectively. The one-sample t-test result indicated they were not significantly different from 3.00 (neutral). Thus, the impact of PRM on project schedule, cost, and quality was also neutral.

The Pearson correlation was performed to investigate the association among the six indicators relating to the effectiveness and impact of PRM (see Table 7). The results showed that overall effectiveness of PRM was positively associated with the overall impact on project outcomes ($r = 0.441$). This was probably because the impact of risk managemet on project outcomes could be considered as an element of PRM effectiveness. Similiarly, the overall effectiveness was positively associated with the effectiveness in identifying and assessing risks ($r = 0.430$) because risk identification and assessment are elements of PRM. These two correlations can explain the positive association bewteen the overall impact and the effectiveness in risk identification and assessment ($r = 0.421$). In addition, the impact of PRM on project schedule was positively correlated with the overall effectiveness ($r = 0.458$), the overall impact ($r = 0.549$) and the effectiveness in identifying and assessing risks ($r = 0.562$), respectively. However, the impact on project costs was only positively associated with the overall effectiveness ($r = 0.357$) while the impact on project quality was not correlated with the effectivess and overall impact of PRM. Furthermore, the impact on project costs was positively correlated with that on project schedule ($r = 0.402$), while the impact on project quality was not associated with that on project schedule and costs.

Also, the Pearson correlation was used to examine the association beween the resources invested in PRM and the six indicators relating to the effectiveness and impact of PRM (see Table 7). It was found that the time invested was only positively associated with the impact on project costs ($r = 0.347$). This implied that the more time spent on PRM was likely to lead to the better assurance of the project cost objective. In addition, the labor invested for PRM was negatively assciated with the overall effectiveness ($r = -0.384$), overall impact ($r = -0.326$) and impact on project schedule ($r = -0.311$), respectively. The results suggested that the higher labor invested would result in the lower effectiveness and impact of PRM. Moreover, the costs invested were not significantly associated with any indicator relating to the effectiveness and impact of PRM, indicating that high costs allocated to PRM would not necessarily bring about effectiveness and impact of PRM. This was consistent with the findings of some previous studies. Rahman and Kumaraswamy (2002) believed that the optimal PRM should minimize the total cost of risk to a project and allow all the project parties to jointly manage risks. Kutsch and Hall (2010) indicated that social and cognitive factors, such as the deliberate ignorance of risk-related information, could constrain the effectiveness of project risk manageemnt. Klemetti (2006) also suggeted that the relationships among the project players would influence the effectiveness of PRM. Furthermore, the three types of resources (i.e. costs, time and labor) invested in PRM were not associated with each other as the three correlation coefficients were very close to 0.000, which confirmed the opinions of some interviewees that the contextual settings of projects can significantly affect the resource allocation for PRM.

4.4 Understanding of Project Risk Management

The understanding level of PRM within the firms of the respondents was evaluated according to with a five-point scale (1 = very low and 5 = very high). The mean score of the understanding of PRM within the company of the respondents was 2.44 (see Table 8). The one-sample t-test result suggested that the understanding of PRM was significantly low (p-value = 0.000). As the interviewees reported, the poor understanding of PRM was mainly due to the insufficient knowledge, apathetic attitude and inadequate time for PRM implementation. This seemed to coincide with Hlaing *et al.* (2008), who found that the lack of time was ranked as the first barrier to PRM implementation in the Singapore construction industry. In addition, Ahmed and Azhar (2004) observed a similar lack of time trend in the Florida construction industry. Furthermore, Uher and Toakley (1999) found that the lack of knowledge and inadequate skill were the two most important obstacles to applying PRM to work processes. This signified the reason for neutrality in the assessment of effectiveness of PRM. A positive impact might not be experienced unless the PRM process is applied in a comprehensive manner to the project as a whole.

As the firms with higher understanding level of PRM are likely to have the PRM programs with higher overall effectiveness and impact on project outcomes, two hypotheses can be drawn: H_1: The effectiveness of PRM differs according to the different levels of understanding of PRM; and H_2: The overall impact of PRM on project outcomes differs according to the levels of understanding of PRM.

The one-way Analysis of Variance (ANOVA) was conducted to test the hypotheses at the 0.10 significance level (see Table 9). The F value of 1.666 with the p-value of 0.178 indicated that there were not significant differences in the overall effectiveness of PRM among the firms with different levels of understanding of PRM. Thus, H_1 had to be rejected. In addition, the F value of 3.094 with the p-value of 0.027 implied significant differences in the overall impact of PRM on project outcomes among the firms with different levels of understanding of PRM. Thus, H_2 could be accepted. The Tukey test was used as the past hoc test to identify the understanding levels between which the PRM impact on project outcomes significantly differed. Through the multiple comparison shown in Table 9, the Tukey test results suggested that there were significant differences in the overall impact of PRM on project outcomes between the companies with level 1 and level 5 (p-value = 0.011), level 2 and level 5 (0.072), and level 3 and level 5 (p-value = 0.047), respectively. Hence, the firms with very high levels of understanding of PRM could implement PRM with significantly more impact on project outcomes than those with middle, low and very low levels of understanding. In other words, the firms that can better understand PRM would benefit more from PRM.

Table 8. Understanding of PRM

Score	N	%	Mean	SD	p-value
1	12	28	2.44	1.27	0.007*
2	12	28			
3	12	28			
4	2	5			
5	5	11			

*The one-sample t-test result was significant at the 0.05 significance level (two-tailed).

Table 9. Effectiveness and Impact of PRM by Understanding

Indicators	One-way ANOVA		Post hoc test (Tukey)	
	F	p-value	Comparison	p-value
Overall effectiveness	1.666	0.178	No significant differences	
Overall Impact on Project Outcomes	3.094	0.027*	Level 1 and 2	0.863
			Level 1 and 3	0.947
			Level 1 and 4	0.984
			Level 1 and 5	0.011**
			Level 2 and 3	0.999
			Level 2 and 4	1.000
			Level 2 and 5	0.072**
			Level 3 and 4	1.000
			Level 3 and 5	0.047**
			Level 4 and 5	0.434

*The ANOVA result was significant at the 0.10 significance level (two-tailed).
**The post hoc test results were significant at the 0.10 significance level (two-tailed).

Table 10. Level of Agreement on PRM Principles and Guidelines

Statement	Mean	Rank	*p*-value
Training and education is important for construction professionals to deal with risks effectively.	3.70	7	0.000*
There is no one-size-fit-all risk management program for construction projects.	4.23	1	0.000*
Construction professionals and companies should continuously maintain a health record of risk management data.	3.86	3	0.000*
Technology, especially Information Technology, is important for companies to adopt effective risk management in international projects.	3.51	9	0.000*
Involvement of employees (not only limited to risk management teams) is essential for effective risk management in projects.	3.77	5	0.000*
Forming collaborative partnerships with groups such as subcontractors is important for risk management.	3.58	8	0.000*
Risks and opportunities are two-sides of the same coin.	3.79	4	0.000*
Assessment of risks should be done systematically based on facts and figures, with as little human subjectivity as possible.	3.72	6	0.000*
Risk management should be able to interoperate with other management theories and systems such as Total Quality Management.	4.07	2	0.000*

*The one-sample t-test (test value = 3.00) result was significant at the 0.05 significance level (two-tailed).

4.5 Risk Management Consultancy Firms vs. In-House Experts

Respondents were enquired if they were aware of the existence of risk consultancy firms that could provide training for construction-related risks. The result indicated that 86% of them were unaware while the remaining 14% were unsurprisingly, risk managers themselves. This could be attributed to the following two scenarios: (1) there were too few risk training firms; or (2) PRM was not considered very important. If it was the latter, it would explain the reason for qualitative or expert judgment-types of non-quantitative analysis techniques that have been predominantly used (Thevendran and Mawdesley, 2004; Wiguna and Scott, 2006). These techniques do not require complicated software but rely primarily on human experience, which is a more commercially 'viable' option since it requires less resources (Akintoye and MacLeod, 1997). Since PRM is considered unimportant in the opinions of the respondents, it also explained the rationale behind the tendency towards neutrality as to whether PRM is crucial for the achieving of the corporate objectives.

Closely related to the awareness of risk training firms, 77% of the professionals replied that their company did not have in-house construction risk experts. Supposing that indeed there was a low awareness with regards to risk training firms, then the high response rating for 'no in-house risk experts' should not be surprising since there might not be any relevant training for professionals. The low awareness and lack of PRM expertise were a concern of Edwards and Bowen (1998), who argued that PRM techniques would only offer advantages if the project partakers were knowledgeable and proficient in using them. Thus, it would appear that the quality rather than quantity of human resource for PRM would be able to explain the effectiveness level of PRM. However, this human oriented aspect associated with PRM has rarely been focused on.

4.6 Principles and Guidelines for Project Risk Management Practices

The last question of the survey required respondents to indicate their level of agreement with certain principles and guidelines of PRM (1 = strongly disagree and 5 = strongly agree). The one-sample t-test results suggested that all the nine principles and guidelines were significantly agreed by the respondents (p-value = 0.000). As summarized in Table 10, the statement "there is no one-size-fit-all risk management program for construction projects (mean = 4.23)" got the highest level of agreement. This result ecohed the findings of Wang *et al.* (2004). Construction projects are one-off endeavors with unique features such as long period, complicated processes, abominable environment, financial intensity and dynamic organization structures (Zou *et al.*, 2007). Thus, each project tends to involve a unique environment and the PRM appropriate for one project may be inappropriate for another.

The statement with the second highest level of agreement was "risk management should be able to interoperate with other management theories and systems such as Total Quality Management" (mean = 4.07), suggesting that the respondents agreed that PRM should be incorporated into other management processes. This was consistent with the fundamental concept of Enterprise Risk Management (ERM) that risk management should be fully integrated into the business and management processes of an enterprise (Chitakornkijsil, 2010; Sharman, 2002). In addition, such a high level of agreement indicated that ERM would be implemented in the construction industry, which confirmed the forecast of Adibi (2007) that ERM would grow in construction firms.

Another mostly agreed principle was "construction professionals and companies should continuously maintain a healthy record of risk management data" (mean = 3.86), indicating that the respondents agreed that PRM data should be recorded. This was consistent with the ISO31000:2009 (ISO, 2009), which recommended that the risk management process should be recorded to enable risk management activities to be traceable, thereby providing the foundation for continuous improvement in the overall process.

Althought the statement realitng to the infromation technology was ranked the bottom, it still got a significant level of agreement. Information technology should play a key role in enabling information flow across a project and an enterprise (Dafikpaku, 2011). In most cases, inforamtion technology is not considered as a single source for guaranting successful PRM implementation. Instead, it would function as a tool to increase synergy among the rest of the principles and guidelines.

5. Conclusions

This study explores the amount of resources invested in PRM and specific types of risk, evaluates the effectiveness and impact of PRM on project outcomes and its association with the resource invested, investigates the understanding of PRM and the relationship between such an understanding and the overall effectiveness and impact of PRM, and examines the agreement to the principles and guidelines for PRM. To achieve the objectives, a questionnaire survey was conducted and 43 complete questionnaires were returned. The analysis results implied that most projects set aside a significant portion of project resources for PRM and that higher proportion of costs was invested in PRM than that of time and labor resources, respectively. Also, the results indicated that higher proportion of cost and labor resources were invested in contractual risk management while higher percentage of time was spent on procurement risk management. Thus, the allocation of resources towards depends on the nature of risk. In addition, despite the resources invested, both the overall effectiveness of PRM and the effectiveness of risk identification and assessment were perceived at the neutral level. Similarly, the overall impact of PRM and the impact on three project objectives, i.e. schedule, costs and quality were also neutral. Moreover, the results of the Pearson correlation implied the positve association between the time spent and the impact on project costs and the negative associations between the labor invested and the overall effectiveness, overall impact and impact on project schedule, respectively. However, the costs invested were found not associated with the indicators relating to the effectiveness and impact of PRM. Thus, more resources invested would not necessarily lead to a higher level of PRM effectiveness and greater assurance with the achievement of project objectives. Furthermore, the analysis results indicated the low-level understanding of PRM in Singapore contractors and suggested that the overall impact of PRM on project outcomes differed according to the levels of understanding. Finally, all the nine principles and guidelines presented in the questionnaire survey were significantly agreed, indicating they could be used to guide PRM practices in construciton projects in Singapore.

Although the objectives of this study were achieved, there were some limitations to the conclusions drawn from the results. First, the amount of the resources for PRM and the effectiveness and impact of PRM was estimated based on their experience and subjective judgment because there would not be clear boundaries among the time, cost and labor resources invested and PRM could be integrated into other management and business processes in most cases. As most assessment relating to PRM on experience and subjective judgment (Raz and Michael, 2001; Wiguna and Scott, 2006), the imprecision and subjectivity could be seen as common problems. Second, as the statistical tests were performed with a small sample, cautions should be warranted when the results are interpreted and generalized. Lastly, in some cases, the impact of PRM on project outcomes may be intangible as PRM is conducted to guarantee the achievement of project objectives. This could disturb the perceptions of the respondents on the impact of PRM on project outcomes.

This study provides the industry practitioners with the benchmarks of resource allocation for PRM, predominantly for small-to-medium sized projects. Future studies are recommended to investigate the resource invested in PRM in large-scale projects. Also, as the contextual settings of projects were more influential for resource allocation, it would be interesting to explore how some specific projects invest resources in PRM using in-depth case studies.

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