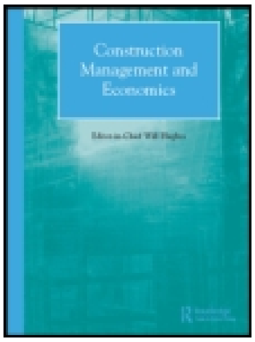

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Relating risk to project performance in Indonesian building contracts

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A construction project is unique, specific and dynamic, and therefore projects have different levels and combinations of risks, different responses are taken to minimise those risks and different consequences affect project performance. The primary aim of this study was to analyse the impacts of perceived project risk on project performance. A path model was developed and path analysis was used to determine the relationships between risk and performance. The main survey was predominantly based on a series of interviews with project managers. A total of 22 building projects under construction were surveyed; however, only 13 projects used an 'S' curve to monitor their project performance. The study focused on these 13 projects and found that perceived project risk had a direct negative effect on monthly progress achievement, while monthly progress had a direct positive impact on schedule performance. Although project risk had no direct effect on schedule performance, this was influenced indirectly with monthly progress as the mediator between them. These findings indicate that the higher the project risk in a project, the greater the negative impact on monthly progress, and consequently the worse the schedule performance will be.

Keywords: Building project, path analysis, project delay, project performance, risk management

Introduction

The issue of risk management has always been important in construction projects. Risks play a significant part in decision making and it is generally accepted that they may affect the performance of a project. If they are not dealt with sensibly, it is argued that they may cause cost overruns, delays in schedule and even poor quality. As a result, considerable efforts are spent on minimising these effects rather than attempting to maximise the chances of welcome positive effects.

The systematic approach to evaluating project risk, with the intention of eliminating or reducing risks and enhancing opportunities, is commonly called risk management. Formal project risk management associations, including the Association for Project Management (APM, 1997), the Institution of Civil Engineering and Faculty and Institute of Actuaries (ICE and FIA, 1998), the Australian and New Zealand Standards (AS/NZS, 1999), and the Project Management Institute (PMI, 2000) describe the process in different ways, but the various stages of the process are quite similar. The risk management process proposed by these associations consists of generic steps including risk identification, risk assessment, risk analysis, risk response and risk monitoring. It is a life cycle process and none of the processes should stand alone, but should work together during the project's stages. For example, risks should not be identified only at the beginning of the construction project, but should be analysed and monitored regularly throughout the construction process. To do so will make the project team aware of the risks which might affect project performance. Without understanding the likelihood of the occurrence of risks and the magnitude of their impact, decision makers will not be able to take proper actions to cope with them.

Because risk management is so important in construction projects, a great deal of research has been conducted on a variety of aspects of risk management. Most of the previous studies conducted relate to a particular part of the risk management process, for instance, they may identify risk factors affecting project performance or look at mitigating actions, assess

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risk indices or conduct risk ranking. Many of these studies have been identified through an intensive literature review and the aspects covered include: risk perception and preferred allocation of risk (Kangari, 1995; Kartam and Kartam, 2001; Rahman and Kumaraswamy, 2002); risk identification (Assaf *et al.*, 1995; Nkado, 1995; Chan and Kumaraswamy, 1997; Akinci and Fischer, 1998; Mezher and Tawil, 1998; Kumaraswamy and Chan, 1998; Elinwa and Joshua, 2001; Odeh and Battaineh, 2002); risk assessment (Zhi, 1995; Mulholland and Christian, 1999); risk management practice in different countries (Bajaj *et al.*, 1997; Bing and Tiong, 1999; Wang and Chou, 2003); and risk response (Baker *et al.*, 1999).

Although many aspects of risk management in construction projects have been studied, less attention has been paid to monitoring the impacts of project risk on project performance. Therefore, the primary aim of the research reported in this paper was to gain a detailed understanding of the relationship between project risk and project performance in Indonesian building projects.

Risk assessment

A survey conducted by Raz and Michael (2001) showed that risk impact and risk probability assessments are frequently used for assessing project risk. Most of the practitioners surveyed generally used their subjective judgements or experiences to estimate the probability of risk occurrence, in a range from very unlikely to very likely, and their impacts, in a range from low to high impact. This form of risk assessment was also used by Shen *et al.* (2001) and Santoso *et al.* (2003) when conducting their surveys, in order to evaluate project risk and to identify the most critical risks.

In many publications on risk management in construction projects, it is generally accepted that the degree of project risk is determined by multiplying the probability of a risk's occurrence by its impact on project performance. However, Williams (1996) and Ward (1999) stressed that to rank risk simply by multiplying probability by impact is misleading. Obviously, projects face many risks, but sometimes project managers consider only the highest ranked risks. Using this approach, which concentrates attention on the 'most risky', is said to be dangerous. Both dimensions of probability and impact must be considered at all times. Even though the method of risk assessment which multiplies probability by impact has limitations for identifying critical risks, it is still well known and widely used amongst practitioners.

To cope with this limitation in assessing project risk, a pair-wise comparison method normally used as part of the analytic hierarchy process (AHP), added to the risk assessment approach described above, was suggested by Hastak and Shaked (2000) and Zayed and Chang (2002). Pair-wise comparison compares the elements in each level of a hierarchy in pairs, according to their contribution to the element at the level immediately above, in order to determine their relative weight. Hastak and Shaked (2000) used pair-wise comparison to determine the relative importance of each risk factor within each level, and by multiplying the relative weight of each risk factor by its probability and impact, the level of project risk can be determined. This approach, which is described in more detail in a later section, has been adopted for the research described in this paper.

Conducting the survey

For this study, the risk factors affecting construction delay were identified through an intensive literature review and a comprehensive listing was established. A total of 30 risk factors were identified and found to fall easily into four major risk categories: external and site condition risks, economic and financial risks, technical and contractual risks, and managerial risks.

In order to identify the most significant risk factors in each major risk category, a preliminary questionnaire was designed and delivered to a total of 80 contractors in Surabaya and Denpasar, selected randomly from the list of 'GAPENSI', the Indonesian Association of Construction Companies. The questionnaires were delivered to the contractors in March 2003 and 26 responses were received, comprising 11 from large building contractors and 15 from medium-sized building contractors. The questionnaires were completed by directors, project managers and site managers.

The intention of this preliminary survey was to produce a list of four critical risk factors in each category, or 16 risk factors in all. To determine these critical risk factors a weighting approach was adopted. The 26 contractors who responded had ranked each of the risks in each category and this then allowed the top four risk factors in each major risk category to be determined. This approach, of reducing the number of risk factors, was adopted to make it easier for the respondents, who were later asked to compare risk factors in pairs. This process is quite demanding on those involved and so a pragmatic decision to limit the number of comparisons required, by reducing the number of risk factors, was taken.

The main survey that followed was predominantly based on serial interviews with project teams using a structured and semi-structured questionnaire. For the first interview, a structured questionnaire was designed to assess the project risk index of time, which is a measure of the likelihood that the risks in a project will affect the project's duration. The respondents, who were project managers, were asked to assess the probability that each of the 16 risk factors would occur on their project and to estimate the impact on time if the risks did occur, using a five-point scale. They were also requested to assess the relative importance of each risk on time, using pair-wise comparisons. For each risk factor, the risk level of time was then calculated by multiplying together its probability, impact and importance (following Hastak and Shaked's procedure) as explained in the following section.

The intention of the subsequent interviews, conducted in the following months, was to monitor each project's performance for up to three months using a semi-structured questionnaire. The respondents were asked to identify the risk factors that had occurred in the previous months, to define the impacts of those risks on their project's performance and to specify the actions taken to minimise those risks. Finally, the actual progress achieved in those months was recorded and compared to the planned 'S' curve.

A total of 22 building projects under construction in East Java and Bali provinces were surveyed during the period from mid-December 2003 to the end of June 2004. However, only 13 projects used an 'S' curve to monitor project performance and therefore only these 13 projects were analysed in this study, since the 'S' curve is an essential measurement tool for determining progress performance and the schedule performance index. These terms have been adopted from earned value analysis (EVA), which is usually used to help project teams assess project performance quickly and reliably (PMI, 2000). These evaluations are based on comparisons between the work completed and the planned value at a specific time during the construction period. The contract values of the 13 projects studied were between 3.5 billion rupiahs and 16.5 billion rupiahs (US$410K–1,940K).

Assessing the project risk index

As discussed earlier, the project risk index of time was assessed at the beginning of the study using the following formula:

$$\mathrm{RI} = \sum_{i=1}^{n} w_i \times \mathrm{P}_i \times \mathrm{I}_i, \text{ where:}$$

RI=project risk index of time
w=weight of the importance of each risk on time (using pair-wise comparisons)
P=probability that risk would occur
I=impact on time if the risk did occur
i=risk factors (1….n)

In the interviews conducted as part of the main survey, the respondents were asked to assess the probability that each risk would occur and the impact on time if it did occur, using a qualitative scale as shown in Table 1. After assessing the probability and impact, the respondents were also requested to assess the relative importance of each risk on time using pair-wise comparison.

The pair-wise comparison method compares the elements in each level of a hierarchy in pairs, according to their contribution to the element at the level immediately above. To assess the relative importance of each risk factor, a model of risk hierarchy was developed as shown in Figure 1. The lowest level of the hierarchy comprised the 16 individual risk factors and the upper level the four major risk categories. From the upper level, six sets of pair-wise comparisons were established to allow each major risk category to be compared with all the other major risk categories. Then, within each major risk category, six sets of pair-wise comparisons were established to allow each risk factor to be compared with all the other risk factors. Altogether, this produced 30 sets of pair-wise comparisons, all of which used a scale from 1 to 9, representing equal importance to extreme importance, as proposed by Saaty (1995).

After all the major risk categories and risk factors in each major risk category had been compared, their individual relative weight was obtained. The weight of importance of each risk factor on time was achieved by taking the relative weight of each major risk category and multiplying it by the relative weight of each risk in each major risk category, respectively. For a more detailed discussion of the procedures for developing pair-wise comparisons and establishing priorities, refer to Saaty (1995); for assessing project risk indices using

Table 1 Qualitative scale of probability and impact assessment

Scale	Probability	Impact on time
1	Very low	Very low
2	Low	Low
3	Medium	Medium
4	High	High
5	Very high	Very high

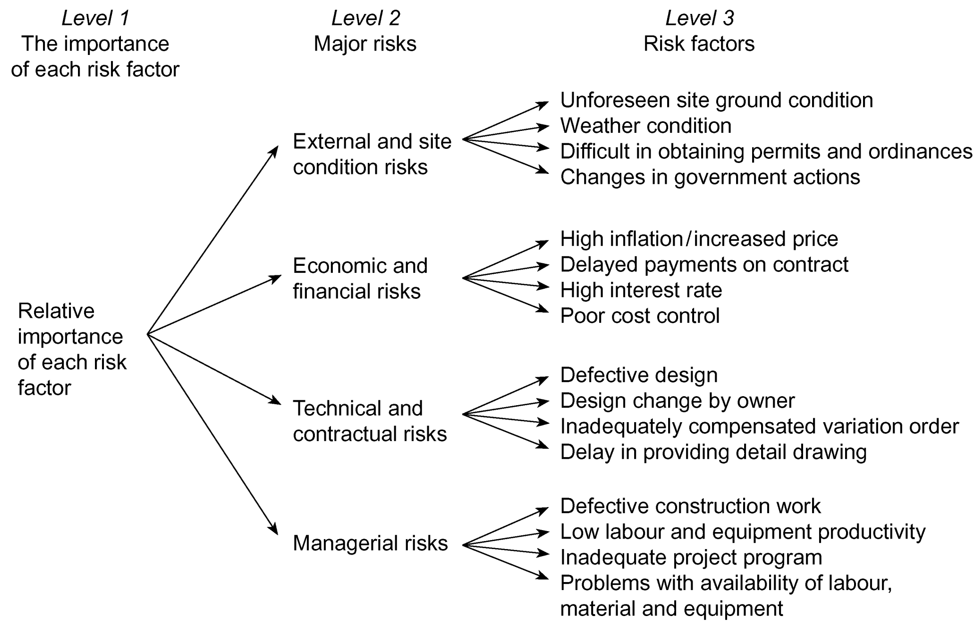

Figure 1 Risk hierarchy

pair-wise comparison, refer to Zhi (1995), Dias and Ioannou (1996), Hastak and Shaked (2000), and Zayed and Chang (2002).

Using this approach, the maximum possible value of the project risk index is 25 and the minimum value is 1, therefore the project risk index was grouped into five classifications as follows:

Project risk index	Classification
1 to <5	very low risk
5 to <10	low risk
10 to <15	moderate risk
15 to <20	high risk
20 to 25	very high risk

An example of a computation to determine the project risk index of time on Project 9 is shown in Table 2. The four major risk categories and their risk factors are shown in the left-hand column of Table 2, followed by the three values assessed by the respondents for each risk factor which are: importance (w), probability (P) and impact (I) in the middle columns. By multiplying together the importance, probability and impact, the risk levels of time for each risk factor were calculated as shown in the right-hand column. Finally, the project risk index of time was ascertained by summing up all risk levels as shown in the bottom row. The project risk index of time for Project 9 was 8.0194 and it was classified in the low risk category.

Assessing progress performance and schedule performance index

To define project performance, the terms progress performance (PP) and schedule performance index (SPI) have been adopted from earned value analysis (EVA). EVA is usually used to help project teams assess project performance quickly and reliably (PMI, 2000). These evaluations are based on comparisons between the work completed and the planned value at a particular time during the construction period. An example from Project 9 illustrating these terms is shown in Figure 2, where the dotted line shows the planned progress and the full line shows the cumulative actual progress achieved at a particular time. The planned progress is determined by calculating the ratio of the total budget for all work packages scheduled, including the overheads, to be completed in a particular time, to the total contract price. The actual progress is determined by dividing the total budgets of work packages *actually* completed, including the overhead budget, by the total contract price.

In Project 9, the project risk index was assessed on 6 March 2004, and at this point the actual progress achieved was 3.88% and the planned progress was 3.87%. In this survey, project performance was monitored every month and the review date for the following month was 3 April 2004. The actual progress achieved by this date was 7.42% and the planned progress for the same date was 10.30%. Based on this information, the progress performance (PP) and schedule performance index (SPI) for this period were calculated as follows:

$$PP = \frac{\text{(actual progress achieved during 6 March to 3 April)}}{\text{(planned progress during 6 March to 3 April)}}$$

$$SPI = \frac{\text{(actual progress on 3 April)}}{\text{(planned progress on 3 April)}}$$

$$PP = \frac{(7.42\% - 3.88\%)}{(10.30\% - 3.87\%)} = 0.55$$

$$SPI = \frac{7.42\%}{10.30\%} = 0.72$$

Table 2 Analysing the project risk index of time for Project 9

Major risk categories and risk factors	Importance on time (w)	Probability (P)	Impact on time (I)	Risk level of time (RL)
I. External and site condition risks				
Unforeseen site ground condition	0.0174	2	1	0.0347
Weather condition	0.0293	1	1	0.0293
Difficulty in obtaining permits and ordinances	0.0055	3	2	0.0327
Changes in government actions	0.0031	1	1	0.0031
II. Economic and financial risks				
High inflation/increased price	0.0429	4	3	0.5144
Delayed payments on contract	0.1356	2	3	0.8134
High interest rate	0.0243	2	3	0.1460
Poor cost control	0.0799	3	3	0.7195
III. Technical and contractual risks				
Defective design	0.2905	2	4	2.3241
Design change by owner	0.1333	3	4	1.5995
Inadequately compensated variation order	0.0657	2	4	0.5256
Delay in providing detail drawing	0.0368	3	4	0.4420
IV. Managerial risks				
Defective construction work	0.0687	2	3	0.4125
Low labour and equipment productivity	0.0200	2	4	0.1603
Inadequate project programme	0.0371	2	3	0.2225
Problems with availability of labour, material and equipment	0.0099	2	2	0.0396
Project risk index of time (RI)				8.0194 (low risk)

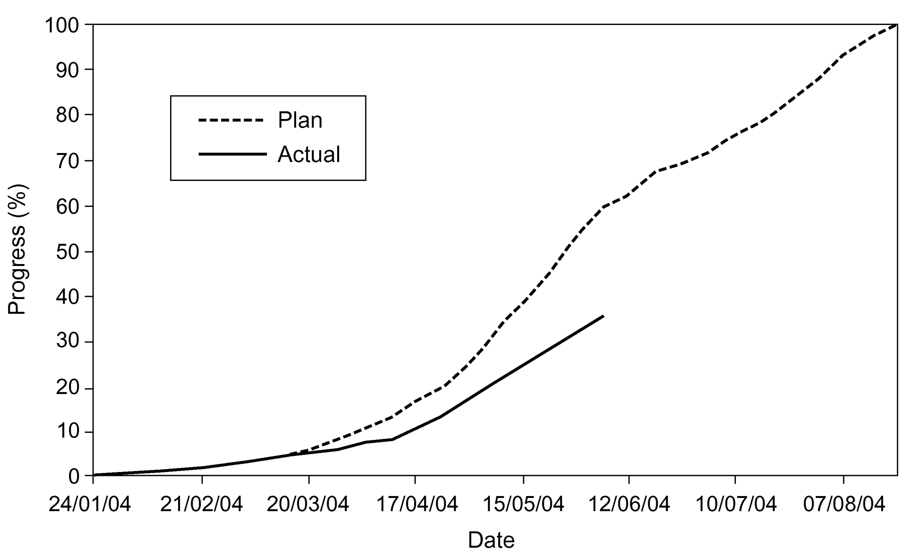

Figure 2 'S' curve of Building Project 9

All the data obtained from the projects surveyed, i.e. risk indices, project durations, progress performances and schedule performance indices are presented in Table 3.

Developing the path model

In order to give an illustration of the relationships between project risk and project performance, a path model was developed composed of four variables, which were project risk index of time (RI), project duration (Dur), progress performance (PP) and schedule performance index (SPI). To indicate the expected connections, two different types of arrows have been used. A straight, one-headed arrow shows an expected causal connection between two variables, and a curved, double-headed arrow indicates a correlation between two variables (Loehlin, 1992). The path model is shown in Figure 3.

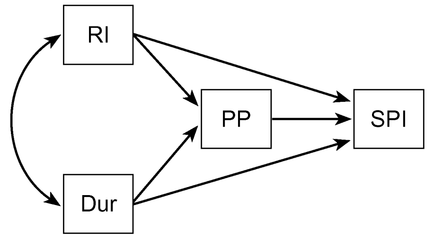

Figure 3 The path model relating project risk to project performance

The project risk index of time is a measure of the likelihood that the risks in a project will affect the project's duration. The higher the project risk index of time in a project, the more likely it is perceived to be that the project will be delayed. The duration of the project is defined as the total time spent to accomplish the project, as stated in the original master schedule. Progress performance is determined by the ratio of actual progress achieved in a particular period to planned progress for the same period, sometimes called the monthly progress performance. This proportion indicates how the actual progress achieved compares to the planned progress for a particular period. A PP value below 1 shows that the actual progress achieved during a given period is less than the planned progress, whereas if PP is above 1, it shows that the actual progress achieved is greater than planned progress. The schedule performance index is determined by comparing the actual progress achieved at a given point to the planned progress at that point. It indicates how far the project is ahead of or behind schedule at a given point. An SPI value of less than 1 indicates that the project is behind schedule, and in contrast, if the SPI value is greater than 1, it indicates that the project is ahead of schedule.

As shown in Figure 3, the variables involved in the path model were assumed to be related as follows:

Assumption 1: There is a correlation between the project risk index of time (RI) and project duration (Dur).

Assumption 2: A higher project risk index of time (RI) and shorter project duration (Dur) may lead to a lower progress performance (PP).

Assumption 3: A higher *project* risk index of time (RI), shorter project duration (Dur) and a lower progress performance (PP) may also lead to a lower schedule performance index (SPI).

Table 3 Data from the project assessment

Projects	Project risk index	Duration (weeks/days)	Monitoring project performance					
			First month		Second month		Third month	
			PP	SPI	PP	SPI	PP	SPI
Building Project 1	9.98	26/5	0.49	0.71	0.81	0.87	0.94	0.95
Building Project 2	5.95	25/0	1.01	0.98	project completed			
Building Project 3	6.22	57/6	1.28	1.22	0.94	0.94	0.83	0.83
Building Project 4	4.03	32/2	1.65	1.00	1.51	1.01	1.38	1.00
Building Project 5	6.03	38/6	0.80	0.93	1.28	1.18	0.94	0.94
Building Project 6	7.42	38/3	1.35	1.02	1.04	0.96	0.96	0.94
Building Project 7	4.22	22/3	0.75	0.86	0.86	0.89	1.12	1.00
Building Project 8	10.46	38/3	0.57	0.73	0.83	0.81	0.88	0.83
Building Project 9	8.02	30/3	0.55	0.72	0.63	0.69	0.57	0.60
Building Project 10	9.22	57/0	0.40	0.74	0.45	0.70	0.55	0.72
Building Project 11	12.72	33/4	0.34	0.62	0.70	0.70	0.85	0.76
Building Project 12	9.15	32/0	0.77	0.75	0.91	0.81	0.97	0.84
Building Project 13	7.28	23/6	0.79	0.82	0.84	0.83	1.13	0.96

To analyse these causal relationships between the variables, path analysis was used. Path analysis uses the principle of multiple regression and correlation to derive path coefficients in the path model (Bryman and Cramer, 1990), which represent the relationships between variables in the path model (Loehlin, 1992). The path coefficients are standardised regression coefficients (Li, 1975). Because the path coefficients are standardised, it enables them to be directly compared, therefore direct effects, indirect effects and total effects can be obtained. A direct effect is a path coefficient directly between two variables, an indirect effect is a path coefficient caused by the intervention of other variable(s) indirectly between two variables, and a total effect is a path coefficient between two variables that is produced by adding a direct effect to indirect effect(s). The goodness of fit model can also be obtained to test how well the model developed fits the data.

Analysis and results

The path model was analysed using AMOS software package version 5 (Arbuckle, 2003), which provides path coefficients, direct, indirect and total effects among variables and also the goodness of fit model.

In order to gain an understanding of the causal effect of the project risk index on project performance during the construction projects, the path model was evaluated for the three different periods during which the projects were studied. The first period for evaluating how the project risk index affected project performance was one month after the project risk index was assessed and the model generated was called path model 1. Path models 2 and 3 were produced two months and three months respectively after the project risk index had been assessed.

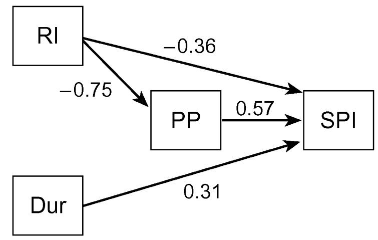

Figure 4 Path model 1

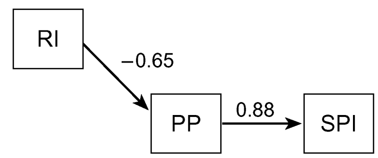

Figure 5 Path model 2

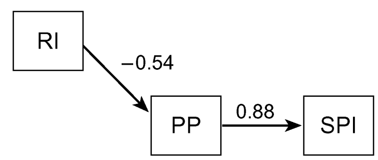

Figure 6 Path model 3

Initially, the three path models developed were analysed based on the original path model proposed, as shown in Figure 3; afterwards, any path with an insignificant path coefficient was eliminated from the path model. Finally, the results of path models established for the three periods are shown in Figures 4 to 6, and the significant path coefficients between two variables are presented by the values on the arrows linking them. The associated effects between variables in each path model are shown in Tables 4 to 6 respectively.

Table 4 Associated effects between variables in path model 1

Var	Direct effect			Indirect effect			Total effect		
	Dur	RI	PP	Dur	RI	PP	Dur	RI	PP
PP	–	−0.75	–	–	–	–	–	−0.75	–
SPI	0.31	−0.36	0.57	–	−0.43	–	0.31	−0.79	0.57

Table 5 Associated effects between variables in path model 2

Var	Direct effect		Indirect effect		Total effect	
	RI	PP	RI	PP	RI	PP
PP	−0.65	–	–	–	−0.65	–
SPI	–	0.88	−0.57	–	−0.57	0.88

Table 6 Associated effects between variables in path model 3

Var	Direct effect		Indirect effect		Total effect	
	RI	PP	RI	PP	RI	PP
PP	−0.54	–	–	–	−0.54	–
SPI	–	0.88	−0.48	–	−0.48	0.88

As shown in Figure 4, the double-headed curved arrow connecting the project risk index and project duration has been eliminated. This uncoupling indicates that there was no significant correlation between the project risk index and project duration at the level 0.05. It was also found that the project risk index had a significant direct negative effect on progress performance, whereas project duration had no significant effect on progress performance. All the variables in this model affected the schedule performance index: there was a direct negative effect from the project risk index, a direct positive effect from project duration and also from progress performance.

The effects between variables, including direct effects, indirect effects and total effects are presented in Table 4. The goodness of fit index (GFI) of path model 1 was 96.40%; the normed fit index (NFI) was 90.9%; and the root mean-square residual (RMR) was 0%. These measures indicate that path model 1 was near perfect.

As can be seen in Figure 5, on path model 2, path coefficients between the project risk index and the schedule performance index, and between duration and schedule performance index are no longer significant at the level 0.05. However, the project risk index still had a negative effect on progress performance, and the positive effect of progress performance on the schedule performance index remains consistent. The effects, including direct effect, indirect effect and total effect between variables are listed in Table 5. Path model 2 fitted at 95.40% of GFI, 84% of NFI and 20.9% of RMR which demonstrate a fairly good model.

Path model 3, as shown in Figure 6, was similar to path model 2, but the direct effect of the project risk index on progress performance in path model 3 was less than that in path model 2. All associated effects between variables are shown in Table 6. Path model 3 was also good for predicting the dependent variables which was indicated by 98.10% of GFI, 93.5% of NFI and 10.1% of RMR.

During the three months of monitoring project performance, the influence of the project risk index on project performance changed in each period. The total negative effect of the project risk index on progress performance and on the schedule performance index gradually decreased through the subsequent periods, as shown in Figure 7. On the other hand, a steady increase in the positive effect of progress performance on the

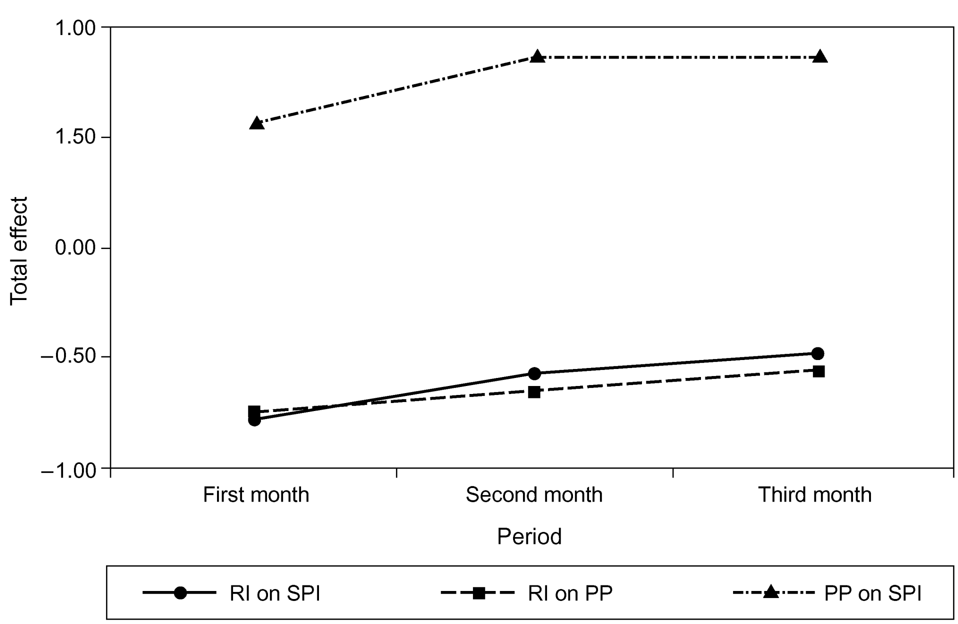

Figure 7 The standardised total effect between variables in the three periods

schedule performance index occurred in the second period and was maintained in the third period.

Discussion

The results showed that there was no significant correlation between the project risk index of time (the perceived riskiness of the project in terms of its impact on project completion) and project duration. Therefore, in this case, Assumption 1 is rejected. It might have been expected that a high risk index of time would have had more effect on a short duration project, as on such a project, there is little time to deal with the effects of any risks that occur before the project ends. Alternatively, the expectation might have been that a long project may well be more complex than a short one and thus provide more opportunities for risks to occur. Here, neither of the above suppositions is borne out, and it can be inferred that the project risk index and project duration are uncorrelated independent variables. Although other researchers have found links between duration and other factors, such as project cost (Kaka and Price, 1991), floor areas (Kumaraswamy and Chan, 1995), and number of storeys (Chan and Kumaraswamy, 1995), this is the first piece of research that has been identified in the literature that attempts to assess the link between project duration and risk.

As shown in all path models, progress performance was affected by project risk index but was not affected by project duration. Thus, Assumption 2 was partially supported given that the link Dur–PP was not significant. Assumption 3, on the other hand, was fully supported only in model 1; however, in the subsequent models, it was partially supported as there was a direct positive effect of progress performance on schedule performance index. These findings are explained below.

An inspection of the three models in successive months shows that for model 1, there is a direct link between the project risk index of time and the schedule performance index (the cumulative measure of project performance with respect to time). This link is not shown in models 2 and 3 as it was found to be insignificant. In fact, this link in model 1 only just registers as significant and so the general conclusion to be drawn here is that there is effectively no direct link between the project risk index of time and the schedule performance index. There is, of course, an indirect link between these two variables through the variable progress performance (the monthly measure of project performance with respect to time) and this will be discussed a little later in this section.

In just the same way that the direct link between the project risk index of time and the schedule performance index occurs in the first model and not in models 2 and 3, the direct link between project duration and schedule performance index follows the same pattern. In this case, the link in model 1 is stronger, but is still 10 times weaker than the direct links between project risk index of time and progress performance, and between progress performance and schedule performance index. Effectively then, it can be said that no direct link was found between project duration and schedule performance index.

By far the strongest links in the model were between project risk index of time and progress performance and between progress performance and schedule performance index, and these were strong for all three models. The first link, between project risk index of time and progress performance, indicates that the greater the perception of time risk in the project, the worse is the progress performance. In this case, the assessment of risk had been carried out a month before the first assessment of project performance (model 1), two months before the second assessment (model 2) and three months before the third assessment (model 3). It appears then that the level of risk perceived by the contractors was negatively related to performance in successive months. The strong direct link between progress performance (assessed monthly) and schedule performance index (assessed cumulatively) is easy to accept. Clearly the cumulative performance measure is built up from successive monthly measures, so a good performance in any month will necessarily impact positively on cumulative performance to date.

The final point to be discussed is to question why project risk index of time affects schedule performance index only through the mediator, progress performance, and not directly. The answer may lie in the understanding that although the project risk index of time was always assessed one month before the first assessment of project performance, for different projects this was sometimes early in the project's life, sometimes part-way through the project and sometimes towards the end of the project. Clearly, this situation could not have been avoided—to study 13 projects in a relatively short period, it would have been extremely unlikely that all 13 would have been just starting. This meant that at the time the project risk index was assessed, for some projects, the cumulative measure of performance, schedule performance index, had already received contributions from a number of previous months' performance. In this light, it can more easily be understood why no strong direct link was identified.

Based on this discussion, to reduce the likelihood of project delay, contractors must reduce the project risk index, which will, in turn, increase progress performance and hence, schedule performance. The need to treat risk seriously is thus reinforced by this study.

Conclusion

Although much research has been conducted in risk management, less attention has been paid to dealing with the influence of risk factors that affect project performance. Using path models, causal effects between the project risk index and project performance were revealed. It was found that there was no correlation between the perceived riskiness of the project and project duration. The results also showed that the schedule performance index was not affected by project duration and neither was it affected directly by the project risk index; however, it is interesting that the project risk index influenced the schedule performance index indirectly, with progress performance as the mediator between them. These findings indicate that the lower the project risk in a project, the lower the negative impact on monthly progress, and consequently the better the schedule performance will be.

Different projects will have different project risk indices, different actions will be taken to minimise those risks, and different impacts will affect the project's performance. Because the project risk index had an indirect effect on the schedule performance index through progress performance, to obtain better performance, not only should risk factors be assessed at the beginning of the construction stage but also effective strategies should be carefully prepared to minimise those risks. Clearly, it would be wise for any contractor working in this area to check how these risks should be shared with other parties for contracts on which he intends to bid and also to carefully consider how these risks should be shared or transferred to other parties in order to manage the risks that might occur during the construction period.

It is recommended that the project risk index should be assessed and actions taken to minimise those risks should be implemented carefully, and impact on project performance should be monitored. Through this process, it should be possible to keep progress on track, otherwise there is every chance that projects will be delayed.

References

Akinci, B. and Fischer, M. (1998) Factors affecting contractors' risk of cost overburden. *Journal of Management in Engineering*, **14**(1), 67–76.

APM (1997) *Project Risk Analysis and Management*, The APM Group Ltd, Norwich Norfolk.

Arbuckle, J.L. (2003) *Amos 5, Student Version*, Amos Development Corporation, Chicago, IL.

AS/NZS (1999) *Risk Management*, Standards Association of Australia, Sydney, NSW.

Assaf, S.A., Al-Khalil, M. and Al-Hazim, M. (1995) Causes of delay in large building construction projects. *Journal of Management in Engineering*, **11**(2), 45–50.

Bajaj, D., Oluwoye, J. and Lenard, D. (1997) An analysis of contractors' approaches to risk identification in New South Wales, Australia. *Construction Management and Economics*, **15**, 363–9.

Baker, S., Ponniah, D. and Smith, S. (1999) Risk response techniques employed currently for major projects. *Construction Management and Economics*, **17**(2), 205–13.

Bing, L. and Tiong, R.L.-K. (1999) Risk management in international construction joint ventures. *Journal of Construction Engineering and Management*, **125**(4), 277–84.

Bryman, A. and Cramer, D. (1990) *Quantitative Data Analysis for Social Scientists*, Routledge, London, New York.

Chan, D.W. and Kumaraswamy, M.M. (1997) A comparative study of causes of time overruns in Hong Kong construction projects. *International Journal of Project Management*, **15**(1), 55–63.

Chan, D.W.M. and Kumaraswamy, M.M. (1995) A study of the factors affecting construction durations in Hong Kong. *Construction Management and Economics*, **13**(4), 319–34.

Dias, A.J. and Ioannou, P.G. (1996) Company and project evaluation model for privately promoted infrastructure projects. *Journal of Construction Engineering and Management*, **122**(1), 71–82.

Elinwa, A.U. and Joshua, M. (2001) Time-overrun factors in Nigerian construction industry. *Journal of Construction Engineering and Management*, **127**(5), 419–25.

Hastak, M. and Shaked, A. (2000) ICRAM-1: Model for international construction risk assessment. *Journal of Management in Engineering*, **16**(1), 59–69.

ICE and FIA (1998) RAMP: Risk Analysis and Management for Projects Thomas Telford, London.

Kaka, A. and Price, A.D.F. (1991) Relationship between value and duration of construction projects. *Construction Management and Economics*, **9**(4), 383–400.

Kangari, R. (1995) Risk management perceptions and trends of US construction. *Journal of Construction Engineering and Management*, **121**(4), 422–9.

Kartam, N.A. and Kartam, S.A. (2001) Risk and its management in the Kuwaiti construction industry: a contractors' perspective. *International Journal of Project Management*, **19**(6), 325–35.

Kumaraswamy, M.M. and Chan, D.W.M. (1995) Determinants of construction duration. *Construction Management and Economics*, **13**(3), 209–18.

Kumaraswamy, M.M. and Chan, D.W.M. (1998) Contributors to construction delays. *Construction Management and Economics*, **16**(1), 17–29.

Li, C.C. (1975) *Path Analysis: A Primer*, Boxwood Press, Pacific Grove, CA.

Loehlin, J.C. (1992) *Latent Variable Models: An Introduction to Factor, Path, and Structural Analysis*, 2nd edn, Lawrence Erlbaum Associates, Hillsdale, NJ.

Mezher, T.M. and Tawil, W. (1998) Causes of delays in the construction industry in Lebanon. *Engineering Construction and Architectural Management*, **5**(3), 252–60.

Mulholland, B. and Christian, J. (1999) Risk assessment in construction schedules. *Journal of Construction Engineering and Management*, **125**(1), 8–15.

Nkado, R.N. (1995) Construction time-influencing factors: the contractor's perspective. *Construction Management and Economics*, **13**(1), 81–9.

Odeh, A.M. and Battaineh, H.T. (2002) Causes of construction delay: traditional contracts. *International Journal of Project Management*, **20**(1), 67–73.

PMI (2000) *A Guide to the Project Management Body of Knowledge*, Project Management Institute, Pennsylvania.

Rahman, M.M. and Kumaraswamy, M.M. (2002) Risk management trends in the construction industry: moving towards joint risk management. *Engineering Construction and Architectural Management*, **9**(2), 131–51.

Raz, T. and Michael, E. (2001) Use and benefits of tools for project risk management. *International Journal of Project Management*, **19**(1), 9–17.

Saaty, T.L. (1995) *Decision Making for Leaders. The Analytic Hierarchy Process for Decisions in a Complex World*, The Analytic Hierarchy Process, Vol. 2, RWS Publications, Pittsburgh, PA.

Santoso, D.S., Ogunlana, S.O. and Minato, T. (2003) Assessment of risk in high risk building construction in Jakarta. *Engineering Construction and Architectural Management*, **10**(1), 43–55.

Shen, L.Y., Wu, G.W.C. and Ng, C.S.K. (2001) Risk assessment for construction joint ventures in China. *Journal of Construction Engineering and Management*, **127**(1), 76–81.

Wang, M.-T. and Chou, H.-Y. (2003) Risk allocation and risk handling of highway projects in Taiwan. *Journal of Management in Engineering*, **19**(2), 60–8.

Ward, S.C. (1999) Assessing and managing important risks. *International Journal of Project Management*, **17**(6), 331–6.

Williams, T. (1996) The two-dimensionality of project risk. *International Journal of Project Management*, **14**(3), 185–6.

Zayed, T.M. and Chang, L.-M. (2002) Prototype model for build-operate-transfer risk assessment. *Journal of Management in Engineering*, **18**(1), 7–16.

Zhi, H. (1995) Risk management for overseas construction projects. *International Journal of Project Management*, **13**(4), 231–7.